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FERTILIZER PRODUCTION, MARKETING, and USE

A Handbook for Short Courses

Prepared for the
Agency for International Development
By the
Tennessee Valley Authority
National Fertilizer Development Center
Muscle Shoals, Alabama
1969

FOREWORD

The production of food needed by a hungry world will require much larger quantities of fertilizer—especially in the developing countries. For most developing countries, fertilizer use for other than plantation-grown export crops is relatively new. Food crops will require large investments in production, distribution, and marketing to bring about the rapid increase that is indicated in the use of fertilizers. Another, and probably more difficult, problem will be that of supplying trained personnel in all phases of fertilizer production, marketing, and use.

The National Fertilizer Development Center of the Tennessee Valley Authority in recent years has offered courses in fertilizer production, marketing, and use. Although more than 100 persons from developing nations have attended these general courses, and more than 60 have participated in more specialized training programs, many more could benefit from this type of training.

This is the basic reason for preparing this training guide—to extend the benefits from such courses and to expand their influence. Hopefully, the manual will encourage and better prepare the developing nations to train personnel they need so badly in the broad field of fertilizers. If so, it will be a step toward removing the lack of fertilizer or its use as a limiting factor in properly feeding their rapidly growing populations. The manual also may be useful in fertilizer training programs of private and public organizations elsewhere.

The guide was prepared with the encouragement and financial help of the Agency for International Development, U.S. Department of State.

Introduction

The purpose in preparing this manual is to extend fertilizer training techniques used at the National Fertilizer Development Center into the training channels in developing nations. The manual has been specifically designed for people who will plan and conduct courses in fertilizer production, marketing, and use. It offers one way of conducting such courses; there are many other approaches. However, this approach has been effective in courses conducted at the National Fertilizer Development Center.

Our courses have been conducted for representatives from as many as six countries. We call these "multination courses." Other courses have been conducted for representatives from only one nation. In both types, multidisciplines have been involved.

Our training methods have proved effective for both types of courses. They also should be effective in other settings. Whenever training is conducted, participants will represent different areas of a nation and different disciplines. Sometimes more than one language will be involved, even within one nation.

Many of the techniques we use are designed to capitalize on differences in background and interests of participants. We are convinced that a major accomplishment of our courses has been to demonstrate how people with divergent training can work together to solve common problems. This can be done as well within a country as among countries.

How to Use This Handbook

This handbook is divided into four parts. Section 1 suggests how to plan and conduct a fertilizer shortcourse. It considers setting objectives and techniques involved in structuring an agenda, whether it be for a one-day, one-week, or several weeks' course. Suggestions are made for conducting the course. This includes a guide for planning group discussions, types of effective visuals, arranging the meeting place, and evaluating a shortcourse.

Section 2 contains agendas for shortcourses in fertilizer production, marketing, and use. There is an 8-week agenda based on the TVA course. Also included are agendas for one-week engineering and marketing courses. The section discusses the flexibility of the agenda in preparing for any length of shortcourse desired. It provides descriptions and strategy of daily agenda elements such as the "Subject of the Day" and "Professional Discussion" periods. The section also considers the relationship of resource materials found in Section 4 to the suggested agenda.

Section 3 describes the philosophy and objectives of using problem-solving situations in training. Particular emphasis is placed on the use of New Devland—a mythical country—created for use in TVA fertilizer shortcourses to overcome tradition and bias so common to all of us when we are evaluating and criticizing our own countries. Included are techniques that have worked in TVA courses where panel problems have been assigned. Examples of problems are illustrated, along with a discussion on how they are assigned. There is also a discussion of how solutions to panel problems are presented, discussed, and critiqued by the trainees.

Section 4 contains several resource items to help prepare for the classroom situation. There are almost 70 technical outlines, based on the agenda found in Section 2. These are expanded outlines which contain a considerable amount of technical information and are fully referenced. The idea has been to provide enough information so that a prospective teacher can prepare a lesson plan from each outline. A complete description of New Devland and a suggested critique questionnaire are also included.

This manual was prepared by TVA staff members who participate in the training course under the guidance of the TVA training committee.

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SECTION 1
DEVELOPING A TRAINING COURSE

A training course is regarded here as the kind, amount, and organization of content in a short course in fertilizer production, marketing, and use. This section reviews some of the factors that are helpful in planning, conducting, and evaluating fertilizer training courses. Methodology is based on the Tennessee Valley Authority way of conducting international short courses in fertilizer production, marketing, and use.

In most educational effort, course building responsibility rests largely with the teacher. And the teacher is usually concerned with:

1. Purpose for which the course is to be offered.
2. Educative environment and training background of participants.
3. Sources of instructors and available information.
4. Requirements of the participants' professions.

These factors are also important in developing a fertilizer training course. Our experience at the National Fertilizer Development Center has shown, however, that course development is best handled by a group of specialists rather than one teacher. This group consists of an agronomist, an economist, a chemical engineer, and a communications specialist. Such a team establishes training objectives and plans, and conducts and evaluates the course. This early cross-disciplinary approach to course development is a key element we try to maintain throughout our training courses. A similar team approach to training may be useful in any country.

Set Objectives Early

The first requirement for developing a course is to create a clear conception of the purposes or objectives. Objectives should be so stated that the people who develop the course can plan specific topics to meet specific objectives. It is important to emphasize that the goal of any training course should be to meet the professional needs of the participants. The strategy should be to show how a problem is recognized, researched, evaluated, and an action program designed and implemented. In our courses, the guiding thought has been to include topics that will be of most use to participants when they return to their own positions. Our judgment has been based on four kinds of experiences:

1. Many years of experiences by the TVA in developing and introducing new fertilizers to American farmers;
2. Reports of TVA technical teams who have analyzed potentials for fertilizer production and use in several developing countries;
3. Experience with international training courses; and
4. Discussions with technical visitors to the National Fertilizer Development Center.

Most participants in our courses have been in positions where they can influence the development of a fertilizer industry in their nations. Thus, we make an effort to expose them to all phases of fertilizer production, marketing, and use. This is done in the classroom where research and development specialists share their knowledge and experience with participants and in the field where problem-solving programs are in progress.

TVA's course in *Fertilizer Production, Marketing, and Use* has the following objectives:

1. Examine problems in establishing and operating a fertilizer program in a developing country.
2. Study developments in fertilizer production, marketing, and use in the United States and relate them to needs and resources of each country represented in the course.
3. Show the interrelationship and interdependence among chemical engineering research on development and production of improved fertilizers, agronomic research on fertilizers and economics of their use, and educational programs for fertilizer introduction and use.

Perhaps these objectives will be useful to course planners in developing nations. The multidiscipline approach described in objective 3 is an important consideration for any undertaking.

Preparing the Training Course

The first step—following statement of objectives—in preparing the course is to establish time elements. This includes number of days to be devoted to the course and number of classroom hours.

If there is an absolute limit to the length of the course, this time must be divided among the topics to be covered. No general rule can be laid down about time elements; time may vary according to needs and local preferences.

In courses at the National Fertilizer Development Center, however, we plan for full-time participation. The class day begins at 8:30 a.m. and ends at 4:00 p.m. We follow this schedule five days a week for 8 weeks. Again, however, time and length can vary. Two-week short courses as well as 2-or 3-day technology seminars can be useful. But if intensive training is the goal, the course should be no shorter than 5 weeks.

The next step is to construct a typical day's schedule which shows time elements available for discussion periods. A summary description of each program element follows.

Subject of the day. This is the key to the activities for the day. Usually presented as a lecture, the subject of the day ranges across several disciplines and thus illustrates the interrelationships among them. Thus, it is designed for *all* training course participants. The teacher presenting the subject of the day should be cautioned to avoid details. Presumably, in a multidiscipline audience some will be exposed to several aspects of the topic for the first time. They are not yet prepared to learn details but they can become fascinated with the broad perspective and with how new vistas might affect their own endeavors. They, then, are prepared to enter into the professional discussions which follow.

Professional discussions. These discussion periods compose the bulk of technically oriented classroom time. It has been proved many times that adults respond more freely to learning situations when there is more discussion time and fewer lecture periods. Agronomists and engineers separate into different groups to consider the subject of the day in more technical detail. (Economists may choose which sessions they will attend. Or, if there are several economists in the course, a three-way discussion course can be designed.) Primary purpose of these discussion periods is to permit participants to ask specific questions about the subject under study. This helps them get individual consultation and specific information that can be useful in their own positions.

The discussion leader usually begins the period with a brief technical lecture about the subject. He maintains a permissive atmosphere, encouraging questions and participant contributions. During and following the brief lecture, the floor is open to questions or other statements relating to the subject. Such a free exchange of ideas between discussion leader and participants has proved helpful in solving individual problems.

Problem-solving panels and library time. Problem-solving is discussed in Section 3. Suffice it to say here that a mythical country is the basis for the panel problem element. Purpose, of course, is to supplement the classroom sessions and help evaluate what is being taught. We also provide time for participants to freely use the technical library and visit specialists for personal consultation.

Participant time and breaks. These are minor, but very important periods. Participant time is free time for the purpose of receiving mail, discussing housing arrangements, transportation, and other such personal interests. Two 30-minute breaks each day serve the purpose of relieving the tedium of confinement in these highly technical training courses. We have found that such breaks help keep participants physically and mentally refreshed throughout each day.

In addition to the above, we also have a few other course elements. These are discussed as a part of the typical week in our courses. Purpose of the typical week schedule is to help evaluate the amount of time that should be devoted to each topic that must be covered and amount devoted to classroom and non-classroom activities. Our typical week, for example, features four days of lecture and discussion activity and one day of a non-lecture session. The standard method of arranging such a schedule is for Monday, Tuesday, Thursday, and Friday to feature lecture and discussions. Wednesday is the non-lecture day. This format has proven effective in our courses and may be considered a good guide for developing nations.

We have two purposes in using the non-lecture day. The first and most important is to supplement classroom discussions with field trips, library research, personal consultations with specialists, and other related activities. We have found that most participants have interests and problems about which they would like specific information. The non-lecture activity gives participants a better opportunity to research their own special needs.

The non-lecture day activities are also learning situations in their own right. They also help relieve the tedium of classroom confinement.

Following the building of the typical day and typical week schedules, we then construct a total course

schedule. Purpose, of course, is to ensure that agenda topics cover specific needs of participants and relate closely to objectives established for the course.

A typical TVA eight-week course schedule follows:

1 day – orientation
22 days – technical lecture – discussion
10 days – field trips
5 days – seminars
1 day – critique
1 day – prepare to leave TVA

Orientation is just that–orienting participants to their new surroundings and to the course in which they are about to participate. Brief orientation helps participants in any course develop an easy frame of mind before training begins.

Technical lectures and discussions have already been described. A full-course agenda of lecture and discussion periods is recommended in Section 2.

Field trips are usually one-day visits to local farms and fertilizer plants. One extended field trip–four to five days–is usually planned to visit fertilizer production facilities.

Seminars are included so that participants can report on their national fertilizer industries. Seminars also give participants a chance to talk about things they know well. Each nation is allotted from two hours to a half-day to present its seminar. There are three reasons for having seminars:

1. To give participants an opportunity to evaluate their home industry.
2. To permit participants from other nations to gain ideas. Experience shows that seminars have helped many people take usable techniques back to their own countries.
3. A training course, if needed, is always about new things; students are not supposed to be on familiar grounds. So the seminar lets them regress a few minutes into more familiar surroundings and return to intensive study with assurance that familiar things still exist.

Seminars can also be useful in any nation because the exchange of ideas among disciplines and areas of the country represented can be just as helpful as exchanges among nations.

Critiques help us evaluate the training sessions. They are discussed in detail later in this section.

Tips on Conducting the Course

Good prior planning helps make the course manageable. We have found that selecting a "Chairman of the Day" for each day in the course is a worthwhile practice. His function is to make sure that each speaker has been alerted, that needed audio-visual equipment is ready, and arrangements made for disseminating lecture outlines and notes. He is also responsible for keeping the day's meeting on time, introducing speakers, and assuming responsibility for other details during the course. This includes channeling participant requests for information to the right people.

It is best to assign the chairman-of-the-day functions in advance of the course. We usually prefer that one person perform this function throughout the course. This seems to stimulate freer communication between the course planners and the trainees. But, two or more persons can be assigned to the job. They can arrange a schedule that permits them to share chairman-of-the-day responsibilities.

Another important point: The chairman of the day should know how each phase of a day's training course is to be conducted. He should be well versed on the interrelationship of typical day elements.

The chairman should also be responsible for preparing the meeting room. The room should be in a relatively quiet area. Training sessions can be ruined by disturbing noise outside the classroom–typewriters, people shouting, and highway or railroad noise.

Use of audio-visuals. Course lecturers and discussion leaders should be encouraged to use effective audio-visuals. Research shows that people learn through their five senses–sound, sight, touch, taste, and smell. The more senses that are used in a learning experience, the more knowledge transfer takes place. Further research shows that the visual sense accounts for about 75% of all learning.

We have found visuals to be most effective in helping overcome language barriers, too. Let's look at a few types of effective classroom visuals.

We usually divide classroom visuals into two groups–projected and non-projected. As a rule, projected visuals require equipment not readily available in all situations. Such visuals as motion pictures, film strips, slides, overhead projectuals, and opaque materials are included in this group.

Non-projected visuals are limited only by the imagination of the discussion leaders, and can be used successfully in most any situation. Visuals in this group can be professional or crude, expensive or home-made, and elaborate or simple. Included are drawings, charts and graphs, pictures, chalkboards, bulletin boards, flannelboards, globes and maps, actual objects, and models and specimens.

The most effective and probably the least expensive of all visuals are actual objects. Situations that permit use of the real thing contain a meaningful experience for the students. As a rule, the closer visuals are to reality, the more effective the experience they create. If the discussion concerns a new fertilizer product, what visual could replace a real sample of the material for students to see, feel, or smell? Chances are good they will remember the new product after this experience.

Other non-projected visuals, in order of effectiveness as related to reality, include: (2) models and specimens, (3) pictures of real objects, (4) drawings of real objects, (5) maps and globes, (6) flannelboard, (7) chalkboard, and (8) charts and graphs.

A good discussion leader will select not one, but the best combination of visuals that fit his individual situation. He might use an actual object, show pictures related to the presentation, and summarize the lesson with charts and graphs.

Effective discussion leaders use visuals to supplement and emphasize main points in the lesson. Good visuals emphasize one point at the time and are legible from the back of the room. If the visual can't be seen by everyone, don't use it!

A good rule of legibility is to make letters 1 inch in height for each 25 feet of viewing distance. For example, if the distance from visual to the last seat in the room is 75 feet, lettering should be 3 inches high.

Group discussion. This approach to training can help create a cooperative environment in which participants actively help one another learn. The special knowledge and experience that each course participant possesses increase the total amount of "know-how" that can be exchanged in a course. The effective discussion leader recognizes that each participant has much to offer and creates a permissive atmosphere in the classroom where ideas are freely exchanged.

The skilled discussion leader acknowledges any special technical information he may possess and puts himself at the service of the group as a resource person. We have found that when discussion wanders, the leader can get the meeting under control by making procedural suggestions and reminders of goals. He also prevents individuals from dominating the conference, and other factors from thwarting it.

The following series of questions—summarized from the TVA "Reach and Grow" training presentation—can help a discussion leader equip himself to conduct more effective meetings:

1. I've never run a "group-discussion" meeting; how long does it take to become a skilled Discussion Leader?

There's no known time limit—no magic formula. But you'll have good meetings if you can think of yourself as a helper rather than as someone conducting the meeting to tell participants what you know.

2. What's considered the hardest job in conducting Group Discussion?

The hardest job seems to be in learning to exercise self-restraint. Here's why.

You're the Group Discussion Leader because you already have the recognized superiority or abilities which brought you to your present position. You wouldn't have made the grade if you hadn't been able to speak up and express yourself.

But—this is exactly the valuable personal ability which has to be held back in a Group Discussion Meeting of which you are the GUIDE. A Group Discussion Leader must exert CONSCIOUS and CONSTANT controls over his NATURAL ABILITY and his NATURAL DESIRE to TELL.

IMPORTANT: In a fertilizer training course you will be trying to teach participants to WANT to LEARN more about fertilizer production, marketing, and use. They will learn more—remember more—and put more of what they remember into practice when they are given the freedom to think things out for themselves.

3. Suppose some participants are slow to speak up—or don't say anything at all? Should you consider this your fault?

Not necessarily. A Group Discussion Leader must expect certain reactions which are normal and natural for people in a group situation. It is perfectly natural for most people to hold back at first.

4. But what about the few people who want to talk all the time?

These are the ones you'll have to help hold back. These fast starters are helpful in starting a discussion, but if you let them go on too long, the slow starters may not start at all! Thank them for entering the discussion but try to steer the controls away from them by saying something like this: "Fine—thank you, John. What do the rest of you think?" "Is this what you mean, John? (Repeat or rephrase what he said.) Fine. Any other ideas?" "Let's see if we understand where it is you disagree, John." (Repeat person's statement. Watch here to make sure that the tone of your voice doesn't indicate objection to him personally or to his ideas.) "OK, what are some other opinions on this subject?"

5. Is there anything a Group Discussion Leader can do to speed up the learning process?

Your own honest desire to help participants learn, rather than to tell them the answers will accomplish

much. Participants will sense this feeling and will respond to it more readily.

If you can establish a real climate of FREEDOM in the meeting—letting each feel free not only to speak up but to disagree with you and each other—they'll participate in the discussion more enthusiastically and as a result—learn more rapidly.

NOTE: Here's where you really have to watch yourself. Sometimes the tone of one's voice will indicate the person's inability to endure being disagreed with —even if his words are carefully chosen!

6. Perhaps, you're wondering now when—or how soon you can expect every participant to get into the discussion?

Only when each one, according to his own nature, has truly recognized and begun to trust your statement "that they aren't there to be judged or graded."

But, that the meetings are being held for them to help themselves to learn to do what most people really want to do—which is to perform our jobs as well as we'd like other people to think we do!

And please—don't lose heart because one or two of the participants hold back longer than the others. Even these people will speak up when an answer from their own experience seems right. In other words—when the "bell rings for them."

Just don't rush them. Don't turn the spotlight on them until they're ready. They'll let you know when.

7. Then which are the most important things the Group Discussion Leader should aim for in every meeting?

. . .to keep in mind always that you can help people learn more by the way you feel and act than by what you say.

. . .to remember that in a meeting the Group Discussion Leader should never criticize either by words or tone of voice. If criticism of a participant comes from another participant—OK. Guide the discussion out of the woods, fast. But such criticism must not come from you. The Leader should emphasize only the positives.

. . .to try to keep in mind that a Group Discussion Leader must keep from imposing his own opinions or answering his own questions. Let the group do that.

They won't always be right—but who is?

. . .to try to wait until you summarize the meeting to add the important points which might have been bypassed during the discussions. Even then, try to phrase these as questions, rather than giving them as answers or your opinions. Use the discussion questions in your Guides for this. This will help.

. . .to remember always to credit by name the participant who contributed the ideas you quote in your summary.

8. And finally—how can a person tell how well he conducted his Group Discussion Meeting?

You can determine your score partially by how well you held back—freeing your participants to TALK UP. But you can also credit yourself by how well the participants listened. Did they listen eagerly? Intently?

Active thought and learning can be taking place even without speech.

And, just as you will find yourself developing more patience with, and better understanding of, your participants—so, it's hoped, you will be equally patient and understanding about your own performance as a Group Discussion Leader. You will continue improving with each meeting as you grow more competent and more confortable. And. . .the professional disciplines you develop in Group Discussion Leadership will surely be found valuable in your day-to-day relationships with colleagues.

Practical Approaches to Evaluation

Now to the final step in conducting a fertilizer training course: evaluation. This is an attempt to seek answers to the questions: "How did we do? Would the participants have been better off if we had tried something else?"

The purpose of evaluation is to measure the amount of learning that takes place. This measurement is important from two viewpoints. First, we are interested in whether or not the participants gained enough new knowledge and experience to make their attendance worthwhile. Second, a thorough evaluation by the participants helps us identify ways and means of improving the course for future training groups.

In an earlier discussion we emphasized the importance of objectives in planning course content. Clearly defined training objectives are also important in evaluation. Objectives determine what is taught, how it is taught, and how the effort is evaluated. Good evaluation, then, should identify the degree to which objectives are being attained and wherein they are not being attained. Such a measure gives evidence of the progress of participants in reaching their training goals.

In evaluating courses at the National Fertilizer Development Center, we use practical evaluation techniques—oral and written critiques and special tests. The New Devland panel problems, seminars, and special assignments also help us with evaluation during the conduct of the course. But we will discuss only the critiques and tests since they are our "formal" evaluation tools.

Oral and written critiques. Such critiques have been helpful in improving the TVA courses. Oral critiques usually consist of a two-hour session. Participants are asked to discuss frankly their attitudes about the course. They are urged to concentrate on ways and means of improving the course.

As long as participants make suggestions, the critic makes no effort to channel their thinking into different phases of the training program. However, if the discussion begins to bog down on a few elements of the course, he may channel thought into other areas. This is done by asking participants to evaluate:

*Topic-of-the-day lectures—Were there too many or not enough subjects? What subjects should be deleted or added?

*Field trips and library time—Were field trips useful? Was library time about right, too much, or too little?

*New Devland panel problems—Did the mythical country approach help you gain new concepts in problem-solving? What were any weaknesses in this approach?

*Professional discussions—Did you benefit from the professional discussion periods? Is it worthwhile to have separate discussions for different disciplines?

*Other areas—Was use of visuals by instructor adequate? Was enough free time allocated?

Written critiques are also used so that each participant can evaluate the course without any inhibitions that might be in play during the oral critique. The written critique is also more complete. Course planners rely on it to give a permanent record of participant suggestions. This record is useful in planning future courses.

The critique questionnaire—reprinted in Section 4—asks trainees to evaluate the following areas in detail:

*Were the objectives of the training course accomplished?

*Explain any changes you feel should be made in the typical day format.

*Evaluate the time devoted to each topic of the day in terms of whether or not time was adequate, inadequate, or the topic should have been eliminated.

*Which—if any—of the professional discussions should be omitted? What subjects should be added?

*Were panel problems useful as a teaching tool? Were there too few or too many panel problems?

*Was the amount of time in communications about right, not enough, or too much?

*The amount of time for conducting personal business was too small, too much, or about right?

*The number of field trips was about right, too few, or too many?

*Evaluate the library time in terms of length and adequacy of library.

*Evaluate speaker's use of visual aids.

One major function of evaluation not covered in the preceding discussion is to discover at the beginning what level of fertilizer technology the participants possess. Then at the end of the course another measurement should help determine knowledge transfer that occurred.

This is a complicated area—as is all evaluation—and generally cannot be handled in a training course with as much academic depth as in a classroom situation.

However, we use a special examination to give a practical approach to this element of evaluation.

The examination is simply written along these lines: "List in topical detail the factors that must be considered in developing a fertilizer industry in a developing nation." This test is given to participants at the beginning of the course—preferably before any lectures are given. Very little explanation is given, except to say that it will help course planners evaluate participant needs.

We give the same examination at the end of the course and the same explanation for asking participants to complete it.

If the training has been successful, there should be a much better concept of what is involved in developing a fertilizer industry at the end of the course. Each professional should also have a much broader picture of the role of other disciplinary areas in bringing an industry into existence.

Granted, this examination is a simplified approach to evaluation. But it is an effective method for our use in measuring the impact a training course may have on attitudes and concepts.

The process of evaluation is and will continue to be an integral part of short course training.

SECTION 2
SELECTING COURSE CONTENT

This section contains an outline for an eight-week shortcourse in fertilizer production, marketing, and use. We recommend the outline as generally appropriate in length, number of topics to be taught, and number of professional discussion categories—for agronomists, economists, and chemical engineers. We use the outline to plan courses for specific groups—be they agronomists, chemical engineers or more than one profession—and formal training periods ranging from two to eight weeks. We have not had to use the outline in its entirety for any group.

Purpose

Flexibility is important and is the main reason this section is included in the manual. Properly used, the outline can help course developers anywhere in the world plan a good course agenda.

For example, the outline on most days features a *Subject of the Day* which is followed by morning and afternoon discussion periods for agronomists, economists, and engineers. We have never had enough economists in our courses to justify a three-way break in professional discussion periods. But this does not mean that the economic discussion periods are, or should be, ignored. Even if agronomy and/or engineering is the only profession in the course, economics cannot be forgotten, because so many decisions about national development have economic significance. Thus, we choose those topics from the outline that seem to best augment the subject of the day. This same philosophy applies if we have agronomists and economists or economists and engineers or any other professional groupings.

Day No. 6 in the outline can be used to illustrate this. Assume that only agronomists and engineers are scheduled for a training course. There is no problem with the morning session. Both agronomists and engineers attend the subject-of-the-day lecture—"Raw Materials for Fertilizer Production: Phosphate Rock, Fixed Nitrogen, Potash, and Sulfur." Both professional groups also participate in their respective morning discussion periods.

For the afternoon discussion period, however, the course planners may wish to inject economics into the day's proceedings. Since any nation prefers to use its own natural resources for development, the agronomists and engineers could be exposed to an economics discussion in the afternoon. In fact, it might be very useful for them to consider "Evaluating Natural Resources for Their Development Potential."

Sometimes it is useful to plan joint sessions for the professional discussions. An example of this is Day No. 22. The morning professional discussion period features a joint session of agronomists and economists to consider "Agronomic-economic research for increasing agricultural production—problems, goals, and solutions." Such a subject would be less effective if agronomists and economists separated into groups.

The above illustration shows the flexibility of the outline in selecting topics for a daily course agenda that can be planned to meet student needs.

The outline also permits flexibility in determining course content. It can be used to construct courses in fertilizer education, fertilizer marketing, and in selecting components for a fertilizer industry. These are in addition to the broad course in fertilizer production, marketing, and use.

The outline also is flexible in terms of course length. For shorter courses, planners will have to decide what to delete from the outline by considering the specific backgrounds and needs of the students scheduled to attend the course. Is the extended field trip needed? If most participants are engineers, can a few of the farmer field trips be eliminated? Can several subject-of-the-day lectures be given on only one day and brief discussion periods follow each presentation? These are only a few of the questions course planners must ask when adjusting the outline to fit specific time periods. But it is important to remember the key factors in deciding what to keep and what to delete from the outline. These factors are overall objectives of the individual course and specific needs of the students.

Length of course flexibility is illustrated on pages 18-20. A one-week shortcourse for engineers has been structured for trainees who might represent a company that has a plant for production of diammonium phosphate and triple superphosphate. Potash can be added. A one-week marketing course is based on trainees representing a company that processes most of its materials through a bulk blending plant.

Interrelationship of Daily Course Elements

The recommended course outline is prepared on the basis of the typical day elements discussed in Section 1. Perhaps it would be of interest at this point, however, to discuss the interrelationship of daily course elements. Hopefully, such a discussion will reiterate the importance of the daily course elements and help illustrate the flexibility of the typical day.

Let's select Day No. 7 as our example. Its purpose is to consider "Phosphorus Fertilizers."

The first hour—Subject of the Day—is devoted to the topic "Production, Marketing, and Use of Phosphorus Fertilizers." The discussion leader considers the subject on a broad front, covering the agronomic, engineering, and economic factors of the subject.

The next step is for the agronomists, economists, and engineers to separate into professional discussion groups. Agronomists consider "The Effect of Water-Soluble Phosphorus Concentration and Granule Size on Use of Phosphorus Fertilizers." Economists discuss "Mine-Site vs Use-Site Processing of Phosphate Rock." Engineers study "Design and Operation of Phosphoric Acid Plants."

Following lunch, the professional discussions continue. The agronomists now discuss "Reaction of Phosphorus Fertilizers in Soils." The economists consider "World Trade Demand for Raw Rock Phosphate Intermediates and Finished Phosphates." And the chemical engineers study "Design and Operation of Ordinary and Triple Superphosphate Plants."

The discussion periods begin with brief lectures and are then open to intensive and in-depth discussions pertinent to the disciplinary areas involved. If there are not enough students in any one of the professional groups to justify a separate discussion period, those involved may attend either of the two planned discussion groups. In some cases, there may be only one dominant disciplinary area involved; therefore, only one professional discussion group could be justified. In such a situation, the discussion leader should try to include topics or discussion considerations of importance in other disciplines. This accomplishes two important things. First, the minority representatives feel that they are getting something from the course. Second, it exposes the dominant discipline representatives to a different viewpoint of the subject and thus helps strengthen the overall learning situation.

Following the afternoon break on Day No. 7, participants solve a New Devland panel problem. This activity is discussed fully in Section 3. Suffice it to say here that the panel problem would relate to a previous subject of the day. If all three disciplinary areas were represented in the course, the panel would consist of an agronomist, an economist, and an engineer.

In most cases the recommended course outline follows the above arrangement. For subjects such as educational programs, credit, and communications, however, participants in all three disciplinary areas meet with the same discussion leader.

Relationship of the Course Outline to Section 4

The above discussion, coupled with the course outline later in this section, can help course planners to determine what topics to use in a fertilizer short course. The next most important consideration is subject matter to be covered under each topic.

In Section 4—the Resource Materials Section—are nearly 70 subject matter outlines. They were selected because they are the ones most commonly used in international training courses at the National Fertilizer Development Center. Since the majority of our courses have been for five weeks and have been composed of agronomists and chemical engineers, the outlines tend to fit this situation quite well. As discussed earlier, however, we did not ignore economics; many of the outlines consider important economic factors in fertilizer production, marketing, and use.

Each outline includes important information about the subject. It is much more than an ordinary topical outline which is commonly used in training courses. The aim has been to give potential discussion leaders enough basic data—along with good references—to allow them to prepare a lesson plan, lecture and/or discussion around the subject. Each outline is fully referenced.

Sections 2 and 4, then, have a very close relationship. The recommended course outline in this section can be a practical guide in developing agendas for specific courses. The subject matter outlines in Section 4 can help discussion leaders plan their presentations.

Day No. 1	ORIENTATION

This day is scheduled to orient the students to their new surroundings, to the agency or company sponsoring the training course, and to the area where the training will be held.

Part of this orientation day should also be devoted to explaining the purpose, organization, and general content of the training course.

Personal requirements should also be discussed. . .how mail is to be handled, transportation, rest periods, and etc.

Day No. 2	FERTILIZER POTENTIALS
8:30– 9:00	Importance of agriculture in economic development
9:00– 9:30	Role of fertilizer in agriculture in developing countries
9:30– 9:45	Discussion
9:45–10:15	Break
10:15–10:45	Assessing agricultural needs and potentials for fertilizer use
10:45–11:15	Determining the need for a fertilizer industry
11:15–11:30	Discussion
11:30–11:45	Multination time
11:45–12:45	Lunch
12:45– 1:15	Techniques for selecting fertilizer plant locations
	Agronomists–Predicting response to fertilizers in developing countries
	Economists–Using agronomic and engineering data in economic decisions
	Engineers–Making economic feasibility studies for fertilizer plants
2:45– 3:15	Break
3:15– 3:45	Problem-solving panels as a teaching tool

Day No. 3	COMMUNICATIONS–ORIENTATION
8:30– 8:45	Assemble for instructions and division into groups
8:45–11:30	Communications workshop; continue orientation
11:30–11:45	Multination time
11:45–12:45	Lunch
12:45– 4:00	Communications workshop; continue orientation

Day No. 4	COMMUNICATIONS–ORIENTATION
8:30– 8:45	Assemble for instructions and division into groups
8:45–11:30	Communications workshop; continue orientation
11:30–11:45	Multination time
11:45–12:45	Lunch
12:45– 4:00	Communications workshop; continue orientation

Day No. 5	WORLD FERTILIZERS
8:30– 9:00	History of world fertilizers and fertilizer manufacturing processes
9:00– 9:30	Estimated world fertilizer production capacity as related to future needs
9:30–10:00	Break
10:00–11:30	*Agronomists*–Trends in the use of nitrogen, phosphorus, and potassium fertilizers
	Economists–Importation vs domestic production of fertilizers
	Engineers–Recent trends in fertilizer processes and types of plants–developed countries
11:30–11:45	Multination time
11:45–12:45	Lunch
12:45– 2:15	Each group continue its morning discussion
2:15– 2:45	Break
2:45– 4:00	New Devland panel problem
Day No. 6	RAW MATERIALS
8:30– 9:30	Raw materials for fertilizer production: phosphate rock, fixed nitrogen, potash, and sulfur
9:30–10:00	Break
10:00–11:30	*Agronomists*–Agronomic evaluation of fertilizers
	Economists–Evaluating natural resources for their development potential
	Engineers–Characteristics of phosphate rock from various sources
11:30–11:45	Multination time
11:45–12:45	Lunch
12:45– 2:15	*Agronomists*–Relationship between agronomic response and economic response to fertilizers
	Economists–Costs of natural resource development and operation
	Engineers–Characteristics of phosphate rock from various sources
2:15– 2:45	Break
2:45– 4:00	New Devland panel problem
Day No. 7	PHOSPHORUS FERTILIZERS
8:30– 9:30	Production, marketing, and use of phosphorus fertilizers
9:30–10:00	Break
10:00–11:30	*Agronomists*–Effect of water-soluble phosphorus concentration and granule size on use of phosphorus fertilizers
	Economists–Mine-site vs use-site processing of phosphate rock
	Engineers–Design and operation of phosphoric acid plants
11:30–11:45	Multination time
11:45–12:45	Lunch
12:45– 2:15	*Agronomists*–Reactions of phosphorus fertilizers in soils
	Economists–World trade demand for raw rock, phosphate intermediates and finished phosphates
	Engineers–Design and operation of ordinary and triple superphosphate plants
2:15– 2:45	Break
2:45– 4:00	New Devland panel problem

Day No. 8	FIELD TRIPS
8:30– 4:00	*Agronomists*–Field trip to greenhouses and forage research area; Library
	Economists–Library; Field trip to raw materials and production control offices
	Engineers–Field trip to normal superphosphate plant
Day No. 9	NITROGEN FERTILIZERS
8:30– 9:30	Production, marketing, and use of nitrogen fertilizers
9:30–10:00	Break
10:00–11:30	*Agronomists*–Chemical, biological, and agronomic characteristics of nitrogen fertilizers
	Economists–Comparison of alternative nitrogen fertilizers in terms of production and distribution costs and market prices
	Engineers–Design and operation of ammonia plants
11:30–11:45	Multination time
11:45–12:45	Lunch
12:45– 2:15	*Agronomists*–New perspectives in nitrogen research
	Economists–Size and location of nitrogen plants related to consumption density and raw material costs
	Engineers–Design and operation of nitric acid plants
2:15– 2:45	Break
2:45– 4:00	New Devland panel problems
Day No. 10	NITROGEN FERTILIZERS
8:30– 9:30	Factors influencing the use of nitrogen in developed and developing countries
9:30–10:00	Break
10:00–11:30	*Agronomists*–Fertilizer–available moisture relationships
	Economists–Cost comparison of ocean shipment of anhydrous ammonia and solid urea vs urea-ammonia solution
	Engineers–Design and operation of ammonium sulfate and ammonium nitrate plants
11:30–11:45	Multination time
11:45–12:45	Lunch
12:45– 2:15	*Agronomists*–Nitrogen–crop variety interactions
	Economists–Determining rate of return from alternative sources of nitrogen
	Engineers–Design and operation of urea plants
2:15– 2:45	Break
2:45– 4:00	New Devland panel problem
Day No. 11	AMMONIUM PHOSPHATE FERTILIZERS
8:30– 9:30	Production, marketing, and use of ammonium phosphates
9:30–10:00	Break
10:00–11:30	*Agronomists*–Fertilizer placement
	Economists–Economics of various N:P ratios
	Engineers–Design and operation of ammonium phosphate plants
11:30–11:45	Multination time

11:45–12:45	Lunch
12:45– 2:15	*Agronomists*–Fertilizer and soil pH relationships
	Economists–Alternative investment opportunities other than fertilizer production facilities
	Engineers–Flexibility of diammonium phosphate process and plants
2:15– 2:45	Break
2:45– 4:00	New Devland panel problems

Day No. 12	NITRIC PHOSPHATE FERTILIZERS
8:30– 9:30	Production, marketing, and use of nitric phosphate fertilizers
9:30–10:00	Break
10:00–11:30	*Agronomists*–Developing a soil testing program
	Economists–Supply response of fertilizer ingredients to changing prices–use of sulfur
	Engineers–Alternative processes for production of nitric phosphates
11:30–11:45	Multination time
11:45–12:45	Lunch
12:45– 2:15	*Agronomists*–Using soil tests to predict the need for fertilizers
	Economists–Economics of large vs small plants
	Engineers–Design and operation of nitric phosphate plants
2:15– 2:45	Break
2:45– 4:00	New Devland panel problem

Day No. 13	FIELD TRIPS
8:30– 4:00	*Agronomists*–Field trip to farm fertilizer test plots
	Economists–Field trip to railroad's district traffic office
	Engineers–Field trip to chemical company's ammonia plant

Day No. 14	POTASSIUM FERTILIZERS
8:30– 9:30	Production, marketing, and use of potassium fertilizers
9:30–10:00	Break
10:00–11:30	*Agronomists*–Potassium fertilization
	Economists–Evaluation of alternative sources of N, P, and K and relative cost of each
	Engineers–Characteristics of potash raw materials
11:30–11:45	Multination time
11:45–12:45	Lunch
12:45– 2:15	*Agronomists*–Balanced fertilization
	Economists–Estimation of future demand for N, P, and K
	Engineers–Use of potash in mixed fertilizers
2:15– 2:45	Break
2:45– 4:00	New Devland panel problem

Day No. 15	MIXED FERTILIZERS
8:30– 9:30	Production, marketing, and use of homogenous mixed fertilizers
9:30–10:00	Break
10:00–11:30	*Agronomists*–Selecting grades and ratios in a developing country
	Economists–Economics of NPK production–types of mixed fertilizers and relative costs of plant investment and production
	Engineers–Design and operation of ammoniation-granulation plants
11:30–11:45	Multination time
11:45–12:45	Lunch
12:45– 2:15	*Agronomists*–Crop fertilization vs soil fertilization
	Economists–Economics of location of mixed fertilizer plant in relation to source of P and use of fertilizer
	Engineers–Design and operation of ammoniation-granulation plants
2:15– 2:45	Break
2:45– 4:00	New Devland panel problem
Day No. 16	BULK BLENDS AND LIQUIDS
8:30– 9:00	Production, marketing, and use of bulk-blended fertilizers
9:00– 9:30	Production, marketing, and use of fluid fertilizers
9:30–10:00	Break
10:00–11:30	*Agronomists*–Agronomic aspects of bulk distributed dry and liquid fertilizers
	Economists–Location of blending plants and economics of bulk blending
	Engineers–Design and operation of bulk-blending plants
11:30–11:45	Multination time
11:45–12:45	Lunch
12:45– 2:15	*Agronomists*–Using micronutrients with mixed fertilizers
	Economists–Minimizing the cost of mixed fertilizers
	Engineers–Design and operation of liquid and suspension fertilizer plants
2:15– 2:45	Break
2:45– 4:00	New Devland panel problem
Day No. 17	PHYSICAL PROPERTIES
8:30– 9:00	Producing and maintaining good physical properties in fertilizers
9:00– 9:30	Identification of compounds in mixed fertilizers
9:30–10:00	Break
10:00–11:30	*Agronomists*–Greenhouse evaluation of nutrient properties of fertilizers
	Economists–Economics of handling fertilizers in bulk vs bags
	Engineers–Quality control in the manufacturing plant
11:30–11:45	Multination time
11:45–12:45	Lunch

12:45– 2:15	*Agronomists, Economists, and Engineers*–Pilot-plant demonstration of ammoniation-granulation
2:15– 2:45	Break
2:45– 4:00	New Devland panel problem
Day No. 18	FIELD TRIPS
8:30– 4:00	*Agronomists, Economists, and Engineers*–Field trip to study equipment for applying fertilizer to the soil
Day No. 19	STORAGE AND DISTRIBUTION
8:30– 9:30	Distribution systems and in-transit storage for fertilizers
9:30–10:00	Break
10:00–11:30	*Agronomists*–Adjusting fertilizer recommendations to available fertilizers
	Economists–Cost determination throughout a system of marketing and distribution
	Engineers–Mechanical vs manual handling systems
11:30–11:45	Multination time
11:45–12:45	Lunch
12:45– 2:15	*Agronomists*–Dependence of crop yield on fertilizer, variety, and yield
	Economists–Developing cost comparisons of two or more production and distribution systems
	Engineers–Value of high analysis in cost of transporting and handling fertilizers
2:15– 2:45	Break
2:45– 4:00	New Devland panel problem
Day No. 20	FERTILIZER PRICING
8:30– 9:30	Components of price
9:30–10:00	Break
10:00–11:30	*Agronomists*–Estimating cost-benefit ratios for use of fertilizers
	Economists–Effect of policy for various price components on a country's economy
	Engineers–Visit to NFDC nitric acid plant
11:30–11:45	Multination time
11:45–12:45	Lunch
12:45– 2:15	*Agronomists and Economists*–Pricing of fertilizers in relation to crop value, use, and stability of farm prices
	Engineers–Visit to NFDC bulk blending tower and liquid fertilizer plant
2:15– 2:45	Break
2:45– 4:00	New Devland panel problem
Day No 21	CAPITAL AND CREDIT
8:30– 9:30	Capital and credit for fertilizer plant construction and fertilizer use
9:30–10:00	Break
10:00–11:30	*Agronomists*–Adjusting fertilizer recommendations on basis of farmers' management abilities

	Economists–Sources of funds for financing fertilizer plants
	Engineers–Estimating plant construction costs
11:30–11:45	Multination time
11:45–12:45	Lunch
12:45– 2:15	*Agronomists*–Fertilizing for high yields to increase food production
	Economists–Financing agricultural production and fertilizer use by farmers
	Engineers–Estimating plant operation costs
2:15– 2:45	Break
2:45– 4:00	New Devland panel problem

Day No. 22	RESEARCH AND DEVELOPMENT
8:30– 9:30	Organizing research and development programs
9:30–10:00	Break
10:00–11:30	*Agronomists and Economists*–Agronomic-economic research for increasing agricultural production–problems, goals, and solutions
	Engineers–Construction and operation of pilot plants
11:30–11:45	Multination time
11:45–12:45	Lunch
12:45– 2:15	*Agronomists*–In-service educational programs
	Economists–In-service educational programs
	Engineers–In-service educational programs
2:15– 2:45	Break
2:45– 4:00	New Devland panel problem

Day No. 23	FIELD TRIPS
8:30– 4:00	*Agronomists, Economists, and Engineers*–Field trip to test demonstration and rapid adjustment farms

Day No. 24	FACTORS IMPEDING USE OF FERTILIZERS
8:30– 9:30	Factors impeding use of fertilizers
9:30–10:00	Break
10:00–11:30	*Agronomists and Economists*–Factors impeding use of fertilizers
	Engineers– Visit to TVA pilot plants
11:30–11:45	Multination time
11:45–12:45	Lunch
12:45– 2:15	*Agronomists and Economists*–Factors impeding use of fertilizers
	Engineers–Scaling up from pilot plant to production plant
2:15– 2:45	Break
2:45– 4:00	New Devland panel problem

Day No. 25	FERTILIZER EDUCATIONAL AND PROMOTIONAL PROGRAMS
8:30– 9:30	Fertilizer education and promotion: comparison of government, local company, and international company programs
9:30–10:00	Break
10:00–11:30	*Agronomists and Economists*–Role of agronomists and economists in government programs
	Engineers–Role of the engineer in providing technical information to others
11:30–11:45	Multination time
11:45–12:45	Lunch
12:45– 2:15	*Agronomists and Economists*–Role of agronomists and economists in commercial programs
	Engineers–Visit to TVA pan granulator
2:15– 2:45	Break
2:45– 4:00	New Devland panel problem
Day No. 26	STATISTICAL DATA
8:30– 9:30	Statistical data requirements for production, marketing, and use of fertilizer
9:30–10:00	Break
10:00–11:30	*Agronomists and Economists*–Statistical reporting services: value and use
	Engineers–Trip to NFDC chemical development laboratories and fertilizer storage facilities
11:30–11:45	Multination time
11:45–12:45	Lunch
12:45– 2:15	*Agronomists and Engineers*–Agronomists and engineers in relation to fertilizer control legislation
	Economists–Visit to NFDC computer facilities
2:15– 2:45	Break
2:45– 4:00	New Devland panel problem
Day No. 27	FERTILIZER COMMUNICATIONS
8:30– 9:30	Communications process in theory and action
9:30–10:00	Break
10:00–10:30	Communicating within an organization
10:30–11:30	Communicating in a developing country
11:30–11:45	Multination time
11:45–12:45	Lunch
12:45– 4:00	Communications workshop
Day No. 28	FIELD TRIPS
8:30– 4:00	*Agronomists, Economists, and Engineers*–Field trip to commercial fertilizer plant

Day No. 29	FERTILIZERS FOR DEVELOPING COUNTRIES
8:30– 9:00	Deciding upon the need for fertilizers and a fertilizer industry in a developing country
9:00–10:00	Assessing fertilizer use potential
10:00–10:30	Break
10:30–11:30	Assessing educational potential
11:30–11:45	Multination time
11:45–12:45	Lunch
12:45– 1:45	Assessing manufacturing and import requirements
1:45– 2:15	Break
2:15– 3:15	Assessing economics of use and production
3:15– 4:00	Assessing communications program

Day No. 30	SEMINAR PREPARATION
8:30– 4:00	Each country participating in the International Training Course is required to organize and present a one-hour seminar. The seminar should be concerned about the present status, potentials, problems, and suggested solutions of fertilizer use and the fertilizer industry of the country. This day is allotted for final preparation of the seminar material.
Days No. 31-35	FIELD TRIP
8:30– 4:00	This week will be spent on an extended field trip for all participants. Although the places visited may vary from course to course and depending upon the background and interests of the participants, the trip generally will have the purpose of visiting various farming areas and manufacturing facilities.
Days No. 36-37	SEMINARS
8:30– 4:00	These two days, or as much of the time as is needed, will be used for the presentation of seminars by the participants. Unused time will be used for consultation with the TVA staff on special problems.
Days No. 38-39	CRITIQUE
8:30– 4:00	In order to continually improve the quality of the International Training Course and to adapt it to the needs of participants, TVA requests participants to pass judgment on the course. The first day is used for a written critique and the second for an oral critique. Unused time will be used for consultation with the TVA staff.
Day No. 40	PACKING
8:30– 4:00	During the International Training Course each participant will accumulate a considerable volume of printed material. This day is provided for packaging such materials for shipping to the participants' home country. This day also will be used by the participants to bid goodbye to their friends.

Fertilizer Production Shortcourse

Day No. 1	RAW MATERIALS
8:30– 9:00	Orientation
9:00–10:00	Raw materials for fertilizer production. Phosphate rock, fixed nitrogen, potash and sulfur
10:00–10:30	Break
10:30–12:00	Characteristics of phosphate rock from various sources
12:00– 1:00	Lunch
1:00– 2:00	Mine-site vs. use-site processing of phosphate rock
2:00– 2:30	Break
2:30– 4:00	World trade demand for raw rock, phosphate intermediates and finished phosphates
Day No. 2	PHOSPHORUS FERTILIZERS
8:30– 9:30	Production, marketing, and use of phosphorus fertilizers
9:30–10:00	Break
10:00–12:00	Design and operation of phosphoric acid plants
12:00– 1:00	Lunch
1:00– 4:00	Design and operation of ordinary and triple superphosphate plants
Day No. 3	AMMONIUM PHOSPHATE FERTILIZERS
8:30– 9:30	Production, marketing, and use of ammonium phosphates
9:30–10:00	Break
10:00–12:00	Design and operation of ammonium phosphate plants
12:00– 1:00	Lunch
1:00– 4:00	Flexibility of diammonium phosphate processes and plants
Day No. 4	POTASSIUM AND MIXED FERTILIZERS
8:30– 9:30	Production, marketing, and use of potassium fertilizers
9:30–10:00	Break
10:00–11:00	Characteristics of potash materials
11:00–12:00	Use of potash in mixed fertilizers
12:00– 1:00	Lunch
1:00– 2:00	Production, marketing, and use of homogenous mixed fertilizers
2:00– 2:30	Break
2:30– 4:00	Design and operation of ammoniation-granulation plants
Day No. 5	PHYSICAL PROPERTIES
8:30– 9:30	Producing and maintaining good physical properties in fertilizers
9:30–10:00	Break

10:00–11:00	Identification of compounds in mixed fertilizers
11:00–12:00	Quality control in the manufacturing plant
12:00– 1:00	Lunch
1:00– 2:00	Distribution systems in in-transit storage for fertilizer
2:00– 2:30	Break
2:30– 3:30	Mechanical vs. manual handling systems
3:30– 4:00	Course summary

Fertilizer Marketing Shortcourse

Day No. 1	BULK BLENDING
8:30– 9:00	Orientation
9:00–10:00	Production, marketing, and use of bulk blended fertilizers
10:00–10:30	Break
10:30–12:00	Location of blending plants and economics of bulk blending
12:00– 1:00	Lunch
1:00– 4:00	Field trip to bulk blending plant
Day No. 2	FACTORS IMPEDING FERTILIZER USE
8:30– 9:30	Factors impeding fertilizer use
9:30–10:00	Break
10:00–11:00	Assessing agricultural needs and potentials for fertilizer use
11:00–12:00	Agronomic vs. economic response to fertilizers
12:00– 1:00	Lunch
1:00– 2:00	Statistical data requirements for marketing and use of fertilizers
2:00– 2:30	Break
2:30– 4:00	Statistical reporting services: value and use
Day No. 3	MARKETING SURVEYS
8:30– 9:30	Techniques of making marketing surveys
9:30–10:00	Break
10:00–12:00	Market surveys at the local dealer level
12:00– 1:00	Lunch
1:00– 4:00	Making market surveys for a company on a regional basis
Day No. 4	EDUCATION AND PROMOTION
8:30– 9:30	Fertilizer education and promotion, a general discussion
9:30–10:00	Break

10:00–11:00	Role of the economist in program development
11:00–12:00	Communications process
12:00– 1:00	Lunch
1:00– 4:00	Communications workshop

Day No. 5	MERCHANDISING TECHNIQUES
8:30–12:00	Techniques of making sales calls. Use role playing situations to illustrate effective sales methods
12:00– 1:00	Lunch
1:00– 3:30	Techniques of conducting farmer education and sales meetings. Use role playing situations
3:30– 4:00	Course summary

SECTION 3
USING THE PROBLEM-SOLVING TECHNIQUE AS A TEACHING TOOL

Lectures and discussions rarely are followed immediately by examinations, especially in non-scholastic courses. Instructors thus have difficulty in evaluating their ability to teach specific bits of information and in determining whether students can apply the right information in the right way. The usual procedure is to repeat information several times—each time in a slightly different way or in a new context. There is an alternative, one that fills many needs: use the problem-solving technique as one of the teaching tools.

Problem-solving is not new. "Problems" are an everyday assignment for first-grade pupils in arithmetic. This is the way they learn that number theory has practical applications. Chemistry laboratory courses and field trips to classify soils again are problem-solving situations whereby lectures and discussions are reinforced and/or applied to a practical situation. Apprentice training programs are a combination of theory and practice.

In all these situations, the training group has some homogeneity. First graders are young children, five to eight years old; college students in a chemistry course have had somewhat similar preparation for their laboratory work; apprentices are learning specific skills that will qualify most of them for similar jobs.

But students in a course on fertilizer production, marketing, and use have no such unifying characteristics. They come with diverse backgrounds and depart for vastly different jobs. A set of well-designed problems will mold such people into a unique group—one that has rapport with the instructors while calling for the utmost capabilities of its individuals.

The objectives of the problem-solving teaching technique, then, are three:

1. Reinforce lectures and discussions
2. Apply theory to practical situations
3. Provide practice in communicating and working with others

Objectives 1 and 2 are rather easily accomplished. Just follow the examples in an arithmetic book. Objective 3 is the crucial one! It provides the payoff in evaluation: Are the teachers teaching? Are the students learning? Objective 3 can make learning an enjoyable experience or, if not handled properly, a real drudge. When problems are designed with Objective 3 firmly in mind, Objectives 1 and 2 become more meaningful. Problem preparation, however, takes on a more formidable aspect.

Before discussing the characteristics of suitable problems, let us consider for a moment just what we are trying to accomplish when we teach. We are not concerned here with a specific course but rather with the philosophy of teaching. Obviously, the acquisition of facts and figures, of theory and principles, and of technique is important. But most facts, figures, theories, and techniques are transitory. New, more precise ones keep intruding. So, we teach where to find the latest needed information. Even more important, we teach students to use facts and figures properly and to become independent beings by the process of thinking for themselves and in concert with others. Hopefully, they will glean an opinion here, collect a couple of facts there, obtain a half dozen figures somewhere else, and synthesize all into a brilliant, new concept. This, also, is what we want of our problems.

Our experience at the National Fertilizer Development Center has been with diverse groups: participants from several countries at the same time—rarely all speaking a single language—several professions represented—a tremendous spread in age, educational background, and job responsibility—and an interest in training ranging from apathy to a real thirst for knowledge. Very early we recognized that we could not provide each individual the facts and figures that he wanted and needed for his own particular job. In some cases we knew very little about the country from which a student came and knew even less about its fertilizer needs and problems. It was obvious that we could not tailor our instruction and problems to suit each individual's unique position—or could we?

Developing countries have many similarities regardless of whether they are located in Africa, Asia, or Latin America. We used these similarities in constructing a series of problems that had conditional answers. In other

words, we found that problems suitable for our purpose had three characteristics:

1. They were based on situations common to many countries
2. They were interdependent, each problem building upon the solutions to previous problems
3. They permitted several plausible solutions, depending upon the knowledge devoted to the solution

New Devland—A Setting for Fertilizer Problems

For our international training courses, we "invented" a new country. We called it New Devland and described it in a booklet (Section 4, p.199). The description is based on the similarities among lesser developed countries: high rate of population increase, agriculture the dominant source of income and employment, little experience in using fertilizers, increasing demand for imported goods, disappearing markets for exports, etc. This mythical country then serves as the base for a set of integrated problems on how to initiate a fertilizer program. Information from the daily lectures and discussions is pertinent to solving the problems but students must call on their own abilities to use the information properly.

There are instructional advantages to using an artificial situation. Insofar as our own multination course is concerned, we are able to use a single country with a single set of parameters. This saves time and avoids confusion [illegible] lems were adapted to each specific country represented by students, many details would have to be repeated time and time again with but little change from country to country. New Devland, however, is not completely unfamiliar to the student. It has characteristics from Latin America, Africa, and Asia. It has a definite location because distance from various world ports is an important consideration in development. By the time we had finished describing this country, it had more problems than any single developing country. Use of a mythical situation facilitates free criticism of customs, practices, official acts, or even individuals without embarrassing a real individual. This frequently is desirable because the success or rate of progress of many agricultural programs depends upon the knowledge and attitudes of government officials and company administrators.

There are other advantages to using an artificial situation. The situation can be described in as much or as little detail as the instructor desires. Theoretically, this puts each student on an equal footing with all other students. No student, regardless of his origin or education, can really know more than the instructor specifies. However, each student can, and should extrapolate his own experiences and knowledge to the problem situation.

Solutions to problems, then, can be quite variable. Some students lack experience (or lack experience in areas specified by a particular problem) and must use only recently acquired knowledge in solving the problem. Other students, with much experience and knowledge, develop quite sophisticated solutions. Our goal, however, is not to emphasize what a student does not know but rather just the opposite: to capitalize on what students do know.

Problems are not assigned to individuals. Progressive organizations now hire very few people to work as individuals. Rather, they want teams. Teams are composed of several disciplines and members of the team must learn to communicate with each other as well as to management and to the technicians who work with them. We simulate this situation; problems are assigned to "teams" or "panels." We use three people on a panel for a couple of reasons. Fertilizer production, marketing, and use implies three main professions—chemical engineering, economics, and agronomy—and these three professions should work together in developing any fertilizer program. Therefore we try to have each of the professions represented on a panel, thus ensuring that no aspect will be overlooked entirely. A reason for limiting the panel to three is the communication problem. We deliberately assign men from different countries to work together. Language dificulties sometimes impede but usually it is the difference in attitudes that keep a group from reaching a solution quickly. Erosion of attitudes, opinions, and prejudices to the hard core of sound engineering, economic, and agronomic principles is a requisite for good solutions. If all else fails, a vote among three—or any other odd number—will result in a solution.

Working as a team, with each member contributing his own specialized knowledge and experience toward a common solution, builds self-confidence. When a person performs satisfactorily as a member of a team here, he can do so also when he returns home. Also, he will be more likely to seek the opinion of a friend or acquaintance in another profession in evaluating some particular problem.

Techniques That Work

Assuming that all problems will be based on a single, well-described situation, the first decision in problem writing is: How many problems? The answer really hinges on how frequently problems should be scheduled. If problems are too frequent, they dilute the quality of the training. They consume an undue proportion of time and detract from other parts of the training schedule. On the other hand, problems must not be so rare that they encompass large amounts of lecture/discussion information. Most any one can paint with a broad brush and solve problems with superficial generalizations. It's the fine strokes and attention to details that give substance to a picture—and to a problem solution too.

Panel Problem No. 1

WHAT IS THE QUANTITY OF PLANT NUTRIENTS NEEDED ANNUALLY BY NEW DEVLAND, 1966-1970?

At 9 a.m. this morning you received a telephone call from the Minister of Agriculture asking that you be in his office in the capital city of Las Lunas at 1 p.m.

It is now 1 p.m.; you have just entered the Minister's office. The Minister makes introductions as follows:

1. Head of the Department of Crops and Soils, University of Las Lunas
2. Chief Engineer, Ministry of National Development
3. Assistant Chief Economist, Ministry of Economic Affairs
4. A technical team from the United States which is introduced as being from TVA; it includes an agronomist, a chemical engineer, and an economist.

After a few minutes, the Prime Minister of New Devland also enters and introductions are again made. The Prime Minister takes charge of the meeting. His remarks can be summarized briefly as follows: New Devland is primarily an agricultural country but industrial growth is excellent. Population also is growing; in fact, it is increasing at the rate of 3% per year. Within two years the production level in New Devland is forecast to be critical for some food crops. He had requested AID assistance in determining what steps should be taken by his country to forestall predicted shortages. A reconnaisance team had recommended that increased fertilizer use had the greatest potential for aiding the country and the present team from the TVA was a result of this recommendation.

The Prime Minister designated the three men from New Devland as a special commission to work with TVA team in preparing various reports to be submitted to the Minister of Agriculture. The Ministry of Agriculture was prepared to provide any assistance needed in the way of travel arrangements, typing of reports, or information.

After concluding the above remarks, the Prime Minister excused himself to meet another engagement. The Minister of Agriculture requested the leader of the TVA team to explain the objectives and general nature of the survey. The team leader explained that the survey was to be completed in one month. The survey would provide an estimate of the potentials for fertilizer use in New Devland, recommendations for obtaining the fertilizer, and suggestions for a program for getting farmers to use fertilizers. He asked the Special Commission to meet with the technical team at 3 p.m.

At the 3 p.m. meeting, the TVA team suggested that the first information needed was an estimate of the quantity of plant nutrients needed annually by New Devland for the five-year period, 1966-1970. The first estimate was to be in total tons each of N, P_2O_5, and K_2O, without regard to the exact nature of the fertilizer material. During the discussion it was decided that the estimate should be broken down on the basis of each of the four geographical areas. Also during this discussion, it was found that New Devland had practically no information regarding the response that could be expected from the fertilization of crops in the various areas. It was decided that the rate of fertilization would be based, then, upon personal knowledge of rates used by other countries.

PROBLEM

You represent the Special Commission. Your job is to prepare the estimated N, P_2O_5, and K_2O requirements for each area and the total requirement of New Devland for the years 1966, 1967, 1968, 1969, and 1970. The report is to be ready in 48 hours.

At the National Fertilizer Development Center we have tried both two and four problems per week. With only two problems, the application of theory to practice lagged further and further behind the daily discussions. When we tried four problems per week, we had to be very careful not to outpace the discussions. We had other difficulties also. Probably three problems per week would be most satisfactory. But, with a five-day training week, structured for the mid-day to be used for field trips, a three-problem schedule is awkward. Ideally, a problem is scheduled whenever a "unit" of instruction has been completed. The number of problems per week might vary, then from none to four or five.

Each problem should be built on the solution(s) to a

Panel Problem No. 2.

SHOULD NEW DEVLAND BUILD ITS OWN AMMONIA PRODUCTION FACILITIES? IF SO, WHERE SHOULD THEY BE LOCATED AND HOW LARGE SHOULD THEY BE?

The Special Commission already has experienced some sharp differences of opinion regarding the estimated need for fertilizers. The Chief Engineer from the Ministry of National Development insisted that the estimate was unrealistic because New Devland could not obtain capital to construct the necessary manufacturing plants. He continually brought up the need for other types of industrial plants in New Devland and justified these needs as being of equal or greater importance than fertilizer plants. The Head of the University's Department of Crops and Soils was amazed at the total fertilizer needs of the country. He was ready to agree with the Chief Engineer until the engineer made an unfortunate remark about the Department Head being a "real storehouse of knowledge." The agronomist decided immediately to defend his figures, right or wrong. This left the economist in the position of having to decide either with the engineer or with the agronomist. With considerable reluctance, he voted to support the agronomist.

The nitrogen needs for New Devland have been estimated for the next five years to be as follows:

Year	Chama Valley	High-lands	Eastern Plateau	Total
	metric tons			
1966	30,201	356	2,623	33,180
1967	36,919	434	3,406	40,759
1968	41,826	532	4,025	46,383
1969	48,205	637	4,665	53,507
1970	54,877	736	5,573	61,186

The Minister of Agriculture and the Chief Engineer have expressed a very strong desire for New Devland to produce its own fertilizers. They have strong support. An ammonia plant and other fertilizer facilities would add measurably to national pride. They also have planned that surplus production of the plant, especially during the first few years, could be sold on the world market; thus, New Devland aspires to be an exporter of fertilizers.

Several politicians also are exerting pressure for the construction of an ammonia plant. The Congressman from San Miguel has obtained information from a German firm that relates how lignite has been used in the synthesis of ammonia. He believes that the lignite deposits in his area should be utilized for this purpose. Representatives from the Eastern Plateau speak of their area as the new frontier of New Devland. They point out that fertilizers will be necessary, however, for the area to be farmed profitably. It is most reasonable, they argue, to establish fertilizer plants in the area where most of the fertilizer eventually will be used.

In contrast to the above attitudes, the Chairman of the Hospital Board of Las Lunas General Hospital is opposed to an ammonia plant near the capital city. He considers the manufacture of ammonia to be dangerous and believes such an industry should be located away from populous cities.

PROBLEM

You still represent the Special Commission. You must prepare a report for the Minister of Agriculture that unequivocally recommends for or against the construction of one or more ammonia plants. If your recommendation is for plant construction, please state where the plant(s) is to be located, what should be used for feedstock, where the feedstock is to be obtained, and what capacity the plant(s) should have. Also indicate when the plant should come on stream. You have 48 hours to prepare your report.

previous problem(s). Thus, a new problem cannot be written–except in general terms–until the solution to the previous problem has been presented. This is one of the disadvantages with scheduling problems too frequently. There just isn't enough time between problems for the instructor to write continuing-type problems.

Building one problem upon another allows the instructor to maintain firm control over learning. When a panel presents a solution that does not fit the facts, the instructor has two choices: he can make a correction by incorporating his solution into the next problem or he can let the situation ride until some later problem.

The first choice is advisable when diverse solutions have been presented, perhaps by different members of the panel or perhaps as suggestions during the discussion of a panel's solution. It also is the precedure to use when errors have been made in mathematical calculations. The instructor (problem writer) inserts and uses corrected figures for future problems. The latter choice is an excellent teaching tool. Sooner or later, some panel will founder because its problem is based on the false tenets of the improperly solved problem. The instructor must guard against overuse of this technique else too much time will be lost from other worthy problems.

Having determined the approximate content of a problem, i.e., the topics covered during lecture/discussion sessions, the problem writer now must accomplish several things simultaneously.

1. He must select those parts of the lecture/discussion that are worthy of repetition and concentrated attention.
2. Within the context of his artificial situation, he must devise a problem that permits these parts (theories) to be applied to a practical situation.
3. He must construct a problem that is broad enough to utilize the knowledge and skill of more than one profession as well as requiring information from the lecture/discussion sessions.
4. To provide the maximum learning experience, the problem writer makes sure that the problem admits alternative solutions.
5. Except for the first problem, the writer integrates each succeeding problem with the preceding problem(s).
6. He presents the problem in a style that stimulates interest and yet demands attention to details.
7. He avoids ambiguity in communicating with the panel. Even though the problem situation may be described in broad terms, he is very definite about the specific objectives of the problem.

All these "requirements" may seem formidable. To illustrate that they are not, two problems follow. They are based on New Devland. Both have been used by the National Fertilizer Development Center in its training courses essentially as shown on the two preceding pages.

Both problems indicate just 48 hours are available for a solution. We have tried as little as 30 minutes and as much as four days. Thirty minutes is adequate for a team to develop several good ideas but is not long enough for it to weigh the merits and demerits of each idea. Four days of deliberations has not produced solutions two times better than those developed in two days or four times better than a 24-hour solution. Many Students delay starting an assignment until just before the deadline and then work diligently well beyond normal working hours. Frequently a solution developed under some time pressure is just as satisfactory as one reached at a slower pace.

One of the objectives of the problem-solving teaching technique is to provide practice in communicating and working with others. Using teams or panels to solve problems goes a long way in accomplishing this objective. But communications practice can be extended still further. Our panels do not prepare a report to be submitted only to the instructor. Their report is submitted to their classmates–verbally. We set a time limit of 30 minutes for this presentation and allow another 30 minutes for questions and discussion. Following this, there is a critique of the solution. Let's consider these three aspects in more detail.

Panel Presentation

We do not require that each member of the panel make an oral presentation. This is a team effort and the team determines how to meet its assignment. When participants are assigned to a panel, we do designate one man as chairman. This man is not necessarily the one with the most education or the most experience. Neither must he be one of the class leaders–although we expect that he will be a leader when he returns home. In most panels, the chairman is just another member of the team. But he is the member who, if necessary, oversees all aspects of solving the problem and presenting the solution. He determines–almost always in consultation with his fellow-panelists–whether the work of data collection is to be subdivided among the panelists or not. Similarly he decides whether he will make the oral presentation, shift his duty to another member (perhaps to one who has had much experience in public speaking), or divide the presentation into two, three, or even more sections with each panelist participating

actively in the presentation.

For problems as broad as the two illustrated above, 30 minutes is required to make an adequate presentation—if the panel has spent sufficient time in developing a solution. Teams that fail to work intensively on a problem find that 30 minutes is a long time to be filled with extraneous matter. Just one such presentation convinces the class that they had best work when their panel assignment is made.

We insist that our panelists use visual aids just as our own lecturers and discussion leaders do. When all communication is audio, it can become dull in a hurry. A visual to stress a point here and there, an outline projected on the screen so the audience follows the plan, a schematic diagram or even a short table of data exhibited to the audience—all do two things. They serve as a "prop" to guide the speaker in his presentation. Visuals also are a part of communications, and practice in their use is a part of the training objective.

Group Discussion

Normally a panel makes its presentation without interruption. Exceptions are due primarily to re-pronunciation or minor clarification of meaning as the words of the speaker are translated into other languages or are assimilated by an audience not familiar with the speaker's inflections. At the conclusion of the presentation, the moderator opens the session for general discussion and questions from the floor. This discussion takes many forms: questions seeking clarification of some point, requests for more details about how certain data were used in arriving at a particular decision, accolades for having done certain things exceptionally well, alternative solutions, and a host of general comments.

The group discussion has been an especially effective medium for exchanging ideas and experiences from all over the world. Participants readily identify a problem situation with one in their own country or locality. They inject local research results and personal observations into the discussion and ask how the panel's solution must be warped to fit "my problem." Answers and suggestions may come from half a world away or from a next [illegible] or neighbor. The astute moderator permits a ge[illegible] amount of this type of discussion but guards the d[illegible]ion from straying too far from the problem of the day. He also insures that all who wish to make comments (but not necessarily speeches) have an opportunity to do so in the half-hour allotted for discussion.

Occasionally a class will contain a few particularly adroit individuals who may form a "loyal opposition." Regardless of the solution presented by the panel, the loyal opposition has an alternative solution. Again, the moderator exploits the situation in order to increase learning. Most problems do have many parts and the solution finally adopted is dependent upon the relative emphasis given to one or another of its parts. The loyal opposition and its supporters admirably serve the function of illustrating how needful it is for a team or many professionals to participate in a final decision.

Critique

In developing the concept of teaching with panel problems, the instructor or training committee must decide whether or not there will be an "official" solution for each problem. Almost without exception, participants in our short courses have asked for the "TVA solution" or the "right answer" to the problem. As mentioned earlier, most problems are composed of many parts. Only a few of these parts can be evaluated adequately with available data and other information. The final solution is very dependent upon the relative emphasis given to the various less tangible parts. Some decisions also must consider the management ability of those who carry out the decision. Whereas a conservative might require 90–10 odds of succeeding before starting a new business venture, others with a real flair for management require only 50-50 odds. To a certain extent, our panels resemble these different entrepreneurs. Some are very methodic[illegible] in listing and evaluating data and surround their solutions with many hedges. Other panels seem intuitively to grasp the crux of a problem and to develop a fitting solution but not necessarily one that "fits the facts." Little wonder, then, that the students want to check their opinion and the panel's solution against a "correct answer." For some situations, such as in courses where grades are issued, a single, correct answer probably is desirable. This is not the practice that we follow.

Much more difficult to handle, but a method that has a lot of merit, is the "acceptable" solution. We have consistently maintained that there is no "right" answer but there may be many acceptable answers to the problems we write. To a certain extent our action is protectionist. There is a possibility that an "official" solution will be applied to a situation in a developing country that resembles the one described in a problem. If the solution ultimately proves unwise, who is to blame, TVA or someone else? Instructors can avoid the

same possible misunderstanding by resisting all requests for a coherent or official solution.

There is a better reason for using the acceptable solution, however. This is the need to teach and demonstrate the adaptability of theory and sound evaluative procedures to situations in less developed and other areas. Many of the problems—as illustrated earlier—are very broad. A correct solution requires days and days of intensive study and evaluation. We do not allow such time to our panels for this is not the objective of this training technique. When a panel demonstrates that it knows what data to select, how to evaluate the data, and that the experience and knowledge of more than one professional discipline has been used in the solution, we are satisfied. An "acceptable" solution has been presented. The panel has showed that classroom instruction is applicable to a country that resembles their own.

We do go one step further. We criticize the solution. Here lies the difficulty of the method. The critique pertains to the solutions given by the panel and to alternative solutions presented by the floor or the loyal opposition. Not only must the instructor pay close attention to all that is said during this hour, but he must also prepare his own constructive suggestions during the same period. Because shortcomings of a panel most likely are detected by classmates in the audience, the instructor constantly re-evaluates the comments that he needs to make. If he has not been especially diligent, he may find that his note pad is empty when it is time for his suggestions.

Since problems range across many disciplines and since the panel itself is multidisciplinary, an instructor trained in a single profession usually cannot present the entire critique. Two or more experts are needed. We suggest that one of these participate in all problems in order to provide consistency in critique standards and continuity from one problem to the next. The instructor could well be the moderator that was described earlier. The additional expert(s) should have abilities that complement those of the moderator or principal instructor. For our panel problems we preferably invite as our guest experts those who have had experience in a developing country. They are best qualified to evaluate whether or not a panel has adapted U.S. methods and theory to a developing country situation.

The critics may find that even they disagree on the details of a solution. Rarely, however, would they disagree on a major decision. Almost always disagreement can be ascribed to either inadequate time to study background information or to professional differences in evaluating various types of information. When a compromise is indicated, it should be worked out immediately if time permits. Otherwise, a need for additional study and evaluation should be indicated. This is not at all undesirable because it illustrates a common happening in the business world.

One additional point concerning a critique perhaps needs to be mentioned. This is the method of making criticisms or constructive suggestions. Obviously, these must not be directed to any individual but just as obviously, a panel is being criticized before its peers. Most people resent criticism regardless of its guise. We pre-condition our classes by describing to them exactly how a panel problem will be handled—including the critique. We also use the sandwich method of presenting our suggestions for a better solution. Most panels work hard and develop a commendable solution. These accomplishments should be recognized. So, we divide our compliments into two parts and "sandwich" our criticism between them.

Our experience is that the acceptable-solution method with its accompanying critique provides another strong teaching/learning situation. The same technique can be used, by analogy, for almost any problem situation that might be used in a training course.

Measures of Success

Teaching ability is difficult to evaluate. Elsewhere we have discussed and illustrated a critique for the entire training course. This critique includes questions on panel problems. Obviously our students have reacted favorably to them else we would not recommend their use. We also have pointed out that panel problems in themselves serve as a check on teaching effectiveness.

Just how effective short course training can be, however, was brought into startling focus during one course. A visiting dignitary, well known to many students in the class, expressed a great interest in the problem-solving teaching technique. The students agreed to demonstrate the technique for their fellow countryman. Due to an extreme shortage of available preparatory time, they decided to re-enact an old problem rather than to tackle a new one. (Copies of scripts and visuals are preserved until at least the end of a course and so the panel planned to read their original solution.) About midway through the reading, however, the panel's spokesman came to an abrupt halt. "Mr. Moderator," he exclaimed, "I no longer agree with this solution. We have learned so much more since we worked on this problem three weeks ago that this solution isn't right!" Although he did continue with the reading in order to complete

the demonstration, his remarks were a measure of the success of the training course in general and of the problem-solving technique in specific. Attitudes can and do change as people work together on a common problem. New knowledge. . .greater breadth in thinking . . .increased self-confidence. . .a better understanding of the interplay of many factors in decision making—all these contribute to this change. It isn't often that the instructor obtains such direct evidence of his effectiveness. When it happens, however, it is most reassuring.

We have had still another measure of success. In a training course lasting six or seven weeks, we may use 50 to 75 different people to present the lectures of the day and to lead the various in-depth discussions. Several will have had experience working in developing countries but most will not. No particular attempt is made by the training committee to involve these teachers in panel problems except [illegible] some of them are called upon to be expert critics. When a group as diverse as this is in teaching [illegible] and interest and in professional training and knowledge begins to focus attention on the problems of the students rather than on their own research problems, the instructor can again chalk up a success.

One final caution: Don't let the panel problems control the training course. The course must be structured to provide the information needed by the student body. Panel problems should be designed after the course has been outlined. They have three objectives:

1. Reinforce lectures and discussions
2. Apply theory to practical situations
3. Provide practice in communicating and working with others.

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RESOURCE MATERIALS

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IMPORTANCE OF AGRICULTURE IN ECONOMIC DEVELOPMENT

A. Economic development defined

Economic development is learning to (1) produce higher quality goods with fixed resources or (2) produce more of the same quality goods with fixed resources.

There are many differences between developed and undeveloped areas. The most easily observed difference is the amount and kind of food consumed. People in developed countries usually have higher quality food, receive higher incomes, live longer, are more fully employed, are better educated, and have more services, such as medical, education, transportation, and water supply.

Economic development is essentially a process of learning, changing, and creating more of what man wants from fixed natural resources. Resources available in the world have changed very little during recorded history—but how they are used and what they produce have changed.

B. Area development

The Tennessee Valley is an example of a backward area developing. It had about the same relationship to the rest of the United States in 1930 as the present less developed countries now have to the developed countries. Studying the Tennessee Valley illustrates how an area can develop both agriculturally and industrially.

1. Increased food production—Value of farm product sales in the Tennessee Valley increased twelve-fold since the initiation of TVA. Much of the increase has been in changing the quality of foods.

2. Produce more per unit of resource—Much of the increased production has been from increased efficiency. More is produced per acre and per animal.

3. Accumulate capital and substitute mechanical labor for human labor—After production expanded, farmers saved money to buy labor-saving devices and multiply the production of their labor.

4. Build nonfarm industry—When agriculture was producing efficiently, labor savings could be used in developing industry and producing nonfarm goods. The expansion of nonfarm enterprises too early in some countries has pulled critical resources (especially capital and skilled labor) from agriculture so fast that neither agriculture nor industry can develop at a satisfactory rate.

5. Enjoy part of benefits—Only after a person, an area, or a country is producing at a high level can it afford to increase consumption. In early development stages, little production can be consumed, since limited capital would be consumed and further growth retarded.

C. Agriculture contributes to total development

1. Subsistence—Food for production of present and expanded goods is the first requirement of development. Development usually creates demand for more and higher quality food.

2. Manpower—Labor born, reared, and educated on farms provides industry with a source of labor. It is the better educated individuals that leave farms for industry.

3. Capital—Savings in agriculture are used to build roads, furnish transportation, buy machinery, and build factories.

4. Foreign exchange—American tobacco and cotton bought the first industrial plants. About 80% of India's earned foreign exchange is from the sale of agricultural exports.

5. Stimulation to other sectors—Agriculture expands input purchases from industry as agriculture develops. Farm people provide a mass market for consumer goods from industry. Increases in farm income stimulate the entire economy. Estimates indicate an increase of $1 in farm sales generates $3 to $4 in other business.

D. Learning is the key to growth

In the United States at least half of the recent economic growth is due to new knowledge and faster communication of that knowledge. Another 11% is due to transferring unneeded land and labor from agriculture to industry.

Developing countries with high rates of growth in agricultural production—such as Japan, Taiwan, and Yugoslavia—have high population rates working in agricultural research. Almost without exception the countries with little research have not yet started rapid development. Fast-developing countries—such as Japan, Taiwan, and West Germany—have an average of 40 agricultural research workers for each 100,000 cultivators. Slow-developing countries have only eight research workers per 100,000 farmers.

E. The development process

1. Agricultural development must accompany or precede industrial development.

2. Increases in production must precede increases in consumption.

3. Development takes place inside an area—not outside.

4. Use of knowledge is the key to success.

Agriculture serves to stimulate other sectors. When agricultural production is increased, it starts a chain of events that makes possible and stimulates total development. Among these are such vital elements as capital for investments, exports to buy vital foreign exchange, and demand for industrial products that may later be produced. New knowledge applied to problems is the main ingredient of growth.

REFERENCES: 40, 84, 97, 168, 213, 221, 258, 271, 340, 341

ROLE OF FERTILIZERS IN AGRICULTURE IN DEVELOPING COUNTRIES

A. Introduction

Highly productive, sustained agriculture is always accompanied by liberal use of fertilizers. It is, however, difficult to say what share of the current world food output is attributable to fertilizers. No doubt a stopping of the use of fertilizer in the advanced agricultural countries like Japan and Western Europe would have a tremendous effect on agricultural production per unit area—much more so than a curtailment in developing southeast Asia where per hectare usage is still low.

Conversely, the developing, low-fertilizer-using regions have more to gain from the use of additional fertilizers than do those areas which now use large amounts of fertilizers. They also have more need for increasing their fertilizer usage to increase their indigenous food production.

B. Interaction with other inputs

Important as fertilizers may be, their effectiveness is dependent on the adequacy of other inputs. Without adequate root zone and available moisture, adapted crop and variety, and proper protection against disease and pests, fertilizers can have little effect on crop yields. Examples of interdependencies among inputs are numerous and point out the fallacy of an individual input approach.

Proper combinations of all inputs not only can improve the yield of any given crop but also can go a long way toward maximizing production from any given area of land and available solar energy. Keeping land occupied and solar energy used are essential to maximizing production in regions where seasonality does not severely limit crop production.

Mechanization in such a system becomes mandatory for timely performance of key operations that make even the cheapest hand labor costly. Mechanization can also overcome physical handicaps such as hardpans that severely limit production under any fertilization level. The availability of artificial drying facilities, which facilitate earlier harvests, can improve production efficiency per unit area of land.

C. Fertilizers as a "lead" practice

Acceptance of new and rejection of traditional practices by large masses of farmers are difficult to achieve. Farmers with limited resources, education, and vision are understandably hesitant to change from traditional practices. A key to overcoming this inertia in the Tennessee Valley and in other areas of the world has been to gain farmer acceptance of one or more practices which can be carried out easily and give quick, visible results.

Fertilizers can be such a "lead." Its effects show up quickly in growth and color and within a few weeks or months an increase in yield and/or profits is realized. Heavily cropped soils are generally quite responsive, especially to nitrogen and once a farmer's confidence is gained he is more apt to try other practices. Fertilizers are also easy to make and can, along with instructions for use, be put into the hands of demonstrators quite easily.

D. Economics of fertilizer usage

A demonstrated physical response to fertilizers does not ensure increased usage. The most

influential factor influencing farmers to use fertilizers is the prospect for increased financial returns. Wise use of fertilizers to assure profit is essential. Also, wise use of limited capital available for fertilizer and other inputs is important. Before conducting fertilizer demonstrations one must determine what is to be demonstrated and know the steps necessary to assure crop response.

Once an increase in production is attained, a stable market for the increased production must be assured. Lack of it can bring on failure and disaster.

Fertilizers are essential for increased agricultural production, but they will assure success only when used wisely.

REFERENCES: 60, 61, 101, 329, 334

ASSESSING AGRICULTURAL NEEDS AND POTENTIALS FOR FERTILIZER USE

A. Background

The reason for assessing present and future food and fertilizer needs in the developing countries is to increase food availability in line with increasing population, increased agricultural production, and increased economic growth.

More than 40 million metric tons of fertilizer are used annually in agricultural production throughout the world. On the basis of need, 80 to 100 million tons—twice as much—will be required by 1980. The problem is in countries where present fertilizer usage is low, future needs are greatest, and capacities are least to provide these needs. For example, in 1962-63, the developed countries of the world used 29.7 kg of fertilizer per hectare, while the developing countries averaged only 1.6 kg/ha; yet it is in the developing countries that population is expected to increase fastest.

B. Factors to consider in evaluating fertilizer needs in developing countries

1. Human factor

   a. Level of education and knowledge of the population—Agricultural production and fertilizer use are highest in the developed countries which have the highest levels of education and are lowest in the less developed countries, especially those with high rates of illiteracy. Rate of fertilizer use is thus correlated with the level of education on an individual basis and on a national basis. If developing countries are to increase agricultural production and fertilizer use, the governments of these countries must devote a larger share of the countries' resources to educational facilities and to teachers.

   b. Number and competency of extension workers trained in agriculture—Extension workers are necessary to take research results to farmers in order to motivate farmers into changing their habits and to adopt new ideas. In countries with few extension workers per 100,000 farm families, the chances of fertilizer use increasing dramatically are limited. Unfortunately, the number of extension workers is very low in developing countries; it is high in developed countries. Again the relationship is self-evident. Those countries with high yields and large agricultural output have allocated more resources to develop an extension service. In

developing countries it will be increasingly necessary to devote financial resources to the establishment, maintenance, and improvement of an agricultural extension service if fertilizer use and agricultural production are to increase.

c. Similarly, countries with high crop yields also have invested more heavily in research than those where yields have been low. If agriculture is to move ahead in developing countries, sufficient funds must be allocated to research to provide the knowledge necessary to help agriculture advance. Those countries in which yields have been low, and where the proportion of government expenditures to total agricultural output devoted to agriculture research and extension are declining, have little chance of increasing their agricultural production.

2. Land tenure arrangements—Traditionally, in both developing and developed countries fertilizer use and crop yields have been higher on land managed by owner-operators and by tenants who have a fixed rent per unit of land than by farmers who have a crop share rent. Because of inflexabilities, crop share leases have tended to favor the landlord more than the tenant. As a result, the tenant has had less incentive to use yield increased inputs such as fertilizers than has the owner-operator.

   For fertilizer use to increase in a country, rental arrangements must be such that the tenant and the landlord share in the increased output in the same proportion as they share expenses. If the tenant has to pay the total cost of fertilizer, there is less incentive for him to use the same amount of fertilizer or to use fertilizer at all than if the landlord and the tenant share in the cost of fertilizer in the same proportion as they share in receipts due to increased yields. Where tenants do not share expenses in the same proportion as receipts, the economic optimum for fertilizer use is lower than for the owner-operator or the tenant who has a fixed share lease. Where tenants share expenses in the same proportion as receipts, the economic optimum for fertilizer use is the same as for an owner-operator. Where land tenure arrangements are adverse, fertilizer use and agriculture output increase more slowly than is needed in most developing countries.

3. Size of farm holdings—Size of farm holdings does not have much effect on fertilizer use; however, fertilizer use and yields sometimes tend to be lower on very large plantations because the extra production resulting from higher fertilizer use may decrease local market prices if the landlord is an extremely large producer. Also, the extra income from higher yields may not have much utility and therefore the large land owner may have little incentive to increase yields. Alternately, where farms are so small that they do not provide an economic unit, farmers may not be willing to use fertilizer because they either do not have the money to buy it, or cannot get credit because of the uneconomic size of their farms. If either of these conditions exist, agricultural production of fertilizer use will be less than possible.

4. Capital, credit, and financial institutions

   a. Developed countries have high rates of capital to labor use in agriculture because the cost of capital has been relatively lower than the cost of labor. On the other hand, the cost of capital is extremely high for agriculture in developing countries. Labor is used instead of capital because the cost of labor is proportionally less than the cost of capital.

   b. Aside from the fact that developing countries are short in capital everywhere, a major reason why capital for farmers has been scarce is that the financial institutions such as banks, cooperatives, production credit associations, etc., have been nonexistent. Therefore, such monies as do exist often are not put to work. As a result, farmers rely on individuals rather

than institutions as a source of money. And individuals generally charge high interest rates since they cannot spread their risks over a broad area. Until financial institutions from which farmers can borrow exist, lack of available credit will restrict fertilizer use. Even if financial institutions are present in the developing country, an educational program probably will be necessary to convince their officials that fertilizer loans can be a sound investment.

If fertilizer use is to be increased in most developing countries, it probably will be necessary for the government to make capital available at reasonable interest rates for purchases of fertilizer. Where farmer capital is in short supply, as is typical in developing countries, the availability and use of credit for purchasing fertilizer must have high priority if the program is to have any success at all.

5. Demand, prices, and output

a. The relationship between the price of fertilizer and the price the farmer receives for crops is one of the most influential factors in increasing fertilizer use; it also is the factor most easily influenced by governmental policies. A policy of low crop prices can be contrary to oft-expressed governmental desire to increase agricultural production; when the marginal return on increased fertilizer use is low, or nonexistent, farmers have no incentive to use appreciable quantities of fertilizer. Unfortunately, it has been traditional for developing countries to keep crop prices low; at the same time, the high costs of importing and distributing cause fertilizer to be high in relation to crop prices.

b. Of the two, the most important is crop price since this affects the farmer's income much more than does the price of fertilizer. Although a high agronomic response is indicated, it is possible to have a situation in which farmers do not use fertilizer simply because the price of the crop is held down.

c. In addition, because farmers in developing countries have such low incomes, a return of 5% to 10% will not be sufficient to stimulate higher fertilizer use and increased output because the risks are too high. As a result, a return of 50% to 100% is more nearly necessary. To achieve this type of return, it will be necessary for the government to provide not only stable crop prices, but also a fertilizer price level that will result in a large return for the use of a yield increasing input such as fertilizer.

F. Marketing and transportation facilities

1. If fertilizer use is to increase in many developing countries, transportation storage facilities will need to be available. Inadequate transportation facilities result in delays in getting fertilizer to farmers in time for crop production and in getting farm output to consumers.

2. High transportation costs result in high fertilizer prices and less than optimal fertilizer use. Equally important is adequate storage facilities for storing both fertilizer and increased agricultural products resulting from higher levels of production.

REFERENCES: 31, 32, 33, 86, 127, 128, 129, 166, 252, 297, 298, 334

DETERMINING THE NEED FOR A FERTILIZER INDUSTRY

A. Introduction

No single mathematical approach can be used to determine the need for a fertilizer industry in a country. Need is dependent upon present and future effective demand for fertilizer, total resources available for producing fertilizer, and design of the optimum method of setting the required demands under constraints of these existing or purchasable resources. Estimation of effective demand cannot be precise, since the many variables which go to make up effective demand are so changeable and uncertain. Analysis of a country's resources may also need to be changed as new technology is discovered. With new technology, some new resources may become more valuable while others diminish in value. Thus, any task of determining the need for a fertilizer industry is not, nor can it be, mathematically precise in the final approach. The method used in studying the need within a country, however, can follow fairly well designed paths of (1) determining actual requirements, (2) determining resources which may be used to fulfill these requirements, and (3) investigating the various alternative production configurations which may be used to join supply and demand for a country.

B. Estimation of effective demand

1. Factors affecting effective demand—Many factors affect demand for fertilizer in any country over a period of time. Below are mentioned a few.

   a. Geography and climate—These should be studied to ensure that additional use of fertilizer can have high benefit/cost ratio. If the geography and climate are such that additional fertilizer use will not produce additional crops and dollars (and this is the case in some areas), there is no need for additional fertilizers–even though there may be need for additional food.

   b. Soils and crops—Different soils and different crops have varying capacities and efficiencies for use of increased amounts of fertilizer. There must be a certainty that the soils and crops of the region can respond favorably to additional fertilizer use before an estimate of increased use is made.

   c. Types of fertilizers customarily used—Farmers, like most everyone else, are generally averse to change. This should be taken into consideration when planning for specific industry plants. Customs and habits can be changed over time; they cannot be changed overnight.

   d. Crop/fertilizer price relationship—Effective demand for fertilizers in any country is highly dependent upon a current and continuing favorable crop/fertilizer price relationship. If prices of crops are low and unstable with respect to fertilizer prices, there may be no need whatsoever for a fertilizer industry, since farmers could not afford to buy the fertilizer even if it should be produced in the country.

   e. Credit arrangements—Apparently, farmers in all countries of the world have need for large amounts of credit if they are to use fertilizer in increasing quantities. If credit arrangements are not adequate, fertilizer use will be slow to increase.

   f. State of knowledge—The state of knowledge of the entire educational system of the

agricultural sector must be surveyed. This includes the agricultural extension service or other educational agencies, the knowledge of the fertilizer retail dealers, and, more important, the state of knowledge of the farmers of the country. Without adequate knowledge of the benefits of fertilizers being transmitted, the demand for fertilizer cannot be expected to grow.

g. Marketing system—Fertilizer can be produced at practically any point in the world. To have an effective demand, however, there must be a marketing system which is workable in the area of the country surveyed. The costs of distribution–marketing fertilizer–frequently exceed the costs of production. If a marketing system is not available or planned for, there is little need for a fertilizer industry; merely producing the fertilizer without marketing it cannot help anyone.

2. Methods of estimating future demand—Many methods have been used to estimate future demand. Below are mentioned a few of these methods; others undoubtedly have been used.

a. Past trends—In some countries simple projections of past trends have been used, sometimes on an arithmetic scale and sometimes on a logarithmic scale. Regardless of the scale used for such projections, this method can prove disastrous if estimated over long periods of time. It is, however, the most frequently used method.

b. Food needs—Future demand for fertilizer in some countries has been calculated on the basis of the amount required to supply a projected "requirement" for food within the country. In some cases this method has been used without any examination of whether the country could actually support such use of fertilizer and resulting food production. Such a method may be useful in assessing goals for national policies; seldom is such a method adequate for determining the need for a fertilizer industry.

c. Available supply—In many countries the level of demand for fertilizer has been estimated based upon a probable supply position. Such an estimate of demand may work well as long as overall demand exceeds the available supply. At some point in the development of an industry, however, supply generally catches up and exceeds effective demand. Such a demand estimate, then, can lead to disastrous consequences in the total industry.

d. Projection of use on specific crops—Various demand estimates have been made based upon detailed studies of the crops which are and will be grown, the percentage of these crops which are and will be fertilized, and the rate at which fertilizer is and will be applied. Such an approach is time-consuming and requires considerable data on an initial base point. It also requires subjective judgments of many specialists. Estimates must be made of current and future trends of many varying factors in the entire national economy. The outcome of the estimated demand may be highly sensitive to any one of several of these judgments.

e. Combination of the above—In recent years most demand estimates have been based on a combination of methods. No way has been found to make this process mathematically certain. Since most of the methods depend upon large numbers of subjective approximations, it is generally essential to have the judgment of teams of people–including agronomists, economists, and engineers–if a good approximation to effective demand is to be made.

3. Refinements required in demand estimation

a. Time of use—In order for a demand estimate to be useful in determining the need for a fertilizer industry, it must be tied to and worked into a time span of years. In short, an approximation must be made of the demand for each of several years over a coming period of time.

b. Type of fertilizer required—To determine the need for a fertilizer industry, the type of material required must be known, as well as the amounts of N, P_2O_5, and K_2O. There must be some approximation as to the product mix of straight materials versus mixed fertilizers. Determination of this requires the concerted effort of the agronomist on the team to determine to the best of his ability the product mix over time.

c. Special fertilizer needs—The agronomist must also determine whether there are certain limitations in types of fertilizers which must be restrictive upon the demand estimate. In some countries all the nitrogen required should be in ammoniacal form rather than in the form of nitrates. When this is the case, it is essential that this fact be clearly set forth.

4. Summary of requirements by types over specified period—For any team studying the need for a fertilizer industry, the end product desired is a summary table showing requirements in terms of plant nutrients and any other specific requirements with relation to type of material or special needs. This table should cover a specified long-run time span. It is certain that as time goes on the table will need to be changed; however, this summary table will report the best approximation of what will be required in the future.

C. Analysis of country's resources

The second major job in determining the need for a fertilizer industry is analyzing in detail the known resources of the country which might be useful in producing fertilizers.

1. Existing production facilities—The production facilities already in operation are among the major resources of a country, of course. These should be analyzed in terms of total plant nutrient content which they produce or can produce, and also by types of material.

2. Additional resources needed for fertilizer production—Every country has some of the additional resources which are needed if an industry is to be developed.

a. Land—A fertilizer industry as such has certain specified requirements for land which must be met. This generally is one of the least restrictive of the resources in terms of ability to produce.

b. Water—To operate efficiently, fertilizer industries of today almost without exception require large amounts of relatively pure water. This supply of water is absolutely essential if the industry is to be successful.

c. People—The fertilizer industry of today requires a relatively high level of technological knowledge. If the plant is to operate efficiently, trained technicians must be available. If they are not available within the country, provision must be made for training people or for importing technicians to do the training process while operating the plant in the initial phases of the work.

d. Raw materials—The fertilizer industry requires certain amounts of raw materials, which must be produced within the country or purchased from abroad. For a nitrogen plant, there must be a source of hydrocarbon. For a phosphate plant, there must be a source of sulfur or sulfuric acid, electricity, and phosphate rock. In addition, for a mixed fertilizer unit, potash must be supplied. Few countries have all of these resources within their own boundaries. The relative cost and availability must be surveyed.

3. Foreign exchange—At some stage in the process of determining the need for a fertilizer industry, major emphasis inevitably falls upon the requirements for foreign exchange expenditures. Few countries, if any, have adequate free foreign exchange. Major emphasis is placed upon this aspect in a later discussion.

D. Economic analysis of production versus importation

This aspect is covered in detail in the discussion titled "Importation versus Production of Fertilizers." At this point, therefore, let it be mentioned that in determining the need for a fertilizer industry a major study should be made comparing the alternatives of having the industry within the country vs the alternatives of importing finished or semi-finished fertilizer products. It is not at all clear that all countries which have a demand for fertilizer also have a need for a fertilizer industry, especially where none of the basic raw materials are available.

E. Economic analysis of total costs of producing the required fertilizers

This also is discussed in detail later. At this point it is sufficient to note that in any such study many alternative production and distribution systems must be weighed in terms of types of production and total costs of producing and distributing these products.

F. Summary

In determining the need for a fertilizer industry for any country, there are no mathematically precise methods. No one has discovered a mathematical model which will predict demand over a long period of time. Technology is rapidly changing, thus changing the extent and value of available natural resources. In such circumstances, we can only follow this general method: (1) Analyze effective demand, (2) analyze available resources, and (3) analyze the costs of the various alternative methods of using these resources to satisfy the total effective demand.

REFERENCES: 44, 88, 113, 297, 305

TECHNIQUES FOR SELECTING FERTILIZER PLANT LOCATIONS

A. Introduction

There is one major point which should be stressed during this discussion: Plant location studies should be based upon minimizing total systems costs of production and distribution. In the past, many plant location studies have included alternative possibilities but final decisions as

to optimum plant location have been based entirely upon production costs of the end product. Such an analysis can, in many cases, lead to drastic errors in terms of total financial feasibility of the entire system. A plant location which reduces the production costs/ton of material by $2, as contrasted with an alternative one, may look good if the analysis of production costs are presented out of context with the costs of the total production and distribution system. In many cases the cost of distribution at the alternate site may be much lower than at the minimum cost production point, thus leading to a total cost which is something other than optimum. The total systems costs are the important data which must be analyzed if the selection of the fertilizer plant site is to be successful.

The cost of the total system is a function of production costs, plus transportation costs, plus distribution costs.

Production costs are a function of basic costs of raw materials, cost of delivery of raw materials to the plant, size of the plant, type of plant, labor costs, and other production costs, as well as inventory and storage costs as related to location of plant and market.

Transportation costs are a function of the location and size of plant, location of market with respect to plant, pattern of use of fertilizer, types of fertilizer produced, and the analysis of final end product.

Distribution costs are a function of the type and analysis of fertilizers, intensity and extensity of market areas, types of farms and farming systems, and the crops and cropping patterns indigenous to the use area.

Thus, the cost of the total system, and therefore the optimum location of any one plant within that system, depends upon many factors other than bare production costs at a specific plant location.

B. Some absolute prerequisites for plant locations

1. Suitable land—Adequate amounts of suitable land must, of course, be available before any major study can be made of placing a plant at any one location. This is generally one of the least restrictive of the factors which go toward selecting a fertilizer plant location. In some cases in the past, however, plants have been placed in geographic locations where sufficient suitable land was not available, thus leading to faulty plant location.

2. Water—One of the prime prerequisites for a modern fertilizer plant is an adequate supply of good water. Without adequate water, a plant cannot operate. If supplies are not available throughout the year, the plant must close or pay tremendous amounts in investment and operating costs to recirculate and reuse the limited quantity of water which is available.

3. Transportation facilities—Fertilizer is essentially a low-value, high-volume product, produced in large quantities throughout the year, and transported generally over long distances. Large amounts of raw materials are required if the plant is to operate. The transportation function of getting the fertilizer from the plant to the farmer is generally costly in terms of money and other resources. It is, therefore, essential that a fertilizer plant be at such a location as to afford adequate transportation to and from the plant. Generally, in the larger complexes, where some amounts of raw materials are imported or where a good portion of the end product is desired for export, there is a requirement for location at a seaport. In any case, transportation facilities must be available for the specific system which is being designed.

C. Other desirable factors for plant locations

1. Communications—Communication facilities must be available between the plant location and source of raw materials. It is equally important that communication facilities be adequate between the plant location and the end use area. If communications are not adequate throughout the entire system, the "system" becomes segmented and cannot operate efficiently.

2. Source of raw materials—It is desirable, of course, that plant location be near the source of the raw materials that will be used in production of the fertilizer. In many production processes, the transportation cost of the raw materials may well exceed the cost of the basic raw material at its mining or production source.

3. Market area—The ideal location of the plant would, of course, be in the center of a market area so as to minimize costs of transportation from the plant to the user. Transportation and distribution costs of many fertilizers in the United States far exceed the total production cost.

4. Energy—All modern plants require relatively large amounts of energy for their operation. Stable sources of energy must be available and relative costs of tentative sources of energy must be analyzed in detail. Electricity in certain amounts is required for operating the plants. This electricity must be stable in its supply. If the supply is not stable, the alternative costs of producing electricity at the plant should be investigated; it is generally much better to increase investment and production cost by some small amount in order to assure a supply of electricity, thus ensuring continuity of operation rather than to risk the uncertainties of interruptions of power which lead to drastic decreases in total annual production.

5. Labor—The highly developed technology of today requires an adequate number of trained persons for fertilizer production. The most desirable locations for plants are those near centers where trained personnel is available. If plants are placed elsewhere, additional investment may may well be required for the social needs of the workers who are to operate the plant. In many developing countries these social requirements of a plant location may well increase total investment cost by 50% or more.

D. One method of selecting optimum location

1. Selection of alternative tentative locations—Under this method, several alternative tentative locations are selected for plant facilities. They are investigated to ensure that at least the absolute prerequisites are available. Analysis is made of the other desired factors at each of these tentative locations.

2. Analysis of estimated production costs at each alternative location—At each tentative location detailed analyses are made. These include analysis with varying fertilizer product mixes. They also include analysis of the costs with varying sizes of plants.

3. Analysis of transportation and distribution costs—Under this method, an analysis would be made of the costs of transportation and distribution of the total end product from each of the tentative locations to the market areas expected to be served. These costs will generally vary for each of the locations considered and for each different product mix of fertilizers to be produced. It is highly essential that these analyses of transportation and distribution costs of each system be analyzed in detail.

4. Summary comparison of total system costs of the alternative locations—When the various cost

data have been compiled—production costs, by the engineers, and distribution costs, by transportation and distribution economists—a budget-type comparison can be made for each of the alternative production and distribution systems. Theoretically at least, if all such combinations and permutations of production locations and transportation and distribution systems are considered, the volume of work may be excessive. Inevitably, however, many of the systems will be eliminated at an early stage as a result of excessive production costs or excessive transportation and distribution costs.

Such a method does not guarantee success, since technology may change, the market may change, or many other changes may come about between the time of the decision on plant location and the actual operation. Nothing can guarantee the success of any plant location in these days of change. By considering the various alternative total systems costs, however, a greater probability of success can be achieved.

E. Mathematical simulation of the entire production and distribution system of a region or a nation

With the computer technology of today's world, it is possible to simulate mathematically the total production and distribution system for a region or a nation and to insert into this system alternative production locations. This mathematical simulation is comprised of series of mathematical equations expressing precisely the demand requirements and the supply restrictions. Cost factors are calculated for each supply activity, which include the total costs of production, transportation, and distribution. These equations are linear approximations of the total system as it would operate at a point of time. This approach has been used infrequently, however, because of the excessive amount of data required and other drawbacks inherent in its practical application.

1. Data requirements—For this mathematical simulation to be successful, there must be a complete knowledge of the precise demand for fertilizer within the market area. In addition, the demand for regional distribution must be well defined. On the supply side, a total mathematical simulation must be made for each alternative plant size and configuration which is being considered. Collecting detailed data to simulate, if possible, alternative plant production facilities would be a monumental task.

2. Other restraints on this system—The system as it has been developed in the past is generally a static approach. It can simulate operation for one period of time; it is exceedingly difficult to simulate operation when demand is changing—as it normally is from year to year in any country. It is also difficult to insert into such a system changing supply factors.

F. Summary

The process of selecting an optimum plant location is at best a difficult and time-consuming one. No way has yet been found to ensure success, since input data are always changing—due to changing supply and demand factors. A major point, however, is that total systems costs must be analyzed in selecting plant locations, not just the bare production costs. By analyzing alternative systems of production and distribution, much greater probability of success can be obtained.

REFERENCES: 44, 88, 113, 297, 305

HISTORY OF WORLD FERTILIZERS AND FERTILIZER MANUFACTURING PROCESSES

A. Early theories and discoveries about plant nutrition

Ancient man observed stimulation of plant growth by organic matter (droppings, ashes, animal bodies) and thus learned to apply manure, ashes, and bones.

Investigators (Van Helmont, Boyle) in 17th and 18th centuries "showed" that water provided all required nutrients.

Lavoisier's concept of mass conservation was applied by de Saussure in plant growth and decay circuit–led to recognition of CO_2 from atmosphere as plant food.

Davy declared that most of the CO_2 was provided by soil, leading to the "humus theory" that products of decay provide nutrients in a soil-plant-soil cycle instead of the later revealed air-plant-air cycle of photosynthesis.

Liebig (1830s) proposed the "mineral theory" that minerals in the soil are of overriding importance. His later work, and that of Lawes and Gilbert, led to the understanding that carbon and nitrogen are supplied mainly by air, hydrogen and oxygen by water, and all other elements by soil.

Whitney concluded that the soil is inexhaustible and would forever provide necessary mineral nutrients.

Understanding later grew that soil minerals, some present in very large supply, are mainly insoluble and become slowly available. Often the rate is too slow and supplementing nutrients must be added. Without addition of fertilizer, productivity approaches a minimum level according to the rate of nutrient conversion in the soil supply.

B. Phosphate fertilizers

Bones were treated with sulfuric acid in Europe (about 1830) to liberate phosphoric acid and provide quick acting phosphate. In the early 1840s, mineral phosphate (phosphate rock) was reacted with sulfuric acid to produce superphosphate. Triple superphosphate–phosphate rock and phosphoric acid–was first produced in Europe in the 1870s.

Phosphate deposits were developed in Norway, France, South Carolina (1868), Florida (1887), Tennessee, western United States, Russia, Algeria, Tunisia, North Carolina (1960s). Lesser deposits have been found in a dozen or more locations.

Pulverized phosphate rock is used for direct application to a considerable extent, particularly in the United States and Russia. Only 5% to 10% of the P_2O_5 in most ores is "available" according to standard tests. Some phosphate rock is superior in assimilability, for example, that from Gafsa and North Carolina. Rock directly applied is best suited for pasture and forage, and for acid soils.

Fused calcium magnesium phosphate, produced in electric furnaces from phosphate rock and serpentine or olivine, is a major fertilizer in Japan.

Early superphosphate production was batchwise acidulation of rock with sulfuric acid. Mixing was

by hand in iron pots. Later developments led to use of mechanical mixers and continuous feeds. Modern plants use continuous feeds and continuous dens which are boxed for fume removal.

Superphosphates have maintained important positions throughout the world. In the United States, the dominant phosphatic materials are superphosphates (production of triple super exceeds that of ordinary), ammonium phosphates, and fluids. Basic slag and nitric phosphate are important in Europe.

C. Nitrogen fertilizers

Natural organics–guano, animal and fish products, plant residues–furnished much fertilizer nitrogen until 30 to 40 years ago.

Chilean nitrate was a heavy contributor from mid-19th to mid-20th centuries.

Ammonia was produced from byproduct coke in 1890. Coke byproducts, particularly ammonium sulfate, have been important nitrogen materials for over a half century.

Synthetic nitrogen processes and products include arc process for nitric acid 1905 (Norway), cyanamide about 1905 (Europe), pressure synthesis of ammonia 1913 (Germany). Ammonia is presently made almost entirely from natural gas or naphtha. Main products from ammonia are ammonium nitrate, ammonium sulfate, nitrogen solutions, and urea. Recent trend is toward increasing urea production.

D. Potash fertilizers

Early sources–vegetables ashes, beet sugar plants.

Salt deposits opened in Germany about 1860 (primary for 75 years), France 1910, Spain 1925, Soviet Union 1930, United States 1931, Canada about 1960.

Low-grade unrefined ores such as manure salts (20% to 25% K_2O) and kainite (19% K_2O) were first products. Refining methods–crystallization, flotation, solution *in situ*–have been developed and improved. Potassium chloride (60% to 62% K_2O) is the dominant material.

World reserves are very large.

E. Other nutrients

Secondary nutrients, calcium and magnesium, are provided as limestone, dolomitic limestone, sulfate of potash-magnesia. Sulfur, also a secondary nutrient, is supplied mainly as a component of superphosphate and sulfates.

A. Gris (France) discovered in 1844 how chlorosis of some plants can be corrected by sprays of iron salts.

Importance of other trace elements, or micronutrients, in the plant life cycle was not realized until the 20th century–manganese (1905), copper (1920s), boron (1920s), zinc (about 1930), molybdenum (1939), chlorine (1954).

Most micronutrients act as necessary parts of the plant enzyme system. (Thus molybdenum acts as

an enzyme in nitrogen fixation and reduction of nitrates in plants.)

The need for micronutrients has been recognized increasingly during the last decade. They are provided as salts, oxides, and frits.

F. Mixed fertilizer

The practice of producing mixed fertilizer began over a century ago in the United States and has since characterized the American fertilizer industry (60% of the fertilizers are mixed). The practice was not originally popular in Europe where straight materials have dominated until recently. Now mixed fertilizers are becoming more popular in many countries. ("Mixed fertilizer" is used here to denote all fertilizers containing at least two and usually all three of the primary nutrients, N, P_2O_5, and K_2O. The term includes "compound" and "complex" fertilizers—terminology used in Europe.)

Early materials were superphosphate, sodium nitrate, potassium chloride, fish meal, peanut hulls, various animal and plant wastes, ammonium sulfate.

Simple mechanical procedures were employed for mixing until the 1920s. Ammoniation-granulation processes for continuous production of high-analysis grades were developed in the 1950s. Low-analysis powdery mixes (batch method) declined rapidly.

Most of the phosphate and potassium is now applied as mixtures in the Unites States and many other countries. A wide variety of materials and compounds are used—ammonia, superphosphate, ammonium nitrate, ammonium phosphates, phosphoric acid, nitric acid, sulfuric acid, etc.

Bulk blending (dry mixtures of materials handled in bulk) developed rapidly in the last decade. Fluid mixed fertilizers are growing rapidly since the advent of superphosphoric acid (polyphosphate).

G. Modern technology and systems

Great technological progress has marked the last decade. The structure of the U.S. industry has changed radically through consolidation and acquisition of plants and companies, mainly by oil firms. Very large new primary phosphate operations have been started by sulfur producers (Texas Gulf, Occidental, Freeport)—two in newly developed phosphate deposits.

Most phosphate products are based on wet-process acid—superphosphate, ammonium phosphate, fluids (partly based on furnace acid). There is increasing production of fluids and blends of granular solids for bulk application.

Nitric phosphate production has grown rapidly in Europe.

Important developments of the last decade: ammoniation-granulation processes, superphosphoric acid and improved fluids, giant ammonia plants with pipeline distribution. Latest technology is centered on polyphosphate compounds. Ultrahigh-analysis compounds from elemental phosphorus are likely to be fertilizers of the future.

REFERENCES: 36, 172, 174, 264, 306, 331, 334, 335, 339

ESTIMATED WORLD FERTILIZER PRODUCTION CAPACITY AS RELATED TO FUTURE NEEDS

A. World fertilizer market

The world fertilizer supply-demand balance affects all regions and countries of the world to some degree. World trade in fertilizers is extensive and is increasing sharply. Thus, changes in demand or supply relationships in one region of the world will affect all regions. Surpluses or shortages, of either a long or short duration, whether regional or worldwide in scope, influence marketing decisions and must be a prime consideration in the long-range development of a country's fertilizer industry.

B. The growing need for fertilizer

1. Population growth—World population is now over 3 billion and is projected to double by the year 2000. Birth rates in developing regions have maintained a relatively constant level while mortality rates have decreased over 60% since 1940. At the same time, cultivated land area has been decreasing. If more food is to be produced, increasing tonnages of fertilizer, along with other agricultural inputs will be needed to boost yields per hectare.

2. Higher living standards—As living standards improve and income levels are increased, the per capita use of fertilizer will increase. Types of foods demanded to satisfy higher dietary levels require higher input levels per unit of food output.

3. Concentration of people—Population concentrations are changing, which is leading to a larger percentage of the world's population living in the regions currently classified as less developed countries. In the year 2000, over 80% of the total population will be located in these areas.

   a. Developed regions which have relatively low population growth rates have increased their per capita food production through the use of large amounts of fertilizer.

   b. On the average, per capita food production is below 1957 levels in the developing regions. Prior to World War II, the developing regions were grain exporters. By 1964, they were importing over 25 million tons of grain.

C. The world's capacity to produce fertilizer

1. Expected growth in capacity—By 1972, the world fertilizer industry will have established the capability to produce over 120 million metric tons of plant nutrients. This will be double the capacity listed in 1965. Production of fertilizers (as plant nutrient) is projected to be almost 90 million metric tons by 1972.

2. Location—This capacity is not located in the areas having the greatest growth in future needs. Comparisons of estimated consumption with projected production levels indicate that the developed regions will have a surplus in fertilizer nutrients that will continue to increase until 1971. Great pressure will be exerted by these surpluses to increase exports to developing regions.

3. Production-use gap—Consumption levels have far exceeded the developing regions ability to produce fertilizer, and the gap is widening. The developing region will continue to rely heavily on imported fertilizers over the next five years.

a. Latin America will continue to import approximately 50% of the total consumed by the region.

b. Africa is expected to increase production more rapidly than demand and could be exporting fertilizer by 1970.

c. The gap between production and consumption in Asia (including Mainland China) has been widening rapidly in recent years and indications are that more than half of the plant food consumed in Asia will be imported from developed nations within its region or from other regions.

4. Supply-demand by nutrients—Supply-demand relationships also vary widely when considered on an individual nutrient basis.

a. Nitrogen capacity in 1972 will be more than double the 1965 level. Consumption estimates, however, indicate that capacity is increasing at a faster rate than the demand and unless production adjustments are made to achieve a supply-demand balance a continuing oversupply situation in the developed regions is forecast through 1970-1971.

b. Phosphate capacity projections and demand forecasts are increasing at similar rates indicating that only minor changes in demand and supply could easily result in a stable phosphate market.

c. Potash overcapacity has far outreached the anticipated demand and will continue to increase more rapidly than demand until after 1970. Little prospect for achieving a balanced situation in potash in the next few years is apparent at this time.

D. Products that will be produced

1. Production shifts—The fertilizer market is shifting to the production of higher analysis materials.

a. Nitrogen products such as urea, complex fertilizer, and nitrogen solutions (including ammonia) are increasing in importance while ammonium sulfate and other low-analysis solid nitrogen carriers are losing their market share.

b. Normal superphosphate and basic slag are losing their relative market share while complex fertilizers of all types have become of primary importance. Phosphate fertilizers based on wet-process phosphoric acid are rapidly replacing the low-analysis materials.

2. Trends in world trade—World trade data also show the trend toward higher analysis fertilizers. If only overseas shipments were analyzed, an even greater shift to high-analysis materials would be apparent.

a. Urea and complex fertilizers are now the primary nitrogen products moving in world trade replacing ammonium sulfate and ammonium nitrate.

b. Concentrated superphosphate and complex fertilizers are replacing normal superphosphate and basic slag in world trade in phosphate fertilizers.

c. Transportation savings favor high-analysis materials. Since freight costs are similar for all solid

fertilizer materials regardless of concentration, a net savings is realized by meeting nutrient requirements by shipping high-analysis materials.

E. Development of fertilizer industry in a developing country and the effects of the world supply-demand situation

The import of finished fertilizers is one phase of the overall program to increase total production within a developing country. Location of a supply source, price levels, and the resulting foreign exchange requirements must be determined. As price levels are affected by the function of supply and demand, changes in the world market balance must be constantly reviewed to determine the feasibility of supplying needs through domestic production facilities vs the continuation of imports.

REFERENCES: 101, 120, 183, 205, 206

TRENDS IN THE USE OF NITROGEN, PHOSPHORUS, AND POTASSIUM

A. World trends in fertilizer consumption

Plotting trends in fertilizer use can be a useful approach in analyzing production, marketing, and use of fertilizer. If fertilizer consumption in a country follows the same trend as the rest of the world, this is some reassurance that correct decisions are being made. If the two trends differ, then it is appropriate to ask why and to be certain that reasons for the variation are valid.

Use of N, P, and K on a worldwide basis can be depicted in the follwoing ways:

1. Total tonnage of each nutrient can be plotted for a period of years sufficient to establish a general trend.

2. Plot per capita consumption of each nutrient, again over a period of years.

3. Rate per hectare can be calculated on a total land area but it is more meaningful to calculate rates on the basis of cultivated land.

4. Percentage change in use from year to year.

B. Trends in developed vs underdeveloped countries

Many factors influence the amount of fertilizer used by farmers. These are discussed to some extent below and in detail under other headings. The objective here is to point up differences between the more developed and the less developed countries. The magnitude of the differences places the two types of countries in perspective; i.e., it points up goals that less developed countries can establish and can be a basis for measuring progress toward these goals. Some useful comparisons might include:

1. Total tonnage used of each nutrient (N, P, and K) over time for one or more developed countries vs one or more less developed countries.

2. Per capita consumption changes over time for the two types of countries.

3. Change in rate per hectare on a gross area basis.

4. Percentage change in fertilizer use over time.

5. Change in percentage of farmers using fertilizer.

6. Comparative rates of fertilization for selected crops in the more developed and the less developed countries.

C. Trends in fertilizer materials used

The statistics used for this section can be presented in various ways as outlined above: worldwide basis, developed vs an underdeveloped country, or even for various regions within a country. The goal is to observe what has been happening in order to better forecast what might happen in the future. The changes that have occurred in fertilizers can be examined in several ways:

1. Changes in plant food content—The concentration of plant food in fertilizers tends to increase with time. This is due partly to technological development *per se* and partly to technological development for the purpose of reducing transportation and handling costs. Information can be presented as the change in plant food concentration over a period of years. It also can be given in terms of products, such as the use of:

   a. Urea vs ammonium nitrate and ammonium sulfate.

   b. Triple superphosphate vs ordinary superphosphate.

   c. Diammonium phosphate vs triple superphosphate plus ammonium sulfate or ammonium nitrate.

2. Single-nutrient vs complex fertilizers—Changes in the relative use of single- vs multinutrient fertilizers are difficult to interpret. Such changes may be a reflection of price, farmer education, development of a domestic manufacturing industry, adoption of bulk blending as a major marketing endeavor, or the need for very limited quantities of a particular nutrient.

3. Granular vs non-granular fertilizers—In the United States the impetus to granulation came from the bulk spreaders because granular materials were less susceptible to drifting with the wind. Other advantages–less bridging over in hopper-type applicators, better physical condition, etc.–and some disadvantages also became apparent. Of principal concern is the effect of granulation on phosphorus availability in the soil. A strong interaction or interdependence exists between the effects phosphorus water solubility and granule size. Also important are soil reaction and method of application, whether broadcast or banded. Water-soluble sources of phosphorus are more effective when granulated, particularly in acid soils.

4. Solid vs non-solid fertilizers—Most fertilizers used throughout the world are solids. In the United States and a few other countries, the use of non-solid fertilizers is increasing. Anhydrous ammonia, nitrogen solutions, liquid mixed fertilizers and suspensions are the common non-solid fertilizers. Some are used because of lower cost and others because of convenience or adaptability to mechanical handling. Any trend to the use of non-solid fertilizers is of interest to market researchers (and to agronomists if urea is one of the liquid components). Similarly,

mechanization and other signs of labor shortages can be warnings that production and marketing of fluid fertilizers need to be investigated.

D. Factors affecting trends in fertilizer use

In countries with limited information about the fertility status of their agricultural soils and the fertilizers needed for desired crop production, plant nutrient use can vary markedly from year to year. Total tonnage probably isn't very high so even small changes in a use pattern appear to have significant effect on trends. Some of the factors that affect trends are:

1. Actual availability of various nutrients through either domestic production or importation channels.

2. Crops produced and the cultural practices used in their production.

3. Farmer knowledge and experience, i.e., tradition.

4. Price of nutrients from time to time; dumping of excess production can have an effect on use trends in small countries.

5. Changes in methods of fertilizer application.

6. Size of farms or of individual fields.

7. Crop/fertilizer price ratio.

REFERENCES: 101, 121, 183, 334

IMPORTATION VS PRODUCTION OF FERTILIZERS

A. Background for discussion

1. Each nation has many requirements for the process of development. Agriculture needs fertilizer, farm machinery, seeds, farmer education, etc. Commerce and industry need roads, communications, mines, factories, credit, etc. Social needs include housing, education, social assistance, etc. For defense a nation needs an army and an air force, a home militia, perhaps a navy, etc.

2. Each nation has limited resources. These resources include manpower, land, minerals and other natural resources, and capital, both as local currency and as foreign exchange.

3. Administrator's job is to satisfy greatest number of most important requirements while making best long-run use of available assets. Fertilizer requirements are only one of many needs.

B. Decision-making on the question of importation vs production of fertilizers must be a teamwork approach.

1. Agronomists' role in helping guide proper resource allocation for fertilizer is to ensure:

a. A proper understanding of the immediate value of fertilizer—to ensure that fertilizer is allocated a proper share of total available resources.

b. Proper evaluation of requirements for fertilizers in terms of quantities and types of materials needed—to help ensure least-cost processes and facilities for making the fertilizer available.

c. Proper dissemination of knowledge to farmers—so that farmers may make best use of fertilizers, thus increasing benefits from use of the material.

2. Engineers' role in helping guide proper resource allocation for fertilizer is to ensure:

a. That alternative production facilities studied are in conformance with amounts and types of fertilizers required;

b. That such facilities make most efficient use of available raw materials;

c. That all alternative facilities studied be feasible within the framework of proved technology.

3. Economists' role in helping guide proper resource allocation for fertilizers is to ensure:

a. That all possible alternatives be studied;

b. That total costs of alternative systems of production and distribution be analyzed—not just segmented production costs or distribution costs;

c. That total costs be considered, including costs for capital and return on investment;

d. That each of the final total systems analyzed is in conformance with the actual requirements over a period of time.

C. Definition of subject — covers a multitude of alternatives

1. Alternative A — import finished fertilizer products

2. Alternative B — import intermediate fertilizer materials and produce finished products

3. Alternative C — import raw materials and produce finished products

4. Alternative D — use national raw materials and produce finished products

D. Some economic factors which influence decision on proper alternative to ensure lowest cost fertilizer:

1. Type of fertilizer needed

2. Quantity of fertilizer needed

3. Raw materials available in country

4. Costs of imported materials in dollars or in trade-outs for local production of other items

5. Production costs of locally produced materials

6. Foreign exchange costs: investment costs and annual costs

E. Discussion of pyrrhotine vs sulfur use in Morocco

1. Raw material cost for sulfuric acid—Pyrrhotine approximately $26/ton sulfur equivalent vs sulfur expected cost at $25/ton

2. Investment cost of production facilities—Pyrrhotine two to three times that of sulfur facilities

3. Operational costs—Pyrrhotine $2/ton acid more than sulfur

4. Net result on total book costs—Use of pyrrhotine more expensive

5. Net result on foreign exchange costs:

   a. Initial investment–none, since in either case foreign exchange costs were essentially being underwritten by someone other than Moroccan Government

   b. Repayment of investment–very little–less than $5/ton of sulfur equivalent

   c. Cost of raw materials–at least $20/ton of sulfur equivalent in favor of using pyrrhotine

F. Discussion of import vs production of NH_3 in Morocco

1. Import at $60/ton (fictitious figure)

2. Produce at $65 to $90/ton

3. Import advantages–no foreign exchange for initial investment; less requirement for trained manpower; better idea of demand, and thus size of unit required, by delaying decision

4. Import disadvantages–annual requirements for foreign exchange

5. Recommended–delay in building NH_3 plant and interim import of NH_3

G. Summary

There is no one answer. The answer may be different for each country. The answer may be different for one country at two different periods of time. The answer may be different within one country and at one point of time–but for different plant nutrient products.

REFERENCES: 44, 88, 113, 297, 305

RECENT TRENDS IN FERTILIZER PROCESSES AND TYPES OF PLANTS IN DEVELOPED AND DEVELOPING COUNTRIES

A. Period of time considered and main changes and trends

The decade of the 1960s has seen a "growing up" of the fertilizer industry of the world. Not only has production capacity increased dramatically in both developed and developing countries but important new patterns and practices have evolved; very large, efficient and economical plant units have arrived on the scene; and new systems of marketing and transporting have been devised. There has been a definite move away from separate nitrogen, phosphate, and potash segments of the industry in developed countries. The production of higher analysis, better quality, and more versatile fertilizer intermediates and finished fertilizers has come about due to improvements in technology and more advanced production and marketing concepts. These advances by the inudstry have led to better fertilizer products of higher analysis being made available at lower cost.

B. Growing prominence of fertilizer production complexes

Recent production patterns for fertilizers have centered around large complexes for production of key fertilizer intermediates and refined or finished products. These are preferably located near the source of key raw materials such as phosphate rock, cheap natural gas for ammonia production, and sulfur. Usually a location that allows ocean or river receipt of certain raw materials and shipment of products is a primary consideration. Sizing of all units to achieve the economy of large-scale operation has become very important. In developing countries location of the complexes at leading ports to allow direct receipt of key raw materials or intermediates that must be imported is an important factor; this sometimes requires some compromise with access to markets and need for development of rail and highway facilities.

C. Advances in basic technology

1. Nitrogen products—The most remarkable development in the 1960s was the great advance in nitrogen fertilizer technology that allowed construction and efficient operation of huge plants for production of ammonia, urea, nitric acid, and ammonium nitrate. Process improvements that led to 1000- and 1500-ton/day units with investment costs greatly lowered and production costs drastically reduced was the highlight of this period. Emergence of urea as the leading nitrogen fertilizer and its rapid growth in new facilities in developing countries became apparent.

2. Phosphate fertilizer products–advances and new problems—Significant achievements were realized in new products and process improvements for production of phosphate fertilizers. Production of phosphate rock in several parts of the world was expanded; use of wet-process acid expanded and larger, more efficient plants for its production were developed; and granular ammonium phosphate emerged during the 1960s as a major and perhaps dominant product or base for fertilizers. A temporary shortage and sharply increased price for sulfur in the mid 1960s caused some revision in plans and a closer look at nitric phosphate and elemental phosphorus (electric furnace) routes to phosphate fertilizers. The sulfur problem became particularly acute in several developing countries. Polyphosphates reached commercial reality in the United States and a few other developed countries.

3. Potash fertilizers—Major producers of potash continued to be United States, Canada, Russia, and western Europe. The greatest change was emergence of Canada as the likely future world leader in production and export. Development of suitable deep-mining technology and successful

employment of solution mining were highlights. Higher grade potash materials of better quality and in a range of particle sizes were made available in plentiful supply at low cost. Continued dependence of most developing countries on import of potassium chloride from the present major suppliers is indicated for the future. Huge capital requirements likely will deter development of production in few developing countries that have suitable deposits.

D. Specific process and product technology

1. Granulation—The practice of granulation from its inception in the early 1950s grew rapidly until two-thirds or more of the fertilizer in developed countries is now granular. Essentially all new facilities for solid fertilizers are for granulated or prilled products. Dependable processes for granulation were developed for superphosphate-based fertilizers, for ammonium phosphates, for nitric phosphates, and combinations of urea or ammonium nitrate with ammonium phosphates. Drum granulation, pug milling, and pan-granulation techniques were employed. Single-train plants that were in the range of 15 to 25 tons/hour are being superseded by 35- to 40-ton/hour units. Prilling technology advanced to allow single-train systems of at least 600 tons/day of urea or ammonium nitrate, and even larger units are planned. New and simplified processes involving melts or other anhydrous feed materials, allowing production of good quality products without a drying step, emerged in the last few years and may set a pattern for the future.

2. Bulk blending—The practice of physically mixing closely-sized granular materials to supply N, P, and K in finished fertilizers in any desired proportions grew rapidly in the United States. Approximately 30% of the United States solid fertilizers was bulk blended in 1967 and more than 4000 of the small blending units were employed. The demand for suitable materials for blending promoted increased production of granular ammonium phosphate and triple superphosphate and prilled urea and ammonium nitrate. It also led to the practice of closer sizing of the granular products. Main advantage of bulk blending is the ability to prepare finished fertilizers on a prescription basis. In many cases, blending equipment can be utilized for addition of micronutrients and other materials, such as herbicides, to the blends. The practice of bulk blending is being used to some extent in developing countries such as Korea and Brazil.

3. Fluid fertilizers—The technology of production of liquid and suspension fertilizers grew steadily in the United States until about 12% of mixed fertilizers was fluids in 1967. About 1700 small plant units in the United States generally produce 1500 to 5000 tons/year each. Polyphosphates from electric-furnace superphosphoric acid or from wet-process superphosphoric acid form an important base for fluids. A direct process for polyphosphate fluids from 54% P_2O_5 wet-process acid is in latter stages of pilot-plant development. Slow but steady growth of suspensions allows high-analysis products such as 15-15-15 and 7-21-21. Main advantages for fluid fertilizers include adaptability to prescription formulation, low investment and operating costs in production plants, and convenience and savings of labor in application. Major disadvantages for fluids are the need for more specialized handling equipment and more highly-trained personnel. Only appreciable production outside the United States is in France. Shift to liquids will likely be slow in developing countries.

E. Prospects for fertilizer intermediates

A trend has been established toward the production of fertilizer materials that serve as intermediates in production of finished fertilizers. Key intermediates such as anhydrous ammonia, nitrogen solutions, phosphoric acid, elemental phosphorus, and nongranular monoammonium phosphate can be produced economically near the site of raw materials. Shipment of the high-analysis intermediates to comparatively simple plants for production of finished fertilizers near

the market simplifies the total system and should lower the delivered cost of fertilizers. Planning of production facilities in some developing countries at the end of the 1960s and in the 1970s involves import of key intermediates such as ammonia or wet-process phosphoric acid. Future years likely will see the intermediates--especially ammonia and elemental phosphorus--become more important.

F. Effect of new transporting and marketing schemes

A definite trend toward bulk transporting and marketing of fertilizers developed during the 1960s. The ability to move granular and fluid materials in bulk by rail, barge, and in some cases by ship promoted the practicality of larger, more efficient production plant units; it also facilitated shifting of finished fertilizer preparation to small plants near the market. Entirely new concepts such as pipeline movement of anhydrous ammonia and other fluid products came into reality and indicate further shifts in this direction.

REFERENCES: 144, 149, 150, 152, 233, 236, 272, 287, 289, 290, 334, 360, 361

RAW MATERIALS FOR FERTILIZER PRODUCTION: NITROGEN, PHOSPHATE ROCK, POTASH, AND SULFUR

A. Nitrogen

1. Nitrogen is the plant nutrient used in the largest tonnages, and its use is increasing faster than the use of other nutrients.

2. Nitrogen fertilizers, such as ammonium nitrate and urea, are made from synthetic ammonia.

3. Ammonia is made from nitrogen and hydrogen. The nitrogen comes from the atmosphere, a limitless supply. Hydrogen is manufactured from reaction of carbon with water, with carbon dioxide a byproduct.

   Natural gas, composed mostly of methane, provides hydrogen directly in addition to carbon. Most of the new ammonia plants use natural gas and the steam-reforming process. Gas is also burned with air to consume the oxygen and leave the nitrogen for reaction with hydrogen.

   Naphtha is the next most preferred material for manufacturing hydrogen. Naphtha is a low-boiling liquid fraction obtained in refining petroleum. It is usually used for making gasoline. Availability and price of naphtha depend on ratio of demand for gasoline to demand for fuel and diesel oil. Naphtha is easier to transport in tanks than natural gas. Naphtha can be vaporized and used in steam-reforming like natural gas.

   Oil can be used for manufacturing hydrogen. When oil is used, the partial oxidation process rather than steam-reforming must be used. An ammonia plant using oil costs more to build and operate than one using natural gas. Atmospheric nitrogen must be separated from oxygen in an air-fractionating plant.

Coke or coal may be used, but the plant is more expensive to build and operate than one using any of the other raw materials.

4. Big questions in deciding on the construction of an ammonia plant: What is the availability and cost of the raw material? What type process, determined by the raw material, should be used? Can ammonia be produced economically by the process as compared with importing a different raw material or importing ammonia? (The economics of ammonia production are much more favorable when plant size is in the range of 600 to 1000 tons/day so that centrifugal compressors can be utilized.)

B. Phosphate rock

1. Phosphate rock deposits are quite widespread over the world. Major producing areas are the United States, North Africa, and Russia. In these areas, known reserves are large, markets are available, and quality of ore is good.

2. Phosphate ore is extremely variable in composition. A deposit must be examined by experts to determine the method of exploitation. Many developing countries have deposits of rock phosphate that are not presently economic to mine.

3. Mining and beneficiation––The ore is usually low in grade and must be beneficiated. Beneficiation routes vary according to type of impurity to be removed. Impurities are usually silica and clay.

   In Florida, phosphate is mined by open-pit method. Phosphate is washed and screened to recover larger size phosphate. Smaller size material is treated further in a water medium to remove finest material, designated "slimes." Slimes contain most of clay in ore and about 30% of the phosphate. Slimes are sent to ponds for disposal, so phosphate is lost from the process. Middle sized material is treated with a surface-active agent and the phosphate is separated from the silica by flotation. The phosphate is dried and is then ready for shipment.

4. Grade of beneficiated phosphate varies from about 30% to 34% P_2O_5, depending upon composition of original ore. Beneficiated material contains various impurities, usually silica and clay. Iron and aluminum from the clay in excess of 3% R_2O_3 can cause trouble. Some ores are limited in fertilizer use because of difficulties in removing iron and aluminum to a sufficiently low level; these can be used satisfactorily in the electric furnace manufacture of phosphorus.

C. Sulfur

1. Importance of sulfur––Converting phosphate rock to soluble phosphatic fertilizer by the use of sulfuric acid is the preferred method of production. The methods using sulfuric acid are cheaper than the electric furnace method. However, in some areas where sulfur costs are high, and power costs are decreasing, the furnace method is becoming competitive. The products from the use of sulfuric acid usually fit the marketing situation better than products from the use of nitric acid because they have more grade ratio flexibility. Usually nitric acid acidulation products result in about two pounds of N output per pound of P_2O_5.

2. Sulfur requirements––For phosphoric acid, a ton of sulfur is consumed for each ton of P_2O_5 produced. For superphosphate, about 0.6 to 0.7 ton of sulfur is consumed for each ton of P_2O_5 produced.

3. Sulfur production methods

   a. Frasch mining––Hot water is pumped to underground deposits of sulfur. The melted and

fluidized sulfur is brought to the surface by compressed air. This method is used in the United States and Mexico.

b. Recovery from natural gas—The amount recovered depends on use of natural gas and concentration of sulfur in the gas. Recently, gas in Canada and France with high sulfur concentrations has been exploited for sulfur.

c. Other sources of sulfuric acid—Pyrites, metal sulfides, are used as a raw material for making sulfuric acid. Sulfuric acid also is obtained as a byproduct from smelters, and it is produced from the calcination of gypsum. Some of the recovery processes for removal of SO_2 from power plant gases result in sulfuric acid production.

4. Supply and demand for sulfur—For years sulfur was low in price, and there was a surplus of sulfur in the United States. There was little incentive to operate marginal deposits or to explore for new deposits. With rise in demand, prices rose and marginal wells were reopened. Exploration is proceeding rapidly. Higher prices encouraged recovery of sulfur from natural gas from wells with high sulfur content and utilization of sulfide ores and smelter gases for sulfuric acid production.

D. Potassium

1. Potassium is recovered from minerals. Most of the mining is deep underground mining in highly mechanized operations with continuous machines. Solution mining by the use of hot brines is a recent innovation utilized primarily in Canada.

   Sylvanite is the principal ore in the United States. It is a potassium chloride-sodium chloride mixture. One method of recovering potassium chloride from sylvanite is by solution and recrystallization. A difference in solubility of potassium chloride and sodium chloride allows crystallization of potassium chloride as the solution cools. The other method of separating the potassium and sodium salts is by flotation. This yields a product containing 97% potassium chloride.

   Langbeinite (K_2SO_4 $2MgSO_4$) is the other principal potassium ore mined in the United States. Langbeinite is processed into potassium sulfate and magnesium sulfate.

2. Potassium is also recovered from natural brines by crystallization methods.

3. Potassium chloride is usually used as a fertilizer material without further processing. The mining companies produce a granular form for some fertilizer uses by compaction or fusion.

REFERENCES: 51, 52, 53, 54, 55, 56, 57, 184, 210, 218, 232, 235, 236, 237, 303, 334, 336, 337, 338

AGRONOMIC EVALUATION OF FERTILIZERS

A. Introduction

Evaluation implies that certain fertilizer-soil-plant relationships are unknown. Through carefully designed and replicated tests, these relationships can be examined. Fertilizer evaluation in the field is expensive. Close attention should be given to the experimental design and to the general conduct of the test.

B. Evaluation principles

1. Measurements used

   a. Crop yields—Effect of fertilizers on crop yield is usually our primary concern, and this is the most common basis for fertilizer evaluation.

   b. Nutrient uptake by crop—Utilization by the crop of nutrients in a fertilizer, however, must occur in order that crop yields may be increased. Thus, crop uptake of a nutrient may be a more accurate basis for evaluation.

   c. Crop uptake of labeled nutrient—Labeling of fertilizer nutrients with radioactive or natural isotopes may be particularly useful to measure uptake from the fertilizer when there is little or no yield response to its application.

   d. Crop quality—Crop quality may be the important basis for evaluation with fruit and vegetable crops.

   e. Crop appearance—Appearance is particularly important for turf crops. Thus, there are five measurements that can be used.

2. Types of evaluation

   a. Product evaluation—Fertilizer product evaluation is commonly the comparison of one product or brand with another, possibly without regard to the nutrient content. Bag-for-bag comparisons are an example.

   b. Comparative value of each plant nutrient—The chief research objective in fertilizer evaluation should be to determine the agronomic effectiveness of each nutrient in a fertilizer product.

   c. Other comparisons—Possible toxicity, physical handling properties, possible leaching and volatilization losses, and farmer preferences must also be considered in a complete evaluation of fertilizer products.

3. Product evaluation—Product evaluation may be useful to introduce a new fertilizer or brand to farmers and extension personnel. However, possibilities for obtaining useful information from such trials are quite limited. This is particularly true if the trials are

poorly conducted, especially if the comparisons are on a whole-field basis. As a result, product evaluation has little or no place in a research program. Such trials frequently can and do lead to erroneous conclusions.

4. Requirements for evaluation of each nutrient—Since we have no absolute standard in fertilizer evaluation because of various crop growth factors which affect yield response to fertilizer nutrients, response to a common nutrient source must be used as the standard. Multiple rates of nutrient in both the standard and test fertilizers to define most of a complete response curve is very desirable. Single-rate comparisons may not yield meaningful results, especially if the results fall on the flat portion of the complete response curve.

   Sufficient yield response to measure possible differences among fertilizers and low experimental error are essential. Growth-limiting factors other than the nutrient under test should be reduced as much as possible.

5. Mathematical models—Various concepts have been developed for describing the results from evaluation tests. The most simple procedure is the direct comparison or relative yield: Plot A yielded more than Plot B. This is an adequate description for people who know little about fertilizers. Research investigators, however, expect their rate to fit some principle that has a mathematical expression. Thus, response may be linear or curvilinear.

C. Screening tests

In some instances there is no prior knowledge about how plants will respond to a chemical compound. This is the situation for compounds undergoing test for the first time as a fertilizer. Such compounds may be toxic, have no effect, or provide a response. Frequently, the more complex compounds provide a response only after an incubation period.

REFERENCES: 322, 325

EVALUATING NATURAL RESOURCES FOR THEIR DEVELOPMENT POTENTIAL

This outline deals specifically with some of the problems of evaluating deposits of phosphate ore in countries that do not have a developed phosphate mining industry. The procedures utilized in rock evaluation are similar to those that would be utilized in evaluation of other natural resources.

A. Background information

It is doubtful that a prosperous, progressive, technologically advanced country can exist in the world today without access to adequate supplies of phosphatic material at reasonable cost. Fortunately, it seems probable that many countries with a reasonably large land area have the potential to develop internal deposits of phosphate rock.

1. The characteristics of phosphate rock—Phosphate rock may be in almost any form, size, color, or texture, ranging from hard rock to soft mud with gradiations in between. Phosphate rock is so varied and often inconspicuous in appearance that its occurrence may be overlooked by experienced geologists. To determine accurately the quality of phosphate rock, it is necessary to use chemical and mineralogical tests.

2. The discovery of phosphate deposits—Phosphate deposits have been discovered in a variety of ways. Some deposits have been discovered by accident, some have been found in searching for other minerals, and some have been located by application of the principles of systematic geology. When a phosphate deposit has been discovered, it is often possible to find other mineable areas by plotting the geology to locate places where conditions have been favorable for the formation of mineable deposits. Today it is possible to search for phosphate deposits by a variety of scientific means using the principles of geology and geophysics.

3. Terminology—Various names are used for phosphate ore in the different mining areas, and by the several trades and professions connected with the industry. Among the nouns used are phosphate, phosphate rock, phosphorite, phosphate ore, mud, matrix, sand, etc.

B. Usual order of procedure in evaluation

The discovery of mineral deposits brings forth suspicion and intrigue in individuals that probably is matched in few other forms of human endeavor. Therefore, it is necessary that the individuals involved in an evaluation have the confidence of each other and the conficence of the individuals for whom the evaluation is being made. Most phosphate mining operations are on a large scale, and large sums of money may be made or lost in the mining. In some cases the decisions to be made at any stage of the evaluation are relatively uncomplicated, e.g., when a deposit looks very good, or obviously will not be mineable. The borderline cases are the most difficult.

1. Stage I: Reconnaissance—The first step in the evaluation of a deposit is often referred to as "reconnaissance." At this point the evaluator will acquire all the available pertinent data. This may include bulletins, maps, oral reports, or anything of possible value. The evaluator will classify the data as to its apparent reliability and usefulness.

2. Stage II: Exploration—If the reconaissance stage warrants, the next step will be to perform some sort of exploratory work. Most often exploration will consist of drilling prospect holes, or sinking shafts, but draglines and other earth moving equipment may be used in certain cases. Whatever the method used, the data should be carefully assembled and evaluated. Information needed will include the thickness of the ore, the thickness of the overburden, the grade of the ore, and the characteristics of the material to be mined.

3. Stage III: Development—The development stage is usually a continuation of the methods of collecting and evaluating data that were used in the exploratory stage. The investigation is more intensive at this stage. The development work should be done on a geometric pattern whenever possible, and should proceed at least to a point where there is assurance that a deposit is available of sufficient quality and quantity to justify the construction of a processing facility of at least minimum economic capacity.

C. Other considerations

It should be noted that the relationship between the quality (P_2O_5 content) of the ore and the quality of the product that can be produced is often confused. Some phosphate is good enough to use as mined, and other ore will have to be concentrated by beneficiation. An ore that may be fairly low in total P_2O_5 content may yield a high grade concentrate by beneficiation, while an ore of higher P_2O_5 content may be difficult or impossible to concentrate economically or may yield only a low-grade product. The first ore would probably be useful; the latter might not be. Some ores cannot be beneficiated at all.

D. Summary

The evaluation of mineral deposits is about the same as the familiar problem-solving sequence in which the data is collected and evaluated and the best possible decision made relative to the data. In the case of mineral deposits the proper evaluation of the potential is a continuing series of problem-solving situations.

REFERENCES: 92, 247, 296, 335

INTERPRETATION OF YIELD RESPONSES TO FERTILIZER NUTRIENTS

A. Introduction

1. Importance of such information—In any agricultural area, it is imperative to have some idea of the optimum rate of such nutrients as are needed for particular soil-crop combinations. This information would presumably result in higher crop yields as well as more efficient use of fertilizer nutrients.

2. Need for good experimental design and technique—The interpretations of yield responses are only as good as the data used. Appropriate experimental design and good plot techniques are essential to avoid misleading information. The latter includes use of adapted varieties, suitable plant population, water control (if available), and effective plant protection measures.

B. Nature of yield response to added fertilizer nutrients

1. Shape of yield response curve—Yield responses to increasing rates of a fertilizer nutrient typically follow the Law of Diminishing Returns. That is, the yield increments decrease with each increment in rate of nutrient applied to point where yield increases are no longer obtained.

2. Effect of soil nutrient levels on response—Naturally, high levels of a particular nutrient in the soil will result in a low or insignificant yield response to additions of this nutrient as fertilizer. Conversely, low or deficient levels in the soil will usually result in responses to additions of that nutrient. It should be pointed out, too, that deficiencies of other essential nutrients will limit the yield response to a particular nutrient. All other limiting factors must be removed to obtain valid response information.

3. Variation in response—Experiments have shown a considerable variation in response from year to year on the same site, or from site to site within years. This variation is unpredictable for the most part and must be treated as part of the general uncertainty that faces a farmer at the beginning of a crop season.

4. Residual effects—The nutrients phosphorus and potassium often accumulate in soils over time as a result of fertilizer application to the point where responses to fresh additions are no longer obtained. Such accumulation depends on the nature of the soil; potassium will not accumulate significantly in a sandy soil, for example.

   Nitrogen does not generally accumulate in mineral form in humid soils as a result of fertilizer application. There often is some residual or "carryover" effect of applied nitrogen from one season to the next, but the extent of this residual effect is quite variable. In certain soils of subhumid or semi-arid regions, nitrogen can accumulate as nitrate in the soil profile and thus affect the response to added nitrogen.

C. Relationship between yield response and net return to fertilizer nutrients

1. Principles of maximization—The nutrient rate at which maximum yield (or limiting yield) occurs is readily identified by the highest point on the curve. The nutrient rate at which the maximum net return or profit occurs is that point where the cost of the last increment of fertilizer just equals the return to that increment. The objective, then, is to equate the marginal cost with the marginal returns. At this point, profit will be maximized on the hectare basis. Since fertilizer has a cost, the most profitable rate will be necessarily less than that required for maximum yield.

   It is also possible to maximize return per increment of fertilizer. This is done by limiting fertilizer application to very low rates, where the slope of the yield response curve is the steepest. This does not result in highest yields or in highest profit per hectare, however.

2. Differences between nutrient rates for maximum yield and economic optimum—Generally speaking, the gap between the rates for maximum yield and for the economic optimum is quite small. This is particularly true where the cost of the fertilizer nutrient is low relative to the price of the crop. In fact, the difference is usually small enough to be meaningless to many farmers, especially in view of uncertainty in the approaching season. However, when the cost of fertilizer is quite high relative to the price of the crop, the difference between the economic

optimum rate and the rate for maximum yield is wider to the extent that it may be meaningful to the farmer.

3. Effect of rate of nutrient on net return——Except for the steepest portion of the yield curve, net return is not a very sensitive function of nutrient rate. That is, for the flatter regions of the yield response curve, the net return is not greatly affected by variation in rate of the applied nutrient. The accuracy of prediction therefore does not need to be particularly high, provided that the rate used is above the steep portion of the yield curve.

D. Summary

In view of the general uncertainty associated with response prediction for approaching seasons, the insensitive relationship between net returns and nutrient rate, and the similarity of the rates for the economic optimum and the maximum yield, the concept of the economically optimum rate is primarily of academic or "hindsight" interest. This optimum rate is therefore not a useful concept for the farmer except in a very broad sense. Generally, farmers maximize either return per dollar invested (low rate) or maximize yield (higher rate).

REFERENCES: 32, 33, 93, 131

PRODUCTION, MARKETING, AND USE OF PHOSPHORUS FERTILIZERS

A. Introduction

1. The fertilizers and fertilizer intermediates included in this topic are the superphosphates, phosphoric acids, elemental phosphorus, and manipulated rock phosphates.

   a. Intermediates–wet-process phosphoric acid, thermal phosphoric acid, superphosphoric acid, and elemental phosphorus

   b. Manipulated rock phosphates–ground rock phosphate, partially acidulated rock phosphate, granulated rock phosphate-sulfur, fused and defluorinated rock phosphate

   c. Superphosphates–normal and ordinary superphosphate; enriched, double and triple superphosphate; concentrated superphosphate

2. Definitions——Technology of producing phosphatic fertilizers is 125 years old and many terms have been used, such as bone phosphate of lime, water-soluble and citrate-soluble phosphorus, P and P_2O_5.

B. Production aspects

1. Raw materials or sources for P_2O_5

   a. Organic materials such as farm manures and guano–supply small proportion of P_2O_5 used

   b. Rock phosphate–supplies practically all fertilizer P_2O_5

(1) Locations of rock deposits—practically all of world's known mineable deposits in U.S. (1/3), Morocco (1/2), and U.S.S.R. (1/6)

(2) Types of rock phosphate—marine (74%) and igneous (26%)

(3) Chemical analyses of typical phosphate rocks and physical characteristics

2. Processing phosphate rock

a. Mining

(1) Open pit—used when rock is on or near the surface

(2) Tunnel—used when rock deposit is underground

b. Method of excavation

(1) Drag-line (open pit only)—used if Florida—high capacity is possible

(2) Mechanical diggers—normally used for tunnel mining

(3) Digging by hand

(4) Blasting—used only when rock is too hard to be separated by other methods

c. Beneficiation

(1) Wet—normally involves washing, wet screening, and flotation

(2) Dry—normally involves crushing, grinding, and screening

3. Production of phosphoric acid

a. Thermal or furnace process—phosphoric acid from phosphorus

(1) Preparation of phosphate charge—phosphate and silica materials are agglomerated

(2) Proportioning phosphate charge and coke

(3) Reduction of calcium phosphate to phosphorus in the furnace

(4) Purification and condensation of phosphorus

(5) Hydration of phosphorus to phosphoric acid

(6) Chemical analysis and physical characteristics

b. Wet process

(1) Rock grinding—normally ring-roller mill is used to grind rock to 60% to 80% –200 mesh

(2) Manufacture of sulfuric acid—usually contact process is utilized

(3) Rock digestion—normally multitank with six to eight hour retention time

(4) Filtration—usually employs tilting pan filters

(5) Concentration—multiple effect vacuum evaporators

(6) Purification of acid by sludge removal

(7) Chemical analyses and physical characteristics

c. Superphosphoric acid

(1) From burning phosphorus—concentrations up to 80% P_2O_5 are possible

(2) From concentration of wet-process acid—concentration may be either by submerged combustion or vacuum evaporation—acid concentration 70% to 74% P_2O_5

(3) Chemical analyses and physical characteristics

d. Comparison of economics of wet-process with furnace process

(1) Capital investment—about 2 to 2.5 times higher for furnace process

(2) Operating costs (cost of S vs cost of electrical power)

(3) Transport costs (transport of P vs transport of wet-process acid)

4. Production of superphosphates

a. Single superphosphate

(1) Rock grinding—about 60% –200 mesh

(2) Acid dilution and preparation—normally done continuously with cooling

(3) Mixing—may be paddle or cone

(4) Denning—usually continuous, such as Broadfield

(5) Curing

b. Triple superphosphate

(1) Continuous slurry process—usually Dorr process is used to make a granular product

(2) Cone mixer process—produces a nongranular material for ammoniation.

(3) Granulation of raw-of-pile material—normally done in a rotary drum with steam added to promote agglomeration.

(4) Product composition and physical characteristics

5. Summary of physical and chemical characteristics and P_2O_5 content

6. Production costs--The purpose of this section is not to present a detailed analysis of production costing procedures. Rather, the objective should be one of comparing the final production cost of the various phosphate fertilizers manufactured by the available processes. Such costs should be determined on both a per-ton and a per-unit-of-plant-food basis. Variable factors affecting production costs should be evaluated. These include:

   a. Location of the plant with respect to raw materials required--(Location with respect to the fertilizer use area also is important and is considered below.) Access to alternative transport methods and transportation costs for raw materials should be considered.

   b. Size of plant--There are economies of scale involved in fertilizer production but these must be tempered by the amount of product that can be sold.

   c. Efficiency of production--Two aspects of efficiency need to be considered: the amount of time that a plant operates during a year and the amount of fertilizer produced per unit of time relative to the amount the plant was designed to produce. Seasonality of fertilizer demand, downtime for repairs, poorly skilled operators, low quality raw materials, and a host of other factors can affect efficiency of production.

C. Marketing aspects

1. Production and consumption statistics

   a. World trends in production of single-component phosphates (superphosphates) individually and collectively vs the ammonium phosphates

   b. U.S. trends as in "a" above

2. Intermediates (elemental P, phosphoric acid, super acid)

   a. Effect of physical and chemical characteristics on storage, handling, and shipping

   b. Shipping costs for intermediates vs raw materials and vs finished fertilizer--These costs have a major effect in determining the location of manufacturing plants with respect to sources of rock phosphate and sulfur and areas in which phosphatic fertilizers will be used.

3. Finished fertilizers (the superphosphates)

   a. Effect of physical and chemical characteristics on storage, handling, and shipping--Items to be considered are free acid content and its effect on bags and stored fertilizer, handling in bags vs bulk, high vs low analysis, and granular vs nongranular materials.

   b. Compatibility with other materials--This is important if any of these materials are to be used in bulk blending.

   c. Shipping costs--These straight materials must compete with the ammoniated superphosphates, ammonium phosphates, and complex fertilizers containing phosphorus. Plant

location and use area location affect the shipping cost as does also the classification as finished fertilizer vs intermediates or raw materials.

d. Other marketing costs and considerations—When enriched and concentrated superphosphates are used in bulk blending, particle size must be controlled more closely. Also, this additional sales outlet requires salesmen or technical services personnel with different training than those assigned to sales for direct application to the soil.

4. Summary of costs at the retail or farmer level—Production and marketing costs, including shipping costs to the retail outlet, can now be summarized for the various superphosphates either bagged or in bulk.

D. Use aspects

The amount of phosphorus actually taken up by crops from phosphate fertilizer is low in comparison to N and K from their fertilizer carriers; only about 25% is used. The actual amount depends upon:

1. Uptake of fertilizer P

   a. Characteristics of the fertilizer—The content of water-soluble and citrate-soluble P and the nature of the citrate-insoluble P affect P uptake. Also particle size is quite important. In complex fertilizers, and especially the NP fertilizers, the presence of an associated salt may enhance P uptake.

   b. Soil and other environmental influences—The soil pH significantly affects the rate at which P dissolves from a granule and the compounds formed as the P dissolves. The level of P already in a soil, the temperature, organic matter content, moisture, and other factors also influence the percentage of the applied P that is used by plants.

   c. Crop characteristics—Crops with fibrous root systems absorb more fertilizer P than crops with few roots—usually. Similarly, crops with long growing seasons are more likely to utilize more of the fertilizer P than crops with intermediate and short growing seasons.

2. Reactions in soils

   a. Chemical reactions—The compounds present in the original fertilizer vary from one material to another. As these dissolve and move into the soil, new compounds are formed. The nature of these new compounds depends upon soil pH and soil composition.

   b. Physical reactions—Phosphorus moves but a very short distance from the point where it is placed in the soil. Distance is a little greater in sands and other very coarse textured soils but still not significant.

3. Time, rate, and method of application

   a. Effect of water-soluble P—Water-soluble P, and also the citrate-soluble portion, soon reverts to less soluble forms—such as calcium, iron, and aluminum phosphates. Application too far in advance of the time that a crop needs P will nullify the value (and cost) of water-soluble P. Thus, fertilizers high in water-soluble P content should be applied at or very close to planting time.

b. Effect of particle size—The larger the particle, the smaller the surface area—per unit of P—exposed to the soil and soil solution. Presumably then, large granules dissolve more slowly than small granules. Thus, water- and citrate-soluble P is preserved for crop use for a longer time when the fertilizer is granular. When a fertilizer does not contain water-soluble P, granulation decreases its effectiveness as a P source.

c. Effect of soil pH—P fertilizers with low contents of citrate-soluble P, i.e., the rock phosphates, normally are not satisfactory on high pH soils. On acid soils, and perhaps under certain cultural conditions in the tropics, the materials with low citrate-soluble P are more effective.

4. Evaluation of P fertilizers

a. Field evaluation—The cost of conducting replicated experiments at a number of locations (i.e., on different soil types) for several years with different crops is quite high. Also it is becoming increasingly difficult to find suitable sites in the United States that are low in P fertility.

b. Greenhouse evaluation—Most materials are now tested in the greenhouse. Total cost is lower, variables are much easier to control, and experimental conditions are easier to duplicate from test to test.

REFERENCES: Production—13, 24, 41, 155, 195, 273, 279, 290, 307, 308, 335. Marketing—41, 120, 147, 150, 189, 273. Use—74, 134, 171, 173, 190, 208, 219, 227, 228, 231, 248, 267, 323, 335, 352.

AGRONOMIC EFFECTS OF FERTILIZER PLACEMENT

A. Objectives

1. To increase effectiveness of the nutrients for crop growth

2. To prevent fertilizer salt injury to plants

3. To provide an economical and convenient operation

Granulation of fertilizer reduces contact with the soil, as compared to powdered fertilizers, and thus is a type of placement. This can affect plant response, particularly of the P components.

B. Principles

1. Microorganisms, weeds and soil constituents compete with the crop for applied fertilizer nutrients.

2. Proper timing and placement permits the crop to compete more effectively.

3. Maximum effectiveness of all nutrients in a fertilizer may not be attained with a given placement.

4. Placement of fertilizers is more important for crops having limited root systems, such as potatoes.

In soils low in phosphate, P fertilizers are usually most effective if banded near the seed. Zinc, however, is usually most effective for crops when broadcast and mixed well with the soil. Placement of mobile nutrients such as N and S is less important.

C. Nitrogen fertilizers

Nitrogen fertilizers are or tend to become mobile in soils.

1. Placement is influenced largely by properties of the N source and by crop needs.

2. Granule size of solid N sources is not agronomically important.

3. NH_4-N–held by exchange complex until nitrified, then moves with water.

$$NH_4 \rightarrow NO_2 \rightarrow NO_3$$

Surface application to alkaline soils may result in loss as NH_3.

Urea and soluble protein N–also are soon nitrified.

$$NH_2 \rightarrow NH_4 \rightarrow NO_2 \rightarrow NO_3$$

Surface application may result in loss as NH_3 on both acid and alkaline soils.

$$CO(NH_2)_2 \rightarrow (NH_4)_2CO_3 \rightarrow H_2O + NH_3$$

Anhydrous NH_3–must be injected into the soil.

NO_3-N–Free to move with water. May be used by crop, immobilized by organisms, lost by leaching, or lost to air by denitrification.

4. N for upland soils

   a. Various N sources give essentially the same results if: (1) incorporated with the soil and (2) applied separate from germinating seedlings.

   b. N most effective if applied near the time of crop use.

5. N for paddy soils–NH_4-N sources best for preplant application

   a. NH_4-N should be placed in the reduced soil zone.

   b. NO_3-N placed in the reduced zone may be entirely lost by denitrification.

   c. Either NH_4 or NO_3 may be satisfactory if applied during rapid growth period.

D. Potassium fertilizers

Potassium fertilizers relatively immobile in soils

1. K is held by the soil base exchange complex.

2. Granule size, placement and time of application not very important.

E. Phosphorus fertilizers

Phosphorus fertilizers are immobile in soil; very limited movement.

1. A high concentration of water-soluble P near the seed stimulates early growth. Need for highly soluble P decreases with increase in level of available P in the soil.

2. Effects of granulation and of banding are usually similar. In acid soils, crop response to water-soluble P increases with increase in granule size. Crop response to water-insoluble P decreases with increase in granule size.

3. In alkaline soils—Usually no advantage from granulation or banding calcium phosphates; higher yields have been reported with banding of ammonium phosphates.

4. In paddy soils—Usually less need for applied P; more of fixed P becomes available.

5. Banding N with P usually increases availability of P.

6. Need for banding phosphates decreases with increase in level of available soil P.

7. In low P soils having a high sorption capacity for P, the amount of P needed to bring the entire soil mass to a satisfactory P level may be prohibitive.

F. Toxicity effects

1. Salt effects much greater with N and K than with P fertilizers.

2. Salt effects per unit of plant nutrients are higher with low-analysis than with high-analysis fertilizers.

3. NH_3 toxicity may result from urea or diammonium phosphate placed with or near the seed.

4. Banding fertilizers three to five cm. or more from seed eliminates most toxicity problems; no problem with broadcasting at normal rates.

5. Danger of seedling toxicity is greater in sandy than in fine textured soils and in dry than in moist soils.

REFERENCES: 230, 277, 327, 331

DESIGN AND OPERATION OF PHOSPHORIC ACID PLANTS

A. Introduction

Phosphoric acid is a principal intermediate for fertilizer production. World production was about 8 million tons of P_2O_5 in 1965 and may rise to 12 million tons by 1970. Two processes are utilized for phosphoric acid production—the wet process, involving sulfuric acid acidulation of phosphate rock, and the thermal process, involving oxidation and hydration of elemental phosphorus.

More than 80% of the acid used in fertilizer manufacture is made by the wet process, which usually is more economic than the thermal process. However, as the cost of electric power tends to decrease, the cost of thermal acid becomes more competitive. Also, some types of low grade phosphate rock, unsuitable for production of wet-process acid, can be used to produce phosphorus and thermal acid.

The thermal acid has a high purity and is particularly suitable for fluid fertilizers. Thermal acid can be readily produced as superphosphoric acid rather than orthophosphoric acid when desirable. Suspended impurities of calcium, iron, aluminum, silica, magnesium, and fluorine often cause problems in storage, handling, and transport of wet-process acid.

B. Wet-process acid production

Wet-process acid production includes three processing steps—reaction, filtration, and acid concentration.

1. Reaction of phosphate rock with sulfuric acid to form phosphoric acid and calcium sulfate.

   a. Rock size—Normally about 50% to 80% passes a 200-mesh screen.

   b. Sulfuric acid concentration—Usually about 93%.

   c. Reaction vessels—Normally one to seven tanks are used. Tanks are usually rubber-lined mild steel or acid-brick. Retention time is usually about four hours.

   d. Forms of calcium sulfate—Temperature in the reactors is controlled to give the desired form of calcium sulfate. Usually the temperature is in the range of 75 to 80° C, and the calcium sulfate is in the dihydrate form (gypsum).

   e. Control of temperature—The reaction temperature is usually controlled either by blowing air onto the material in the reactor or by circulating some material through a reduced pressure flash cooler.

2. Filtration of calcium sulfate from phosphoric acid

   a. Type filter—Normally traveling-tilting pan filters are utilized.

   b. Filter size—Filters as large as about 1800 sq. ft. are now available—up to 1000 ton/day of acid P_2O_5 can be produced using one filter.

c. Washes—Normally two to three countercurrent washes of gypsum cake are utilized.

d. Filter acid concentration—Strength of filter acid is normally about 26% to 30% P_2O_5.

3. Acid concentration—Normally from about 26% to 30% P_2O_5 to about 54% P_2O_5.

a. Type evaporators—Multiple effect, vacuum, forced circulation design normally used.

b. Materials of construction—Usually Karbate or Hastelloy G for tubes and rubber-lined steel for body.

C. Thermal or furnace acid production

1. Process description and history—Production of thermal phosphoric acid involves phosphorus oxidation, P_2O_5 hydration, and acid recovery. Early plants burned phosphorus and carbon monoxide gas leaving a phosphorus furnace to make impure acid. Plants built since about 1940 burn condensed phosphorus. Before the mid 1950s, plants were constructed of ceramics, carbon, or graphite. Thermal stresses crack these materials, however, and repairs to prevent P_2O_5 and acid loss involve costly plant downtime and maintenance.

   Plants built today of unlined stainless steel offer important advantages, such as: High capacity per unit volume; use of prefabricated process units; low investment, operating, and maintenance costs; versatility for continuous or intermittent production of different strength acids at varied rates; and high recovery. Process flows and equipment vary in different plants.

2. Equipment and services—Main equipment items are combustion chamber, hydrator, venturi scrubber, and separator. Auxiliary equipment includes combustion air filter and blower, phosphorus feed system, product-acid cooler and pumps, dilute acid receiver and pumps, cooling water treatment system, and process control instruments. Services include air, electricity, cooling water, and steam. Equipment exposed to combustion gases and acid is of Type 316L stainless steel. Jackets of the water-cooled vessels are of Type 304 stainless steel. Pressure in the system is four to five psig.

3. Process flows—Phosphorus flows into a burner in the combustion chamber where it is atomized with compressed air into a stream of combustion air. Cooling water in jackets removes heat through the vessel walls.

   Gases from the combustion chamber flow downward in the water-jacketed hydrator along with recycle cooled product acid, introduced as spray and falling film, that hydrates P_2O_5 and absorbs heat. Heat is removed by acid and jacket water. Acid absorbs about 50% of the P_2O_5 in the gas and drains into the cooler.

   Gas leaving the hydrator enters the venturi scrubber where it passes through recycled dilute acid spray and its pressure is decreased. The acid, pressure decrease, and jacket water remove heat. Acid mist coalesces.

   Gas then enters a centrifugal separation unit and flows upward through mist eliminator pads to a stack. Water for P_2O_5 hydration comprises that sprayed on the bottom pad,

water added to the dilute acid receiver, and vapor in air. Dilute acid drains from the separator through a gas seal to a receiver and is pumped to the cooler and the venturi scrubber. Recovery is about 99.9% of the phosphorus input.

REFERENCES: 5, 11, 12, 18, 24, 25, 39, 50, 63, 70, 71, 83, 106, 108, 114, 139, 156, 196, 197, 198, 241, 249, 273, 278, 290, 300, 307, 309, 316

REACTIONS OF PHOSPHATIC FERTILIZERS IN SOILS

A. Practical importance of soil-phosphate reactions

It has been estimated that no more than 30% of the fertilizer phosphorus (P) added to most soils is removed by crops during the first growing season. The remaining 70% is present in chemical forms considered "unavailable" to plants. Conversion of "available" fertilizer P to "unavailable" P, commonly called fixation or retention, is the result of chemical reactions between the added P and the soil constituents. To understand these reactions, one must be able to characterize the various components of the reacting system.

B. Phosphatic fertilizers as reactants

Upon applying a solid phosphatic fertilizer to a soil, no reaction occurs until the phosphate undergoes some degree of dissolution. Whether a liquid or solid fertilizer is applied, it is a solution which reacts with the soil. The nature of the reactions, then, is greatly influenced by the properties of the solution, which are in turn determined by several properties of the original fertilizer.

1. Compounds present in the fertilizer

   a. Phosphatic compounds—Although there are numerous different processes used to produce a variety of grades of P fertilizers, only a few different P compounds are present in the products. Most of the fertilizers contain either monocalcium phosphate (MCP), dicalcium phosphate (DCP), monoammonium phosphate (MAP), diammonium phosphate (DP), or apatite, or mixtures of these compounds. There are reliable methods for determining which of these compounds are present in a particular fertilizer, however, intelligent guesses can be made just from knowledge of the manufacturing process used.

   b. Nonphosphatic compounds—Most phosphatic fertilizers also contain nonphosphatic compounds, either as the result of the manufacturing process or because of the intentional inclusion of other plant nutrients. Some of these are calcium sulfate, ammonium sulfate, ammonium nitrate, potassium chloride, and urea.

2. Mechanism of dissolution—When a phosphate particle is placed in a moist soil, a nearly saturated solution of the salt forms on the granule surface. With highly water-soluble fertilizers, this saturated solution is very concentrated, and thus has reduced vapor pressure. The reduced vapor pressure creates a driving force for further movement of water to the fertilizer, resulting in further dissolution and movement of solution into the soil. The continued movement of water to the granule and solution away from the granule causes rapid dissolution of the water-soluble materials. With slightly-soluble fertilizers, the initial saturated

solution is dilute, hence does not create a driving force for water movement to the granule. Dissolution and movement of solution from these materials is much slower.

3. Composition of solutions leaving fertilizer granules—Since nearly-saturated solutions are formed around fertilizer granules, the solution moving into the soil is easily characterized by preparing a saturated solution of the material and analyzing it chemically. This has been done for the major fertilizer phosphates.

   a. Water-soluble materials—Of the major fertilizer phosphates, MCP, MAP, and DP are highly soluble in water and yield saturated solutions which are very concentrated. For instance, MCP, the major component of the superphosphates, gives a saturated solution containing about 4 moles P/liter and 1.4 moles Ca/liter, with a pH of 1.5. A saturated solution of MAP contains 2.9 moles of P and NH_4/liter and has a pH of 3.5. DP yields a solution containing 3.8 moles P/liter and 7.6 moles NH_4/liter, with a pH of about 8. Solutions of these concentrations would be expected to be very reactive toward soil constituents.

   b. Slightly-soluble materials—DCP and apatite are sparingly soluble in water and form saturated solutions containing extremely low concentrations of P and Ca.

   c. Mixed phosphatic and nonphosphatic compounds—A mixed fertilizer may not produce a simple saturated solution of fixed composition. Rather, one of the salts may dissolve more rapidly than another, yielding a solution which changes in composition as dissolution proceeds. Such mixtures can still be characterized in the laboratory so that the composition at any given time can be predicted.

C. Soil constituents as reactants

As the fertilizer solution moves through the soil, many soil minerals or constituents are contacted which may react with the fertilizer P. The most reactive constituents are found in the clay-size fraction. These can be grouped conveniently according to soil pH class.

1. Acid soils—The most reactive minerals in acid soils are the hydrous oxides of iron (Fe) and aluminum (Al). The clay minerals (e.g. kaolinite) may furnish Al ions by breakdown of the crystal lattice. The predominant exchangeable cation in acid soils is Al, which can also enter into reactions with fertilizers. So, in acid soils, the reactive constituents are largely forms of Al and Fe, with lesser amounts of other cations.

2. Calcareous soils—The most reactive minerals in calcareous soils are carbonates, such as calcium-magnesium (Ca-Mg) or Ca-Fe carbonates. The clay minerals may break down to furnish Al or Mg ions (e.g. montmorillonite). Ca and Mg are the predominant exchangeable cations in calcareous soils. So, in calcareous soils the reactive constituents are largely forms of Ca and Mg, with lesser amounts of other cations.

3. Alkaline (noncalcareous) soils—The dominant exchangeable cation in these soils is sodium, which is not a serious contributor toward P fixation. These soils have only small amounts of reactive carbonates, Al and Ca; hence, reactions with phosphates are minimized.

D. Reactions occurring when the fertilizer solution and soil constituents are brought together

The reactions involved when the two reactants are brought together can roughly be classified as

either degradation or synthesis. Fertilizer compounds and soil constituents are dissolved or broken down and the elements recombine to form new compounds. The rates and extents of these reactions depend on the kinds and concentrations of ions in the fertilizer solution and the kinds and amounts of soil constituents which enter into solution.

1. Release of soil ions (degradative reactions)

   a. Exchangeable cations—As the fertilizer solution moves through the soil, the cations from the solution replace the exchangeable cations held by soil colloids. These ions then become a part of the moving solution. In acid soils, Al will be the dominant cation entering solution while in calcareous soils Ca and Mg will dominate. There will be appreciable quantities of other exchangeable cations in both types of soil, however.

   b. Dissolution of clay minerals—A concentrated fertilizer solution is capable of dissolving some of the clay mineral crystals. In kaolinitic clays, Al ions may thus enter the fertilizer solution. In some of the three-layer clays, Al, Mg, Fe, and K may be released to the solution.

   c. Dissolution of other soil minerals—The hydrous oxides of Al and Fe, important components of acid soils, may undergo dissolution in a concentrated fertilizer solution. This would furnish additional Al and Fe to the solution. In calcareous soils, dissolution of the Ca-Mg or Ca-Fe carbonates would increase the amounts of these cations in solution.

2. Precipitation reactions(synthesis)

   a. Initial reactions—As the concentrations of the various soil ions build up in the phosphate solution, a point is reached at which the solution becomes saturated with respect to one or more phosphatic compounds. When this happens, precipitation of these compounds occurs. The composition of the precipitate, of course, depends on the composition of the solution. Examples of possible reaction products are outlined below.

      (1) Acid soil and a mixed fertilizer containing an ammonium salt, a potassium salt, and superphosphate—Al and Fe are the dominant ions dissolved from the soil and NH_4, K, Ca, and P are furnished by the fertilizer. Initial compounds precipitating from such a solution may be: K-NH_4-Al phosphates, K-NH_4-Fe phosphates, amorphous Fe and Al phosphates, and others.

      (2) Calcareous soil and a mixed fertilizer—Dominant cations dissolved from the soil are Ca and Mg with some Fe and Al, while the fertilizer solution furnishes NH_4, K, Ca, and P. Possible initial reaction products are: dicalcium phosphate, Mg-NH_4-phosphate, Ca-NH_4-phosphate, Ca-Al-phosphates, Ca-Fe-phosphates, and others.

      (3) General—The concentrated fertilizer solution, which has dissolved large amounts of soil components, will precipitate crystalline and amorphous phosphates whose compositions are determined by established chemical principles. The kinds of precipitates can be predicted if the fertilizer-soil solution can be characterized. More than 30 possible reaction products have been identified.

   b. Secondary reactions—Many of the types of reaction products discussed above are unstable in soils. In time, they dissolve slowly and release their constituent ions back into the soil solution. If the resulting concentrations in the soil solution exceed the saturation

concentrations of other phosphatic compounds, then these compounds will precipitate. Through the dissolution and reprecipitation process, phosphates in acid soils tend to approach "final" products such as $AlPO_4$ or $FePO_4$. In calcareous soils, possible end products are apatites, in which solubilities are extremely low.

3. "Adsorption" reactions—When dilute fertilizer solutions, such as those leaving granules of slightly-soluble fertilizers, move through the soil, dissolution of soil constituents may be rather limited. Nevertheless, "fixation" of P still occurs. In this case, P is removed from the solution by reaction at the surfaces of hydrous oxides of Fe and Al or of Ca-Mg and Ca-Fe carbonates. The products of these "adsorption" reactions are quite similar to the precipitated compounds in that the Al-P or Fe-P bonds are chemical in nature. Some workers prefer to think of this type fixation as a "surface precipitation."

E. Agronomic implications of soil-phosphate reactions

The sequence of events during the reactions between phosphates and soils has been discussed as if plant life were excluded from the system. This is not usually the case, since the purpose of adding fertilizers to soils is to furnish nutrients to plants. How, then, is the plant affected during the various stages of phosphate-soil reactions?

1. Period of dissolution of the original fertilizer—As the fertilizer material dissolves there are several possible fates of the P in solution. Precipitation reactions will occur, as discussed above; however, these reactions do not instantaneously remove all the P from solution. During this period plant roots near the application site can compete for the P and absorb some before precipitation occurs. The proportion of added P taken up during this period is probably small, but it is an important fraction for the plant because it usually corresponds to a stage of rapid growth and uptake. That portion of added P not absorbed is then subject to precipitation as the initial reaction products.

2. Period of dissolution of initial reaction products—Some of the initial reaction products are unstable in soils and undergo dissolution. The P returned to the soil solution again has two possible fates. Plant roots near the dissolving particle can absorb the P, or the P can recombine with soil constituents to form more stable reaction products. During this period, plant roots are usually well established and widely distributed, so plants have a very good chance of obtaining a steady supply of P from the soil solution. The combination of early uptake from the original solution and steady supply from dissolution of the initial reaction products provides conditions for good plant growth.

3. Intermediate and final reaction products—That portion of P not taken up by the plant during the first two stages reprecipitates as relatively stable compounds. This process may take from months to years, and involve several dissolution and reprecipitation steps. During this period plant roots may absorb some of the P, but the rate of release is usually not rapid enough to provide sufficient P for maximum growth. These compounds are the sources of residual P released to crops in the several years following the fertilizer application. Finally, when the "end product" of fixation is reached, the extremely stable compounds furnish very little P to plants.

REFERENCES: 73, 162, 163, 199, 200, 201, 202, 204, 311

DESIGN AND OPERATION OF ORDINARY AND TRIPLE SUPERPHOSPHATE PLANTS

A. Processing

1. Mixing of rock and acid—Variations in mixing technique have been used or proposed for improving manufacture of superphosphate. The usual objectives have been increased conversion, higher product grade. lower product moisture or increased product granularity to produce a nondusty product. Primary factors affecting rate and degree of reaction of the rock and acid and physical condition of the reactant are related to properties of the raw materials. Other important factors are degree and time of mixing.

2. Denning or setting—Most emphasis in the improvement of plant design has been centered on the den. The den must receive a slurry from the acid-rock mixer, hold it until set and provide for removing the obnoxious gases evolved by the reactions. There are two broad types of dens–batch and continuous.

3. Pile curing—Large storage capacity is desirable both because several weeks' curing is favorable for increased conversion of phosphate to an available form and because of the seasonable nature of fertilizer sales. Good ventilation of the storage building is important to remove fluorine fumes evolved during curing.

4. Crushing, screening, and shipping—The conversion reactions, which continue in curing, cause crystal knitting to the extent that the superphosphate usually sets up fairly hard. The excavated superphosphate usually is lumpy and must be milled and screened at the time of removal.

B. Ordinary superphosphate manufacture

1. Manufacturing variables—The basic variables are (1) particle size and type of rock, (2) acid concentration and temperature, and (3) ratio of acid to rock.

2. Types of mixers used—The vertical shaft pan mixer is the most widely used of the batch type. The capacity of most pan mixers ranges between 1 and 2.5 tons/batch. The trough-type paddle mixer or pug mill is used in most continuous den plants. One modern development in superphosphate mixing is use of the TVA cone mixer. This mixer has no moving parts; all the mixing is accomplished by the swirling action of acid pumped into the cone. The primary advantages of the TVA cone mixer are its simplicity, low cost, and low maintenance.

3. Types of dens used—The first dens were of batch type (box) and were simple wood or brick chambers fitted with a crude exhaust to a stack. Development led to provision for mechanical excavation of the superphosphate from the den chamber. In continuous types of dens, the rock-acid slurry enters the den and is conveyed slowly for a short distance–during which time it sets up and is disintegrated at the end of its journey. In this country the linear, horizontal travel type, as typified by the Broadfield, is the principal continuous den. The Broadfield den, in its modern form, is essentially a slat conveyor on rollers with a long stationary box over it and a

revolving cutter at the end. In recent years a radically different method of superphosphate manufacture and denning has been introduced in Europe. It involves use of a horizontal rotary drum as the den and, in some instances, as both the mixer and den. In a circular type (cake pan) den, the superphosphate travels in a circular path and returns to a point at or near where it started to be cut and discharged.

C. Storage and curing of ordinary superphosphate

1. Pile curing—Average storage capacity of plants in this country is about 15% of annual production capacity. Many plants use bins for superphosphate storage. About four weeks is needed for proper curing.

2. Removal from pile—Modern power shovels or Payloaders are usually powerful enough to break up the superphosphate directly and remove it from the storage pile. A bridge scraper device is often employed in Europe to excavate superphosphate from large storage piles. These devices rake the material from the top of the pile, usually into a conveyor located at one end of the storage building.

3. Transfer to sizing system—In many plants Payloaders are used to excavate material from the storage pile and move it to the crushers and screens. In others draglines and bridge scrapers rake the superphosphate onto conveyors which deliver it to the sizing equipment.

D. Types of crushing and screening equipment

1. Crushers—The milling operation of most plants involves breaking large lumps, then the feeding of this broken material to a cage mill or hammer mill to break up the material to 2½ to 5 mesh in size. Both types of mills require frequent cleaning to remove buildup of sticky material on the impact surfaces. A chain mill is an impact mill with flexible hammers. Since the chains are flexible, these mills tend to be self-cleaning.

2. Screens—Screens are divided into two broad types—mechanically vibrated and electrically vibrated. Screens are usually installed with 1 to 1.5 sq. ft. of screen area per ton of throughput.

E. Shipping

1. Bulk—Most superphosphate is shipped in bulk in this country, usually in enclosed hopper or boxcars to reduce dust losses while in transit.

2. Bagged—The acidic nature and residual fluorine in the superphosphate cause rapid deterioration of most bags. When bagging is required, the superphosphate is usually dusted with limestone or treated with 0.5% to 1% ammonia to reduce bag rot.

F. Details of TVA cone mixer system

Typical mixer dimensions, for a rate of 40 tons/hour, are 26 inches in diameter at the top of the cone, 16 inches in depth (to beginning of extension), and extension length of 5 inches with a diameter of 4 inches. A 60-degree angle, of the sides to the horizontal, gives best results when producing ordinary superphosphate.

G. Triple superphosphate

1. Manufacturing variables—The three basic variables are (1) particle size and type of rock, (2) acid concentration and temperature, and (3) ratio of acid to rock.

2. Production similar to ordinary superphosphate—Triple superphosphate is produced, for the most part, in large plants situated near the phosphate deposits. The cone mixer is widely used. A holding belt (wet belt) is used instead of a den. Pile curing, crushing, screening, etc., is essentially the same as for ordinary superphosphate.

H. Cost information (U.S.A. location)

1. Ordinary superphosphate—A plant design rated for 20 tons/hour will cost $250,000 to $300,000 without storage or $400,000 including storage for 30,000 tons.

2. Triple superphosphate—A plant design rated for 40 tons/hour will cost $300,000 without storage or $700,000 including storage for 50,000 tons.

I. Granulation

1. Ordinary superphosphate

   a. Directly from den in pan granulator—Warm, moist superphosphate as excavated from a den is very amenable to granulation. Large tonnages are processed in pan granulators throughout the world. Drum granulators can also be utilized to granulate fresh superphosphate.

   b. Granulation of cured superphosphate using steam and water—The unit of equipment most widely used to facilitate agglomeration in modern granulation is the rotary drum. The cured superphosphate along with steam and/or water is fed into a rotary drum where the material is agglomerated. The material is then dried, sized, and stored.

2. Triple superphosphate

   a. Direct granulation using rock and acid—The slurry acidulation system with pug mill granulation (Dorr-Oliver granular process) features an integrated sequence of operation that yields hard spherical granules, which require little curing in the storage pile. The rotary drum procedure embraces a continuous cyclic process for the direct production of granular triple superphosphate from phosphate rock and either wet-process or electrothermal phosphoric acid in a single step.

   b. Granulation of cured superphosphate using steam and water—The techniques used to granulate cured triple superphosphate using steam and/or water are essentially the same as that used for ordinary superphosphate.

REFERENCES: 13, 41, 335

PRODUCTION, MARKETING, AND USE OF NITROGEN FERTILIZERS

A. Introduction

This discussion is limited to the intermediates used in producing nitrogen fertilizers, to straight nitrogen fertilizers, and to a few additional fertilizers that contain nitrogen plus other plant nutrients but usually are considered as nitrogen fertilizers.

1. Intermediates—Ammonia and nitric acid usually are considered here. However, aqua ammonia, urea solution, and ammonium nitrate solution also can be classed as intermediates for some products. In contrast, anhydrous ammonia also can be classed as a straight nitrogen fertilizer.

2. Straight nitrogen materials—If desired, these can be subdivided into fluid and dry materials; fluids may be further divided into high-pressure, low-pressure, and nonpressure materials. Included in the fluid class are anhydrous and aqua ammonia and the nitrogen solutions (composed of urea solution and/or ammonium nitrate solution and/or ammonia). The solid materials can be classed as the water-soluble materials and the slow-release materials. The solid materials are ammonium nitrate, urea, ammonium chloride, calcium ammoniun nitrate, sodium nitrate, calcium nitrate, and ureaform.

3. Nitrogen^{+} materials—These fertilizers contain other nutrients essential for plant growth but usually are sold on the basis of their nitrogen content: ammonium sulfate, ammonium nitrate sulfate, ammonium sulfate nitrate, ammonia-sulfur, and urea coated with sulfur. Ammonia-sulfur definitely was developed as a source of N + S, but the material is priced very nearly on the basis of its N content.

B. Production aspects

1. Ammonia—This is the source of nitrogen in practically all chemical fertilizers.

   a. Raw materials—Natural gas is the preferred feedstock and is used in most large plants. When natural gas is not available, naphtha is the next choice. Other starting materials are coke oven gas, oil, and coal.

   b. Production steps—Ammonia is produced continuously, rather than in batches, in all modern plants. Engineers, however, recognize about six steps in the production process. These are reforming, shift conversion, carbon dioxide removal, methanation, compression, and synthesis.

   c. Economics—Use of high-pressure centrifugal compressors is feasible only in plants producing 600 or more tons/day of ammonia. Generally, the more ammonia produced, the lower the cost per ton.

2. Nitric acid—This compound is used primarily as an intermediate in the production of ammonium nitrate and nitric phosphates. It normally is produced by oxidation of ammonia at high temperatures and concentration to 55% to 60% HNO_3.

3. Ammonium sulfate—This material contains 20% to 21% nitrogen and normally is produced in crystalline form. Most ammonium sulfate is a byproduct from coking plants; although, some

plants produce ammonium sulfate direct by reacting ammonia with sulfuric acid.

4. Ammonium nitrate—This material normally is produced in prilled form and contains 33.5% nitrogen. It is sometimes granulated or prilled with calcium carbonate to eliminate its explosive characteristics. Nitrogen content is reduced to 21% or 26% when lime is added. Pure ammonium nitrate is very hygroscopic and should be dried to less than 0.5% moisture and coated with a conditioner.

5. Calcium nitrate—This fertilizer contains 16% nitrogen and is very hygroscopic. It usually is produced as a byproduct from the Odda nitric phosphate process.

6. Urea—This is the most concentrated solid nitrogen fertilizer; it contains 45% to 46% N. Because of its high analysis, it is becoming the most important straight nitrogen product on the market. New production plants are designed to produce more than 1000 tons/day in a single train using total recycle.

7. Solutions and suspensions—Various combinations of urea, ammonia, ammonium nitrate, and water are used both as intermediates and as finished products.

   a. Pressure type—These have a significant vapor pressure of ammonia. They are most often used as intermediates for ammoniation in the production of mixed fertilizers.

   b. Nonpressure type—These fluids generally are lower in analysis than the pressure type. They are more likely to be used for direct application to the soil. There are a large number of nonpressure fluids varying in their proportion of ammonia to nitrate ratio and urea to ammonium nitrate ratio.

8. Ammonium chloride—This product contains 23% to 24% N and is produced mostly in Asia and the Far East. It usually is sold in crystalline form but does not have very good storage properties. Production usually is a result of byproducts. In the dual-salt process the ammonium chloride is the byproduct from soda ash production. In the direct neutralization process hydrochloric acid, a byproduct, is neutralized with ammonia.

9. Summary of physical and chemical characteristics and of N content.

10. Production costs—The same approach to production costs should be used here as with phosphorus fertilizers. Considerations peculiar to nitrogen fertilizers are the alternative feed stocks for ammonia production, the effect of scale on reciprocal vs centrifugal compressors for ammonia production, and the dependence of urea production on the continued operation of the ammonia plant.

C. Marketing aspects

1. Production and consumption statistics

   a. World trends in production and consumption of straight N materials vs mixed fertilizers, including ammonium phosphates.

   b. U.S. trends in production and consumption, as in "a" above.

2. Intermediates

   a. Effect of physical and chemical characteristics on storage, handling, and shipping.

   b. Storage, handling, and shipping costs for raw materials (naphtha and natural gas) vs intermediates (ammonia) vs finished fertilizers. These costs have a major effect in determining the location of manufacturing plants with respect to sources of raw materials, transportation terminals, and areas in which nitrogen fertilizers will be used.

3. Finished fertilizers

   a. Effect of physical and chemical characteristics on storage, handling, and shipping.

   b. Compatibility with other materials. This is important if any of these materials is to be used in bulk blending or even mixed by hand.

   c. Shipping, storage, and handling costs of straight nitrogen materials vs ammoniated superphosphates, ammonium phosphates, and complex fertilizers containing nitrogen.

   d. Effect of byproduct production on prices. Much ammonium sulfate is produced as a byproduct of the coke and steel industry. Cost of production may be considered as zero or even negative if disposition of waste materials to avoid pollution were more expensive by any other method. Such could be the case for SO_2 from coal used to generate power. If not reclaimed or in some way fixed, SO_2 is an atmospheric pollutant. If used to produce ammonium sulfate or some other fertilizer, the massive quantities produced would virtually eliminate need for production of other types of nitrogen fertilizers.

4. Summary of costs at the retail or farmer level. Production and marketing costs, including shipping costs to the retail outlet, can now be summarized. Both bagged and bulk materials should be considered.

D. Use aspects

1. Uptake of fertilizer nitrogen—The amount of nitrogen used by crops from nitrogen fertilizer can be quite variable, ranging from 50% to nearly 100%. The actual amount depends upon:

   a. Characteristics of the fertilizer—Most nitrogen fertilizers are water soluble and dissolve quickly in the soil. Particle size has little effect on rate of solution. Other fertilizers–such as ureaform and the sulfur-coated materials–release nitrogen primarily as the result of microbial action. This release may take place over a long period of time. The length of time that the various forms of nitrogen are exposed to soil conditions affects the amount of nitrogen that is available for absorption.

   b. Characteristics of the soil—Fertilizers usually contain either $NO_3^=$ or NH_4^+ or both ($CN_2^=$ no longer is common as a fertilizer and urea hydrolyzes to NH_4^+). Nitrate is a mobile nutrient and moves with soil moisture. It can be leached out of the rooting profile when rainfall or irrigation is excessive, especially in coarse-textured soils. Ammonium is less mobile. It undergoes exchange reactions with soil colloids like other cations.

   c. Crop characteristics—Most crops preferentially absorb nitrate to ammonium. However, very young plants can use ammonium, and some crops, such as rice, can grow to maturity with ammonium as the nitrogen source.

2. Reactions in soils

   a. Soil minerals——Nitrates undergo few chemical reactions with soil minerals that result in precipitation or immobilization of the nitrogen. Ammonium ions undergo exchange reactions with soil colloids similar to other cations. Some ammonium may even be fixed so that it is unavailable or only slowly available.

   b. Soil organic matter——Soil microorganisms compete with plant roots for nitrogen. They utilize both NO_3^- and NH_4^+ and to a great extent we rely upon microorganisms to oxidize NH_4^+ to NO_3^- so that the nitrogen can be used by plants. The organic residues from dead plants and microorganisms contain some of the nitrogen in forms that are resistant to decay. Frequently, addition of nitrogen fertilizers releases some of this nitrogen. This is known as the priming effect. The apparent efficiency of nitrogen is thus higher than the actual efficiency. This effect is fairly common in developing countries. This priming effect disappears in a year or two, and farmers decide that the fertilizer is no longer any good.

      Some nitrification (oxidation) reactions can result in loss of fertilizer nitrogen to the atmosphere Nitrogen fertilizers that contain ammonium, or ones like urea that produce ammonium upon hydrolysis, are susceptible to volatilization losses. Such losses are influenced by soil pH, moisture, temperature, placement, and many other factors.

3. Time, rate, and method of application

   a. Effect of type of nitrogen on time of application——Ammonia-type fertilizers are much less mobile in soils than those that contain nitrates. Thus, they are adapted to off-season use. Anhydrous ammonia can be applied in the fall for a crop to be planted the next spring. Soil temperatures should be low enough that microorganisms do not convert NH_4^+ to NO_3^- until spring.

      Some calcium cyanamide still is used as fertilizer. $CN_2^=$ is toxic to plants. This fertilizer must be applied sufficiently in advance of planting so that the $CN_2^=$ is converted to NO_3^- before the crop starts to use nitrogen.

      In coarse-textured soils and in medium-textured soils in high rainfall areas, nitrate fertilizers leach readily. In these situations, the total amount of nitrogen needed by the crop is not applied at one time but is divided between two or even more applications.

   b. Effect of rate of application on method of application——Nitrogen fertilizers are chemical salts. If applied in too high a concentration close to seeds, they have the usual salt effects. Seeds may not germinate and seedlings may die. Consequently, crops responding to high rates of nitrogen cannot receive all this nitrogen at seeding time. The total nitrogen needed may be applied in several ways. Some may be applied in the fall, some at planting time, and some as a topdressing or sidedressing. The nitrogen applied at planting time may be broadcast and disked in or it may be banded to the side and below the seed.

   c. Effect of type of nitrogen fertilizer on method of application——All fluid nitrogen fertilizers that are under pressure (anhydrous and aqua ammonia and some nitrogen solutions) must be applied in the soil to prevent gaseous loss. Similarly, application below the soil surface increases the efficiency of the nonpressure fertilizers that contain the ammonium ion or that produce ammonia (such as urea). This is especially true for alkaline

soils. Many of these fertilizers, however, are broadcast on the surface of the soil. The savings in power and time compensate to some extent for the decreased efficiency.

4. Evaluation of nitrogen fertilizers—Remarks appropriate for the evaluation of phosphate fertilizers are appropriate here.

REFERENCES: Production–67, 208, 236, 251, 266, 286, 289, 291. Marketing–3, 85, 120, 122, 175, 239. Use–37, 208, 209, 228, 262, 266, 314.

CHEMICAL, BIOLOGICAL, AND AGRONOMIC CHARACTERISTICS OF NITROGEN FERTILIZERS

A. Types of nitrogen fertilizer materials

1. Physical characteristics—Principal materials marketed as solids: urea, ammonium sulfate, monoammonium phosphate, diammonium phosphate, urea-ammonium phosphate, ammonium chloride, nitro phos, ammonium nitrate and other nitrates. As liquids: anhydrous and aqua ammonia, urea-ammonium nitrate solutions or combinations of the two.

2. Chemical characteristics—Materials added to soil either dissolve readily in soil water or are slowly soluble. Those which dissolve readily form either an acid, alkaline or near-neutral solution at the point of application. This pH may persist up to two or three weeks.

   a. Urea, diammonium phosphate, urea-ammonium phosphate, anhydrous and aqua ammonia form an alkaline solution.

   b. Monoammonium phosphate, ammonium sulfate, chloride and nitrate form an acid solution.

   c. Potassium nitrate and sodium nitrate form a near-neutral solution.

3. Biochemical characteristics—This is not to be confused with residual acidity or basicity. Some materials added in large amount to a small portion of the total soil to be cropped may partially sterilize the soil in the vicinity of the fertilizer reaction zone. This is especially true for materials which produce high ammonium concentrations at high pH, e.g., anhydrous ammonia injected into soil or urea band-placed. Nitrification can be partly inhibited resulting in nitrite accumulation. At lower concentrations of these materials, nitrification is enhanced. Generally, alkaline-forming N fertilizers nitrify faster than acid-forming ones.

4. Agronomic characteristics—The kind of material, solution or solid, form and the manner in which it is applied can affect efficiency of crop use. Agronomic efficiency can be affected by:

   a. Change of the N material from a less mobile form, ammonium, to a more mobile form, nitrate;

   b. Change to a toxic form, nitrite;

c. Change to oxidized forms, nitrite and nitrate, which are subject to loss as N gases through chemical and biological denitrification;

d. Loss of N as ammonia.

Also possible is change in efficiency because of immobilization, retention or preferential crop use of a particular form of N.

B. Chemical and biochemical reactions of N fertilizer of probable agronomic significance

1. Ammonia volatilization—Results from surface application of any alkaline- and ammonium-producing material on acid or alkaline soils or of any ammonium-producing material on calcareous soils.

2. Seed and seedling damage—Materials with a high salt index placed closer than 5 cm to the seed, in general, materials which contain nitrate or which release free ammonia near the seed or root zone. Of more recent interest, materials which accumulate nitrite.

3. Nitrification

   a. Advantages—Reduces immobilization and ammonia fixation.

   b. Disadvantages—Promotes N loss through leaching, runoff, and biological and chemical denitrification. Results in accumulation of nitrate in subsoil and sometimes in ground water produces residual acidity.

   c. Unknown effects—Regulation of crop N nutrition by supplying apparently preferred form of N and through the interaction of ammonium or nitrate with uptake of other crop nutrients.

4. Residual acidity—Any nitrifiable material contributes to soil acidity. Prolonged use of nitrifiable N without lime results in subsoil acidity.

5. Increased study needed—More information is needed on the residual value of various N fertilizers, their effect on organic matter mineralization and on the chemistry of other soil nutrients, and the agronomic significance of these reactions.

C. Ways to increase N fertilizer efficiency

1. Slow-release N materials—These can be classified as delayed-release or controlled-release. The mechanisms differ in the degree by which dissolution of the N fertilizer can be controlled.

   a. By coating; e.g., sulfur-coated urea.

   b. By manufacture of N materials which have slow rates of water solution or which resist degradation by chemical and/or biological action; e.g., oxamide, ureaform, IBDU.

2. Nitrification inhibitors—Under some cropping situations nitrification inhibitors can increase N fertilizer efficiency by decreasing N loss. Several commercial inhibitors are available.

3. Time and method of application.

D. Application of theory to practice

1. Row crops——N fertilizer reactions in relation to time of application; to method of application; and to crop preference for form of N.

2. Pasture——Surface application; foliar spray.

3. Paddy——Nitrification as related to rice soil management practices; denitrification; increasing N fertilizer efficiency.

4. Special situations

E. Trends in N fertilizer production and use

The application of large amounts of high-analysis materials is creating new problems of soil chemistry and biology. This is to be discussed in relation to the change in N materials being used.

REFERENCES: 76, 109, 116, 123, 124, 125, 225, 229, 321

DESIGN AND OPERATION OF AMMONIA PLANTS

A. History of ammonia synthesis

Development of a practical method for ammonia synthesis was a major challenge to the chemists and engineers at the beginning of the twentieth century. Not only was it necessary to work out the thermodynamic and kinetic background essential to the process, but an entire new engineering technology–operation at both high temperature and pressure–also had to be developed. The early pioneers in the field did remarkably well in bringing the process to plant scale in a period of about 13 years. Since then there has been steady progress until today we have tremendous plants operating at levels of efficiency and production cost that probably would not have been thought possible a few decades ago.

B. Raw materials

1. Coal——Although coal is the major fossil resource, the high investment required for using it as feedstock in an ammonia plant is a major handicap. This situation may change in the future as the cost of other fossil fuel feedstocks continue to rise.

2. Oil——Use of oil as feedstock requires partial oxidation as the method for producing hydrogen. The cost of air liquefaction to supply oxygen for partial oxidation is a considerable drawback, to the extent that very few of the newer plants use oil.

3. Natural gas——The purity and relatively low cost of natural gas make it the preferred feedstock where available. It can be said that modern ammonia technology is based mainly on natural gas.

4. Naphtha—Where natural gas is not available, naphtha, a low boiling petroleum fraction, is usually the best choice. It behaves almost like natural gas in hydrogen production.

5. Coke oven gas—Of the several byproduct sources, the hydrogen present in coke oven gas is the most important. Several metallurgical companies in the United States and Europe freeze out the components other than hydrogen in their coke oven gas and use the hydrogen to make ammonia.

C. Reforming

The first step in ammonia production, called reforming, is reaction of the feedstock with water to form hydrogen. For natural gas and naphtha, this is done by heating in the presence of a nickel catalyst carried in tubes suspended in a reforming furnace. There are several furnace designs in use, each with particular advantages and disadvantages. The continuing trend to higher pressure in the reformer makes it difficult to get good service from the catalyst tubes at the high temperatures involved unless expensive alloys are used.

Complete reaction of the feedstock cannot be obtained economically in the tube-type reformer so a secondary reformer, containing a bed of catalyst not contained in tubes, is used after the primary reforming step. Heat is supplied to the secondary unit by injecting into the gas stream entering the vessel the air needed for supplying nitrogen for ammonia synthesis.

D. Shift conversion

Gas from the reformers contains carbon monoxide as well as hydrogen and nitrogen. To remove the carbon monoxide and get some value from it, further reaction with water, at lower temperature and over a different catalyst, is carried out in stages to give hydrogen and carbon dioxide. The last stage employs a relatively new and sensitive catalyst that converts the carbon monoxide almost completely.

E. Carbon dioxide

Practically all the carbon from the original natural gas or naphtha ends up as carbon dioxide after the shift conversion step. It can be removed by any of several methods that have been developed, most of which involve a wet-scrubbing operation with an aqueous solution of an absorbent. Potassium carbonate, usually with small amounts of "promoters" or "activators," is a popular absorbent. Organic absorbents are also used. Development has been rapid in this field in the past decade.

F. Residual oxides

The preceding steps leave small quantities of carbon monoxide and dioxide in the gas, too much for the ammonia synthesis catalyst which is quite sensitive to poisoning by oxides. The gas is therefore passed over another catalyst where the oxides react with hydrogen to give harmless methane.

Purification can also be carried out by chilling the gas stream to a temperature low enough to liquefy everything but the hydrogen and nitrogen. This is done when coke oven gas is the feedstock, when partial oxidation is the method for making hydrogen, and in one of the new processes with natural gas or naphtha as the raw material.

G. Compression

The actual synthesis requires a higher pressure than for the purification step. The compressors used in the modern large plants are centrifugals, which require less investment than the older reciprocating type. Synthesis pressure is generally in the 2500 to 3500 psi range; few, if any of the plants built in the past several years operate at the high pressures (8000 psi and higher) once widely used.

H. Synthesis loop

In contrast to the three catalytic steps in purifying the hydrogen-nitrogen mixture, ammonia synthesis, also a catalytic reaction, is not complete in one pass through the catalyst. Therefore the gas circulates around a loop, which includes the steps of adding the makeup gas, reacting hydrogen and nitrogen at 1000° F or higher over an iron-base catalyst, condensing and removing the product ammonia, and purging the accumulated methane and argon. Many different designs for the loop and the catalytic converter are in use. The main problem in converter design and operation is cooling the catalyst uniformly to allow use of high temperature without hot spots. For the large new plants, a "quench" type is generally employed; the gas passes through catalyst beds arranged in series and cold gas is injected between the beds to control the temperature.

I. Energy recovery

A modern ammonia plant requires a large amount of energy in the form of steam and power, but offsetting this is the large release of heat by the exothermic reactions involved. The problem is to recover this heat economically and use it in the process. Much progress has been made in this area.

J. Future developments

Increase in plant size has been a major factor in lower production cost. The largest size reported so far is 1500 tons/day in a single train, but future plants may produce 3000 tons/day or more. Other developments may be expected in higher reforming pressure (approaching isopiestic operation), better catalysts throughout, and lower cost removal of carbon dioxide.

REFERENCES: 49, 208, 234, 236, 266, 286, 289, 291

DESIGN AND OPERATION OF NITRIC ACID PLANTS

A. Introduction

Nitric acid was used by alchemists to dissolve silver, and with chloride salts to dissolve gold. It was generally a laboratory reagent until the development of nitro-organic explosives (nitroglycerin, nitrocellulose) when its production from sodium nitrate and sulfuric acid expanded rapidly. Today, the only commercial method of production is based on ammonia oxidation, but this method, discovered in 1838, had to await a reliable, plentiful, and cheap ammonia supply. This was provided by the discovery of the Haber synthetic ammonia process in 1908. Present world production of nitric acid is over 10 million tons/year, with about 75% used for fertilizer manufacture.

B. Three-stage oxidation process

Nitric acid is produced in a three-stage operation where: ammonia is oxidized to nitric oxide; nitric oxide is further oxidized to nitrogen dioxide; and nitrogen dioxide is absorbed and reacted with water to give nitric acid. During absorption, some nitric oxide is formed, and it is reoxidized to nitrogen dioxide and reabsorbed.

1. Oxidation of ammonia to nitric oxide—As generally practiced, air is preheated and then mixed with superheated ammonia vapor to give an 8% to 11% ammonia mixture. This mixture is reacted on a platinum-rhodium gauze pad which catalyzes the reaction. Operating conditions after the catalyst range from 800° to 960° C, and pressures from near atmospheric to 150 psig. Short catalyst contact time, high gas velocities, intimate air-ammonia mixing, absence of catalyst poisons and proper burner design give ammonia to nitric oxide conversion efficiencies of 93% to 98%.

2. Nitric oxide oxidation—The nitric oxide produced in the burner is oxidized to nitrogen dioxide with additional air. This reaction is promoted by low temperature and excess oxygen and usually some form of heat recovery is used at this point. Water vapor is condensed during cooling and is withdrawn from this section as a weak acid; generally this acid is cooled and reinjected into the absorption column. Corrosion is usually severe in the cooler-condenser; Type 430 stainless steel is frequently used for equipment where nitric acid is condensed. To prevent dilution of acid in the absorption column, the gas stream leaving the cooler-condenser should be passed through an efficient entrainment separator to remove entrained weak acid.

3. Absorption of nitrogen dioxide—The absorption of nitrogen dioxide in water and the subsequent formation of nitric acid produces heat. The apparent optimum temperature range for both absorption and reaction is 25° to 30° C. Acid is usually produced in a sieve or bubble-cap tray column equipped with cooling coils on each tray. The gas from the cooler-condenser enters near the base of the column while water is fed onto the top tower tray, giving countercurrent contact of the descending liquid and ascending gas. Cooled cooler-condenser acid is injected at the tray where the liquid stream is of equal strength.

C. Bleaching

The acid leaving the absorption tower is saturated with dissolved nitrogen dioxide. The dissolved nitrogen dioxide is removed by blowing with air. The air-nitrogen dioxide is returned to either the cooler-condenser or absorption column for reabsorption of the nitrogen dioxide.

D. Catalyst

The most commonly used catalyst contains 10% rhodium and 90% platinum. The catalytic operation is still speculative and beyond the scope of this discussion. Contact is obtained by the use of multiple layers of fine screens. Atmospheric pressure burners use large flow sections, fine (0.002-inch diameter) wire and few layers while high-pressure units have restricted flow section and use 0.003-inch diameter wire woven as 80-meshes per inch gauzes and have about 39 layers of gauze. Catalyst renewal periods vary with operating temperature and pressure regime; high pressure units require renewal at about four-week intervals. Low pressure units are renewed less frequently. Catalyst loss also varies with operating pressure, gas flowrate and temperature. Platinum lost from the catalyst is in the form of very fine particles. This dust is deposited throughout the equipment and is generally reclaimed on glass wool filter mats. Recovery and conservation of catalyst dust is an important economic consideration. Catalytic action is reduced by elements such as P, S, Pb and

Sn and even pipe scale or rust containing Fe, Cr or Ni or lubrication oil can also impair the desired chemical reaction. In many cases, catalytic activity can be restored by treatment ("pickling") with hydrochloric acid.

E. Pollution control

Since total absorption is impossible, waste gases from the absorption column contain about 1000 to 2000 ppm nitrogen oxides (NO and NO_2) as well as 2.5% to 5.0% oxygen. This waste gas can be decolorized by heating, but reversion of the nitrogen oxides to nitrogen is only possible by combustion with hydrogen or natural gas on a platinum catalyst.

F. Materials of construction and plant sizes

The entire plant where nitrogen oxides or nitric acid is present is made of stainless steel. Plant sizes are up to about 700 tons/day in a single train. A 700 ton/day plant can produce nitric acid for $3 to $4 per ton less than one with a capacity of only 200 tons/day.

REFERENCES: 67, 68, 251, 266, 301

DESIGN AND OPERATION OF AMMONIUM NITRATE AND AMMONIUM SULFATE PLANTS

A. Importance of ammonium nitrate and ammonium sulfate

Most fertilizer nitrogen is applied to the soil in the form of a solid compound, of which ammonium nitrate and ammonium sulfate are first and second, respectively, in world usage.

B. Factors affecting economics and use

1. Thermal sensitivity—Ammonium nitrate is explosive and flammable; ammonium sulfate is neither.

2. Hygroscopicity—Ammonium nitrate is one of the most hygroscopic fertilizer materials in general use. Ammonium sulfate is relatively low in hygroscopicity.

3. Nutrient content—The higher concentration of ammonium nitrate (maximum of 35% vs 21.5% N) is a major advantage in lowering transportation and handling costs.

4. Acid cost—The cost of the sulfuric acid required for ammonium sulfate increased rapidly during the mid-1960s due to higher S costs.

C. Design of ammonium nitrate plants

1. Neutralizer—The first step in making ammonium nitrate is reaction of ammonia and nitric acid. The neutralizer vessel in which this is carried out usually is designed to recover steam from the reaction heat evolved.

2. Evaporation—The concentrated solution from the neutralizer is further evaporated to remove most of the water and produce a highly concentrated solution of ammonium nitrate.

3. Finishing—The concentrated solution is converted to finished fertilizer by prilling, pan granulation, or drum granulation. Each has special advantages. An important factor is the degree of water removal before finishing; the trend is to remove practically all of it (to 0.5% water or lower) so that drying, a difficult operation, will not be required later. Prilling is the most widely used production method.

4. Conditioning—The hygroscopicity of ammonium nitrate requires that it be treated in some way to reduce caking in storage and difficulty in field application. A coating of clay is the usual treatment, but several others are practiced. Susceptibility to detonation and burning is another problem, handled in Europe and some other parts of the world by granulating with the ammonium nitrate an inert material such as calcium carbonate or ammonium sulfate.

D. Design of ammonium sulfate plants

1. Production with sulfuric acid—Production of ammonium sulfate from ammonia and sulfuric acid is much like making ammonium nitrate from ammonia and nitric acid, except that the ammonium sulfate cannot be converted to a highly concentrated solution and prilled or granulated because it has a much lower water solubility. The usual method is to remove part of the water by utilizing the heat of neutralization and remove the ammonium sulfate as crystals. Usually either the ammonia or the sulfuric acid is a byproduct; otherwise the raw material cost would be quite high.

2. Production from gypsum—In some cases the sulfate ion can be supplied economically by gypsum, either from a natural deposit or as a byproduct from a wet-process phosphoric acid plant. Investment is high and the process has not been used very much.

3. Byproduct—A growing source of ammonium sulfate is from operations such as caprolactam production where ammonium sulfate is a byproduct. Another is power plant operation, where sulfur oxides in the stack gas may be recovered as a means of pollution control.

E. Cost considerations

The main cost factors for production of ammonium nitrate and ammonium sulfate are raw material costs. Production costs of ammonium sulfate, however, are less sensitive to scale of operation than those for ammonium nitrate. Ammonium sulfate often is produced in plants with a capacity as low as five tons/hour. This size plant generally would not be practical for prilled ammonium nitrate; construction of a prilling tower to the required height would result in an excessively high cost per unit of output in a small operation.

F. Future developments

Production methods for both ammonium nitrate and ammonium sulfate have reached an advanced state where further major improvements or innovations are unlikely. For ammonium nitrate new departures probably will be concerned mainly with methods for integrating production with that of other fertilizers such as ammonium phosphate. Developments in ammonium sulfate likely will be in the byproduct area.

REFERENCES: 251, 266, 286, 289

DESIGN AND OPERATION OF UREA PLANTS

A. Status of urea as a nitrogen fertilizer

Urea appeared on the fertilizer scene after ammonium nitrate and ammonium sulfate, mainly because the process is quite difficult and took longer to develop. Economical processes are now available and use of urea is growing. The rate of growth is faster than for any other nitrogen fertilizer except perhaps anhydrous ammonia. The relatively high nutrient content and superior agronomic performance for some crops give it a considerable advantage now that production cost has been brought in line with that for other solid nitrogen fertilizers. Moreover, it has wide acceptance in conjunction with ammonium nitrate as a component of liquid nitrogen fertilizer.

B. Urea reactor

Urea is produced by reaction of ammonia and carbon dioxide (obtained as a byproduct in ammonia manufacture) under elevated temperature and pressure. Since water is a coproduct of the reaction, the product formed in the reactor is a very corrosive solution containing urea and ammonium carbamate. Design of a reactor sufficiently resistant to corrosion has been a major problem in development of urea synthesis. In current practice exotic materials such as zirconium and titanium are used; stainless steel is also suitable if a small amount of oxygen is introduced to form a protective oxide coating.

C. Recycle of unreacted ammonia

Another major problem is that the reaction does not go to completion; the ammonia and carbon dioxide not converted to urea form ammonium carbamate, an unstable compound that must be removed from the reactor effluent solution by heating. The resulting gaseous mixture of ammonia and carbon dioxide is difficult to recycle. If compressed in the gaseous state, solid carbamate forms in the compressor cylinders; if absorbed in water to form carbamate solution, the solution is corrosive and difficult to pump back into the reactor, and the water decreases conversion to urea; if the ammonia and carbon dioxide are separated and recycled separately, the additional expense of separation is a handicap.

Several methods of handling unreacted ammonia are in use.

1. Use of the ammonia-carbon dioxide mixture in some other operation such as production of ammonium nitrate.

2. Recycle of carbamate solution.

3. Recycle of carbamate slurry.

4. Separation of ammonia by scrubbing with an absorbent such as monoethanolamine (to absorb carbon dioxide) or ammonium nitrate solution (to absorb ammonia).

D. Biuret formation

Urea is a relatively unstable compound and may either hydrolyze back to ammonia and carbon dioxide or decompose to biuret if care is not taken. Biuret formation is a problem particularly in concentrating the urea solution (after carbamate stripping) and converting the resulting melt to a

solid product. Evaporators capable of very rapid evaporation help in this because the time of exposure to elevated temperature is minimized. Another method is to crystallize the urea and melt the separated crystals to give a melt for the further finishing steps.

E. Finishing

Urea is converted to the finished form by methods similar to those used for ammonium nitrate. In most plants the method is prilling. However, both pan granulation and drum granulation can be used. Granulation or prilling in oil result in larger size product material than is possible by air prilling.

Urea is less hygroscopic than ammonium nitrate, to the extent that it is sometimes used without any conditioning treatment. Where conditioning is necessary, a clay coating can be used and other methods, such as surface treatment with formaldehyde, are also applicable.

F. Economy of scale

Single-train plants up to 600 to 700 tons;day are now in operation. Plants with capacity below 200 tons;day are comparatively uneconomic. There is a significant advance in operating costs in going to the large, single-train units coupled with large ammonia plants.

REFERENCES: 251, 266, 286, 289

PRODUCTION, MARKETING, AND USE OF AMMONIUM PHOSPHATES

A. Introduction

The fertilizers included in this topic are the monoammonium and diammonium phosphates and the ammonium polyphosphates. Analyses vary slightly, depending upon the production process used. The solid monoammonium phosphates are 13-52-0 and 11-48-0; the solid diammonium phosphates are 18-46-0 and 21-53-0. Solid ammonium polyphosphate, still in the experimental stages of production in 1969, has an analysis of 15-61-0. Fluid ammonium phosphates also are made. They are included in the discussion on fluid fertilizers. Ammoniated phosphates also are excluded from the present discussion. They are classed as homogenous mixed fertilizers.

B. Production aspects

1. General—Ammonium phosphates are produced by ammoniation of phosphoric acid. Practically all granular materials are made by ammoniation of wet-process phosphoric acid to either monoammonium phosphate (13-52-0 or 11-48-0 grade) or diammonium phosphate (18-46-0 grade). Fluid products are made from both wet-process and thermal acids. Practically all the solid products are produced by either the TVA process or the pug mill process.

2. TVA process (rotary ammoniator-granulator)

   a. Process steps—These are preneutralization (one stage), ammoniation and granulation,

drying (not needed for production of ammonium polyphosphate from superphosphoric acid), screening, and cooling of product.

b. Products—These include monoammonium phosphate, diammonium phosphate, ammonium polyphosphate, and mixed fertilizers containing ammonium phosphates with other materials such as potassium chloride.

3. Pug mill or Dorr-type process—Granulation is done in a pug mill or blunger.

a. Process steps—These are neutralization (multitank), granulation (may also include a small proportion of ammoniation), drying, screening, and product cooling. .

b. Product grades—These include monoammonium phosphate, diammonium phosphate, and mixed fertilizers containing ammonium phosphates.

4. Summary of physical and chemical characteristics and of plant food content.

5. Production costs—The approach used in evaluating production costs of nitrogen and of phosphorus fertilizers should be used for the various ammonium phosphates. Location for the plant becomes even more complicated since it is not likely that rock phosphate, natural gas (or other feedstock for ammonia production), and use areas for ammonium phosphate will be congruent. Transportation costs for the various raw materials and the finished products become even more important.

C. Marketing aspects

1. Production and consumption statistics

a. World trends in production and consumption of the various ammonium phosphates vs mixed fertilizers. These statistics should be considered on both a simple tonnage and a plant food basis.

b. U.S. trends in production and consumption.

2. Use as intermediates

a. Mixed fertilizers—Nongranular monoammonium phosphate can be steam-granulated with potash and ammonium sulfate or urea in small plants. Such plants might be more suitable to developing countries than alternative methods of obtaining granular mixed fertilizers. Ammonium phosphate also is granulated with straight nitrogen materials during manufacture to produce N-P fertilizers with higher than usual N contents. A 16-20-0 is made with ammonium sulfate. With ammonium nitrate, the common grades are 30-10-0 and 25-25-0. When urea and ammonium phosphate are co-granulated, the analysis can range from 25-35-0, through 29-29-0, to 34-17-0.

b. Bulk blending—The principal use of diammonium phosphate in the United States is in the production of mixed fertilizers by physically blending various sources of the needed plant nutrients. Bulk blending is considered in more detail in a later outline.

c. Ammonium polyphosphate—This fertilizer presently is used almost entirely for the production of fluid fertilizers, either clear liquids or suspensions. The sequestering effect of

the polyphosphate is advantageous especially if micronutrients are to be added to the fluid fertilizer.

3. Storage, handling, and shipping

   a. Effect of physical and chemical characteristics on storage, handling, and shipping requirements.

   b. Compatibility with other materials—This is important because ammonium phosphates are so frequently used in bulk blending.

   c. Cost of storage, handling, and shipping—The costs for ammonium phosphates should be compared to costs for straight materials and for complex fertilizers.

4. Summary of costs at the retail or farmer level—Production and marketing costs, including shipping costs to the retail outlet, can now be summarized for the various ammonium phosphates either bagged or in bulk.

D. Use aspects

In general, the factors described earlier as affecting the use of nitrogen and of phosphorus fertilizers will apply also to the use of ammonium phosphates. The following advantages and disadvantages apply to ammonium phosphates applied directly to the soil.

1. Advantages

   a. The presence of nitrogen in the same granule as the phosphorus enhances the uptake of phosphorus by the crop. This can result in increased growth of the crop. More important, it can result in growth rather than dormancy when soils are cool and wet.

   b. For some crops, such as rice, greater efficiency of nitrogen use can be obtained when all the nitrogen is in the ammonium form. Thus, ammonium phosphates and their combination with ammonium sulfate and urea, are preferred fertilizers when both nitrogen and phosphorus are required.

   c. Because of the sequestration properties of polyphosphates, it has been postulated that they will resist fixation in the soil, move farther away from the placement site, and increase the availability of micronutrients in the soil by dissolving them from soil minerals. Such effects, if they do occur in soils, have not been big enough to increase crop yields consistently. Under unusual conditions, however, the polyphosphates have been superior to orthophosphates.

2. Disadvantages

   a. Ammonium phosphates have a high salt index. Rate and method of application therefore are more critical than for fertilizers with a low salt index.

   b. In alkaline soils especially, but also in acid soils, free ammonia results from the dissolution of ammonium phosphate in the soil water. The free ammonia can have a deleterious effect on seed fermination and seedling growth. Diammonium phosphate produces more free ammonia than monoammonium phosphate and should not be placed very close to seeds.

REFERENCES: 69, 132, 159, 208, 289, 359, 365, 362

DESIGN AND OPERATION OF GRANULAR DIAMMONIUM PHOSPHATE PRODUCTION UNIT

A. History of diammonium phosphate production

As early as 1920 American Cyanamid Company operated a small plant for the production of ammonium phosphate in the United States; the Consolidated Mining and Smelting Company of Canada, Ltd., built a plant at Trail, British Columbia, in 1933. The Tennessee Valley Authority did pilot-plant development work in the late 1940s and began demonstration-scale production of crystalline diammonium phosphate fertilizer using electric-furnace phosphoric acid in 1955. With efficient processes for production of ammonium phosphate in granular form, using wet-process acid, coming into the picture sas a result of the development of the TVA granular DAP process, these fertilizers were the most rapidly growing type in the 1960s. Continued growth in production resulted in ammonium phosphates becoming the leading type of phosphate fertilizer in the United States in 1968.

1. Crystallizer process

   a. TVA pioneered in development and introduction of 21-53-0 produced in a conventional vacuum-type crystallizer using electric-furnace phosphoric acid with anhydrous ammonia.

   b. In recent years, considerable tonnages of crystalline diammonium phosphates have been produced with byproduct ammonia from coke ovens.

   c. Electric-furnace phosphoric acid is used in virtually all of the crystallizer processes. However, some development work has been done on the use of wet-process acid. Most of these systems that use wet-process acid have met with considerable difficulty in avoiding crystallization problems caused by impurities.

2. Dorr-Oliver slurry process—The earliest process for granular ammonium phosphate fertilizers utilized a slurry ammoniation system followed by granulation in a blunger or pug mill. The Dorr-Oliver process is typical of this type of system.

3. Granular diammonium phosphate process

   a. U.S. Phosphoric Products Division of Tennessee Corporation developed and pioneered a process for the production of granular 18-46-0. In this process, wet-process phosphoric acid is distributed on top of a bed of recycling fines in a rotating drum granulator. Ammonia is introduced through a sparger underneath the rolling bed. Heated air is swept through the drum granulator to lower the moisture content to the level for good granulation. Thus, the drum acts as a reaction vessel, mixer, and granulator as well as accomplishing partial drying. A dense, well-formed granular product is produced in a minimum of equipment.

   b. The TVA rotary drum process, utilizing a preneutralizer and TVA-type ammoniator-granulator offers advantages in flexibility, ease of operation, and efficiency in use of heat of reaction. Most of the large commercial plants currently in operation in the United States use this process. The product dried to a moisture content of 1.5% or less stores exceptionally well in bags or in bulk without conditioning.

B. Development and commercial adoption of TVA granular diammonium phosphate process

1. In the TVA process special emphasis is placed on control of the $NH_3:H_3PO_4$ mole ratio to obtain specific advantages. The preneutralizer is controlled at a mole ratio of approximately 1.45, the point of highest solubility, to produce a fluid slurry of the lowest water content. In the ammoniator-granulator drum the ammonium phosphate is ammoniated further to a mole ratio of about 2.0 to take advantage of a point of minimum solubility. The importance of controlling the mole ratio to obtain the desired high or low solubility has been clearly established in commercial plant operating experience.

2. The TVA rotary drum process was readily adopted by commercial fertilizer producers for the production of granular 18-46-0 because it utilized proved process units already in use in many plants. The first commercial-scale plant was built during the course of early pilot-plant development and was an immediate success.

C. Design and operation of TVA granular diammonium phosphate plant system

1. Process flowsheet

   a. Scrubbing systems--Many of the newer diammonium phosphate plants use venturi-type scrubbers, followed by an entrainment separator, for scrubbing the gases from the preneutralizer and granulator with the incoming feed acid. Other plants use a cyclonic scrubber to scrub the ammonia and separate the entrainment from the gas stream. The scrubbers are usually constructed of mild steel lined with rubber. The scrubbing acid is fed into the scrubbers by overflow from a weir, eliminating the problem of stoppage in spray nozzles.

   b. Preneutralizer--Most preneutralizers in the newer diammonium phosphate plants are constructed of mild steel, brick lined with a rubber membrane between the brick and the steel shell. This vessel is usually the same size as the drum granulator and is located at ground level. The slurry discharge is metered by a magnetic flowmeter and pumped to the drum granulator by a variable-speed pump.

   c. Ammoniator-granulator--A TVA-type ammoniator-granulator in a modern diammonium phosphate plant with a design capacity of 30 to 40 tons/hour is usually 10 to 12 ft in diameter and 20 to 24 ft in length. The drum is driven at 6 to 9 revolutions per minute by a 60- to 100-horsepower electric motor. Retaining rings at each end of the ammoniator maintain a bed depth of about 1 to 2 ft. In many plants designed for the production of diammonium phosphate, a flexible rubber lining is used to keep the drum clean. Other plants use various types of shell scrapers.

   d. Drying, cooling, and product sizing--A conventional rotary dryer with cocurrent flow of air is used in most diammonium phosphate plants. The material enters the dryer at 3% to 4% water and is discharged at about 1.5%. In most plants, only the product-size material is cooled. Two basic types of coolers are used in diammonium phosphate plants. A conventional rotary cooler with countercurrent flow of air is utilized in the older plants, while many of the newer plants are using a fluid bed cooler with success. The screens most widely used in diammonium phosphate production are electrically vibrated. An example of this type screen is the Tyler Hum-mer. These screens are usually installed with 1 to 1.5 sq ft of screen area per hourly ton of throughput.

2. Typical operating conditions

a. Scrubbing systems—The scrubbing solution in a diammonium phosphate plant is made up of phosphoric acid and water. This solution usually contains 22% to 40% P_2O_5 and contains 5% to 10% solids. Usually a small amount of chemical antifoam agent is added to the solution to control foaming. The $NH_3:H_3PO_4$ mole ratio is controlled at 0.2 to 0.6 which are points of high solubility.

b. Preneutralizer—Scrubber solution and phosphoric acid (54% P_2O_5) are fed in metered amounts to the preneutralizer. The resultant P_2O_5 content of these two feeds should equal 40%. Anhydrous ammonia is sparged under the liquid level. The major chemical reactions taking place are:

(1) $NH_3 + H_3PO_4 \rightarrow NH_4H_2PO_4$ + heat

(2) $NH_3 + NH_4H_2PO_4 \rightarrow (NH_4)_2HPO_4$ + heat The reaction represented by equation (1) goes to completion in the preneutralizer. The reactor is normally controlled to an ammonia to phosphoric acid mole ratio of 1.4 to 1.5, so the second reaction also takes place to some degree.

c. Ammoniator-granulator—Granulation is controlled by the following factors:

(1) Mole ratio in drum (1.9 to 2.0 $NH_3:H_3PO_4$)

(2) Evaporation rate in drum (materials enter at about 8% and leave at about 4% H_2O)

(3) Moisture content and temperature of recycle (moisture content 1% to 2% H_2O, temperature 150° to 170° F)

(4) Slurry composition and quantity (the slurry should have an $NH_3:H_3PO_4$ mole ratio of 1.4 to 1.5 and contain about 20% H_2O)

(5) Temperature (the temperature of the bed in the drum should be maintained at about 180° to 200° F)

The normal mole ratio of the ammoniator-granulator product is 1.9 to 2.0 or sufficient to produce the desired 18-46-0 product.

d. Drying and cooling

(1) Temperature of dryer inlet gas, 500° to 700° F

(2) Temperature of dryer exit gas, 185° F

(3) Temperature of product exit dryer, 155° to 180° F

(4) Moisture content of dryer product, 1% to 2%

(5) Temperature of product exit cooler, 130° to 160° F

e. Product sizing—The materials are usually sized on 6- and 12- or 14-mesh screens.

3. Typical product grades

   a. 18-46-0 (the main diammonium phosphate grade produced from wet-process acid)

   b. 13-52-0 (the main monoammonium phosphate grade produced from wet-process acid)

   c. 14-35-14 (KCl plus 18-46-0)

   d. 18-18-18 (ammonium nitrate and KCl plus 18-46-0)

   e. 15-15-15 (ammonium sulfate and KCl plus 18-46-0)

D. Cost information (U.S.A. location)

1. 20 to 30 tons/hour; battery limits basis, cost $1,200,000 to $1,500,000

2. Storage for 30,000 tons is $400,000 to $500,000.

E. Conclusion

Diammonium phosphate is an excellent high-analysis fertilizer. It is well suited for direct application or for blending with other fertilizer materials. The capital investment is about $10 to $12 per annual ton of product (battery limits cost in United States).

REFERENCES: 58, 233, 246, 280, 289, 359, 362, 365

PRODUCTION, MARKETING, AND USE OF NITRIC PHOSPHATES

A. Introduction

Nitric phosphates, also called nitrophosphates, are fertilizers produced by processes in which nitric acid is reacted with phosphate rock. Such processes are attractive because nitric acid is used for the two-fold purpose of acidulating the rock and supplying nitrogen. Consumption of sulfur is less than for acidulation with sulfuric or phosphoric acids. These processes have an inherent disadvantage in that more nitrogen is produced than P_2O_5 resulting in a lack of flexibility of ratios. Nitric phosphates have a low proportion of water-soluble phosphorus—about 10% when only nitric acid is used. The amount of water-soluble phosphorus can be increased by using a mixed acid system.

B. Production aspects

1. When sulfur costs are high, as in many countries without domestic sulfur sources, or when demand for it outstrips supply, interest in nitric phosphate processes accelerates. Production processes, however, are relatively complicated in comparison to those for the ammonium phosphates. This is because calcium must be either removed from the process or converted into an insoluble, non-hygroscopic compound.

2. Processes

   a. Calcium removal type-Odda, Norsk-Hydro, sulfate recycle

   b. Mixed acid type (nitric acid plus phosphoric or sulfuric acid)-TVA and PEC

   c. Carbonitric

   d. Soluble sulfate

3. Compounds present in nitric phosphates

   a. Ammonium nitrate

   b. Monoammonium phosphate (water-soluble P_2O_5)

   c. Diammonium phosphate (water-soluble P_2O_5)

   d. Monocalcium phosphate (water-soluble P_2O_5)

   e. Dicalcium phosphate (water-soluble P_2O_5)

   f. Other metallic salts

4. Handling characteristics

   a. Hygroscopicity is about the same as for ammonium nitrate

   b. Rate of moisture penetration is lower than for urea or ammonium nitrate

c. Should not be blended with materials containing urea

5. Summary of physical and chemical characteristics and of plant food content

6. Production costs---Generally, the nitric phosphates will be lower in analysis than the ammonium phosphates. Transportation costs, per unit of plant food, will limit the distance that this type of fertilizer can be shipped and probably will require that the plant be located in the use area. The increased complexity of the manufacturing processes also adds to the production cost. There are other factors, however, that lower the production cost. These include the elimination or reduction of sulfur and the direct production of a two-nutrient fertilizer.

C. Marketing aspects

1. Production and consumption statistics

   a. World trends in the production and consumption of nitric phosphates vs ammonium phosphates, complex fertilizers, and single-component materials

   b. U.S. trends, as in "a" above

2. Storage, handling, and shipping

   a. Effect of physical and chemical characteristics on storage, handling, and shipping

   b. Compatibility of nitric phosphates with other fertilizers

   c. Cost of storing, handling, and shipping nitric phosphates, especially in comparison to alternative fertilizers such as the ammonium phosphates

3. Sulfur costs--As the cost of sulfur rises, the production of nitric phosphates becomes more and more economically feasible. Thus the cost and availability of sulfur (and sulfuric acid) relative to that of nitric acid becomes a decisive factor.

4. Summary of costs at the retail or farmer level--Production and marketing costs can now be summarized for the various nitric phosphates both bagged and in bulk.

D. Use aspects

In general, the factors described earlier as affecting the use of nitrogen and phosphorus fertilizers will apply also to the use of nitric phosphates. Particularly relevant to the nitric phosphates is the water solubility of the phosphorus. Some crops have less need for water-soluble phosphorus than others; also, the need may vary with the age of the plant.

REFERENCES: 6, 64, 79, 91, 135, 148, 154, 160, 164, 211, 256, 257, 268, 270, 287, 288, 289, 316, 317, 332

DEVELOPING A SOIL TESTING PROGRAM

A. Objectives of a soil testing program

Information gained from soil testing is used in many ways. Some of the more important objectives include:

1. To group soils into classes for the purpose of suggesting fertilizer and lime practices.

2. To predict the probability of getting a profitable response to the application of plant nutrients.

3. To help evaluate soil productivity.

4. To determine specific soil conditions which may be improved by addition of soil amendments or cultural practices.

B. Soil sampling

1. Sampling tools—Each soil sample should represent one reasonably uniform portion of the field. A great variety of equipment is used for sampling soils since some tools are better adapted for certain soil conditions than others. The ideal soil sampling tool is relatively easy to use in the field; takes a small enough volume so that 15 to 20 subsamples can be placed in shipping container; is easy to clean and rust-resistant, and is adaptable to different soils.

2. Area to sample—Most instructions designate the entire field as the area to be sampled. Some instructions, however, suggest that a separate composite sample be taken for every 2 to 5 hectares. Judgment in selecting the area to be sampled usually is based on visual inspection of differences in topography, degree of erosion, drainage, past management, etc. Small areas within the field that are obviously different should be sampled separately or omitted.

3. Depth of sampling—For routine soil tests most of the emphasis is placed on taking samples to a depth of 12 to 15 cm. Although the nature of the soil profile below this layer will influence the growth of plants and the eventual yield that will be obtained, fertility conditions of this part of the profile do not change materially from year to year under most farming conditions. Where lime and fertilizer have been broadcast on the surface of the ground, there is evidence that a better relationship exists between analysis of the upper 5 cm of soil and the plant nutrient requirement than can be obtained by testing a 0- to 15-cm soil sample.

4. Time of sampling—Most laboratories recommend taking samples whenever the soil is in a physical condition that it can be plowed or cultivated. It is known that pH, available phosphorus, and potassium determinations vary throughout the year, but factors responsible for these variations have not been fully appraised.

5. Frequency of sampling—Under ordinary management practices, the fertility and acidity level of soils do not change rapidly. Most soil testing laboratories recommend taking soil samples once every three to five years. This should be sufficient to indicate the trend in fertility and acidity levels and to develop a good management program for the cropping system followed. Under specialized types of farming, such as vegetable production, more frequent sampling may be desirable.

6. Sample preparation—In almost all laboratories the soils are air-dried before analysis. This facilitates crushing and thorough mixing of the soil samples. Under some conditions, the soils are air-dried for about 10 days so that illite-type minerals may release K. Evidence indicates that K uptake by plants is better correlated with the exchangeable K of undried rather than of air-dried samples. Determining K on moist samples presents a number of problems in a large-scale testing program.

7. Crushing—The crushing of all the large lumps in the soil sample is essential to accomplish complete mixing. Most laboratories pass samples through either 10- or 20-mesh screens. Mechanical crushers or mills facilitate crushing, insure more uniform treatment, and are now used in a number of laboratories.

8. Measuring samples—Samples usually are measured rather than weighed. This permits more rapid handling of samples. Uniform methods of filling, including striking off the excess soil, result in reproducible amounts of soil.

C. Some aspects of chemical analyses and nutrient availability relationships

1. pH and lime requirement—The determination of soil acidity was one of the first routine soil tests and still is the determination most widely used. Perhaps pH tells more about the fertility status of the soil than any other single measurement.

   a. Methods—There are two general methods for determination of soil reaction—electrometric and colorimetric. The glass electrode has made pH a simple measurement and this instrument is standard equipment in most laboratories. Values are usually reported to the nearest 0.1 pH. Color indicator dyes are employed in some small laboratories and in field kits but must be used by relatively experienced operators. The results must be checked with pH meters periodically if reliable results are to be obtained. The better methods give deviations of 0.2 to 0.5 pH unit compared with the glass electrode.

   b. Some factors affecting pH value—The pH value of a given soil may be influenced by several factors. In general, pH determinations are made at as low a soil-water ratio as practical. Ratios of 1:1 or 1:2 are generally used. Soil pH is also affected by the concentration of salts in solution; generally, an increasing concentration of salts decreases the pH, but this is not always so.

   c. Lime requirement—Definition: amount of liming material required to raise the pH of an acid soil to any desired value for a particular crop under field conditions. There are a number of ways to determine lime requirement; none are completely satisfactory for all soils. Methods fall in four general categories:

      (1) Depression in pH of a buffered solution

      (2) Multi-rate application of liming materials to soil samples and determination of the resulting pH

      (3) Determination of exchangeable hydrogen

      (4) Liming recommendation based on the measurement of soil pH.

2. Nitrogen—Nitrogen is not determined routinely in most laboratories because of the many

complex factors involved in rendering N available in the soil. These factors include quantity and quality of organic matter, nature and quality of residue from preceding crop, moisture and temperature fluctuation patterns, nature of soil microflora, aeration, soil reaction, mineral nutrient status, and other biotic properties of the soil. A number of laboratory "quick-test" methods have been developed. These include rapid oxidation with permanganate, nitrate production during a specified incubation period, and the amount of organic matter used to infer potential nitrogen availability.

3. Phosphorus—Because of the many forms in which phosphorus can exist in the soil, any soil testing procedure for measuring phosphorus availability s empirical. Extractants for P include water, CO_2 saturated water, acids, bases, salts, and buffered solutions. As would be expected, extractants vary in effectiveness depending upon the origin and nature of the soil.

4. Potassium—In determining "available" potassium, most laboratories use chemical methods that remove an amount approximating the exchangeable portion. K extractants include ammonium and sodium acetate and dilute acids. Ammonium is considered to be the best replacing ion for K in U.S. soils with Na and H following in that order.

5. Sulfur, calcium, and magnesium—Available soil S is not routinely determined except in areas where deficiencies are known to exist. About half of the U.S. laboratories analyze for Ca and Mg on a routine basis. However, the value of such analyses is still questionable. In calcareous soils a determination of free carbonates is of more value than a determination of exchangeable Ca. S, Ca, and Mg analyses should be carried out only when a need is indicated.

6. Micronutrients—Most soil-testing laboratories in the United States do not make routine tests for micronutrients except on special samples. So far there is little information as to the relationship between the amount of these elements found in soils and the needs of crops. The pH of the soil is often used as a guide to minor element deficiencies or toxicities. As with S, Ca, and Mg, the determination of one or more micronutrients is carried out when deficiencies are suspected. The development of the absorption spectrophotometer has greatly simplified the analyses of most micronutrients.

D. Soil factors affecting soil test interpretation

1. Concepts—A continuously adequate supply of nutrients is governed by the following factors:

   a. Intensity factor—The concentration of a nutrient in the soil solution.

   b. Capacity factor—The amount of nutrient in the soil that could come into solution (high in clayey soils).

   c. Renewal rate—The rate of transfer of a nutrient from solid to solution phase (rapid in soils high in clay).

2. pH has three meaningful values:

   a. Below pH 4.0 - free acid.

   b. Below pH 5.5 - exchangeable Al.

   c. 7.8 to 8.2 free $CaCO_3$ - above this range Na is present in increased amounts.

3. Conductivity (Salinity)

MMHOS/cc at 25° C	Effect on Plant Growth
0-2	None
2-4	Sensitive plants affected
4-8	Many crops affected
8-16	Only tolerant crops yield well
16+	Few crops yield well

4. Texture, type of clay, and organic matter

   a. Effect on N—Primarily NH_3 fixation and leaching.

   b. Phosphorus—Most soil tests measure a combination of the intensity factor and the capacity factor. In heavy soils they do not truly measure the capacity factor (and never the rate of renewal). Therefore, soil tests tend to underestimate phosphorus availability to plants grown in heavy soils. Heavy soils are also apt to use up soil test reagents.

   c. Potassium—Factors affecting K availability are somewhat similar to P. Availability to plants is a function of the capacity and intensity factors, as well as the renewal rate.

E. Plant factors affecting soil test interpretation

1. Kinds and varieties of crops to be grown—There are wide differences in the nutrient requirements of crops that must be considered. These differences are taken into account when soil test correlation research is carried out. Varieties of crops also differ markedly in their ability to accumulate ions.

2. Plant populations—Higher plant populations require higher rates of fertilizer application.

3. The effect of the previous crop—This is particularly important with nitrogen, although the availability of other nutrients is also affected.

F. Calibration of soil tests

1. The objective of calibration is to determine:

   a. What fertilizer to use.

   b. When and how to apply the fertilizer.

   c. The amount of fertilizer to apply for a given soil, crop, and management level.

2. Two major relationships are involved:

   a. That between soil test value and the sufficiency of the nutrient for crop growth.

   b. That between soil test value and the rate of application of the nutrient for maximum response.

3. Greenhouse studies—If soil test calibration work is carried out under greenhouse conditions,

the same soil can be used for soil tests and plant growth. Calibration studies can be carried out the year round and the control of experimental variables is easier to accomplish than under field conditions. Greenhouse studies should be augmented with calibration under field conditions.

4. Field studies—Field calibration studies are a necessity, particularly for N rate studies. Field experiments must be carefully designed if reliable data are to be obtained.

5. Response curves—Potential yields on the same soil type may be affected from year to year by climatic, biological, and other factors. Yield vs amounts of nutrient applied should be studied over at least several growing seasons in order to properly assess these factors affecting plant growth. The concept of an "average year" needs to be developed in this respect and the probability of a profitable yield response to fertilizer application evaluated.

6. Economics of fertilizer use—The optimum rate of fertilizer application for maximum profit is the objective sought.

G. Interpretation and recommendations

1. A clear, concise soil test report that includes recommended rates and methods of fertilizer application is essential. The development of a standard soil test report form is the best method of handling this.

2. Information sheets that include the nutrient requirements of crops, soil pH preferences, and yield potentials of various soil associations under varying levels of management are exceedingly useful additions to soil test reports.

REFERENCES: 117, 228, 325, 331, 354

DESIGN AND OPERATION OF NITRIC PHOSPHATE PLANTS

A. Nature and importance of nitric phosphate processes

Processes that use nitric acid (rather than sulfuric or phosphoric) as the only or primary acidulating medium have been developed and used for 20 to 30 years. These processes and products are referred to as the nitric phosphate or nitrophosphate type. These fertilizers form a major part of the production in Europe but have not been widely used in the western hemisphere and Asia. Of the total of 55 plants in operation in 1968, at least 40 were in Europe. Economics of production of nitric phosphate fertilizers may be better than alternatives, particularly where sulfur cost is quite high. Some processes allow complete independence of a requirement of sulfur while others use supplemental sulfuric or phosphoric acids and therefore decrease sulfur requirement only by about half. Most of the products are granular N-P or N-P_2O_5-K_2O grades with total content of 40% to 45%. Some popular grades are 20-20-0, 26-13-0, 15-15-15, 11-22-11, and 28-14-0. There is some production of slurry fertilizers of this type with grades such as 9-9-9.

B. Main type of processes

The main processes are the mixed acid type and the Odda or calcium nitrate removal type. Others add soluble sulfates on a once-through or recycle basis to remove calcium as calcium sulfate or carbonate.

1. Mixed acid type—The nitric phosphate processes of the mixed acid or supplemental acid type use either sulfuric or phosphoric acid together with nitric acid. The supplemental acid reacts with excess calcium to avoid objectionable calcium nitrate and to provide higher water solubility of phosphate in the products. Good operation and reasonable economics are practical for water solubility as high as 40% to 50%. All of the six plants in the United States and those in the western hemisphere in operation (1968) and several in Europe are of this type. Design and operation of these plants are similar to conventional or ammonium phosphate granulation systems. The extraction of phosphate from the phosphate rock and partial (or in some cases complete) neutralization is done in a multistage slurry system. Granulation is accomplished in rotary drum or pug mill (blunger) systems followed by drying, cooling, and product sizing. Recycle is used as the primary control of granulation. Main processes include the TVA type using a preneutralizer and rotary drum ammoniator-granulator and the P.E.C. Spherodizer. Several plants in Germany and other European countries use special modifications of similar systems. The mixed acid processes offer greater flexibility in $N:P_2O_5$ ratio and in grades of products than does the calcium removal type.

2. Odda type—The processes that separate and remove calcium nitrate are often referred to as the Odda type. In this type of process only nitric acid is used to extract P_2O_5 from the phosphate rock. After extraction the slurry is cooled with water and refrigerant to crystallize a controlled proportion of calcium as calcium nitrate. The calcium nitrate is removed by centrifuging or filtration and provides a byproduct, or it can be treated to produce ammonium nitrate coproduct. After separation of calcium nitrate, the finished fertilizers are produced by conventional granulation or prilling systems. This type of process is more economical in raw material cost and particularly attractive where eliminating a requirement of scarce or high-priced sulfur is important. The plant is comparatively complex and investment is higher than for the mixed acid type. A number of large plants in Europe use this type of process and one is being built in the United States in 1969. A major disadvantage is the inflexibility in overall $N:P_2O_5$ ratio and the fact that production of a greater proportion of nitrogen than phosphate is the general pattern.

3. Other types—Other major process types in use or under development include use of ammonium sulfate that is available as a cheap byproduct from another process on a once-through basis or by an ammonium sulfate recycle. Where ammonium sulfate solution is available as a cheap byproduct from an operation such as caprolactam production it can be used effectively to precipitate excess calcium as calcium sulfate. The solution is added to the phosphate rock-nitric acid extract in a proportion to remove a large part of the calcium and provide a product with high phosphate solubility. The calcium sulfate is removed by filtration and discarded. The product filtrate that is primarily phosphoric acid and ammonium nitrate is neutralized, concentrated by evaporation, and granulated or prilled. Grades such as 28-14-0 are produced. Potash can be added to produce complete N-P-K grades.

   A sulfate recycle process that converts the calcium sulfate to ammonium sulfate by reaction with ammonia and carbon dioxide and recycles the ammonium sulfate to the precipitation step has been developed in pilot-plant work by TVA. The small amount of makeup sulfate can be added as natural or byproduct gypsum.

Another process type is the carbonitric that utilizes carbon dioxide instead of supplemental acid. However, use of this process has been limited because the phosphate in the product is water insoluble.

C. Comparison of technology, investment, and operating characteristics

The nitric phosphate processes have been developed and operated over a period of years and a number of proved and dependable systems are available. In general, the granular fertilizer production processes (particularly those that do not require supplemental acid) are somewhat more complex than superphosphate-based or ammonium phosphate granulation systems. However, if we consider that a system such as the Odda or sulfate recycle actually replaces a separate phosphoric acid and sulfuric acid plant that would be needed with the superphosphate or ammonium phosphate systems, the total complexity may not be as great. Investment for the final fertilizer manufacturing facility is likely to be higher, but total investment in a production complex including acid plants is likely to be no greater or perhaps may be less than for the alternatives.

Overall operation and process control for the final fertilizer preparation plant is likely to be more difficult, but savings in raw materials cost offers an attractive overall cost of production.

D. Design criteria and materials of construction

The design of nitric phosphate systems is essentially a combination of wet processing slurry and solution systems with conventional granulation or prilling systems to prepare the closely sized products. Primary design and operating problems center around pumping, metering, and handling slurries that are corrosive and abrasive. Alloys such as stainless steel and suitable plastic materials are needed for most of the equipment. Equipment for control of atmospheric and aqueous wastes is important though generally not more complex than for other processes. There is a need to limit input water to the process since a considerable amount is included in feed materials; use of concentrated nitric acid of 60% to 70% concentration is important. Accurate metering of feed materials and process streams is essential, and materials handling and conveying equipment should be rugged and generously sized. Successful operation depends upon good operating technique and minor innovations in equipment and procedure that adapt the basic process to the particular application.

E. Advantages and disadvantages

1. Main advantages of nitric phosphate production are:

   a. Eliminates or substantially decreases requirement of sulfur for production of phosphatic fertilizers.

   b. Raw materials cost usually is lower than for other processes.

   c. A number of process types and modifications are available to adapt to requirements.

   d. Production stems naturally from ammonia that is used to produce the nitric acid that is required. Process benefits from recent improvements in technology and economics of ammonia and nitric acid production.

2. Some disadvantages include:

a. Special technique or supplemental acid needed to obtain high water solubility. All processes can be readily adapted to 40% to 50% water solubility; some as high as 90%.

b. Flexibility of $N:P_2O_5$ ratio is limited—generally in range of 1:2 to 2:1.

c. Nitrate form of nitrogen is not preferred for some crops such as rice.

d. Normally a total of about 2 pounds of N is produced for each pound of P_2O_5 when total output of plant is considered.

F. Future prospects

The sulfur shortage and increased price in the 1966-68 period led to greatly increased interest in the nitric phosphate route to phosphatic fertilizers. Several large new plants, mostly of the Odda type, were announced and planning and evaluation were active in many areas. Construction of the first Odda-type plant in the United States was started in 1968. A continued steady growth is indicated, particularly in areas where sulfur must continue to be imported. Research and development efforts will be directed at process improvements and particularly toward obtaining greater flexibility in overall $N:P_2O_5$ ratio and greater variety of products.

REFERENCES: 79, 135, 148, 154, 160, 268, 270, 287, 289, 316, 317

PRODUCTION, MARKETING, AND USE OF POTASSIUM FERTILIZERS

A. Introduction

Practically all potassium fertilizers are supplied as potassium chloride (KCl, 60% to 62% K_2O), potassium sulfate (K_2SO_4, 50% to 52% K_2O), sulfate of potash-magnesia ($K_2SO_4 \cdot 2MgSO_4$, 22% K_2O and 10.8% Mg), and potassium nitrate (KNO_3, 44% K_2O). The chloride and sulfates usually are mined and the nitrate manufactured.

1. Intermediates—All of the common potash sources are used as intermediates in the manufacture of complete fertilizers. For the manufacture of fluid fertilizers, potassium hydroxide, potassium carbonate, and potassium bicarbonate also may be used.

2. Direct application—The chloride, sulfates, and nitrate are used for direct application. Granular material is preferred for this use.

B. Production aspects

1. Potassium chloride

a. Sources—Sylvite (KCl) and carnallite (KCl and $MgCl_2$)-practically all from naturally occurring minerals

b. Mining methods—Tunnel and solution

c. Purification—Grinding and flotation

d. Product sizes—Coarse, granular, standard

e. Characteristics—Relatively non-hygroscopic, free-flowing, and non-caking

2. Potassium sulfate

a. Sources—Langbenite (K_2SO_4 and $MgSO_4$), polyhalite (K_2SO_4, $MgSO_4$, and $CaSO_4$), and glaserite (K_2SO_4 Na_2SO_4)

b. Mining methods

c. Purification

d. Product sizes

e. Characteristics—Relatively non-hygroscopic

3. Potassium nitrate

a. Sources—Normally produced from the reaction of potassium chloride with nitric acid.

b. Product sizes—Normally prilled

c. Characteristics—Very hygroscopic

4. Multinutrient fertilizers containing potassium

a. Complex fertilizers—Potash can be added during the manufacture of ammonium phosphate, nitric phosphate, triple superphosphate, and in other processes. Grades with a high proportion of potash are difficult to granulate but some forms of potash are easier to granulate than others. Generally, chemical reactions between potash and other materials are not important to the actual production of the fertilizer; however, chemical reactions may occur.

b. Bulk blends—The chief concern here is to obtain granular potash with a size distribution closely matching that of the other materials used in the blend.

c. Fluid fertilizers—Solubility limits the amount of the usual potash carriers that can be used satisfactorily in clear liquid fertilizers. Potassium hydroxide and the carbonates permit higher grades to be made. For suspension fertilizers, small crystals are superior to granular potash.

5. Summary of physical and chemical characteristics and of K_2O content

6. Production costs—Mine site cost of potash varies with the type of mine, quality of the ore, volume of production, and other factors. Since mine sites are fixed, transportation costs to fertilizer manufacturing plants (and to use areas) are significant considerations.

C. Marketing aspects

1. Production and consumption statistics

   a. World trends in production and consumption of the various potash materials.

   b. U.S. trends, as in "a" above.

2. Storage, handling, and distribution costs—These vary depending upon whether the potash is used as an intermediate in the production of multinutrient fertilizers or for direct application.

3. Summary of costs at the retail or farmer level—Production and marketing costs, including shipping costs to the retail outlet, can now be summarized for the various types of potash fertilizers.

D. Use aspects

1. Role of potassium in plants

   a. Physiological processes—Photosynthesis and respiration, carbohydrate metabolism and translocation, reduction of nitrates and synthesis of proteins, and cell division

   b. Quality factors—Color, size, and storage of fruits and vegetables; disease resistance; winter hardiness of perennials; chipping characteristics of potatoes; and smoking quality of tobacco.

2. Plant requirements for potassium

   a. Differences among species

   b. Variations in needs during the growing season

   c. Effect of other nutrients on requirements and availability, such as calcium and lime level and rate of nitrogen applied

3. Soil-plant-potassium relationships

   a. Reaction and movement of potassium in the soil

   b. Mechanism of potassium absorption by plants

   c. Interaction of potassium with other ions

   d. Time, rate, and method of applying potassium fertilizers

4. Evaluation of potassium fertilizers

   Remarks appropriate for the evaluation of phosphate fertilizers are appropriate here.

REFERENCES: 185, 191, 235, 251

FERTILIZING THE CROP VS THE SOIL

The question, Should fertilizer be applied for the immediate crop or for soil buildup, is often asked by farmers, agronomists, and others. Although there is no specific answer to this question, one should consider various factors which can affect the choice and also the plant nutrient to be applied before deciding which alternative to follow.

A. The alternatives

1. Fertilizer for the immediate crop—One must know the nutrient requirements of the crop to be fertilized and the fertility status of the soil. The fertilizer recommendation should supply sufficient nutrients to supplement the available nutrients supplied by the soil. It must take into account the expected plant recovery of each of the applied nutrients.

2. Fertilizer for soil build-up—This implies that enough fertilizer should be applied to raise the nutrient level in the soil to provide for succeeding crops. The fertilizer should be incorporated with as much soil as possible. However, the available level of some plant nutrients is increased in the process of fertilizing for the immediate crop.

B. Factors affecting the choice between alternatives

1. Soil pH—If soils are very acid, added phosphate is likely to be fixed in unavailable forms, therefore Alternative 1 is preferred. Liming acid soils is recommended before Alternative 2 is followed.

2. Level of available soil nutrients—When levels of available soil nutrients are low, broadcast applications may be of more benefit to the crop throughout the year. Increasing the quantities of some nutrients to acceptable levels under Alternative 2 should be of benefit in soils which are extremely low in available plant nutrients.

3. Mobility of plant nutrients in soil—Mobile nutrients such as nitrate nitrogen should be included only in Alternative 1. Only those plant nutrients which are not subject to leaching losses should be applied under Alternative 2.

4. Relation to other management practices—More immediate returns on the extra investment required for Alternative 2 will result if recommended varieties and plant populations are used, together with good weed- insect- and disease-control measures.

5. Capital available for fertilizer purchase—Since fertilizer represents only one production cost, Alternative 1 would be followed when limited funds are available.

6. The fertilizer supply—Alternative 1 would be followed when there is a limited supply of fertilizer. Prices would be higher, and the long-term investment required for Alternative 2 may not be profitable.

7. Land ownership and tenure arrangements—One generally could not afford to follow Alternative 2 if he did not own the land. The tenant and landlord should agree on sharing fertilizer costs if a good soil fertility program is to be followed.

8. Climate and assurance of crop response—Alternative 1 would be followed when the risk or uncertainty of crop production is high. However, fertilizer is the only production cost which can be partially recovered in a succeeding crop in case of a poor crop season.

C. Characteristics of each plant nutrient in relation to the above factors

1. Nitrogen—Conservation of soil organic matter, the use of legumes, green manure crops, and the return of stover to the soil are practices which will help maintain the nitrogen level in the soil. Nitrogen is a mobile nutrient, so it may leach beyond the root zone if applied long before it is needed. There is little residual effect from applied nitrogen beyond the second year after application.

2. Phosphorus—Application of this nutrient is generally considered as suitable for Alternative 2. The amount required to raise the level of available phosphorus depends upon the soil texture, soil pH, and types of clay minerals which influence the phosphorus fixation capacity. This nutrient does not move far from its application site in the soil.

3. Potassium—Sandy soils will not retain as much potassium as heavier textured soils; therefore, Alternative 2 should not be used in sandy soils. Certain micaceous minerals will fix potassium so that it is unavailable to plants. It may not be profitable to follow Alternative 2 on soils with large amounts of these minerals.

4. Calcium and magnesium—These nutrients are usually well supplied if the soil pH is maintained at the proper levels. Dolomitic limestone provides both nutrients, and Alternative 2 is preferred because of the important relationships between soil pH and availability of other nutrients.

5. Sulfur—This nutrient is mobile in the sulfate form, but most of the available supply is found in the organic fraction which is not subject to leaching. When sulfur deficiencies exist, the sulfate form should be applied to the crop, but Alternative 2 may be followed by applying elemental sulfur, which is slowly oxidized to the sulfate form.

6. Micronutrients—Most micronutrients are relatively immobile in soils. The available supply is related to the organic matter content and the soil parent materials. More research is required to determine if these nutrients may be applied under Alternative 2. Boron and copper are toxic to plants when applied in amounts slightly above the normal recommendations. Many interactions occur among the micronutrients and also with other nutrients; therefore, much care is required in applying the micronutrients to soils.

D. Summary

Fertilizer is usually applied to soils to produce the most profitable yield and quality of a crop. Under some conditions, it is most profitable to fertilize for the immediate crop only. Fertilizing to build the soil fertility level can be considered when soils retain the nutrients in an available form and when economic conditions are suitable for a profitable return on a long-term investment.

REFERENCES: 30, 48, 75, 96, 176, 178, 180, 222, 230

PRODUCTION, MARKETING, AND USE OF HOMOGENOUS MIXED FERTILIZERS

A. Introduction

1. Definitions

   a. Homogenous mixed fertilizer vs bulk blended fertilizer

   b. Synonyms: complex fertilizer, complete fertilizer, chemically combined multinutrient fertilizer, granular mixed fertilizer, etc.

2. Importance of subject—Over half the plant nutrients used in the United States are applied as mixed fertilizers. Although the fluid mixtures and the bulk blends are included in this figure, homogenous mixed solid fertilizers form an important segment of the total fertilizer production. These fertilizers also are important in many other regions of the world.

B. Production aspects

Production of homogeneous mixed fertilizers usually involves chemical reactions to produce heat and moisture for granulation. It usually is economical to provide heat by fixation of ammonia with phosphoric acid, superphosphates, or sulfuric acid.

1. Raw materials (chemical and physical characteristics)

   a. Nitrogen sources

      (1) Anhydrous ammonia

      (2) Ammonia-ammonium nitrate-water ammoniating solutions

      (3) Ammonium sulfate

   b. Phosphate sources

      (1) Phosphoric acid

      (2) Single superphosphate

      (3) Triple superphosphate—nongranular

   c. Potassium sources

      (1) Potassium chloride (most common)

      (2) Potassium sulfate

2. Processing steps and description of equipment

   a. Weighing and proportioning raw materials

b. Ammoniation

c. Granulation (often simultaneous with ammoniation)

(1) TVA rotary ammoniator-granulator

(2) Pug mill

(3) Pan granulator

d. Drying

e. Sizing

3. Quality control

a. Size and shape of product

b. Chemical analysis of product

c. Storage characteristics of product

4. Formulating——Determining which raw materials will be used and their relative proportions.

a. Product mix must have proper nutrient content.

b. Feed materials must have sufficient liquid phase for granulation.

c. Most economic combination of materials must be used.

5. Some common grades and ratios

a. 1:4:4 ratio——6-24-24; 5-20-20

b. 1:2:2 ratio——10-20-20; 8-16-16

c. 1:1:1 ratio——15-15-15; 12-12-12; 10-10-10

d. 2:1:1 ratio——20-10-10; 16-8-8

6. Summary of physical and chemical characteristics

7. Production costs——Plant investment for granulation plants usually is higher than for bulk blending or liquid cold mix plants. Economy of scale is important in reducing operating costs (per ton of material or plant food)—but increased distribution costs will nullify some of these economies. Also, as plant size is increased, so is the size of the distribution area. This increases the diversity of soils and crops and may lead to an expansion in the number of grades manufactured, again increasing production costs. Location of plants with respect to the market area and the source of raw materials requires an extensive market analysis.

C. Marketing aspects

1. Production and consumption statistics

   a. World trends in production and consumption of homogenous mixed fertilizers vs bulk blends and single component materials used for direct application.

   b. U.S. trends, as in "a" above.

2. Cost of storing, handling, and distributing homogenous mixed fertilizers in comparison to other methods of supplying plant nutrients to the retail dealer or the farmer.

D. Use aspects

1. Matching available grades to soil test recommendations.

2. For farmers with little knowledge about fertilizers, the use of homogenous mixtures reduces chances for errors in application and simplifies fertilizer educational programs.

REFERENCES: 133, 136, 137, 138, 140, 145, 244, 245, 246, 285, 359, 363, 364, 366

SELECTING GRADES AND RATIOS FOR DEVELOPING COUNTRIES

A. Introduction

1. Definition of terms—A fertilizer ratio is the proportion of nitrogen to phosphorus to potassium ($N:P_2O_5:K_2O$ or N:P:K). Ratios are expressed in whole numbers reduced to the lowest possible values, as 1:1:1 and 3:1:2. Grade is the actual percentage of nitrogen, phosphorus, and potassium in a fertilizer ($N\text{-}P_2O_5\text{-}K_2O$ or N-P-K), such as 10-10-10, 15-15-15, 12-4-8, and 18-6-12.

2. Importance of subject—Too few ratios prevents efficient use of fertilizer relative to the fertility of a soil and crop needs for nutrients. An excessive number of grades and ratios increases costs of production and marketing and also increases the complexity of the fertilizer educational program.

B. Grades and ratios in the United States

1. Reasons for proliferation of grades—The flexibility of manufacturing processes, the wide variety of raw materials available for fertilizer production, and competition in a free market have resulted in the annual production of over 3000 grades in the United States.

2. Examples of grades and ratios in various states and regions—The United States is divided into 9 geographical regions. For each region the 10 leading grades of fertilizer can be determined. These 90 grades, in 1962, comprised only 25 different ratios. Only 3 ratios had annual sales in excess of a million tons.

3. Effects of an excessive number of grades on production, marketing, and use of fertilizers—An excessive number of grades complicates manufacturing processes, requires expensive raw materials, reduces volume purchases, increases inventory, increases advertising, requires more supervision, increases labor costs, and increases the cost of fertilizer.

4. U.S. methods of controlling proliferation—Annual conferences among representatives of industry, land-grant universities, and state control organizations result in state or regional "Grades and Ratios Lists." Such lists are guides to the ratios needed in an area and the grades that can be produced by manufacturers selling in that area.

C. Soil testing and bulk blending in relation to grades and ratios

1. Soil testing—Research agronomists classify N, P, and K soil test values into a few broad categories. If three categories (high, medium, and low) are used for each nutrient, 27 different nutrient combinations are possible. At this point, practical considerations must be injected to prevent 27 different ratios from being recommended for use–for just one crop.

2. Bulk blending—Bulk blending and distribution allows the fertilizer dealer to supply the exact amount of plant food recommended by soil tests. Only four or five base materials need to be stocked to provide the exact fertilizer for each customer. Grades and ratios are meaningless, but state fertilizer control laws require that they be reported. (Many bulk blenders do sell specific grades, both bagged and in bulk, in order to provide a full service to their customers.)

D. Agronomic significance of grades and ratios

1. Effect of varying ratios—Agronomic-economic investigations with NPK experiments show that plant nutrients "substitute" for each other in a nonphysiological sense. As a result, nutrient ratios are not very critical in affecting either yield or profit from fertilizer use.

2. Effect of changes in soil fertility status—Use of fertilizer at low to moderate rates over long periods of time or at high rates for just a few years can greatly modify the fertility status of a soil. Agronomists must watch for such shifts and warn manufacturers of impending changes in the ratios that farmers need.

3. Placement and time of application—Generally, when a low rate of fertilizer is used, all is applied at planting time. A rather precise ratio of $N:P_2O_5:K_2O$ must be used. As rates increase and fertilizer is split into preplant, planting time, and sidedressing or topdressing applications, ratios become much less important. Various mixed fertilizers are balanced with straight materials to meet the total fertilizer requirement.

E. Economic significance of grades and ratios

1. High analysis vs low analysis grades—Transportation costs make up a substantial portion of the total cost of fertilizer. Since fertilizer is shipped on a weight basis rather than on a composition basis, the higher the plant food content, the lower the cost per unit of plant food.

2. Least-cost grades within a ratio—There are many ways and materials that can be used to produce a fertilizer with a particular ratio. Process choices vary according to the availability of various raw materials and long term price expectations. Within these broad limitations, short term variations in prices may determine the grade actually produced.

F. Application of theory to a practical situation

A survey of the fertilizer needs in Morocco resulted in a list of 24 grades that could be justified on an agronomic basis. Manufacturing facilities consisted of a diammonium phosphate plant that could produce 18-46-0 and a triple superphosphate plant that produced 0-46-0. A slight modification to the diammonium phosphate plant would permit a range of $N:P_2O_5$ ratios to be produced instead of the single 18:46 ratio. Other modifications, again minor, would permit the addition of potash to these fertilizers. A similar modification in the triple super plant would provide a broad range of PK fertilizers. By using straight materials along with the five mixed fertilizers finally recommended for production, any farmer could follow precisely the fertilizer recommendations of the agronomist.

G. Summary

In view of the costs involved in producing and marketing a wide variety of grades and because there is little loss in yield or profit when farmers are limited to a few grades, developing countries should decide quickly which grades will be produced. It is much easier to control the number of grades and ratios in the early stages of industry development than after the proliferation already has taken place. Low-analysis grades should be discouraged and every effort made to keep the cost of nutrients to the farmer as low as possible.

REFERENCES: 93, 95, 119, 131, 181, 294, 334

DESIGN AND OPERATION OF AMMONIATION-GRANULATION PLANTS

A. Introduction

All modern ammoniation-granulation plants are based on continuous operation. Heat and liquid phase for granulation are normally derived from reaction of ammonia with superphosphates, sulfuric acid or phosphoric acid. Fertilizer granulation is usually a combination of layering and agglomeration of the concentrated salt materials. Ammoniation and granulation can both be done in one equipment unit or they may be carried out in separate units.

B. Design factors

1. Simultaneous ammoniation and granulation—Normally done in TVA-type rotary ammoniator-granulator. Ammoniation is usually done over about the first half of the length of the unit with granulation over the second half. Ammonia is injected beneath a rolling bed of material.

a. Size—Up to about 11 feet diameter by 23 feet long.

b. Capacity—Up to about 250 ton/hour throughput (product + recycle)

c. Materials of construction—Normally mild steel with stainless steel distributors for fluid reactants.

2. Separate ammoniation and granulation—Ammoniation usually done in mixing tank to produce a slurry. The slurry is then fed to a granulation unit where it is used to granulate recycle (undersize) material.

   a. Pug mill or blunder—Usually two rotating shafts with mixing paddles to mix undersize and slurry. Can handle up to about 200 ton/hour throughput.

   b. Pan granulator—Inclined rotary pan tilted at about a 60° angle with horizontal. Recycle material is coated by a spray of hot, concentrated slurry. The maximum diameter is about 14 feet. It is of mild steel construction and can handle up to about 100 ton/hour throughput.

   c. Spheroidizer—Rotary, horizontal unit that serves as combination granulator-dryer. Slurry is sprayed into recycle cascading from lifting flights. It is of mild steel construction with about 100 ton/hour usual maximum throughput.

C. Operating factors

Operation must be controlled to give a product of the desired plant food concentration with the proper size and shape. The product must also have good storage and handling properties.

1. Chemical analysis—Determined by formulation or ratio of various feed materials. Good control of feed materials is essential. Slight adjustments in feed rates are based on control analyses taken during operation.

2. Size and shape of product—This is affected by many variables, such as composition of the mix, temperature, moisture content, particle size of the feeds, proportion of recycled material, etc. Many of these variables cannot be regulated closely. Usually practice is to vary proportion of recycle to give desired product size and shape.

REFERENCES: 79, 133, 136, 137, 138, 140, 214, 215, 244, 245, 246, 251, 265, 359, 363, 364, 366

PRODUCTION, MARKETING, AND USE OF BULK BLENDED AND FLUID FERTILIZERS

A. Introduction

1. Definitions

   a. Bulk blended vs homogenous mixed fertilizers; bulk spreading

   b. Fluid, clear liquid, suspension, and slurry fertilizers. Single nutrient fluids, such as the nitrogen solutions, have been considered in an earlier outline.

2. Significance of the subject—Bulk blending was started in 1947 as a bulk spreading operation in Woodford County, Illinois. It rapidly developed into a new system of handling, marketing, and applying fertilizers in the United States. It appears to have considerable potential in developing countries that are unable to justify their own manufacturing facilities yet need some flexibility in providing the plant nutrients required for crop production.

   If liquid manures and nitrogen solutions are eliminated from consideration, then the fluid mixed fertilizers can be said to have originated in 1946 in California. Growth of the fluid fertilizers was very slow until they became sufficiently important to create a demand for new types of raw materials, manufacturing techniques, and application machinery. Fluid fertilizers now include the clear liquid mixtures and the suspension and slurry fertilizers.

B. Production aspects of bulk blended fertilizers

Bulk blending is physically mixing solid fertilizer materials. The more popular blending materials are triple superphosphate, diammonium phosphate, ammonium nitrate, potassium chloride, and urea.

1. Processing steps

   a. Unloading raw materials into storage.

   b. Transporting raw materials to weighing or proportioning device.

   c. Mixing or blending the raw materials.

   d. Either bagging the blended materials or feeding them to a bulk spreading truck.

   e. Transporting the blended product to the field.

2. Reasons why blending is attractive

   a. Economy—Finished nitrogen, phosphate, and potassium fertilizers can be produced in large economic plants in different areas and combined in market area.

   b. Versatility—Practically any grade or ratio can be produced.

c. Convenience—Bulk spreader truck can carry freshly blended material directly to field. No bagging or storage of fertilizers is necessary. No farmer labor is required.

3. Costs of blending

   a. Capital costs—Usually $40,000 to $50,000, not including distribution equipment. (Little or no foreign exchange would be needed for most countries.)

   b. Operating costs—$5 to $7/ton plus $8 to $10/ton for bagging (if bagged)

   c. Bulk transport and spreading cost—Normally, $8 to $10/ton

4. Pitfalls in blending

   a. Materials must have same particle size.

   b. Materials must be chemically compatible.

      (1) Do not blend urea and ammonium nitrate.

      (2) Do not blend urea and TSP or NSP.

5. Summary of physical and chemical characteristics

C. Production aspects of fluid fertilizers

Fluid fertilizers can be divided into three broad categories–solutions, slurries and suspensions. Nutrient ratios for the three types of fluids are primarily the same, but grade varies in accordance with salt concentrations and additives. The manufacture of all types of fluids involves the following steps: (1) receiving and storing raw materials, (2) proportioning raw materials, (3) mixing, and (4) storing product. Polyphosphate P_2O_5 materials increase solubility of N-P fertilizer salts and some metallic impurities.

1. Solutions—All or practically all of salts are in solution.

   a. Possible grades—Limited to about 25% to 30% nutrients. Polyphosphates not required.

      (1) 8-24-0 grade

      (2) 8-8-8 grade

   b. Processing—Proportioning

      (1) Cold mix—No chemical reactions

      (2) Hot mix—Chemical reaction supplies heat by ammoniation

   c. Stability—Can salt out at lower temperatures

2. Slurries—Salt concentrations exceed saturation point, but no stabilizing agents are added.

a. Possible grades—Limited to about 25% to 39% plant nutrients. Polyphosphates are needed.

(1) 11-37-0

(2) 12-12-12

b. Processing—May be hot mix or cold mix.

c. Stability—Mixing must be continued to prevent salting out.

3. Suspensions—Salt concentrations exceed saturation point, but stabilizing agents, such as clay, are added to increase viscosity and slow settling rates of suspended salts.

a. Possible grades—40% or more nutrients. Polyphosphates are needed.

(1) 12-40-0 grade

(2) 15-15-15 grade

b. Processing may be either hot mix or cold mix.

c. Stability—Slow segregation occurs when allowed to stand without continuous mixing.

4. Summary of physical and chemical characteristics

5. Production costs—These costs vary according to type of plant and type of product. Cold-mix plants are less expensive to build and to operate than are hot-mix plants. They also are more limited in the types of materials that can be used in producing liquid fertilizers, and this limitation frequently requires the use of more expensive raw materials. Clear liquids are more likely to have a lower plant food content than suspension fertilizers. Thus, cost per ton of fertilizer may be lower. On the other hand, clear liquids also require a very careful selection of raw materials, as compared to suspensions, and these may be more expensive. For both clear liquids and suspensions, the manufacturing technique must be followed rather precisely; and thus, the plant manager must be very capable.

D. Marketing aspects

1. Production and consumption statistics

a. World trends in the production and consumption of bulk blended fertilizers

b. U.S. trends

c. World trends in the production and consumption of fluid fertilizers

d. U.S. trends

2. Storage, handling, and distribution problems

a. Segregation in bulk blends, salt out in clear liquids, and settling in suspensions

b. Size of area serviced by the production plant

c. Custom application vs farmer-owned equipment and application

d. Seasonal demand

e. Costs due to storage, handling, and distribution

3. Summary of costs at the farmer level—Production and marketing costs can now be summarized at the farmer level.

E. Use aspects

1. Bulk blended fertilizer—These fertilizers can be, and are, applied with equipment that places them precisely in the ground, probably to the side and below the seed. On the other hand, by far the largest proportion of bulk blends in the United States are applied broadcast on the surface of the soil and then worked in by plowing, disking, or other ways. For this method of application, there are several considerations.

   a. Effect of broadcast applications on the amount of plant nutrients needed for desired crop growth.

   b. Supplementing broadcast fertilizers with starter and sidedressing or topdressed fertilizer.

   c. Timing applications to adjust labor input and cash flow more evenly throughout the year.

   d. Uneven distribution due to segregation, unequal rates of application, or other causes is considered in more detail in another outline.

2. Fluid fertilizers—These are applied either broadcast or banded as desired. Research shows that the physical form of the plant nutrient, dry or fluid, has no measureable effect on its agronomic properties. Fluids, however, are used in preference to solids by farmers seeking to reduce labor requirements to a minimum as well as those who are concerned by evenness and timeliness of fertilizer application. Some of the considerations listed above for bulk blends apply also to fluid fertilizers.

REFERENCES: 1, 2, 110, 111, 141, 142, 143, 144, 146, 151, 153, 156, 157, 226, 274, 276, 282, 284, 313, 367

AGRONOMIC CONSIDERATIONS IN THE BULK DISTRIBUTION OF DRY AND FLUID FERTILIZERS

A. Introduction

1. Definition of terms—Bulk distribution refers to the mechanical handling and application of fertilizer materials in non-packaged form, i.e., in large lots. Dry fertilizer usually refers in this context to granulated materials, both bulk blends and homogenous mixtures; fluid fertilizer to both liquid (true solutions) and suspensions (suspended solids + solution).

2. Significance of this subject—Handling and applying fertilizers in bulk introduces the possibility of nonuniform application of nutrients. It is the purpose of this outline to examine the causes and agronomic effects of nonuniform application such as might arise from this approach to fertilizer distribution.

B. Causes of nonuniform distribution

1. Segregation of materials—One of the causes of nonuniform distribution is that frequently bulk blends will separate into the original components through handling. Research has shown that segregation can be minimized by careful matching of granule sizes. For suspensions, segregation through "settling" of solids are prevented by agitation before and during application.

2. Poor spreading technique—The spreading of either dry or fluid fertilizers calls for skill in handling equipment. If poor technique is used, uneven distribution of fertilizer nutrients will often be visible in the crop. The farmer is usually quite concerned about such evidence.

C. Agronomic effects of nonuniform distribution

1. Segregation effects—Segregation can result in a nonuniform nutrient mix in the fertilizer, with variation in nutrient ratio. While this creates problems for quality control inspection, it would have to be quite serious before causing noticeable agronomic effects or losses in farmer profit. This is a problem primarily for granulated solids; however, it can also occur with suspensions if proper agitation is not obtained.

2. Effects of nonuniform spreading—The effects of nonuniform spreading would be equally relevant to granular solids, liquid, or suspension forms. The agronomic importance of nonuniform spreading depends largely on the magnitude of the deviation from the average rate, the shape of the response curve or surface, the rate of nutrients applied, and the level of soil fertility. With these variables to consider, it is difficult to predict the yield or profit effects of nonuniform application in advance. However, studies that have been conducted indicate that fairly wide deviations can be tolerated without serious yield or profit losses. This would not be true for sites of low soil nutrient levels and when average rates of application were also quite low.

D. Summary

The agronomic effects of nonuniform application as a result of either segregation or poor spreading technique would be important primarily with a combination of low soil nutrient levels and low rates of application. At higher soil levels and average rates of application, fairly wide deviations in uniformity of application can be tolerated without serious yield or profit losses. Segregation relates primarily to granular solid blends or to suspensions; no problems would ordinarily be expected with liquid if all nutrients were in solution. The effects of poor spreading technique would apply equally to solid, liquid, or suspension forms.

LOCATION OF BULK BLENDING PLANTS AND THE ECONOMICS OF BULK BLENDING

A. Considerations regarding location

Fertilizer bulk blending plants provide a convenient and economical means of mixing dry fertilizer materials to produce specified ratios or grades. A principal virtue of blending is the ability of the blender to produce an unlimited number of ratios and grades to suit individual needs–frequently determined by soil testing. Blending plants usually serve a marketing area of 12 to 15 miles or less. Often, the bulk blending enterprise is incorporated within a firm having other farm supply and/or farm product buying enterprises to provide a well-rounded business serving farmers' needs. The location of the blending plant can be an important determinant of its success in the area it is supposed to serve.

1. Market environment––The market environment at any location consists of the numerous aspects of an area that affect bulk blended fertilizer sales or potential sales from a designated plant. The blending plant is the center of the marketing or distribution activity. Hence, the density or intensity of uses of fertilizers within the normal marketing radius of the plant dictates the immediate potential for sales. As a practical matter, only a small portion of the total potential use within a blending plant's area represents the quantity one should expect to market from that plant. The remaining fertilizer requirements will be supplied by competitors or by other forms of fertilizer– chemically mixed, straight dry materials, and/or liquids. The area's potential for growth in blended fertilizer use is another important consideration regarding plant location.

2. Specific location considerations––There are numerous considerations regarding the exact location of bulk blending plants so that economy of operation can be achieved. Location within a marketing area having a high potential for using bulk blended fertilizers is of paramount importance. Location on a rail siding and on a good road network covering the agricultural market area also is basic to securing economy of operation in bulk blending.

   Avoidance of natural barriers to a blending plant's marketing area also is very important. A site of adequate size yet not unduly costly should be utilized; it should be available for use over an extended period of time–certainly not less than 15 to 20 years. Site should be well drained and not subject to flooding. Due consideration also must be given to existing or planned competing fertilizer dealer facilities and fertilizer producing facilities near the bulk blending location.

B. Considerations regarding economy in blending

There are several aspects of obtaining economy in fertilizer bulk blending. Usually this matter is thought of in terms of the unit costs (costs per ton, for instance) relative to the returns. However, this is an overall cost economy concept and a reflection of several subparts which need to be examined separately and critically.

1. Investment, administrative, and operating costs––Investment costs pertain to capital items of site, facilities, and equipment which have an initial cost, useful life, depreciation, repairs or upkeep, and interest on investment. The larger the investment cost and the investment associated costs, the larger the throughput required to reduce unit costs to a reasonable level. Somewhat like investment cost, administrative costs tend to be somewhat fixed and are

reduced per unit by increasing throughput. Operating costs tend, on the other hand, to be relatively constant per unit of throughput and vary in total with the amount of throughput of a blending plant.

2. Materials, costs, and economy——Numerous materials are available from which satisfactory bulk blended fertilizer can be made. Some contain only one plant nutrient while others contain two or more. It is not a simple matter to determine a least-cost blend. However, advanced mathematical techniques have been developed (called linear programming) which make it possible to determine most economical mixtures to satisfy specified conditions with materials containing one or more desired attributes. In addition to specified nutrient requirements, acidity limits or other conditions may be imposed and maximum economy maintained while satisfying specified conditions. At the same time, it can be determined at what price (cost) materials that did not enter the mathematical solution to the minimum cost blending problem would have entered the solution.

REFERENCES: 87, 100, 158, 169, 313

DESIGN AND OPERATION OF BULK BLENDING PLANTS

A. Introduction

Bulk blending plants vary widely in type and are somewhat difficult to classify. They vary from crude wooden hoppers to reasonably complex plants. The usual flow of materials in a bulk blending plant is for raw materials to be removed from a railway car by a materials handling system, conveyed to a weigh device, mixed in a mixing device, and finally conveyed to a bulk truck or a bagging machine.

B. Type of storage

1. Flat storage——This is the type of building used most frequently by bulk blenders. The raw materials are removed from the hopper-bottom railway cars by a screw conveyor which is usually mounted below the track. They are then elevated and conveyed to bulk storage bins which usually have concrete floors and wooden walls. The materials are removed from the storage bins by a front-end loader or a scoop truck. The cost of a flat storage building with six bins each having a capacity of 100 to 150 tons is about $10,000, depending on the location of the building.

2. Vertical storage——This storage usually consists of elevated storage bins which can be constructed of either metal or wood. These bins usually have a capacity of 25 tons each. They are small enough to be fabricated at a central location and transported on a railway flat car, and they are easy to install in the field. The larger compartmented bins must be fabricated in the field, and they are somewhat more difficult to install. However, there are fewer materials of construction in the larger bins; therefore, the cost of materials is less for these bins than for the smaller multiple bins. The total construction and installation cost for this type of elevated storage bins is about $15 to $20 per ton of fertilizer to be stored.

C. Weighing devices

The usual weighing device consists of a hopper scale which is mounted above the mixer. The raw materials are usually collected in small storage bins which are mounted above this weigh hopper. In some plants the raw materials are collected in a retaining hopper which is mounted above a weigh belt, and the materials are weighed and conveyed by this belt to the mixer. In other plants, the materials are weighed in a front-end loader which is run onto platform scales. In still other plants, the materials are not weighed but are measured by volumetric belt feeders; and in some plants, the materials are measured volumetrically by calibrated screw conveyors.

D. Mixers

1. Rotary mixer—Most bulk blending plants use this type of mixer. There are two general types of rotary mixers. The one which is most prevalent is that type of mixer which is fed in one end and discharged from its other end. The mixing efficiency of this mixer is excellent. Another type of rotary mixer is the type which is used on a portable concrete truck. This is the type of mixer which rotates in a clockwise direction to be loaded and to mix the materials. It rotates in a counterclockwise direction to discharge the materials. Tests have shown that the mixing efficiency of this mixer is poor. The reason for this poor mixing is that the scroll at the end of the mixer causes the materials to be segregated as they are discharged from the mixer.

2. Mixing screw conveyor—Mixers of this type are similar to the conventional screw conveyor except that slots have been cut in the flights to provide for additional mixing. In some plants, the materials are recycled through the screw conveyor several times, and this recycling causes thorough mixing of the materials. In still other plants, the materials are mixed in a horizontal mixing screw and then in a vertical one so that thorough mixing is accomplished. Test data indicate that the mixing efficiency of this mixer is as good as, or in some instances superior to, the rotary mixer.

3. Ribbon mixer—This mixer has a ribbon scroll-type agitator which revolves in a stationary mixer. The materials are added to the mixer and are agitated and thoroughly mixed by these revolving ribbons in the stationary mixer. The mixer is usually installed on a scale, and the materials are weighed and mixed in it. Tests indicate that the ribbon-type mixer has an excellent mixing efficiency; however, considerable time is required to empty it, and for this reason its capacity is low.

4. Gravity-flow mixers—Several types of plants have mixers in which the gravity-flow of the materials is utilized to cause the mixing of the raw materials. One type utilizes mixing cones. The weighed raw materials are usually collected in a retaining hopper mounted above the cones. The materials flow from this retaining hopper through a quick-opening gate. Mixing is accomplished as the materials fall alternately over and into the cones. In some plants the cones are enclosed in a tank so that a minimum amount of dust is transferred from the mixer to the surrounding area.

   Another type of gravity-flow mixer is the TVA bulk blending tower. This tower is constructed of wood and is rectangular in shape. The overall height is about 30 feet, and the cross section is 4 feet by 4 feet. Most towers of this type are constructed in four sections with a retaining section at the top of the mixing section. The mixing section consists of steps which are constructed at a 60-degree angle with the horizontal. These steps have diangular cleats mounted on them. When the trap door below the retaining section is opened, the materials flow swiftly across the steps, mixing as they fall.

5. Field blending equipment—Several companies use bulk spreader trucks designed to blend and spread two or three fertilizer materials. A typical truck of this type is one which has two hoppers for solid materials and one tank for liquid nitrogen. The liquid nitrogen is metered by a piston-type metering pump which pumps the liquid to a boom where it is forced through spray nozzles. Usually mono-nutrient materials, such as triple superphosphate and potash, are used in two solid hoppers of the truck. Each solid ingredient is metered by a rotary feeder. The rotors are mounted on a common shaft that runs the length of both hoppers. The rate of materials delivery by the rotary feeders is controlled by varying the gate opening which covers the feeders. Both rotary feeders discharge into a common screw conveyor which runs beneath the hoppers. This screw conveyor discharges onto a fan-type spinner for the distribution of solid materials. The truck can be used in conjunction with elevated bulk storage, weighing, and handling systems. In this type of handling system, the solid raw materials are removed from hopper bottom railway cars by a screw conveyor which discharges into an elevator by which these materials are elevated to storage bins. These bins are installed at an elevation above a truck scale so that a truck can be run beneath the bins and the materials can be weighed in the truck. The liquids are pumped from storage through a meter into a solution tank of the truck. The bulk station of this type weighs the liquids as well as the solid materials in the truck while it is on the scales.

E. Requirements for a good blend

1. Nonreactive ingredients—In selecting raw materials for a bulk blend, care should be taken to select materials which do not react with one another. For example, it would not be advisable to blend urea with triple superphosphate, since these materials react to release water that will cause buildup and mechanical difficulties in applying the product. Urea and ammonium nitrate materials should not be mixed. Urea, in combination with nitric phosphate, will form a very hygroscopic mixture which will become too damp in the application equipment to be applied satisfactorily. Care should be taken in the use of diammonium phosphate to replace superphosphate. Diammonium phosphate will react with triple superphosphate. The diammonium phosphate ammoniates the monocalcium phosphate of the triple superphosphate to form dicalcium phosphate and ammonium phosphate with the release of some water. This reaction is rather slow, and if the materials are applied soon after they are mixed, no difficulty should arise in the use of diammonium phosphate in combination with triple superphosphate.

2. Uniform mixing—A few minutes of mixing in a well-designed mixer is usually sufficient.

3. Nonsegregating—A good blend can be handled in conveyors, hoppers, bagging machines, etc., without becoming segregated.

F. How to make a nonsegregating blend

1. The most important factor is to use ingredients which have particles that are approximately the same size. Segregation can be prevented by closely matching the particle size of each raw material used in the blend.

2. Differences in shape or density have only a very small effect on the tendency of the blend to segregate.

G. What degree of size matching is necessary and practical?

1. Most granular fertilizer materials fall within the limits of minus 6 plus 16 mesh, but size

distribution varies widely within this range. The blender should specify that the size distribution within the minus 6- plus 16-mesh range of each of his materials be approximately the same.

2. A good rule to follow is for the size distribution of any ingredient to differ from the average of the blend by more than 10 to 15 percentage points.

H. Handling methods that reduce segregation of blends

1. Use a minimum amount of handling. Experience has shown that the more a material is handled, the greater the possibility that segregation of the mixture will occur.

2. Avoid coning. When the materials are allowed to cone, the large-size particles collect on the periphery of the pile, while the smaller-size particles collect in the center. In this way, the materials of the mixture are allowed to segregate. In handling the raw materials in the blend, a blender operator should avoid coning of the final blended mixture. He should design special hoppers so that the materials will not cone in these hoppers. This can be done by installing walls which compartment the hoppers. He should use special devices in loading the application or transport trucks. These devices usually consist of a flexible hose whereby the blended mixture can be led into the truck and thus prevent coning of the mixture as it is added to the truck.

I. Segregation by fertilizer spreading machinery

1. Tests have shown that blends which contain matched particle sizes spread reasonably uniform, and it is rather easy to obtain a uniform application of the blend across the field.

2. To avoid nonuniform application of the blend, care should be taken to use the proper degree of overlap. It is preferable to use excessive overlap than not enough.

J. Multinutrient materials

The effects of segregation can be reduced somewhat by the use of multicomponent raw materials, such as 18-46-0, 30-10-0, and 20-20-0. These raw materials are homogeneous. Therefore, the nitrogen and P_2O_5 in them are combined in each granule. Since these are combined materials, segregation is not possible in them; and for this reason, the blend should have less tendency to segregate.

REFERENCES: 313

STORAGE PROPERTIES OF FERTILIZERS—PREVENTION OF CAKING

A. The need for good storage properties

Present demand is for non-caking, granular fertilizers that will flow freely and uniformly from standard application equipment. Otherwise, farmers will be dissatisfied, return product, etc.

B. Factors that contribute to lumping or caking

Moisture, high temperature, pressure, chemical reaction. Moisture content is the most significant.

C. Mechanism of caking

Intergrowth or bonding of crystals of soluble salts. Caking is usually worse with multicomponent materials with high water solubility. Materials containing ammonium nitrate have more of a tendency to cake than those with ammonium phosphate or ammonium sulfate.

D. Methods for preventing caking

1. Drying—Decreases moisture and solution phase.
2. Curing—(Intermediate storage) permits chemical reaction to go to completion.
3. Conditioning—Coating particles with an inert material.
   a. Inert conditioner absorbs solution phase and acts as a parting agent.
   b. Chemical conditioners change crystal habit or compound on surfaces of granules to prevent bonding or intergrowth.

E. Bulk storage of fertilizers

1. Relative humidity of atmosphere of storage area should be below the critical relative humidity (CRH) of the fertilizer salts to be stored. (CRH is humidity at which a material will absorb moisture from the air at a given temperature.)
2. Mixtures of salts may have a lower CRH than that of individual salts in the mixture (solution phase at touching points = caking). Conditioner may be needed.
3. Effect of humid atmosphere on storage characteristics—Make laboratory tests to show rate of absorption and penetration of moisture in pile of fertilizer.

F. Storage building with controlled humidity (describe TVA storage building).

G. Bag storage

Bags should have adequate moisture barriers; also, be sure to add conditioner when indicated by significant lowering of CRH as the result of two salts touching.

1. Conditioning agents used in this country and relative effectiveness.

a. Diatomaceous earth, kaolin clay, organic-treated clay.

b. Some companies are incorporating crystal modifiers in urea.

2. Types of bags—Cloth, paper, plastics—may have waterproof liners.

3. Bag-storage test procedures (also can be an indication of what could happen in pile). Test materials are bagged, stacked, and handled to simulate normal storage conditions. Condition of material in bags is evaluated after 1, 3, 6, 9, and 12 months of storage.

REFERENCES: 265, 281, 283

THE COMPOUNDS IN FERTILIZERS

A. Importance to current fertilizer technology

Knowledge of the actual compounds in a fertilizer has become essential for process control, predicting storage properties, and evaluating its economic value to crops. Conventional descriptions in terms of N-P-K grade, process type, and gross chemical composition are no longer adequate criteria. They do not define the actual solid phases in a product, but the behavior of the fertilizer during storage and on application to soil reflects the physical, chemical, and solubility properties of the individual compounds. Thus in addition to economic and engineering considerations, a prospective fertilizer should have a solid phase composition best suited for the specific conditions of soil, climate, and crop.

B. Solid phase composition—the key to quality control and evaluation

1. Impact of advances in technology—Until fairly recently, fertilizers were simple mixtures of a rather small number of well-described compounds, and the conventional control tests were adequate. With the rapid changes in technology, single-component fertilizers have been replaced by new multicomponent, high-analysis mixtures. Many new and complex compounds have appeared, and the number of recognized solid phases now exceeds 300.

2. How this affects process control—These new fertilizer processes involve a complex series of chemical reactions that can yield different mixtures of solid phases, depending on process conditions. Day-to-day variations in product composition can occur, or two manufacturers may produce similar grades by the same process and yet have quite different solid-phase compositions. The usual analytical control tests give little or no indication of these different combinations of chemical constituents.

3. How this affects agronomic evaluation—Since the release of nutrients is controlled by the physical and chemical properties of the component solid phases, the differences in the solid-phase composition of fertilizers are likely to be reflected in crop response. The ultimate task of the soil chemist and agronomist, therefore, is to distinguish between good and bad compounds, leading to improved fertilizer formulations. This is a key consideration in a scientific approach to developing an effective fertilizer program.

4. Important groups of compounds—The type and number of phosphate compounds have increased greatly. In place of bone meal, superphosphate, and ground rock, we now find a wide assortment of orthophosphates, pyrophosphates, and highly condensed phosphates of the alkali metals, alkaline earths, and R_2O_3 group. The familiar nitrogen sources, such as ammonium nitrate, ammonium sulfate, and Chilean Nitre, have been largely replaced by an extensive group of ammonium phosphates, cyclic nitrogen compounds, and organic compounds, which differ widely in solubility characteristics. Potassium chloride has been displaced by a variety of potassium-bearing compounds, many of which are phosphates. On the other hand, the inert compounds present as diluents or fillers have been largely eliminated or avoided in modern processes.

C. Steps to identify compounds

1. Some basic considerations—The physical structure of a typical fertilizer granule, as revealed under a microscope, consists of discrete crystalline compounds. The individual crystals may be small, poorly formed, and intermingled in the form of complex aggregates. It is their crystalline nature, however, that allows identification by optical, x-ray, and infrared methods. The poorly crystalline condition of some compounds tends to complicate the identifications, and usually requires a combination of the instrumental methods to obtain positive identifications.

2. Microscopic examination—the initial step—Using a polarizing microscope, the number of different component solid phases can be recognized. Some can be identified immediately from their optical properties. The next step is to isolate or concentrate the unidentified constituents by physical and chemical methods, using the microscope as a guide.

3. X-ray diffraction methods—X-ray patterns of the whole mixture of compounds are usually too complex to be readily interpreted. The most effective use of this method is to examine specially prepared concentrates to provide the identifications of poorly crystallized compounds that cannot be identified by optical methods. X-ray methods alone will not detect low concentrations of important compounds in a product.

4. Infrared spectroscopy of solid compounds—Each compound has a characteristic infrared absorption spectrum, just as it has a characteristic x-ray pattern. The method cannot be used effectively for examination of the whole mixture because of overlapping absorption features. On the other hand, only a few milligrams of an unknown compound needs to be isolated for identification by this method. Infrared methods provide supporting evidence and help to verify the results of optical and x-ray examinations.

5. Chemical characterization—After the individual compounds have been recognized and identified, the next step is to obtain the chemical analyses of important constituents. This information allows making quantitative estimates of the relative abundance of each compound. Chemical methods alone will not reveal how the constituents are combined in the solid phases of a fertilizer product.

D. Specific examples of where information is useful

1. Problems in commercial production—Products, such as ammoniated superphosphates and nitric phosphates, are obtained by a complex series of reaction steps that can yield mixtures of as many as 15, or so, compounds, but not always in the same relative proportions. When problems of quality control, storage failure, poor availability, and objectionable impurities

arise, knowledge of the solid phase composition provides a focal point for direct attack of the problem and offers clues to what went wrong. This approach is very useful during the initial operation of new production facilities or when changing over to new process conditions and raw material sources.

2. Storage and handling behavior—In storage, some combinations of compounds can be predicted to form reciprocal salt pairs. Other combinations may represent non-equilibrium mixtures that will undergo alteration. Free moisture may allow water-soluble salts to hydrolyze or form crystalline adducts. All these mechanisms lead to the formation of new compounds in a stored mixture, and this is the underlying cause of caking, bag rot, and hygroscopic mixtures. These problems cannot be corrected until the undesired compounds have been identified.

3. Behavior of fertilizer mixtures in soil—Individual compounds in the granule dissolve at different rates, and may interact at the placement site to precipitate new compounds. It is known that mixtures of compounds having the same N-P-K grade will behave quite differently when placed in soil. The reactions at the placement site affect the outward movement of nutrients, and may also lead to salt injury of germinating seeds. Without knowledge of the reacting compounds, a soil chemist can merely distinguish between good and bad products, but is unable to specify what modifications in a fertilizer's composition are necessary to make it a satisfactory product.

E. Importance to the total fertilizer development program

Specific information about the compounds in a fertilizer is needed at every step in its production, storage, and field application. Consideration of this analytical requirement should not be overshadowed by other economic and engineering considerations. The fertilizer chemistry cannot be ignored. Success of a fertilizer development program, and the ultimate worth of the products in terms of increased crop yields will depend on the combination of compounds in your products.

REFERENCES: 8, 9, 10, 46, 62, 104, 105, 106, 163, 193, 194, 199, 283, 312, 324

GREENHOUSE EVALUATION OF NUTRIENT PROPERTIES OF FERTILIZERS

A. Principles on which fertilizer evaluation is based

1. The most important criterion is a single limiting nutrient. All nutrients except the one being evaluated should be applied at optimum rates.

2. Test nutrients should be added at relatively low rates where maximum response per unit of applied nutrient may be expected. Better results may be expected from comparisons at two or more rates of application.

3. It is difficult to evaluate fertilizers in the absence of a yield response. Results must then be based on total uptake of nutrient, which may be unacceptable if all nutrients are present in the luxury consumption range.

4. All supplemental nutrients should be balanced at a uniform level. Example: If experimental P sources contain N, the total N level should be adjusted accordingly.

5. Placement of fertilizers may be varied to suit experimental needs. Example: Mixed vs layered P sources. In this case, it may be preferable to place a single nutrient as required by experimental design and mix all supplemental nutrients.

B. Objective

1. The objective is to evaluate the effectiveness of single nutrient carriers or to evaluate separately the effectiveness of each nutrient in multinutrient fertilizers.

2. The most accurate evaluation may be made from single nutrient carriers.

3. There is little need to evaluate fertilizers on several soils. As a general rule, results obtained on one soil may be extrapolated to other soil situations.

C. Preparation of fertilizers

1. The sample should be uniform and non-hygroscopic.

2. If hygroscopic, samples should be dried, weighed immediately, and stored in a desiccator until needed.

3. Granules for special purposes are best prepared in the laboratory and screened to the desired granule size.

4. An accurate chemical analysis is required to facilitate weighing small samples for each individual pot.

D. Selection of soil

1. The soil should be very responsive to the nutrient under investigation.

2. Cultivated soils of low fertility are more suitable than virgin soils.

3. Loam or sandy loam soils are easiest to manage in pot culture since water infiltrates readily, and the water-holding capacity is relatively high.

4. The soil should be free of weeds, soil-borne diseases, and nematodes.

E. Preparation of soils for greenhouse use

1. It is best to shred in the field and store the soil in bins at a relatively low, but not excessively dry, moisture level.

2. A conventional screen with ¼-inch mesh may be used if power processing equipment is not available.

F. Liming soils

1. If soil pH is below 6.0, lime should be added for most crops.

2. The lime level should be adjusted to near optimum for the indicator crop under investigation. Determine the rate of lime to be added by a preliminary soil test.

G. Selection of crop

1. The crop must be responsive to the nutrient under investigation.

2. Corn grows well in the greenhouse all year.

3. Ryegrass, wheat, etc., are best for cool seasons.

4. Bermudagrass, sorghum, etc., are best for warm seasons.

5. All cultures should be seeded with uniform populations.

H. Culture vessels

1. Plastic pots holding 3 to 5 kg of soil are best for routine use. They are inexpensive, and the plastic contributes no soluble nutrients to the system.

2. Number 10 food cans lined with plastic or painted with asphaltum are also very useful culture vessels.

3. Wood boxes about 1 square foot in area are suitable for turf or forage research.

I. Water management

1. The most common method of watering is to maintain the soil at the desired moisture level by weighing cultures frequently and adding water as needed.

2. Subirrigation or automatic irrigation methods work well only with coarse-textured soils that transport water rapidly.

3. Deionized or distilled water should be used, especially for micronutrient experiments.

4. Rain water stored in asphalt-painted concrete tanks may be suitable for macronutrient research.

J. Harvesting crops

1. It is not necessary to carry crops to maturity for fertilizer evaluation. Growth periods of 6 to 8 weeks are usually sufficient.

2. Cut plants at ground level, or clip at a suitable height, if the crop is to be harvested several times.

3. Wash out root systems if uptake by roots is also under investigation.

4. Dry tissue in an oven maintained at 65° to 70° C. Drying in the sun with adequate ventilation may be an acceptable alternative if no oven is available.

5. Determine the dry weight and grind the sample for chemical analysis.

6. Analyze in the laboratory for the nutrient under investigation.

7. Determine the isotope content if tracer methods are used.

K. Interpretation of results

1. Compare yields with standard fertilizer applied at the same rate.

2. Compare nutrient uptake with standard fertilizer.

3. Determine uptake from applied fertilizer if isotope label is used.

4. Base conclusions on comparisons of 1, 2, and 3 above.

L. Evaluation of fertilizers by radio-isotope procedures

1. The tracer method is based on a radio-label in the applied fertilizer and none in the soil. Example: P in the crop derived from fertilizer is radioactive; P derived from the soil is not.

2. Determination of the isotope ratio in the crop gives an accurate measure of fertilizer effectiveness.

3. Uptake from radio-labelled sources may be the only suitable measure of effectiveness in the absence of a yield response. Relative uptake from good and poor sources follows the same pattern regardless of yield response. With effective sources, the crop takes up nutrient from applied fertilizer and less from the soil (similar total uptake from all sources).

4. Techniques and interpretation are similar for stable isotopes (N_{15}), but detection requires a mass spectrometer, rather than radio-isotope equipment.

REFERENCES: 28, 42, 45, 302, 320, 323, 325, 326

ECONOMICS OF HANDLING FERTILIZERS—BULK VS BAGGED

A. Introduction

Generally, handling material in bulk is more economical than bagged handling because the costs of bags are saved and handling and transport costs are lowered. However, some materials cannot be handled in bulk because of their hygroscopic nature and because bulk handling requires special equipment.

B. Costs of bags and bagging

1. Bag costs—Normally about $8/ton for jute bags with plastic liners. Paper bags may cost only 50% to 75% as much as jute bags.

2. Costs of bagging—Usually about $1.50 to $3.00/ton.

3. Costs of handling—Normally about $1 to $2/ton for transfer to and from trucks and rail cars and $4 to $5/ton for transfer to and from ships.

4. Costs of storage building—Normally $5 to $10/ton of product.

C. Costs of bulk handling

1. Storage costs

   a. Controlled humidity—For hygroscopic materials such as ammonium nitrate–$15/ton of materials.

   b. No humidity control—For non-hygroscopic materials such as diammonium phosphate–$10/ton of material.

2. Loading and unloading equipment costs—Range from about $100,000 to more than $1,000,000, depending on degree of sophistication. Highest costs are for equipment for unloading large bulk transport ships. Lowest costs are for conveyors for loading and unloading rail cars and trucks and for loading ships.

3. Operating costs—Normally less than $1/ton for each transfer of material.

D. Comparison of costs

1. Cost of equipment and facilities—Generally, the capital cost expenditure will be somewhat higher for bulk storage and facilities.

2. Operating costs—The costs of labor, bags, etc., will usually result in about a $10 to $20/ton higher cost for bagged materials, depending on the number of transfers of material, type bags used, etc.

REFERENCES: 17, 27, 330

QUALITY CONTROL IN THE MANUFACTURING PLANT

A. Purpose of quality control

Quality control means different things to different people. The purchasing people want to know "Are we getting what we paid for?"; the plant engineer wants to know if in-process materials are suitable for further processing; the plant manager wants to know if the finished product meets, but

does not grossly exceed, product standards; and the customer closes the circle by asking "Are we getting what we paid for?" Many times, material specifications are based on misunderstood or misapplied standards. The persistent and frequent question of "How do we use this analysis?" or "Is it necessary to the operation?" must be asked to prevent the accumulation of expensive but unnecessary data. The longer a process operates, the sharper these questions become.

B. Elements of quality control

1. Sampling—This element is most frequently overlooked or slighted in fertilizer plant operation and yet it should be equal in importance with analytical methods. Generally, the mining industry, especially the precious metals area, has developed the theory, techniques, and equipment for proper sampling. Sampling can be by automatic equipment or by operator or sample men with special sampling tools. Consideration of sample storage and preparation for analysis must be made, as fertilizer material can change by gain or loss of moisture, biological degradation, continuation of reactions, loss of conditioner during grinding, and other changes that cause the prepared sample to be different from the original material. The other item to be considered is the storage and disposal of samples. The elements that will remain reliable, during storage, the least-cost method of storage, the retention time of samples, and the method that returns the sample back to the process safely while preventing pollution must be evaluated.

2. Analyses

   a. Physical analyses—The most common physical analysis is particle size distribution, and for most materials this means a screen analysis. Proper techniques and equipment are necessary. Other physical attributes are specific gravity, light absorption, infrared or ultraviolet absorption, viscosity, and temperature, and many times a combination of these attributes can be used to infer chemical concentration. An example is that specific gravity and temperature of nitric acid can be used to infer concentration. Often these inferential methods are used to measure and control chemical processes, sometimes by operator feedback and increasingly by instrumentation.

   b. Chemical analyses—These may range from simple screening analyses performed by operators to elaborate sequential chemical methods. The cardinal rule should be that the method is sufficient for its end use; that is, using a long, involved, very precise method for analyzing a varying stream is a futile waste of time. Timeliness for reporting control analyses is necessary so that corrective action may be taken before large quantities of off-quality fertilizer is produced. The services of a chemist who understands the plant processes and relation of sample results to the process is most valuable. An up-to-date laboratory manual detailing the analytical procedures, reagents, and equipment required should be on hand at all times. Standard or resubmitted samples should be analyzed frequently to determine analytical variation.

3. Other work—The laboratory will also be called upon to support plant studies, work on process improvement, and to aid in solution of customer problems.

   a. Plant studies—Engineers will be involved in improving the plant operating efficiencies, and this requires special samples and analyses. The measurement of losses from units is an effective means to obtain insight into efficiencies.

   b. Customers' problems—Samples of products will be returned with customer complaints. These samples will require special handling and reporting. They offer a means for plant

production people to adjust operation and provide more suitable products.

C. Summary

The quality control group has an opportunity to see the total operation–raw materials, in-process material, finished products, shipments, special studies materials, and customer problem materials. With this information, properly applied, many valuable suggestions for plant operation and improvement can be made.

REFERENCES: 268, 269, 310

DISTRIBUTION SYSTEMS AND IN-TRANSIT STORAGE

A. Introduction

1. Definition––A distribution system usually is considered to include finished materials only. This is movement of fertilizers (not raw materials) from manufacturer to farmer. However, some raw materials are applied directly, e.g., anhydrous ammonia and KCl. So, a distribution system can include these also.

2. Parts of the distribution system––Personnel, storage, inventory, manufacturer, wholesaler, retailer, and transportation facilities– bulk and bagged.

3. Importance––Source of delay in delivery; up to 40% of cost of fertilizer is in handling and shipment. A ton of fertilizer may be handled 7 to 15 times from the day it is manufactured until the day it is applied.

B. Methods of shipping

1. Railroads––Until recently, most long distance movement of fertilizer in the United States was by rail.

   a. Type of equipment

      (1) Box car––Used for bulk and bagged material. Small cars–30 tons–used for short distances, usually to one farmer or small warehouse; medium cars–40 tons–not used extensively; large cars–50 tons plus–use is increasing rapidly.

      (2) Hopper cars––Used for bulk shipments. Fifty-ton cars were standard and used almost exclusively until recent years; 70- to 80-ton cars are usually rebuilt 50-ton cars made with higher sides for additional tonnages; 100-ton cars are increasing rapidly because of cheaper rates for larger tonnages.

      (3) Tank cars––Pressurized cars for handling gaseous products; insulated cars are used for maintaining constant temperatures; standard cars normally used for liquid non-corrosive products.

(4) Flat cars for containers.

b. Rates

(1) Minimum car loads depend on capacity of car

(2) Multiple car

(3) Competitive rates based on other means of transportation

(4) Unit trains

2. Trucks—Movement of fertilizer by trucks has increased in recent years. Factors behind this trend include improved roads, manufacturing plants closer to market, larger and more powerful trucks, and more versatile to points of delivery.

3. Barges—Have made great strides in the movement of large tonnages of fertilizers over long distances where waterways permit and where storage facilities, financing, and equipment permit large tonnage movements.

4. Ocean-going vessels

a. Overseas shipments

(1) Bagged and loaded at port

(a) Direct from production

(b) Shipped by rail to port and transferred to ship

(c) Shipped in bulk to port and bagged at port then loaded on ship

(2) Bulk shipments

(a) Loaded directly from production to ship

(b) Moved to port by rail, truck, or barge then loaded on ship

(3) Container—Usually holds 15 to 25 tons of bulk or bagged fertilizers

(a) Fertilizer loaded in container at point of production then moved to port by truck or rail for loading on ship

(b) Loaded in container at port then loaded directly on ship

C. Storage

1. Plant storage—Has always been a problem of fertilizer manufacturers, especially with raw materials, since fertilizer business is extremely seasonal.

a. Raw materials—Produced on a year-round basis and must be stored by industry for seasonal use.

b. Finished product—Some raw materials do not require further processing but still require storing. Other raw materials are stored, made into finished products, and stored again.

2. In-transit storage—With the origin of large producing plants and increase in use of fertilizers that are extremely seasonal, it has been necessary to establish in-transit storage facilities as close to market as feasible. Fertilizers are shipped to these storage facilities in the form of raw materials or finished products as the materials are produced or as soon thereafter as practical.

a. Warehouses—Usually built in locations to take advantage of shipping economies—waterways, competitive rail points—and near the largest fertilizer market area. Characteristics: Air conditioned, long, low, narrow facilities for bagging.

b. Storage tanks—Constructed in locations to take advantage of water transportation or existing pipeline routes and close to the largest markets. This permits minimum transportation costs over long distances for solids and liquids.

D. Conclusion

To say that we have reached the period of perfection or even that all recent innovations in methods of transporting and storing fertilizers will be successful would be misleading. Many of the new methods are in the trial-and-error stage, and no doubt some will be eliminated or changed for newer and better methods. However, more has been done in recent years than ever before to improve and cheapen the cost of fertilizers to points of use.

COST DETERMINATION THROUGHOUT A SYSTEM OF PRODUCTION, DISTRIBUTION, AND MARKETING

A. Least-cost scale of production

There are a number of references (41, 334) which give rough cost estimates for different types of fertilizer processes designed for different annual throughputs. Economies to scale in production seem to exist in every case. This means that average production cost decreases with increasing scale of production. To illustrate this point, an ammonia cost curve can be presented which has sizes up to 1,000 tons per day. From the point of view of production, the largest size ammonia plant is least-cost.

B. Least-cost scale of distribution

As the scale of production increases, the scale of distribution must also increase. Diseconomies to scale in distribution exist, since shipping distances (extensive expansion) and general marketing costs (intensive expansion) tend to increase with scale (references 357,107). This can be illustrated rather easily for the case of extensive expansion by assuming the marketing area to be circular with radius, R. Given a uniform consumption density, D, it can be shown that the average length of

haul, ALH, is two-thirds the radius. It follows from the formula for the area of a circle that the quantity of product, X, equals

$$X = \rho (\pi R^2) \text{ and}$$

$$ALH = 2/3 \, (x/\pi \rho)^{1/2}$$

Average distribution costs can then be plotted as a function of average length of haul and hence the quantity of product. An example, such as the above, need not be developed fully, but some of the reasoning for diseconomies should be presented. From the plot of average distribution cost versus the quantity of ammonia production, it might then be pointed out that from the point of view of distribution alone, the least-cost plant size is the smallest feasible plant size.

C. Least-cost scale of production and distribution

By adding the average production and distribution cost curves, it can be illustrated—choose a suitable density, D—that economies to scale in production are partially offset by diseconomies to scale in distribution in such a manner that the least-cost plant size is between the above extremes—600 to 700 tons/day. If only the production point of view is considered, there can be a tendency to build too few plants which are too large for least-costs throughout the production and distribution system.

D. Optimum scale of production, distribution, and marketing

When it can be assumed that conditions of perfect competition prevail, the long-run equilibrium plant size is that which is least-cost. Such conditions generally hold for developed countries which have many independent fertilizer producers and which trade rather freely in international markets. In many LDCs, however, the individual fertilizer producer may represent such a large share of the market that its supply actions affect prices. This is particularly true when trade barriers limit international competition. In such cases, marketing considerations may be extremely important. This can be illustrated by plotting a demand and marginal revenue curve on the previously developed cost curves. Marginal cost could equal marginal revenue at a plant size of 300 tons/day. If the least-cost plant is built and operated at capacity, then net revenue may go from a maximum to negative. The reason is simply that the size of the market is the limiting factor. In such cases, marketing considerations are extremely important and completely overshadow production.

REFERENCES: 41, 107, 334, 357

FERTILIZER-CROP VARIETY INTERACTIONS

A. Introduction

The effect of the new, high-yielding cereal varieties on food grain production is an illustration of the far-reaching consequences caused by the transfer of technology to developing nations. The principal world food grain crops are rice, wheat, maize, and sorghum. Plant breeders and other research people have been working with these crops to develop new varieties that produce very high yields in response to high rates of fertilizer application. They have been successful but their

success has added to the problems of agricultural development. Total production can fluctuate from shortage to surplus in response to the weather, causing prices to skyrocket or plummet. Much of this difficulty is due to imperfect knowledge of how crop varieties interact with fertilizer and other cultural practices.

B. Classification of varieties

Most varieties within each of the four crops can be divided into two broad categories. The division is based on morphological characteristics and response to cultural practices.

1. Native varieties--These varieties usually are not very responsive to changes in growing conditions or in cultural practices. A graph of yield per unit area shows that for many decades about the only factor that has a significant effect on yield is severe drouth. When weather is ideal, yield goes up slightly; when weather is below par, yield goes down slightly. The average yield tends neither to rise nor to fall. There have been selections that show some response to improved cultural practices. These have the same general growth characteristics as the native varieties from which they were developed. Thus, they are long stemmed or open pollinated varieties that are susceptible to shading effects and lodging. Under good management, however, they yield more than the unimproved varieties.

2. High-yielding varieties--For rice and wheat, the high-yielding varieties (HYV) usually can be interpreted as the dwarf and semidwarf varieties. For the row crops, maize and sorghum, the varieties in this category are hybrids. All have been bred to produce high yields when fertilized at a high rate. Without fertilizer, HYV may or may not yield more than native varieties.

C. Response to N, P, and K

Response to the different nutrients, and to their various combinations, can be measured in many ways. Two broad divisions are the agronomic and the economic. Within each of these categories, different measures are used to evaluate response.

1. Agronomic response

   a. Efficiency of fertilizer use--The portion of applied fertilizer taken up by a crop usually decreases as rate of application increases. Some of the HYV, however, have a different growth habit and may utilize fertilizer differently. Daily nutrient uptake also varies from variety to variety. Daily uptake can be used to predict the need for split applications and/or the need for controlled release of nutrients.

   b. Yield response--Grain yield is of primary interest but many other yield factors also can be evaluated: Number of tillers and grains per panicle (for rice and wheat), weight per grain, grain to straw ratio, and root to top ratio, to name but a few. The two varietal classes within a crop show pronounced differences in their response to fertilizer by these yield components. Of greatest interest, of course, is the effect of rate, especially of nitrogen, on harvestable yield.

   c. Chemical composition--The effect of the different plant nutrients on the chemical composition of the grain is of most interest. Increased protein content and mineral enrichment are of dietary importance. Nutrients contained in grain usually are considered as lost from the soil. If the straw or fodder is not returned to the soil, then knowledge of its chemical composition also is useful in determining soil nutrient depletion rates.

2. Economic response

a. Economic vs agronomic optimum rate of fertilization—The rate of fertilization that provides the maximum economic return per unit area is lower than the rate that provides the maximum yield. This rate also shifts as the price of fertilizer and/or the value of the product change whereas the agronomic optimum does not shift. However, if income is maximized at some percentage of the optimum, say plus or minus 5%, the rate of application can vary within rather broad limits.

b. Maximum return per dollar invested—The lower the rate of fertilizer application to a responsive soil, the greater the return on the cost of the fertilizer. When capital is limited, then, the best use of fertilizer is at low rates on the most responsive, highest valued crops.

D. Long-range implications

Changing varieties can inadvertently change the efficiency with which a crop uses fertilizer. If indigenous production of this crop is substantial, such changes markedly affect the total fertilizer requirements of a nation and its infrastructure too. If efficiency is improved, total fertilizer needs at that date when the country becomes self-sufficient in food grain production will be less than predicted. For some countries planning their own manufacturing facilities, domestic production may not be warranted, or a delay in construction may be desirable. For the more immediate future, needs may accelerate much faster than anticipated. Transportation and storage systems and other infrastructure may not develop quickly enough to handle the fertilizer and the marketable produce.

REFERENCES: 26, 82, 203, 240, 255, 263, 299

COMPONENTS OF PRICE

A. General price level

Since the real component factors which determine price can best be understood only in the context of economic theory, some time should be devoted to a review of supply, demand, and equilibrium concepts.

1. Demand price—Demand price depends mainly on the quantity supplied, and decreases with this quantity. Price serves as an allocator of a given quantity of (scarce) fertilizer. The concept of a demand curve should be explained in terms of value of marginal product, diminishing returns to increasing intensity of fertilizer use and the importance of crop prices. (The actual mechanics of optimum fertilizer use should have been covered in earlier lectures.) Some time should also be spent illustrating how various crops compete for fertilizer use and how increasing fertilizer supplies go on lower valued crops, grown on less fertile soil, under poorer management, in more isolated areas, etc.

2. Supply—Supply quantity depends on demand price and increases with increasing price. A brief look at the theory of the firm should be taken to again illustrate the important concepts of diminishing returns and marginal cost. The difference between the long- and short-run supply curve should be covered.

3. Equilibrium—The equating of supply and demand to determine equilibrium price and quantity should be explained, pointing out that such an equilibrium satisfies both suppliers and demanders. At this point, it should be stressed that markets are natural phenomena. A country cannot decide whether or not it wants markets—only whether or not it wants to control its markets. It might also be mentioned that the theory of welfare economics points out that, in most cases, free markets are the best allocators of scarce resources. The results of price controls may also be illustrated at this time. For example, if the price of fertilizer is pegged too low, the quantity demanded exceeds that supplied, and black markets tend to arise in an attempt to better allocate fertilizer resources.

B. Relative prices

An individual firm is generally more concerned with the relative price of different fertilizers than the general price level since there is little it can do to influence the general level. On the other hand, many different fertilizer ratios and analyses can substitute for one another at the right relative price.

1. Single-nutrient product pricing—When single-nutrient products are considered, the main concern is generally the value of high analysis As an example, cite products such as (1) ammonium sulfate (21-0-0), (2) ammonium nitrate lime (21-0-0), (3) ammonium nitrate (33.5-0-0), and (4) urea (45-0-0). As a rule of thumb, it is generally assumed that farmers pay only for primary plant nutrients If this is the case, the relative prices of nitrogen would be identical at the farm. At the manufacturing point, however, urea could earn more because its high analysis saves some freight and other weight-related costs.

2. Multinutrient product pricing With products such as diammonium phosphate (18-46-0), a price for both nitrogen and phosphate must be determined In this case, pricing is generally done relative to triple superphosphate (0-46-0) Since both products contain the same quantity of phosphate, the price of the 18 units of nitrogen is the price of (18-46-0) minus the price (0-46-0). Since these two products are generally produced at the same location, they incur equal distribution costs. This method gives a delivered price of nitrogen. This price is actually a "shadow price" in the sense that if nitrogen can be purchased for less in some other form, it may pay to buy it and triple superphosphate For more sophisticated pricing problems, try to set up a linear programming model to describe bulk blending or granulation. Linear programming solutions not only give the optimum combination of inputs to produce a given mixed fertilizer, but also give shadow prices for the inputs not used, and also gives an inputed price for each plant nutrient.

EFFECT OF GOVERNMENT POLICY ON ESTIMATING COST-BENEFIT RATES FOR USE OF FERTILIZERS

A. Economic reasons for low fertilizer use in developing countries

1. Low and unevenly distributed incomes—Small farmers have no salable surplus and respond extremely slow to market conditions.

2. High rates of interest, such as 15% per month, deter the use of credit by farmers in the acquisition of fertilizers.

3. Unstable crop prices from fluctuations in prevailing supply-demand situation—Farmers tend not to use fertilizer since high yields result in low prices.

4. Unfavorable price relations between fertilizers and crops inhibit fertilizer use. Developing countries usually have high fertilizer costs due to higher transport costs, high rates of interest, high distribution costs, and the greater risk to dealers. Crop prices are usually held at low levels to pacify urban dwellers who have the most political power.

B. Computing cost-benefit ratios for the use of fertilizers

1. Cost-benefit ratios for the use of fertilizers on a selected crop are obtained when the value of increased yield from the use of fertilizers is divided by the cost of the applied fertilizers. This is illustrated by the following table:

Physical and Economic Returns from the Application of Fertilizers to Rice on Thailand Farmers' Fields

Fertilizer applied (kg/rai)	Added yield from fertilizer (kg/rai)	Cost of fertilizer (baht)	Value of increase in rice (baht)	Value of incr. yield above fert. cost (baht)	Ratio of cost to return
Check	(204)[a]	–	–	–	–
N_2	43	13	34	21	1:2.6
P_4	74	32	59	27	1:1.84

[a]Base yield

The value of the increased rice yield from the use of fertilizer (N_2) is 34 baht; the cost of the fertilizer (N_2) is 13 baht. Dividing 34 baht by 13 baht obtains a solution of 2.6—which means that at the level of fertilizer use (N_2) each baht of fertilizer cost results in an added value of rice equal to 2.6 baht. Thus, the cost-benefit ratio is 1:2.6.

2. Because of the many risks involved, such as weather, most farmers will not use fertilizers unless the cost-benefit ratios approach 1:4. Studies show that when the cost-benefit ratio falls below 1:2 almost no farmers will use fertilizers.

3. As illustrated in the above table, when fertilizer is used at the rate (P_4), the cost-benefit ratio is 1:1.84. We would expect farmers to apply fertilizers at the rate (N_2) but not at the rate (P_4).

C. Suggested methodological approach to illustrating that government policy affects cost-benefit ratios and thereby levels of fertilizer use.

1. Step one—Select a major crop commonly grown in a number of less developed countries. For this crop in each country tabulate the following data:

   a. Average amounts of nitrogen, phosphate (P_2O_5), and potash (K_2O) used per acre on selected crop.

   b. Average price farmers pay per pound for nitrogen, phosphate (P_2O_5), and potash (K_2O).

   c. Average price received per pound by farmers for the sale of selected crop.

   d. Rates of N, P_2O_5, and K_2O per acre recommended for use on selected crop.

e. Rates of N, P_2O_5, and K_2O actually applied per acre for selected crop.

f. Average yield of selected crop produced per acre.

2. Step two—Prepare a series of tables which show the relationship among fertilizer costs, the price received for the selected crop, actual fertilizer use, and fertilizer yields. As noted previously, any crop can be used in the analysis. For purposes of illustration, rice is the crop used in this outline. A suggested ordering of tables, table headings, and outlined discussion follows.

D. Illustrating response to fertilizers

Prepare a graph showing that the selected crop responds to fertilizer treatment. Three levels of application are recommended: (1) nitrogen only, (2) nitrogen and phosphorus (P_2O_5), and (3) nitrogen, phosphorus (P_2O_5), and potash (K_2O). The graph will illustrate that fertilizer treatments increase yields of the selected crop.

Prepare a graph showing the relationship between the average yield of the selected crop and the average amount of fertilizer used per acre on the selected crop. Data for a number of years should be used. This graph will show that a close relationship exists between the yield of the selected crop and the level of fertilizer use.

E. Price of selected crop and fertilizer in countries used in analysis

Price of Rice and Fertilizer in Selected Countries

	Rough rice price/kg		Sulfate of ammonia price/kg of N		Superphosphate price/kg of P_2O_5		Muriate of potash price/kg of K_2O	
	U.S.	Japan	U.S.	Japan	U.S.	Japan	U.S.	Japan
Country	cents	price = 100	cents	price = 100	cents	price = 100	cents	price = 100
Japan	18.5	100	26.5	100	22.2	100	9.5	100
Korea	13.0	70	31.4	119	20.5	92	9.8	103

1. For purposes of comparison, one country should be selected as the basis country. In this and following tables Japan is shown as the basis country.

2. Comparisons in the table include rice and fertilizer prices to farmers expressed in both cents/kg and in ratios.

3. More variation exists in rice prices than in fertilizer prices, suggesting government policy is influencing rice prices.

F. Fertilizer costs expressed in crop equivalents

Fertilizer Costs Expressed in Rice Equivalents

	1 kg of (N) expressed	1 kg of (P_2O_5) expressed	1 kg of (K_2O) expressed	1 kg of NPK as 1:1:1 ratio	
Country	as kg of rice	as kg of rice	as kg of rice	Kg of rice	Japan = 100
Japan	1.44	1.21	.51	1.05	100
Korea	2.42	1.58	.76	1.59	151

1. This table shows fertilizer costs expressed in terms of rice production, that is, the kgs of rice that must be produced and sold to equal the cost of 1 kg of fertilizer.

2. Anticipated farmer uses of fertilizer could be determined from this table except that yield response to fertilizer is not considered. The kgs of rice produced with 1 kg of fertilizer affect the economics of fertilizer use.

G. Computing relative fertilizer cost

$$\text{relative fertilizer cost} = \frac{\text{yield in basis country (Japan)}}{\text{yield in respective country (Korea)}} \times \frac{\text{cost of 1 kg of NPK in terms of rice in respective country (Korea)}}{\text{cost of 1 kg of NPK in terms of rice in basis country (Japan)}}$$

Steps

1. Rice yield basis country (Japan) = 4,750 kg/ha

2. Cost of 1 kg NPK in terms of kg rice in basis country (Japan) = 1.05 kg

3. Rice yield in respective country (Korea) = 2,920 kg/ha

4. Cost of 1 kg NPK in terms of kg rice in respective country (Korea) = 1.59 kg

$$\text{i.e., } \frac{4{,}750 \times 1.59}{2{,}920 \times 1.05} = 2.46$$

These mathematical computations are a means of comparing relative fertilizer costs to farmers in different countries. Note that farmers in Korea have a fertilizer cost for rice 2.46 times higher than farmers in Japan. Other comparisons also can be made, as in the following table:

Country	Fert. costs in U.S. dollar equivalents	Fert. costs in terms of rice in proportion to Japan	Fert. cost in relation to cost and yield in Japan	Yield of rough rice in kg/ha
Japan	1.00	1.00	1.00	4,750
Korea	1.06	1.51	2.46	2,920

Fertilizer costs in some countries are much greater than in the basis country (Japan). Relative fertilizer costs to farmers are closely related to average yields on a country-by-country basis.

H. Recommended and actual rates of fertilizer application, relative fertilizer cost, and average rice yield

Recommended and Actual Rates of Fertilizer Application, Relative Fertilizer Cost, and Average Rice Yield

Country	Recommended fertilizer rates kg NPK/ha	Rates of fertilizer actually applied kg NPK/ha	Relative fertilizer costs Japan = 100	Yield in kg/ha
Japan	196	204	1.00	4,750
Korea	206	117	2.46	2,920

These data show that actual fertilizer use is closely correlated with relative fertilizer costs; average yields are closely correlated to actual rates of fertilizer use; and, the higher the relative fertilizer cost, the wider the difference between recommended and actual fertilizer use.

In summary, the preceding tables verify that the relationship between crop prices and fertilizer costs is the most important factor affecting fertilizer use. Thus, government policy can be used to affect this relationship and thereby change incentive to produce.

SOURCES OF FUNDS FOR FINANCING FERTILIZER PRODUCTION AND MARKETING FACILITIES

A. Introduction

Without adequate capital, fertilizer plants and necessary marketing facilities cannot be built. Acquisition of capital is essential, but it is not the major limiting factor to meeting fertilizer needs of developing countries. Trained manpower—three skilled and five unskilled people—is required for each 1,000 tons of plant nutrients produced and distributed each year.

B. Magnitude of investment needs

1. Use of plant nutrients in developing countries is estimated to rise from about 6 million metric tons in 1966 to about 40 million metric tons by 1985. To supply the 34 million metric tons of additional fertilizer will require a cumulative capital investment of $17 billion—about $1 billion per year.

2. The $17 billion of capital investment will provide for warehousing, mining, production plants, transportation, and distribution. It will not provide capital investment needed for developing plant infrastructures, irrigation, and other accompanying requirements.

3. Governments in the developing countries are presently providing about $80 million of capital aid per year to build fertilizer plants. An increased expenditure of about $900 million annually is needed to attain projected requirements. About $650 million of this total will be foreign exchange expenditures.

C. Sources of capital for financing fertilizer plant construction

1. Private capital is available both within developing countries and from foreign sources. Indigenous private capital is usually very scarce. Developing countries have poorly developed stock markets and investors tend to seek projects offering better returns than fertilizer. Foreign private capital is more readily available, but tends to be a controversial source of funds. Such capital has implications of imperialism or colonialism. However, foreign private capital brings with it technical and management know-how which helps a project get government capital. Examples of foreign private capital are:

   a. Esso Chemical Company's Philippines plant

   b. Phillips Petroleum Company's Mexico plant

c. Extended Risk Guarantee Program of USAID–liberalized regulations are permitting U.S. institutional investors to take part in fertilizer projects. Such investors have billions of dollars in capital.

d. Private development corporations or development financing companies–over 100 development corporations offer sources of capital and project analysis.

e. Equipment suppliers provide credits for helping build plants.

2. Governmental capital is available from many national sources. Sources of national, single-government capital are of great importance, and include:

a. Most developing countries can provide some local capital for fertilizer projects. However, the required foreign exchange may be hard to supply. Local government participation usually consists of (1) borrowing money from foreign sources and constructing 100% government-owned facilities, or (2) using local government funds to form partnership with private foreign capital sources to construct fertilizer facilities.

b. Equipment credit or suppliers' credit guaranteed by national government—Approximately 25 different groups in the world provide insurance for suppliers' credit. Examples are the Export Credit Guarantee Department (ECGD) of the United Kingdom and the Export-Import Bank of the United States.

c. Foreign national governmental loan sources include:

(1) The Export-Import Bank is the hard currency source for American project loans—Purchases of goods financed by Export-Import Bank must be made in the United States. Total loans are about $1,000 million per year.

(2) Agency for International Development (AID) provides loans to governments and development banks of developing countries—Interest terms are low, usually 2.5% or less, but a potential borrower must have exhausted all other possible loan sources.

(3) Foreign currencies held by home governments of fertilizer firms—United States has $100 million of foreign currencies in 18 developing countries.

3. There also are sources of international governmental financing:

a. The International Bank for Reconstruction and Development is the major source of international financing. Funds are provided through:

(1) The World Bank which is active in 100 member countries—The World Bank will lend to autonomous governmental agencies, private individuals or private corporations. Loans are made only if private capital is unavailable. Present loan level of about $7,000 million was financed by sale of bonds on the world market.

(2) The International Development Association which is active in about 100 member countries—Loans are made only to member countries classified as developing. No interest is charged and loans are repayable over a 50-year period. Present loan level is about $1,400 million.

(3) The International Finance Corporation active in about 36 member countries—When loans are made, IFC usually takes an equity position in the project. IFC will invest a maximum of $20 million in any single project.

b. The European Development Fund lends specifically to overseas countries and territories associated with countries of the Common Market.

c. The Inter-American Development Bank is active in 19 Latin American countries and the United States. Most loans are for 25 years at 6.5% interest. Some loans are made available through local development banks at reduced interest.

d. The Asian and African Development Banks were recently established to raise money and make development loans to Asian and African countries.

4. Credit for financing large fertilizer plants increasingly comes from four or five sources. Usually one source is private enterprise which contributes not only money, but also managerial skill and know-how.

D. Financing marketing facilities has generally been left to local governmental and private groups.

Financial resources available for marketing are severely limited. An increasing number of governments and private investors are recognizing the shortsightedness of this policy, especially in view of the present world fertilizer surplus.

FINANCING AGRICULTURAL PRODUCTION

A. The nature of agricultural production credit

A convenient traditional classification of the factors of agricultural production is land, labor, capital, and management. The level of farm income depends on the combination of these factors. Capital can be substituted for both land and labor which leaves only two primary production factors—capital and management. Financing agriculture in the United States involves extensive use of credit. Agriculture requires substantially more capital investment per man than other major industries. The purpose of credit is to increase resource efficiency or incomes and levels of living. When capital is limited relative to other resources, the addition of more capital (via credit) increases the economic efficiency of all the resources.

Historically, the financing of agriculture has been a major economic problem. With the shift in agriculture from self-sufficing farms having low incomes to commercialized and highly specialized farms, credit has become increasingly important as a means of providing necessary capital. A major reason for the great increase in the use of credit by farmers is the much larger investment now called for in farm real estate, equipment, and operating costs.

There are two major questions about the use of credit capital. The first is the proper amount of capital to use. The second involves the correct allocation of capital. Budgets are the chief device used in answering these questions. The amount to use is determined by comparing the marginal productivity of capital with the interest rate. Allocation is based on the highest return per dollar of input in given productive resources.

B. The basis for credit

The amount of credit extended to a farmer depends upon his capital position, management ability, honesty, and the productivity of the credit capital. Net worth statements are becoming more important. Security may be in the form of mortgage on real estate, buildings, or other fixed assets, or granting property rights in crops or livestock. Production loans should be self-liquidating. Profits are usually higher on capital invested in fertilizer, basic machinery, livestock, and other working capital than in land.

C. The kinds of credit needed by farmers

Differences in conversion rates suggest that credit is needed for different time periods.

1. Short-term credit––Short-term credit is used for other than real estate purposes. It finances those investments where capital is completely converted into product in the near future–usually within a year. Its main purposes are to (1) finance current farm operating expenses, (2) pay living expenses until the season's crops or livestock are marketed, and (3) refinance short-term obligations. It should supplement the farmers own capital rather than substitute for it. Individuals, commercial banks, production credit associations, FHA, merchants, and dealers are the major sources of short-term credit. County banks handle the greatest volume of credit.

2. Intermediate credit––Intermediate credit finances those investments where capital is converted into product in a period from one to eight years. These investments include soil conservation practices, lime, basic treatments of phosphate and potash, pasture renovation, fences, livestock production, and some types of buildings. While there is a great need for this kind of credit, it is not generally available. Usually a modification of short-term credit is used.

3. Long-term credit––The primary uses of long-term credit are for real estate and permanent improvements, such as buildings. Other uses include refinancing short-term debts and existing mortgages. The principal sources of long-term credit are individuals, commercial banks, life insurance companies, Federal land banks, and FHA.

D. Sources of credit

There are many sources of credit available to farmers. The best source depends upon the type of credit desired and the individual farmer's circumstances. Credit sources may be classified as institutional or individual. Institutional sources may be broken down into public, cooperative or private.

1. Individuals––Individuals are an important source of credit to farmers. This is particularly true for mortgage credit. This source is quite variable in terms of desirableness from an agricultural standpoint. Individuals may be lacking in experience, reluctant to renew, unrealistic about credit terms, or may not have sufficient resources to carry loans.

2. Private sources of credit

   a. Commercial banks––Commercial banks extend most of the short-term credit in agriculture and will probably continue to be a major source of production credit in agriculture. A commercial bank's first obligation is to its depositors. Its assets must be fairly liquid to meet withdrawals. They are better adapted to short-term than to long-term credit.

b. Insurance companies—Insurance companies are an important competitive force in meeting farmers' long-term credit needs at reasonable costs. They are primarily interested in security of investment plus a high return. They tend to move in and out of the agricultural credit field as security and profitability change.

c. Merchants and dealers—Merchants and dealers extend considerable production credit to agriculture. Lending is not their primary business. They lend to attract buyers or sellers. They are usually unable to extend credit for a long period of time. Their interest rates may be rather high.

d. Loan companies—Loan companies often attract the higher risk customers and suffer more losses. Their interest rates and loan costs usually reflect this fact. They may not be a satisfactory source of agricultural credit, but there are some farmers for whom they provide the best source of credit available.

3. Public sources of credit

a. The Commodity Credit Corporation—The Commodity Credit Corporation was created for the purpose of implementing government price-supporting operations for agricultural commodities. While not primarily a credit agency, it does have the effect of increasing the quantity of capital available to farmers.

b. Farmers Home Administration—The Farm Security Administration was created during the depression of the 1930s as an emergency measure to provide a source of credit to farmers who could not obtain credit elsewhere. It was succeeded by the Farmers Home Administration in 1946. The purpose of the FHA is to make both long- and short-term credit available to specific groups of farmers. It also insures loans by private institutions. Its source of funds are (1) annual appropriations by Congress, (2) balances in revolving funds, and (3) private lenders who provide funds which are insured by the Agency. The FHA has three principal characteristics: First, to be eligible, the borrower must be unable to obtain credit at reasonable rates elsewhere. Second, the FHA expects the loan to be repaid. Third, FHA provides considerable supervisory help in the extension of credit.

4. Cooperative sources of credit—The Farm Credit Administration was established as an independent agency in 1933. It became a part of the Department of Agriculture in 1939. The Farm Credit Act of 1953 made the Farm Credit Administration an independent agency of the executive branch of the government. The purpose of the FCA is to supervise and coordinate a cooperative credit system for agriculture in the United States. This system provides long- and short-term credit to farmers and their cooperative marketing, purchasing, and business service organizations.

The United States is divided into 12 farm credit districts. In one city in each district is a Federal land bank, a Federal intermediate credit bank, and a bank for cooperatives. A 13-member board makes policy (one member from each credit district and one appointed by and representing the Secretary of Agriculture). The Board selects a governor who is the chief executive officer. Each of the three credit services–land bank, short-term credit, and cooperative bank–is headed by a governor.

a. Federal land banks and Federal land bank associations—The Federal land bank system is cooperative and is completely farmer owned. All stock is owned by member borrowers. The borrower purchases stock in the Association in an amount equal to 5% of his loan. The

Association in turn purchases a like amount of stock in the bank. Farmers obtain long-term mortgage loans from the land banks through Federal land bank associations giving a first mortgage on their farms as security. They may borrow up to 65% of the appraised normal value of their property. Rate of interest is based on the cost of funds in the investment market plus costs of operation. Source of funds are from farm loan banks secured by notes and mortgages.

b. Federal intermediate credit banks—Federal intermediate credit banks were initially government owned. Since the last of 1968, they are farmer owned. FIC banks make loans to and discount agricultural paper for production credit associations, state and national banks, agricultural credit corporations, livestock loan companies and similar lending groups. They do not lend directly to farmers or otherwise conduct a general banking business. Sources of funds are principally from sales to the investing public of short-term consolidated collateral trust debentures which are obligations to the bank.

c. Production credit associations—The production credit associations are supervised by the Federal intermediate credit banks (merged January 1957). They were originally capitalized by the government-owned production credit corporations. All government capital has now been retired and they are completely owned by farmer-members. All voting stock is owned by member-borrowers. Farmers obtain short-term credit for all types of farm operations from local production credit associations. Loans may be from one to seven years. Interest is low and for only the actual number of days each dollar is outstanding. The source of funds is from rediscounting farmers' notes with the Federal intermediate credit banks.

d. Banks for cooperatives—The bank for cooperatives was established to provide a permanent source of credit on a sound business basis to farmer cooperatives. The central bank for cooperatives serves district banks for cooperatives by making direct loans to them. (One located in each of the 12 districts.) Cooperatives own all of the capital stock in six banks and are increasing their investment in the others. As their investment grows, government-owned capital will be repaid. They lend money only to cooperatives. Both term and seasonal loans are made to farmer cooperatives for a complete loan service. Over 3,000 farmer cooperatives use the credit facilities of the banks for cooperatives.

REFERENCES: 7, 43, 65, 98, 99, 103, 130, 223, 349

ORGANIZING RESEARCH AND DEVELOPMENT PROGRAMS

A. The nature of fertilizer research and development

Fertilizer R and D covers a broad front. It involves chemistry, engineering, agronomy, and economics and, to a lesser extent, other disciplines. It includes such things as developing a technological base; discovering and perfecting new products and processes; improving existing products and processes; determining plant nutrient needs on different soils and crops; improving efficiency of fertilizer use on farms; and developing improved transportation, marketing, and distribution systems for fertilizers and intermediates. It encompasses fundamental and exploratory, applied, and developmental research ranging from the laboratory to the manufacturing plant and the farmer's field. It leans heavily upon advances and discoveries made in the more basic fields

of chemistry, biology, metallurgy, the agronomic sciences, and other disciplines. It is strongly influenced by advances in the fields of transportation, mining, construction, agriculture, energy, and the like. No single organization attempts to conduct fertilizer R and D on all fronts, even TVA's National Fertilizer Development Center.

B. Setting R and D policy and objectives

1. Policy decisions—The decision to undertake R and D, the determination of its scope, and the amount of money to allocate must rest with the top officials of a company, organization, or government. In all cases, the R and D program must be an integrated component of the parent organization and contribute to the achievement of its overall goals and objectives. Industry necessarily looks upon R and D primarily as a way to gain a competitive advantage and increase profits. Government agencies and others may look upon it as a means for accomplishing the specific job for which they were commissioned, such as advancing social and human welfare or increasing national economic growth.

2. Selecting objectives—Any R and D organization must be given specific and clear-cut objectives. These will determine the direction the R and D will take, its scope, and size. Carefully thought out objectives assure that R and D zeroes in on the types of projects for which it was commissioned. At the same time, the objectives must not be so restrictive as to hamper performance.

C. Organizing for R and D effort

1. Planning the organization—Once the basic policy decisions are made and objectives set, top management must avoid excessive domination of the R and D effort. However, the R and D organization must be accountable for its progress and actions.

   The main purpose of the R and D organization is to provide a mechanism to aid its personnel in accomplishing the objectives set out for them. It serves as a channel of communication, makes major decisions, pinpoints responsibility, carries out necessary housekeeping functions, and, most important, is responsible for building an environment in which quality R and D can exist and thrive. The best organization is one that delegates a considerable amount of authority and accountability to its people but, at the same time, remains responsive to the needs of the parent organization.

   Most R and D organizations follow a similar pattern. The individual is the basic building block, but his activities are closely integrated and coordinated with others, usually under the direction of a unit leader. Interrelated groups, in turn, are combined into sections and branches. In very large organizations, consolidation may continue into one or more major divisions; however, the chain of command through which a scientist or engineer reports to the top must be as short as possible. One person must always be held accountable for the entire R and D effort.

2. Staffing—Successful staffing involves (1) obtaining a central core of scientists and engineers who are highly creative and can invent and discover, (2) complementing these with others who are willing and capable to work and assist in the development of new ideas and innovations, (3) selecting top-notch leaders who are both knowledgeable in research and capable of getting things done through people, and (4) providing dedicated people to attend to necessary administrative details and functions. Successful staffing of an R and D organization requires a certain amount of winnowing and sifting of young recruits and diversion into other fields of

those who do not possess R and D capabilities. Selection of leaders from within the organization depends largely upon placing R and D personnel in situations requiring some leadership responsibilities, and then advancing those who excel. In developing a new organization, it is necessary to recruit the leaders and a nucleus of scientists and engineers who have already demonstrated their abilities elsewhere.

3. Creating a good environment—Regardless of the caliber of the staff, a poor environment can stifle motivation and slow progress. A good environment results when the individual scientist or engineer receives only the minimal supervision to adequately perform his job; when he can participate in professional societies of his choice, and publish and patent; when he has opportunities for continued self development; and when he is assured that his work not only is important but also is in areas of his own interests and capabilities. Other key factors include adequate equipment, ready access to a good library, enlightened and nondictatorial leadership, provision of one or more technical assistants, a good salary, opportunities for advancement, and job security.

D. Conduct, operation, and controls

1. Selection of projects—Selecting major projects and areas of investigation involves a careful analysis of the costs vs expected benefits, possibilities of success, capabilities of the staff and of the personnel available to conduct the program, availability of funds and facilities, and the relative value to the overall objectives. Invariably there are more ideas and projects than capabilities and funds. Final decisions, therefore, are selections of the most promising from a number of attractive contenders. In low-cost laboratory stages, a number of exploratory and high-risk projects may be undertaken with a minimum of evaluation and control. However, as a project progresses, ever-increasing amounts of capital, equipment, and personnel must be committed. Evaluations thus must become more precise, go or no-go decisions more hard-headed, and progressively higher levels of management involved. Knowing when to stop a project or line of research is important. A point of rapidly diminishing returns eventually will be reached in any area of activity. A major pitfall in R and D is in unknowing duplication of work already done by others. Thorough literature and patent searches must precede any new project.

2. Conduct of R and D—A number of research problems may be resolved by a single individual or a small group. However, a team approach is required on most projects. This involves people representing different disciplines with each contributing his particular skill and knowledge. Major product and process developments require progression from one group of specialists to another, in which the various groups continue to cooperate together.

   The pathway from invention to adoption of a new fertilizer process is roughly: laboratory research, pilot plants, advanced engineering design, and prototype commercial plant. New products follow the order: laboratory research, greenhouse product screening and testing, pilot plants, advanced product evaluation and testing under actual field conditions, advanced engineering design, prototype commercial plant, and market development. R and D is involved to varying degrees at each step and there is continual feedback. For example, problems frequently arise in a prototype plant that require fundamental laboratory research for solution.

3. Reporting and patenting—Written progress and problem reports are necessary in any R and D organization. The researcher or project group reports periodically to their leader, usually at weekly or monthly intervals. Individual reports are summarized and reported to the top R and D management, usually on a quarterly basis and always annually. Summary reports to the

parent organization also are made at the same intervals; however, these primarily stress the significance of progress as it relates to overall objectives. Systematic reporting is essential in coordinating research, evaluating direction and progress, and documenting accomplishments and failures. Final reports on all projects are a necessity. The precise form and detail required by different research directors and organizations may differ, but all should be well-written and carefully thought out. Poor reporting has doomed many otherwise promising R and D projects.

Nearly all organizations use patents to protect or capitalize on important inventions resulting from R and D. Both personnel and management must be constantly alert to possibilities. It is important that original records be kept carefully, dated, and witnessed to provide satisfactory legal evidence for patent applications and possible patent suits. In large laboratories and organizations, patent attorneys are assigned to work with the research organization.

4. Budgeting and cost controls—Most organizations operate their R and D programs on an annual budgetary basis; however, it is inadvisable to expand or contract an R and D budget rapidly. A proposed budget usually starts at the research level and is reviewed and modified at progressively higher levels of management. It is highly important that budget items for all major projects be thoroughly justified and possible alternatives evaluated. Budgets offer a means to control expenditures, shift emphasis in direction, or speed high-priority projects. The budget document serves as another channel of communication between the research staff and top management, and as such should be carefully prepared and place proposals in proper perspective. An opportunity to revise the budget somewhat usually exists during the year. R and D budgets can be followed rather closely since the major expense item is salaries, and other fixed costs are easy to estimate.

   Once a budget is approved, a system of cost controls is followed to keep expenditures within the overall limits. In R and D, considerable flexibility is allowed among minor and exploratory projects. Cost controls permit a running evaluation of a development in relation to expected benefits.

REFERENCES: 170, 212, 254, 304, 353

CONSTRUCTION AND OPERATION OF PILOT PLANTS

A. Purpose of pilot plants

Pilot-plant operations may vary in type and scope from one company to another. However, they are usually defined as the intermediate steps in the development of a process from basic research to commercial operation. The equipment used in a pilot plant is normally of the industrial type rather than of the laboratory type, and the pilot plant is a model for the scaleup of a commercial-size plant. Pilot plants are usually constructed and operated for one of two main reasons: (1) a promising new process has been tested in laboratory equipment and found to be technically feasible, or (2) the need for improving one or more steps in a commercial operation has become evident and experimentation on large plant scale is not economically feasible.

B. Organization of staff

Construction of a pilot plant should start with the necessary planning by the project engineer who will be directly responsible for the program. Normally, this engineer is expected to possess the experience and training necessary to handle both the design and the operation of the pilot plant. In a large research and development organization, the project engineer is normally supported by competent assistants and backed up by an organized supply of mechanical and operating services. The key positions are normally staffed by professional engineers having at least a bachelor's degree in engineering and by nonprofessional support personnel with extensive experience in pilot-plant and laboratory work.

1. Design—To begin the design of a pilot plant, the engineers assigned to the project usually spend several weeks in reviewing known process technology, including results of laboratory tests and the literature. Then a preliminary design and a cost estimate are made for administrative review. Two to six months would normally be required for final design and acquisition of equipment for a pilot plant such as those built by TVA to study the production of wet-process acid by the foam process and the production of ammonium polyphosphate by the direct process (References 78, 238).

2. Size—There is no generally acceptable answer to the question, "What should be the size of a pilot plant?" Generally, the larger the plant size, the more reliable the data will be. When the process under development involves a new, untried product, market development work may be required. In this case, the size of the pilot plant should be large enough to produce several tons of product per day. However, if engineering data are the main requirement from the pilot plant, as would be the case in developing a new process to produce an established product, then a small pilot plant with a production rate of a few pounds per day may be adequate.

3. Location—Where possible, it is desirable to locate pilot plants in an area assigned for experimental work. Such an area must provide adequate process services, such as water, steam, electric power, fuel gas, etc., in a "readily available" manner, as well as housing structures, and accessibility for engineering personnel.

4. Construction—With some minor variations, the basic principles to be followed for efficient construction of pilot plants are like those for any other construction project. In order to avoid confusion, minimize construction time, and save money, one—and only one—member of the engineering team should be designated to supervise the construction force. The project engineer should organize the schedule of construction so as to ensure prompt delivery of equipment needed and thereby avoid delays once the construction has been started. The engineer in charge should make a special effort to ensure that the craftsmen building the plant are adequately supplied with the materials needed in order to avoid delays, and that clear instructions backed up by adequate engineering drawings are available to them at all times.

5. Operation—The actual operation of pilot plants may be carried out by operating personnel (labor) under the supervision of engineers or technicians in a large research organization; however, in a small organization with small pilot plants, such duties are commonly performed by engineers and technicians. Since almost all pilot-plant operation is carried out for the purpose of obtaining engineering data, operating personnel should have at least a high school or equivalent education.

6. Analytical work—No phase of pilot-plant work is more important than the analytical work. Accurate, dependable chemical analyses are the bases for conclusions on the value of a process.

It is very helpful if the analytical laboratory is in close physical proximity to the pilot plant. This will provide for rapid transmission of samples from the pilot plant to the laboratory and equally rapid reporting of the results. Also of foremost importance is the provision for close contact between engineers operating the pilot plant and chemists doing the analytical work. Control analyses may be done by operating personnel or technicians at, or near, the pilot-plant site. Feed and product analyses are normally done in an analytical laboratory equipped to run complete analyses.

7. Collaboration between research laboratory and pilot-plant personnel——Generally, research workers will have had as much as one year or more of experience with a process before a pilot plant is built. Therefore, it is apparent that close cooperation should exist between the research laboratory and the pilot-plant personnel. The exchange of information and ideas between these two groups is often a critical factor in the success of pilot-plant work. Also, just as some plant problems can be solved most economically by pilot-plant studies, some pilot-plant problems can best be solved by reverting to bench-scale studies.

8. Economics——The cost of constructing pilot plants may range from a few thousand dollars for a miniature-size installation employing laboratory equipment to around $200,000 for a large-size, completely integrated pilot plant. The cost of operating these pilot plants in keeping with the size can amount to as much as $30,000 to $40,000 a month.

   The cash-position diagram for a commercial chemical development can be constructed using various details of calculations with regard to the time value of money, the monetary inflation rate, and the method of accounting for depreciation (Reference 186). The absolute and relative magnitudes of the amounts of time and money will depend on the project. It is apparent that maximum effort should be made to minimize the time required for laboratory, pilot-plant, and commercial-plant design.

9. Safety——In addition to the normally recommended safety practices for chemical plants, it is imperative that special attention be given to safety in pilot plants. Most pilot plants involve exploration of some unknown areas, and periodic inspections by an engineer who has had experience in chemical plant safety are needed to avert accidents.

REFERENCES: 78, 186, 238

IN-SERVICE EDUCATIONAL PROGRAMS FOR PROFESSIONALS

A. Introduction

The subject of continuing in-service education has been widely discussed in recent years because of the "information explosion." Technical knowledge in most fields is growing so fast that it doubles every 10 years. At one time, new techniques and products took 20 years to move from the invention stage to inclusion in the undergraduate curriculum of universities. Today this trip is often made in 5 years. Such progress soon leaves behind the college graduate who does not discipline himself to continued study.

B. Importance of continuing education

The purpose of continuing education is to prevent technical obsolescence. This is important from the standpoint of the employer and the employee.

1. To employer—It is not easy for the management of a company to evaluate what obsolescence is costing in dollars and cents. Technical obsolescence can be hidden by such things as an aggressive sales force, clever exploitation of existing patents, lack of determined competition, and many other factors. Sooner or later, however, obsolescence will appear if management and employees become technically stagnant. This results in loss of profits.

   Continuing education is important also from the viewpoint of recruitment. According to one major U.S. company, for example, it costs $10,000 to recruit a new employee and bring him to a productive point in the laboratory. If this man becomes technically obsolescent in 10 years, and is replaced by a new recruit, the $10,000 process is started again. However, the company can afford to spend up to $1,000 per year in continuing education to keep the original employee technically equipped for many more years' service.

2. To employee—Somehow, in the development of the professional man, there needs to be built into his thinking this urge for his own continuing improvement. He must have intellectual curiosity. Unless this occurs, the professional begins to stagnate the moment he leaves college. He must deepen and broaden his knowledge. The main thrust and continued motivation, the true desire to achieve, to adapt, to continually strive for improvement, must be assumed by each individual. Only by maintaining his competence can the professional reach his employment potentials.

C. Responsibilities for in-service education

1. The employer—The employing organization has a responsibility to help provide education, including proper attitude and financial assistance, to those employees who aspire to "keep educated." The degree of this responsibility varies with each organization. Some assume no responsibility; employees must "keep educated" on their own time. Other organizations provide 100% of the time and cost of continuing education. The company referred to above believes that a professional on a continuing study course should spend 10% of his time on the course.

2. The employee—The employee must be willing to participate in educational programs. It is a personal challenge. Self-analysis may be difficult, but it is possible and it is imperative. The professional must be willing to volunteer for formal company educational programs, whether they be at the company or on the college campus. The employee also has the responsibility to devote much of his nonworking time to self-education. He must spend time reading technical journals and reports. He must be active in professional societies. He has the responsibility to discuss new findings with colleagues in his and other professions. In short, he must be self-motivated to keep current in his field.

D. Types of educational programs

1. On-campus courses—These courses vary from periodic college evening courses to acquisition of advanced degrees.

2. Within-company courses—Senior professionals who have been out of school for a long time

and have developed many family and community obligations may not want to commute to an inconveniently located college several nights a week. Setting up the training within the company can be as good and sometimes even better than at the campus. The company's philosophies can also be better taught within house. These courses can also be a good recruiting tool.

3. Shortcourses—Such courses have the advantage of taking a specific subject–say fertilizer production, marketing, and use–and intensively covering important new developments. Shortcourses vary in length from a day to several weeks, depending upon objectives. The courses may be offered by a company, university, or a third party.

4. Seminars—These may simply be a one-hour lecture or discussion of a new development or a known fact that is receiving new emphasis. Seminars within an organization are also useful as a cross-disciplinary communications aid. The main function of a seminar is to keep company personnel informed and current on company operations and technical developments.

5. Professional meetings—These are usually annual events where professionals assemble to discuss new research and other developments. The main objective is to keep current in the field. But there are also many fringe benefits associated with attendance at such meetings. Personal and professional contacts are made which benefit the employer as well as the employee. Improved morale results when organizations encourage employees to attend professional meetings.

6. Personal study and reading—Although not necessarily a formal method of education, this one should be the most intense of all. In the final analysis, the individual professional is affected most by technical obsolescence. Educated men are general readers; they must learn to read rapidly and study what they read.

7. Others—There are many other methods of continuing education. These include correspondence courses, programmed instruction, and sessions with technical consultants.

E. National effects

Continuing education can keep a nation's technical leaders alert and equipped to bridge the gap between national stagnation and economic and personal growth of the people. For example, in the United States, 78% of the 1929 to 1957 increase in income per person employed resulted from increases in the education of labor and the advances of knowledge.

REFERENCES: 14, 15, 16, 19, 20, 21, 22, 23, 81, 89, 90, 112, 187, 188, 224, 250, 259, 295, 333, 350

FACTORS IMPEDING THE USE OF FERTILIZERS

A. The human factor

1. Many factors may tend to impede the use of fertilizers in a new "fertilizer use area." One of the major considerations is the human factor. Those responsible for changing people's customs

(as in the case of fertilizer introduction) carry a heavy responsibility. Altering people's way of life can affect the well-being of this generation and those to come. If the skill of the program people involved is poor, or their judgment bad, they can destroy potential cooperative relationships and create distrust and even hatreds that will greatly handicap ongoing operations as well as future programs. On the other hand, if knowledge and skills are great, the probability is that understanding of the people and their needs will be obtained and that confidence and trust will be established. Cooperation will develop which will allow rapid fertilizer introduction, assuming certain physical, chemical, biological, and economic requirements are also met.

2. A second major consideration, and one that is too often overlooked, is the makeup of the group which originates plans for fertilizer production, distribution, introduction, and use. It is extremely important that the fields of agronomy, economics, chemical engineering, and educational communications be represented and a team approach be used.

B. Lack of adequate crop response information

Often fertilizer response information is not available for proper detailed planning and execution of a sound fertilizer introduction program. It is desirable to have field trials in such a manner that response from several levels of fertilizer application may be measured and a response curve established for the crops and soils concerned. This kind of information lends itself to economic as well as agronomic analyses.

C. Lack of marketing and transportation facilities and of assured satisfactory price for crops

It is disastrous to any fertilizer introduction program if the farmer cannot be assured an adequate return on his investment. Good marketing conditions and an assured satisfactory price for the crops he will produce are extremely important. The relationship of the price the farmer will be expected to pay for fertilizers and the probable price he will receive for his crops should be carefully examined at an early stage of program planning.

D. Insufficient field demonstrations

It has been said that the most convincing teacher of all is the self-teacher. For many farmers this is certainly true. To be convinced, they must see the results of applied fertilizer on their own farm or that of a neighbor's. A sound education program including many well-planned and well-conducted field demonstrations is essential for program success.

E. Lack of adequate credit

Many farmers will need to borrow money to buy their fertilizer. If credit is difficult to obtain or if interest rates are excessive, this will definitely retard fertilizer introduction and use.

F. Lack of adequate and timely supply of high-quality fertilizer

It greatly handicaps a going fertilizer demonstration and use program, after having created a fertilizer demand among farmers, to receive a different kind of fertilizer from the one already demonstrated, or to receive fertilizer of poor physical or chemical quality.

G. Lack of crop insurance

Under many circumstances some type of crop insurance against drought or other disasters may need to be considered. This might be true where farmers have no capital and must borrow heavily for fertilizer purchases. Such an arrangement might be especially appealing to farmers who did not irrigate and who may be afraid to risk the investment in fertilizer for fear of drought.

H. Conclusion

These are some of the factors which may be expected to impede fertilizer introduction and use if not properly handled. As the team of agronomists, economists, chemical engineers, and educational communicators meets to discuss program potentials and problems, many other factors will no doubt be identified which will need to be considered.

REFERENCES: 31, 32, 33, 167, 207, 209, 228, 315, 331, 334, 346

SCALING UP CHEMICAL PROCESSES FROM PILOT PLANT TO PRODUCTION PLANT

A. Background and purpose

The pilot-plant stage is a major "midpoint" in the research and development program for new products and processes. The technical and economic feasibilities usually are proved or disproved at this stage of the development and decisions of "go" or "no go" to commercial-scale application are made. A sound pilot-plant program provides needed data, general information, and experience for reaching decisions on final utilization of new or improved chemical processes.

1. Purpose of a pilot plant——The primary purpose is to obtain engineering design and operating data for design and operation of a commercial-scale plant. Such data include raw materials specifications and requirements, heat and material balance data, information for making a sound economic evaluation, and practical experience to define troublesome steps and establish suitable process equipment and operating techniques. The optimum ranges of operating conditions are defined. Pilot-plant operation on a scale of a few hundred pounds to 1 or 2 tons/hour of product provides a "trickle production" of product material for chemical and physical evaluation and for limited evaluation in use.

2. Design of pilot plants to facilitate scaleup——Only items of process equipment and control systems that cannot be designed safely from past experience or known principles are piloted in detail. Expedients and simple cost-saving procedures can be used for some items. Instrumentation and automatic controls often are not elaborate in pilot plants, but modern technology is causing a shift toward more complete systems of this type in pilot plants.

B. Pilot-plant operation

1. The conditions of operation and process features outlined in earlier studies on smaller scale are proved and more clearly defined in the pilot-plant operation. The jump from laboratory or

small scale to pilot plant may be about as severe as the later scaleup to commercial size. The pilot plant usually is a reasonably well-integrated system, the operation of which imposes essentially all of the key operating problems that would be expected in a large plant. Continuous flow is desirable for all process steps to identify problems and to establish stable conditions for the process.

2. Tests to obtain design data and to provide basis for economic evaluation—After the pilot-plant equipment for key process steps has been decided upon and optimum range of operating conditions established, test work often is directed specifically toward obtaining data needed for scaleup of the process. This requires obtaining physical and chemical data and tests over sufficient range to establish capacity of key equipment. Periods of stable operation "around the clock" usually are necessary to determine dependability and to establish continuity of process control. Such periods also allow adequate material balance and energy balance data to be obtained. All of this information is needed to provide a sound basis for reliable estimates of investment and production costs.

3. Extent and scope of pilot-plant development—Time and budgetary limitations likely will dictate the depth and detail of pilot-plant studies. It may not be practical to make a complete study of all process variables; selection of key parameters that require in-depth study may be necessary.

C. Scaleup guidelines and procedures

1. General considerations—This process involves an orderly sequence in the development program starting with design and construction of the pilot-plant facilities, proceeding through operation to obtain the needed data, and finally using the data and experience for the final objective of applying the process on commercial scale. Sound engineering judgment, together with good common sense and evaluation of economics, is essential.

2. Quantitative process flowsheet—A very vital means of organizing pilot-plant data and visualizing the process is through preparation of accurate and detailed process flowsheets. These are used in earlier stages of design and operation of the pilot plant; as full data are obtained, the final quantitative flowsheets giving quantitative material and heat and energy balance data provide an important tool in scaleup.

3. Selection of size of pilot plant in relation to commercial units—Selection of proper size of a pilot plant is important. If the unit is too small, a single step to commercial scale may be quite risky. If it is too large, the investment and cost of raw materials will be high, and use of product and disposal of wastes may impose undue problems. Generally, if the capacity of the pilot plant is from one-twentieth to one-thirtieth that of an expected economical commercial unit, the scaleup should be reasonably safe.

4. Sizing individual items of process equipment

   a. General rules—Considerable data, rules of thumb, and engineering criteria are available in the literature for sizing and selecting process equipment for a commercial plant from pilot-plant data and experience. For commonly used equipment for standard unit operations such as reaction or extraction, evaporation, distillation, filtration, and drying, the procedures are sound and well established. For unique equipment specifically developed for a new process, there is a need to obtain more pilot-plant data and to exercise more ingenuity and sound judgment in scaleup.

b. Principle of similarity—The principle of similarity is concerned with the relationship between physical systems of different sizes, and it is therefore fundamental to scaling up physical and chemical processes. Four states of similarity can be important in chemical engineering, namely: geometric, mechanical, thermal, and chemical.

c. Boundary effects—Every experimental system has limitations in the form of a boundary which separates it from its surroundings and delimits the variables which are under control of the experimentor. As the system or component is scaled up, the ratio of boundary surface to internal volume decreases. Wall effects, flow patterns, and surface catalysis are related to boundary effects.

D. Other important considerations

There are a number of facets of pilot-plant development work that can greatly affect the ease and confidence of scaleup. Some of these are:

1. Auxiliary systems for process—The basic process usually is accentuated, and accessory features such as dust and fume control are often overlooked until a large plant is being designed. Greater emphasis on control of all effluents to obtain greater economy and to meet pollution control standards will be necessary in the future; inclusion of adequate studies of these in the pilot plant will be essential.

2. Use of more sophisticated technique—There is a definite trend toward more precise chemical process systems. This allows reasonable use of process simulation, mathematical models, and statistical design and evaluation of experimental work. The computer has opened up entirely new opportunities in this area and can be very effective if properly applied.

3. Unique nature of fertilizer process development work—Pilot-plant work on development of new fertilizer products and processes must take into account that the products are large-volume, low-cost materials. Cost of raw materials is of great importance and economy in investment and operating cost must be emphasized. On the other hand, quality of the products must be emphasized. The great sensitivity to economics and the close profit margins in fertilizer manufacture impose a considerable restraint.

E. Examples of scaleup

TVA has had a number of examples of successful scaleup of processes for new or improved fertilizers. Pilot-plant work has been an essential step, and in several cases a need for a demonstration-scale unit (of essentially commercial size) has been apparent and was demonstrated. The pilot plants usually have been of larger capacity such as 0.5 to 2 tons/hour, and in some cases, followed large bench-scale units. A number of granulation processes were effectively scaled up from a 0.5- to 2-ton/hour pilot plant to 20- to 30-ton/hour commercial units.

REFERENCES: 79, 140, 177, 182, 215, 275

FERTILIZER EDUCATION AND PROMOTION: COMPARISON OF GOVERNMENT AND FERTILIZER INDUSTRY PROGRAMS

A. Introduction

Education and promotion activities are basic building blocks in a fertilizer and agricultural development program. Studies in the United States show that farmers receive useful agricultural information from many sources. In the area of fertilizer information, the most important sources are fertilizer dealers, government agencies, friends and neighbors, and mass media. Land-grant universities are considered here as a part of the government agency description. In reality, however, universities are not controlled by the U.S. Government. The Federal government does contribute funds to the university's agricultural extension service programs.

B. Fertilizer industry programs

Several factors contribute to the concern of the individual fertilizer firm about the welfare of its customers. The keen competition in the industry is most important. Although several firms are giant corporations, no one firm has a large percentage of the fertilizer sales in a local market area. The manufacturer is also concerned with repeat sales. Another reason for the concern of the manufacturer for the economic use of his product is that a prosperous farmer is better able to purchase more fertilizer and pay for it promptly.

1. Marketing department relies on information programs—The marketing side of the organization is concerned with the distribution to and use of the fertilizer by the consumer. In a large company, production and marketing are usually separate, but in a small firm one individual will probably supervise both functions. In firms of all sizes, a retail outlet is an essential part of the organization. It is within the framework of the marketing organization that the companies in the fertilizer industry make their contribution to the best economic use of fertilizer by the farmer. And in most cases, it is done by assembling as much information as possible and providing an educational program for passing on this information to the farmer.

2. Education programs benefit dealer and farmer—The objectives of the educational program are to get as much information as possible on proper fertilization practices to the user so that he will receive the maximum economic gain. Four major avenues are used in disseminating information on fertilizers and their use: dealer meetings, farmer meetings, field demonstrations, and mass media.

   a. Dealer meetings—Although part of the time is occupied in discussing sales programs, promotions, pricing and product availability, considerable time is used to discuss the agronomic relationships of fertilizer to soils and crops. Emphasis is given to such things as soil reactions, plant nutrient uptake, placement, availability of nutrients, and all of the other kinds of information relating to soil-plant-fertilizer relationships. It is expected that dealers will gain enough knowledge from such meetings to enable them to counsel farmers on fertility problems.

   b. Farmer meetings—The dealer makes all arrangements for the farmer meetings, which include providing a place for the meetings and issuing invitations. A meal is sometimes given those attending as an added inducement to come. The company agronomist—and in some cases, college specialists—conducts the discussion, which again is primarily concerned with principles of fertilizer-soil-plant relationships at a level understandable by the

audience. The company's product will be mentioned, but no attempt at direct selling is done at this kind of meeting. It is intended to be informational.

c. Demonstrations—The objective is to show the advantage of proper fertilization; but of course, the fertilizers used are those produced by the company. The company agronomist is usually the leader, but he encourages cooperation from state extension specialists, county agents, vocational agriculture teachers, dealers, farmers, business clubs, and any others who are interested.

d. Mass information activity—Advertising programs on TV, radio, and in newspapers are used seasonally by many companies. Many companies also prepare brochures that discuss the details of producing different crops. These include information on fertilizer, seeds, herbicides, insecticides, and other improved practices. Companies use other mass media information ideas including contests and prizes, posters, roadside exhibits, and direct mail materials.

C. Government agency programs

The land-grant university system has had a major role in promoting improved agricultural practices–including fertilizer use. The universities encompass three major programs: campus instruction, agricultural experiment station, and the agricultural extension service. The extension service carries agricultural, home economics, and other information to the people in each state and encourages them to use this information to help themselves. Extension workers are off-campus teachers. Men, women, boys, and girls are their students. The U.S. Government does not own nor control the universities. But other government agencies, USDA and TVA, contribute to the university agricultural program.

1. Need for fertilizer education—The needs for fertilizer education are determined through several sources. These include:

   a. Research analysis—Analysis of research conducted by the experiment station system. Soil test reports are excellent tools for determining the need for fertilizer education.

   b. Farmer knowledge—Farmer experience in fertilizer use provides another means of determining the needs for fertilizer education. Test-demonstration farms participating in the Cooperative Extension-Tennessee Valley Authority program play an important role. Many other farmers and 4-H members conduct fertilizer demonstrations under the supervision of their respective county extension workers. Comparison of fertilizer needs obtained from fertilizer sale records provides excellent means of determining areas that should be emphasized.

2. Role of specialists—The extension service does not have research personnel on its staff. Agronomists and other subject matter specialists have a close working relationship with research personnel assigned to their area of interest. Specialists keep themselves posted on research under way and analyze data to determine recommendations that should be made. Specialists in fertilizer and soils work closely with research personnel assigned to the soil testing laboratory. They also conduct training programs for county extension staff members, cooperate with county staffs in training meetings for leaders and fertilizer dealers, and prepare bulletins for distribution to extension's clientele through the county extension office and demonstration outlines for use by county workers in conducting fertilizer demonstrations. Specialists also prepare news releases and radio scripts, assist with meetings, observe

demonstrations, help delineate problems and keep extension workers informed.

3. Types of education effort

   a. Demonstrations—Result demonstrations, conducted under the supervision of county extension personnel, are one of the best teaching tools in fertilizer education. These demonstrations provide opportunities for on-site study, as well as information for use in meetings, circular letters, news articles, radio programs, office calls and farm visits.

   b. Test-demonstration program—The test-demonstration farm program is a cooperative effort between extension and the Tennessee Valley Authority. Whole farms are used as result demonstrations. These have served as excellent fertilizer teaching tools. They provide opportunities for on-site studies of the whole-farm fertilizer use program as well as the use of fertilizer materials for specific cash, grain, and forage production. They submit total farm records that include the kind and amount of fertilizer used as well as fertilizer costs.

   c. Rapid adjustment farms—In addition to test-demonstration farms, several rapid adjustment whole-farm demonstrations are used in the Tennessee Valley states. Studies of resources and potentials are made on each farm. Benchmark data relative to land use, fertilizer use, cropping systems, yields and sources of income are obtained. Plans are developed for reaching indicated potentials within a given period. Maximum use is made of fertilizer materials applied according to soil test. These programs have shown that management programs can be developed to double net farm income within a few years. Fertilizers play an important part in this development.

   d. Meetings, tours, and mass media—County-wide, community and 4-H meetings, meetings at demonstrations and tours of demonstrations have been extension's useful tool in fertilizer education. Meetings at demonstrations are the most effective since seeing is believing. Mass media, including circular letters, bulletins, news articles, radio and TV provide other useful means of communication.

4. Evaluating education—The results of fertilizer education activities can be evaluated in many ways. A comparison of the tonnage of plant nutrients purchased by farmers in a given year with purchases made during preceding years is one of the best indicators. Increases in the number of soil samples submitted for testing provide another excellent means of evaluating fertilizer education. Increased yields provide another measure of the results from fertilizer education.

REFERENCES: 72, 358

PLANNING AND CONDUCTING PROGRAMS IN FERTILIZER EDUCATION

A. Importance of fertilizer education

High quality educational activities to increase farmers' knowledge about fertilizers, change their attitudes toward fertilizer use, and improve their skills in using fertilizers should be an essential

part of every developing country's fertilizer program. Availability of adequate supplies of good fertilizers and an abundance of information on responses which can be expected from their use under a wide range of soil-crop combinations do not automatically ensure acceptance and use of fertilizers by farmers. In addition, educational, motivational and promotional activities are needed to acquaint farmers with the various fertilizers which are available and the benefits which can be expected from their use.

B. Selecting a plan to reach and motivate farmers

Studies in the United States have shown that farmers acquire information about fertilizer materials and fertilizer practices from a variety of sources. The most important sources are fertilizer dealers, public agencies, friends and neighbors, and mass media. Different types of farmers tend to look to different sources for information. The better educated farmers tend to depend on public agencies, principally the experiment station and the extension service. Farmers with limited education depend largely upon relatives, friends, neighbors, and mass media. Fertilizer dealers are important sources of information for all classes of farmers but are more important for the older and less educated than for those who are younger and better educated. Most farmers seek information from more than one source. An effective fertilizer educational program should include a variety of communication techniques and information sources. The overall plan should be prepared in detail. The audience for each phase of the program should be identified. Delegation of responsibilities should be made to each person in a leadership position. Those responsible should be held accountable for performance.

C. Application of TVA experience to developing countries

When the TVA fertilizer program was started in 1935, conditions on farms in the Valley were similar in many ways to those now existing in many developing countries. Farms were small, soils were poor, education was limited especially among the older farmers, capital was scarce, and farmers were discouraged and reluctant to change. TVA experience has shown that under these conditions farmers respond best to the demonstration method of teaching. The demonstration method is based on the concept expressed more than 50 years ago by Dr. Seaman A. Knapp, the father of cooperative agricultural extension work in the United States. Dr. Knapp stated, "What a man hears, he may doubt; what he sees, he may possibly doubt; what he does himself, he cannot doubt." The purpose of a result demonstration is to reproduce an already proven fact, not to discover new truths. Fertilizer demonstration programs should include provisions for farmer motivation.

Farmers learn more from fertilizer programs planned with them than for them. Planning with farmers is an educational process. It helps them become skilled in making sound decisions and gives them more confidence in their ability to make decisions. They grow in the process and become more self-reliant.

Fertilizer recommendations should be based on research information–known facts–not on opinions or hunches. If there is doubt about the results likely to be obtained, establish fertilizer trials. Farmers should understand that the results from a trial may not be favorable. Its purpose is to obtain additional information; however, it would have some demonstration value.

D. Planning and using fertilizer demonstrations

Fertilizer demonstrations provide a teaching situation for the educator and a learning experience for farmers. Demonstrations should not be complicated. They should be simple, easy to see, and

planned for dramatic responses. They should be promoted, yields should be harvested, and wide use should be made of results.

1. Keep them simple—Keep demonstrations simple by showing only one or two things at a time. Complex demonstrations confuse farmers.

2. Make them easy to see—Plan demonstration so that it will be easy to see differences in yields. Demonstration sites should be located accessible to large numbers of farmers and labeled with attention-getting signs on which the story is told in few words. The average farmer is influenced more by a demonstration than by printed information.

3. Plan for dramatic responses—Small differences in crop yields are hard to see. Select demonstration sites known to be deficient in the fertilizer nutrient or nutrients to be demonstrated. Under normal conditions, striking differences should be expected on the sites selected.

4. Promote the demonstration—What's the use of setting up a demonstration if nobody comes to see it? Sell the results through all available means such as tours, picture displays, news articles, bulletins, and use of results in farmers' meetings.

5. Harvest yields and use results—Harvest and record yields to extend the value of the demonstration beyond the immediate year in which conducted. One effective technique for displaying results is to harvest the crop from small, equal-sized plots from the fertilized and unfertilized areas or from areas fertilized at different rates, store in plastic bags to eliminate insects and weather damage and prominently display the results at the demonstration site or some other place visited by large numbers of farmers.

REFERENCES: 34, 165, 203, 217, 220, 260, 315, 346

ROLE OF FERTILIZER DEALERS IN FERTILIZER EDUCATIONAL PROGRAMS

A. Who is a fertilizer dealer?

The owners and managers of stores which sell fertilizer to farmers are called fertilizer dealers. The fertilizer dealer is the last person the farmer talks to before the sale is made. The fertilizer dealer delivers the goods and services to the ultimate user—the farmer. He is the industry spokesman in the eyes of most of his farmer customers.

B. Characteristics of dealers

It is impossible to categorize dealers as to type. However, based on their perception of the role of fertilizer in their businesses, it is possible to establish four major types of dealers. Dealers categorized by their perception fall in the four major types:

1. Those who handle fertilizer because it is a good money-maker.

2. Those who handle fertilizer because they are rendering an important service to farmers.

3. Those who handle fertilizer because it is a service required by farmers.

4. Those who handle fertilizer for competitive reasons.

C. Relationship of dealers and farmer customers

Fertilizer dealers who handle fertilizer because it is a good money-maker and because of their interest in rendering an important service to farmers have considerable influence in the farmer decision-making process. Those who handle fertilizers as just another service required by farmers and for competitive reasons are recognized by farmers as just another order-taker. They have very little influence in the farmer's decision-making process.

D. Farmer's opinion of fertilizer dealers

A study by Southern Illinois University gives information on what farmers think and expect of their fertilizer dealer. A summary of the study follows:

1. Most farmers believe that fertilizer dealers have a real interest in their farming operation and indicate a rather high confidence in their qualifications.

2. Farmers rate rather highly the idea of fertilizer dealers providing soil sample collection, soil testing, and fertilizer recommendations as a service.

3. Farmers think rather highly of educational makings conducted by dealers.

4. Farmers think rather highly of crop yields and fertilizer use record service provided by dealers.

E. Role of dealers in farmer's decision-making process

The following information is based on a recent research study:

1. Ninety-seven percent of farmers interviewed said they thought their fertilizer dealer should be a reliable source of information.

2. Seventy-nine percent said they expected their fertilizer dealer to recommend the method by which they should apply fertilizer.

3. Sixty-nine percent said they expected their fertilizer dealer to recommend the analysis to apply.

4. Sixty percent said they expected their dealer to recommend the amount of fertilizer to apply.

F. County agent-dealer educational team

The agricultural extension service, through its county agents, is charged with the responsibility for extending to the farmer research information developed by the agricultural experiment stations. The local fertilizer dealer, through his close contact with the farmer, is the farmer's primary source of information. It is clear that both fertilizer dealers and the county agents serve a major role in informing farmers as to use of fertilizers. This is a perfect setup for teamwork which provides the

dealer with a sound educational program to present to his farmer customers. It also helps the extension service to make its educational work more effective through quicker adoption of information. The farmer benefits from this teamwork by getting the best available information with a minimum of conflict between sources.

G. What dealers need to know in order to perform educational services

A panel of 12 specialists representing retail fertilizer dealers compiled the following list of subjects of which persons engaged in retail fertilizer distribution must have a good working knowledge in order to market fertilizer successfully:

1. Characteristics of different fertilizer materials.
2. Physical and chemical properties of soil in relation to plant growth and yield potential.
3. Fertility needs for various levels of crop production.
4. Cropping plans for specific soil types.
5. Fertility needs based on soil test information.
6. How to conduct demonstrations.
7. Seed quality and plant population in relation to fertilizer response.
8. Soil pH and how to maintain it at its most productive level.
9. Weed and insect problems and their control.
10. Micronutrients and their effect on crops.

H. Skills needed by dealers

In addition to having a good knowledge of soil fertility and fertilizers, dealers need to be able to do the following:

1. Take an accurate soil sample.
2. Interpret a soil test report.
3. Identify various fertilizer materials and evaluate fertilizer formulas.
4. Make recommendations to customers regarding proper use of fertilizers and assist customers in keeping a fertilizer history on their farms.
5. Recognize nutrient deficiencies in growing crops.
6. Operate and maintain fertilizer handling equipment.
7. Make recommendations regarding amounts of fertilizer to use in absence of a soil test report.
8. Estimate potential demand for fertilizers in his trade area.

I. Some services being performed

The following are some of the services being performed by fertilizer dealers:

1. Making recommendations based on soil test–78%
2. Taking soil samples–69%
3. Offering credit service–68%
4. Contacting customers personally–67%
5. Giving complete fertility plan service–32%
6. Using test plot demonstrations–31%
7. Following up on sales survey–18%

J. Personal and specialized services

The aggressive fertilizer dealer figures very closely with the farmer just what plant foods and amounts the crop will need to get the yield the farmer wants. He also consults with the farmer on materials to be supplied, method of application, application equipment, the pH of the soil, variety of crop to be grown, population goal, herbicide, pesticide, planting dates, harvesting, yield goal, and investment in fertilizers and other items he must make per acre to get these yields. By comparing the total cost of production items with expected high yields, it is easy for the farmer to see the profits he can expect to get. Good dealers sell a program, not just fertilizer.

REFERENCES: 35, 318, 319, 342

STATISTICAL DATA REQUIREMENTS FOR PRODUCTION, MARKETING AND USE OF FERTILIZERS

A. The chemical fertilizer project

1. Chemical fertilizer projects are usually large and costly undertakings which, particularly in developing countries, have a major impact on the economy, the availability of foreign exchange, resource demands, and on the population and their food and living standards. Great care is needed to ensure that the optimum type and size plant is installed at the best location, and is operated in a manner most suited to the specific conditions. The best way of achieving these goals is through a detailed project study. Market research methodology for such a study and the information sources necessary to complete such a study are the subjects considered in this paper.

2. To be realistic and successful a project must have valid reasons for its creation. A venture established for purposes of national pride, or needless self-sufficiency is likely to prove very costly and may become an ultimate handicap to the country. A new undertaking must meet

real needs. It may:

a. Increase domestic food supplies

b. Result in foreign exchange savings

c. Generate foreign exchange by producing for export from indigenous raw materials

d. Develop national strength and resources

3. The project must provide an adequate financial return on investment. Private and public investment cannot be expected to support doubtful enterprises when more realistic opportunities exist elsewhere. Projects built with government funds should be based on the same criteria if they are to be of benefit to the people financially.

B. Basic information required for fertilizer project studies

Before a fertilizer project can be established, the type or types of product needed, sales volume, distribution patterns, price structure, and other related items must be known. This necessitates a detailed market study based on the analysis of pertinent information and official statistics, and inquiry and investigations in the field, including interviews with potential customers, distributors, and others.

1. Market data requirements

a. Official soil, crop, climatic, population, and geographic data—Soil type, climatic conditions, and cropping practices go hand in hand. Investigations should include review of potential to change cropping practices or crop varieties to higher yielding crops that demand higher fertilization rates. Risk factors caused by weather patterns and their effect on fertilizer use must also be considered. Population density and growth along with location of markets in relation to farm areas must be taken into account.

b. Past, current, and projected fertilizer consumption by market area—Potential fertilizer use by crops should be determined in estimating future demand. Crops that are approaching their potential offer little in additional fertilizer use growth unless large acreages are added to production or because demand for crop is growing rapidly. The relative position of potential usage to current usage must be determined to find out there is economic justification for a rapid movement toward the potential use.

c. Seasonal trends, local preferences or customs

d. Existing suppliers and supply sources

e. Current prices, discounts, and contract terms

f. Past price history and projected trends

g. Storage facilities, distribution patterns, transport availability, shipping and port facilities, and freight rates

2. Production patterns

   a. Types of fertilizer—Production of single-nutrient materials, especially nitrogen materials, based on past consumption patterns and projected use patterns. Markets for new materials should be considered along with rate of development for these new markets. Must also consider single nutrient P_2O_5 carriers, and relative economics of multinutrient materials, such as the ammonium phosphates. Determine products that will form basis of granular mixed fertilizers if market demand dictates this type of fertilizer.

   b. Required specifications—Ratios of plant nutrients required, physical properties, and packaging and method of shipment. Bag sizes and extent of handling required must be considered.

   c. Production and shipping programs—Anticipated annual shipments, or plant capacity. Must also know anticipated shipments by regions. Month-by-month shipping schedules and effects of seasons on shipping and transport facilities.

   d. Principal consumers and their locations.

   e. Pricing structures—Consideration of costs of production, costs of distribution and retail price. Also, in this category are included methods and terms of payment, financing, insurance and price levels and other government controls.

3. Raw materials—Once a study of market demand and product mix has been completed, a detailed study of available raw material supplies should be undertaken.

   a. Nitrogen—Anhydrous ammonia forms the basis of almost all nitrogen fertilizer production; thus, feedstocks of natural gas or refinery gas must be investigated. Liquid feedstocks, such as oil or naphtha, along with solid forms, coal and lignite, and their availability should be considered along with the costs of production for each of the various processes.

   b. Phosphate rock—Location of mines and cost of development of possible mines along with economic feasibility of developing deposits must be studied.

   c. Potash—Location of mines and economic feasibility for development.

   d. Sulfur—Native sulfur, byproduct or recovered sulfur, or development of pyrite deposits should be investigated.

   e. Raw material prices—Current and future price trends, and alternative supply sources.

C. Study personnel and data collection

1. The type of data required dictates the makeup of the team members who should be responsible for these studies.

   a. Agronomist—To compile and analyze data on soils, crop, and potential fertilizer demand by products.

   b. Chemical engineer—To develop production processes, costs of production, and evaluate raw material resources.

c. Geologist or mining engineer—To evaluate raw material prospects and developments.

d. Economist—Put all phases of study together to determine overall economic feasibility of project.

2. A central data collection agency should be responsible for information. Not only for fertilizer industry, but much of this information also will be needed for marketing studies involving other phases of industrial development. Marketing information should be available to market research people both within the country and to outside interests. If a country is to encourage investment from developed countries, a clear picture of potential markets must be presented. Outside sources of information are only going to be as good as the information that your country submits to these organizations for publication.

D. Sources of statistical information

1. Various government organizations within the country are of primary importance as a source of information. The Ministry of Agriculture, or a similar organization, can supply such data on domestic food production supply and needs. Foreign exchange regulations and position can be obtained from the Ministry of Finance and Trade. Natural resources and information on their development are usually handled by the Ministry of Commerce or Mining. Agricultural colleges or universities located within the country offer a wealth of information. Soil types, crop recommendations, population studies, and the like may be under investigation by a staff located at these schools. Experiment stations should be especially useful sources of information.

2. The United Nations Food and Agriculture Organization and the U.S. Agency for International Development, along with personnel from other developed countries, can be found in many of the developing countries. In many cases, they have field staff who have firsthand knowledge of the problems that must be overcome. They also may have much of the necessary information. Interregional organizations, such as ECLA and ECAFE, conduct regional studies on fertilizer development; such organizations as the World Bank may have information of value, especially on financial matters, investment opportunities, exchange, etc.

3. Many government organizations in the United States also maintain up-to-date information on developments in foreign countries. The U.S. Department of Agriculture has conducted many such studies and the U.S. Department of Commerce keeps an up-to-date reference library of publications dealing with the developments in foreign countries. TVA, through its work with USAID, has also developed much knowledge on the fertilizer industries of most countries of the world.

4. Marketing and development specialists or consultants can prove of invaluable help in compiling data and in evaluation of prospects. This important source of talent should not be overlooked where available.

E. Questions marketing research should answer

Following are some questions which good market research can help answer: Does the projected fertilizer demand justify the building of a fertilizer plant or industry? Is demand regionalized to justify one large plant or several small units, and what products will be in demand in each region? How do the costs of production (at normal rates of return on investment) compare with alternative supply sources (imports)? How do available raw material supplies affect production

costs and distribution costs? What will the overall effect on the economy be under the various alternatives?

F. Responsibility of the market researcher

The success or failure of a fertilizer enterprise will depend to a large extent on the planning that is undertaken before building the project. The market researcher has a large contribution to make toward the success of the undertaking.

THE VALUE AND USE OF FERTILIZER MARKETING STATISTICS

A. Need for statistics

1. This is an age in which a tremendous need exists for market research and analysis of product potentials. In many instances, market research and analysis has been inadequate in scope and depth in the fertilizer industry. This analytical work requires accurate and reliable compilation of statistics. While the United States has developed a body of social and economic statistics which has no equal in the world, it is unfortunate that we are lacking valid, prompt, and interrelated statistical information adequate for aiding government and the private sector in the formulation and evaluation of the economic advances they seek.

2. Three major factors prompt the need for special emphasis on statistical reporting services:

   a. Inability to make statistics a truly integrated body of information (deficiencies).

   b. The wide-range nature of analysis which has increasingly crossed the lines of past behavior.

   c. The accelerated improvement and use of the computer.

B. Available statistical reports

1. Current reports available in the United States require joint efforts on the part of several agencies such as the Department of Agriculture, Department of Commerce, Bureau of Mines, Federal Trade Commission, Bureau of Census, and others.

2. Reports showing world fertilizer production and consumption of fertilizer are currently being published by the FAO, AID, and TVA. These reports are compiled from data supplied by statistical reporting services of each country without any standard guidelines for comparison. For example, some countries have designated different periods of time as "fertilizer years."

3. Going from the international level to the national, there is a need for detailed breakdown of statistics by region, state, and country. Reporting methods for the lower levels (state, county, etc.) vary. There is no standardization of reporting at the local level. Some rely on the invoice system, others use manufacturers' reports. One problem in the United States is the questionable comparability of production and consumption statistics because of differences in reporting, and the fact that the data is collected by different agencies.

C. Historical use—measure of progress

1. These statistics are vital to national interest. They serve as integral parts of an overall picture that helps to promote industrialization of a country, state, or county.

2. The various reporting services provide individual statistics that enable further analytical work for industrial development marketing studies. Examples of the use TVA has made of these statistics may be seen in *Fertilizer Trends* and *Fertilizer Summary Data*. These two publications are well received and used by fertilizer marketing specialists in the United States. They also serve to compile the statistical data from all agencies into one comprehensive data source.

D. Predicting the future—forecasting

1. Statistics serve as the basis for the market analyst as he predicts production and consumption patterns. They help him to make sound value judgements in evaluating the alternatives available to the management which he serves. The alternatives are many and varied such as demand for individual fertilizer materials, mixtures, direct application, bulk or bag, seasonal use, and average analysis. All are important factors in determining future market potentials.

2. By analyzing actual fertilizer use statistics by crops and comparing this with recommendations from the colleges and/or universities, the analyst can determine potential fertilizer use. This type of data collection can then be correlated with field survey data to better evaluate market trends.

E. Planning for statistical reporting service

1. The value and use of statistical reporting services is paramount. Therefore, every country needs to place special emphasis on this service. In this time of scarce investment capital, the country or area that can best provide a sound basis for decision making will show the most rapid industrial and agricultural development.

2. Consideration should be made to meet the need for statistical information with a minimum burden of reporting on individuals, businesses, and other reporting units. Do not become overburdened with data collections of specific information if only the overall general picture is to be presented.

3. A detailed study should be made as to what type of information is required and should be included in the responsibilities of a statistical data collection agency. Studies have been made in the United States that will be of value in attempting to establish a statistical center to benefit a nation's overall economic development.

REFERENCES: 47, 118, 120, 293, 343, 344, 345, 347

FITTING FERTILIZER CONTROL LEGISLATION TO MODERN TECHNOLOGY

A. Purpose and nature of fertilizer control legislation

Fertilizer control legislation is designed to give reasonable protection to both the consumer and the producer. Government, through legislation, requires sellers to guarantee nutrient content, provides for impartial and accurate measurement of nutrients, and provides for assessment of penalties for deficiencies. Enforcement of these laws and regulations ensures that the consumer receives what he intended to buy and protects the fertilizer industry from dishonest competition. Professional workers and fertilizer control officials must fulfill several responsibilities for the laws and regulations to fully realize their intent.

B. Keeping control legislation up to date

1. Responsibility of the engineer—As new manufacturing processes are developed, as the economy of production changes, and as manufacturing plants are constructed in new locations, the legislation regulating the quality and sale of fertilizers may require modification. Such modifications, in many situations, should be made before engineering changes are made. For example, control legislation may permit phosphates to be sold only on the basis of water-soluble P content. A change that includes citrate-soluble P should be made before a nitric phosphate plant is erected. Similarly, construction of facilities for the production of liquid fertilizers should not be started unless control legislation permits their sale. The engineer thus has the responsibility of evaluating the advent of technology in his professional area and of informing control officials (or others responsible for control legislation) of the probable effect of such technology.

2. Responsibility of the agronomist—Over a period of time crop production practices change. New varieties with altered fertilizer requirements are introduced. Soil fertility levels change, but not uniformly for all nutrients; new N:P:K ratios may be needed. New methods of fertilizer application may develop, requiring fertilizers in different forms. Technological changes in agriculture, as in engineering, should be anticipated and evaluated. The agronomist, then, has the responsibility of informing control officials (or others responsible for control legislation) of the probable effects of such changes so that legislative restrictions will not hold back desirable progress.

3. Responsibility of the chemist—The official procedures for determining the plant food content of fertilizers tend to be time consuming and tedious. This is not necessarily a detriment when few samples must be analyzed. As sample volume increases, however, time-saving procedures become more important. Screening procedures can be used to select only those samples requiring an official analysis–provided control legislation permits this. New procedures for determining the various nutrients are under constant development. When such procedures have been proved superior to official procedures, they should be used. The chemist is responsible for following the new developments in his field and insisting that full advantage be taken of modern technology. If revisions in control legislation are required, he should advise on the nature of the revisions.

4. Responsibility of the control official—The dual responsibility of control officials to both manufacturers and consumers of fertilizers requires that they have a working knowledge in such diverse fields as engineering, agriculture, and chemistry. Since most cannot be really

proficient in each of these fields, they must rely on others for information and advice. Formal hearings provide one method of obtaining information, particularly as related to some specific topic that demands immediate attention. Control officials have the further responsibility of keeping generally informed of the myriad changes that may affect their responsibilities in the future. If such information is not supplied them on a voluntary basis by the chemists, agronomists, and engineers, the officials should actively solicit it.

C. Need for uniform regulations within a country

1. Variability in U.S. regulations and laws—In the United States, fertilizer control is the responsibility of each state. As legislation developed in the states, there was little coordination among officials of the various states. There is, therefore, wide variability among the state laws. Registration may be permanent or on an annual basis, renewal dates vary, registration fees vary from none to as much as $50 and the basis for charging the fees varies. Amount of the inspection fee is different among states ranging from 1 to 50 cents per ton. Tolerances on guaranteed analysis and penalties for deficiencies are also different among states. These variations cause undue hardships on fertilizer companies trading in interstate commerce.

2. A uniform bill—The Association of American Plant Food Control Officials has been working for several years toward obtaining more uniform fertilizer control legislation. The Association has drafted a uniform state fertilizer bill to be used as a guide to state legislatures in preparing individual acts to regulate the sale and distribution of commercial fertilizers. More recently the National Plant Food Institute has worked with the Association particularly in the area of obtaining uniform reporting on tonnage of fertilizers sold. Uniform, accurate, and timely tonnage reports can be a valuable service to the industry especially in market analysis.

REFERENCES: 29, 94, 292

COMMUNICATIONS PROCESS IN THEORY AND ACTION

A. Nature and importance of communication

The world has never seen a time when the need to communicate has been more important. This is so because the world has never seen a time when there was so much to know and so many people who need to know so quickly. In rural development, nothing is more important than the transfer of useful ideas from one person to another. The process of communications, then, is vital in overcoming ignorance, poverty, and disease—three important reasons why millions of people in developing countries are versed in lore, rather than technology, unaccustomed to systematic learning, hardly touched by modern life.

B. Role of communications in economic development

1. Bridging the knowledge gap—The greatest knowledge gap is between the mass of people and the elite. The mass lives in an unchanging traditional world; the elite are cosmopolitan and have absorbed modern ideas. A developing nation must teach skills, attitudes, and concepts which will help the people move from a traditional to modern society.

2. Developing communication facilities—Much work remains to be done in developing communication facilities. UNESCO has suggested a minimum mass media growth plan: For every 100 inhabitants provide 10 copies of a daily newspaper, 5 radio receivers, 2 cinema seats, and 2 television receivers.

3. Effect of mass media on economic development—There is a striking relationship between the level of economic advance and the level of education and mass media. The higher per capita income of a country, the higher is the level of literacy, number of children in school, and the circulation of mass media to the public.

C. How do you communicate?

1. Basic methods of communication—To communicate, two or more people must exchange ideas, facts, feelings, or impressions through speaking, writing, and showing. The three basic methods are: (1) one-to-one–personal contact; (2) one-to-few–demonstrations, exhibits, and meetings; and (3) one-to-many–radio, television, newspapers, and direct mail.

2. The learning process—People learn by using one or more of their five senses. Seeing accounts for about 75% of all learning; hearing is next with 13%; smell and taste account for 6%; and feeling about 6%. As more senses are combined in a learning process, more transfer of knowledge takes place.

3. The motivation process—The most vital motivational needs are food, clothing, water, and sex. Once these are satisfied, the person seeks security and safety. Then he seeks to belong–to become part of a group and feel accepted and loved. Then he wants prestige, achievement, and status. And finally he seeks self-actualization–the feeling that he is making the best use of his abilities.

D. The role of the communicator

He is the source or originator of messages–the sender of messages–and the person who puts the communications process in action. He may be a county agent, health agent, technical specialist, or other social change agent. He must have skills in the following:

1. Transferring ideas—Knowing his objectives and channels that will reach his audience.

2. Understanding the audience—Knowing where his audience is in the learning process, their hopes, needs, desires, and what forms of communication motivate them to change.

3. Understanding ideas to be communicated—Becoming aware of how his messages can help people including message content, validity, usefulness, and importance.

4. Evaluating results—Preparing a communication plan which follows through to good objective evaluation.

E. Evaluating communication techniques

Through personal contact, one can reach only a limited number of people. More people are reached through demonstrations, field trips, and exhibits. The masses of people are reached through radio, newspapers, and television. Each channel of communication has its strong and weak points. Most communication takes place when the right combination of these channels is used.

Thorough evaluation of how each channel fits into a national situation will help determine that combination.

REFERENCES: 38, 66, 161, 179, 192, 243, 261

COMMUNICATING—SOME PRACTICAL CONSIDERATIONS

A. Communicating is a science

Until about 50 years ago, man told his story to his fellow men with printed words and pictures or with conversation. Now there are motion pictures, radio, and television. Add to this new styles of writing, a photographic revolution which has placed a camera within reach of all, and scientific achievements such as television relay satellites and one must agree that communicating has suddenly become a complex industry. Because of these developments you may easily conclude that you are too far away from all this to be concerned, but you aren't. Your story—or someone else's—must still be told. And while the techniques may be too complex to understand, basic communication concepts must be used—whether you write or speak, whether you want to persuade or to inform, or whether your audience is a group of engineers, farmers, or government officials.

B. The three-member team approach to communicating

All but the simplest communication projects are beyond the scope of one individual. A team approach which allows different talents to be used is necessary. The team, which can be individuals or groups of people, consists of three members.

1. The first member—He is a subject-matter specialist. He knows what is to be communicated and supplies all the technical information.

2. The second member—He is a professional communication specialist. He is a writer and an editor. He is familiar with all methods of communicating.

3. The third member—He is a professional communications technique specialist. He may be a photographer, an artist, or a designer. He provides the physical design or the elements required for a communication project.

C. Analyzing the audience

1. Education—Imagine a triangle divided into three parts. The bottom part represents that part of the audience with no schooling. The next part represents those with a high school education. The top part represents college graduates. If you write or speak for those represented by the top part of the triangle, it probably won't be understood by anyone in the lower two parts. Even if they could understand, they would soon lose interest because of the complexity of the presentation. But the triangle also shows that if you can communicate with those represented by the bottom part, your message will automatically be understood by the other two groups above it.

2. Age—Young people tend to think differently from older people. They have different ideas, are more aggressive, and are often more willing to seek facts and take risks. Older people are generally more conservative and demand more reasons for changing their ways of doing things. Your communication project must consider these differences.

3. Religion—Sometimes in our communicating- either in words or pictures–we can easily offend people by accidently showing or telling something that is against their religion. This problem is worse in countries with more than one religious custom or belief.

4. Location—In many parts of the world, only a few miles can make the difference between plenty and poverty, between sparcely settled wasteland and thickly populated farmland, between people eager to adopt new ideas and those who hesitate to give up old ways. Even ranges of mountains and large rivers can cause people to be different from one location to the other.

5. Interest—People must want the information you are giving them. If they do not, they will not accept what you tell them and your communication efforts will be wasted.

6. Language—You must talk the language of the people. Remember that each group within a society tends to identify itself closely with certain expressions and mannerisms.

D. Communications pretesting

One reason many communication projects fail is that people who prepare them do not visualize the presentation as the audience will see it. Always assume that you are part of the audience. Only then can you determine whether the information is being effectively presented. Always remember what you are trying to say. If you mix too many objectives together or lose sight of the main objective, the project may become too weak. Also make sure that your project is consistent with your thorough analysis of the audience.

E. Communications evaluation

No communicator can be successful unless he is willing to study the results of his projects. He must evaluate to determine if the proper techniques were used; to determine audience response; and to see if planning, organization, and production methods need changing. A communications project can be evaluated three ways.

1. Personal consultation—This is the most direct method. However, personal interviews take time and many people will not say what they really think in the presence of an interviewer.

2. Questionnaires—These are inexpensive and ideal for masses of people. For completely objective answers, however, questions must be neutral, not positive or negative. Also, rate of return can be a problem unless there is an incentive offered to those who receive the questionnaire.

3. Internal discussion—Those responsible for a communication project can often determine among themselves whether the project was successful. Every project, no matter how good it seems at completion, can always be improved.

REFERENCES: 38, 80

COMMUNICATING FERTILIZER INFORMATION IN DEVELOPING COUNTRIES

A. The role of communication

The goal of developing countries is rapid improvement and development. For this to occur in the agricultural sector there must be: (1) capable scientists at work on current problems, (2) interested farmers who believe that science can help them, and (3) a bridge of communication to carry knowledge from the scientists to the farmers. This bridge involves communication–getting, interpreting, and transmitting the knowledge so farmers will use it.

B. Communications in development

The communication bridge speeds farmer adoption of ideas and techniques developed by researchers. The agricultural extension service in the United States and other developed nations has relied heavily on the many facets of communications to help farmers produce food and fiber in abundance. Farmer education programs in the United States have traditionally–and successfully–been based on the belief that "seing is believing." That is why result demonstrations have been so effective, particularly in fertilizer use and in use of other improved farm practices.

But one is quick to note that only relatively few farmers can be reached by result demonstrations if a farm tour is the only means to study the results. Communications efforts provide the channels to spread results of demonstrations to many other farmers and to the public. Such activities as television and radio programs, newspaper and magazine articles, publications, exhibits, and direct mail are useful communication tools to help farmers "see" and "believe."

C. Communicating with semi-literate audiences

The approach of illiterate people to life is visual. They see and react to whole situations directly as they see them. They are not usually skilled in the process of analysis, nor are they "logical" in the same sense that people who have had schooling are logical. Illiterate persons, therefore, can much more quickly understand ideas presented in pictorial form than in any other. Such pictorial presentation needs to be organized in the sequence of experience rather than in the sequence of logic.

D. Role of visuals in communication

About 75% of what we know can be attributed to the visual sense. Visuals are especially important in developing countries where a large portion of the population may be illiterate. Visuals can be divided into two groups:

1. Visuals used to obtain a primary learning experience––This group exposes students to a new experience. To be successful, these must be supplemented with written or spoken words. Included are tours, field trips, slides, filmstrips, and photographs.

2. Visuals used to recall a primary learning experience––Recall visuals to make use of the "association" principle in producing new experiences. They include books, charts, diagrams, chalkboards, and flannelgraphs.

E. Presentation visuals

Many kinds of presentation visuals are available, both to obtain and to recall learning experiences. A partial listing in their order of importance follows: (1) actual objects, (2) models and specimens, (3) motion pictures, (4) photographs, (5) projected visuals, (6) chalkboard, (7) flannelgraph, and (8) charts and graphs.

F. Some presentation visuals ideal for developing countries

1. Actual object—The "real thing" is the best visual an instructor can use. He can slice a real loaf of bread into sections to represent costs and profits from growing wheat. The only limitation with this type of visual is the imagination of the instructor.

2. The flannelgraph—This recall visual has a sense of magic, provides rapid presentation, contains material that is easy to prepare, provides for continuity, is portable, and can add variety to a presentation. An instructor can list the value of a new fertilizer on individual cards.

3. The chalkboard—This commonly used visual provides a quick and easy way to illustrate a point, is immediately available to teacher and student, can add variety and contrast, can be quickly erased, is inexpensive, and some models are portable. The chalkboard can be quickly used to show a sketch of the proper way to sample a field for a soil test.

REFERENCES: 38, 59, 77

COMMUNICATING WITHIN AN ORGANIZATION

A. Nature and importance

Every principle of communication applies to communication within an organization. Communication within the organization is as important as communication among organizations. Ideas typically originate inside a single organization. Solutions to problems are formulated within an organization. Thus, communication within is essential to cultivate and nurture the ideas or solutions before they are ready to be channeled to others. It promotes the refinement and reinforcement needed to make basic ideas usable.

B. Barriers and oportunities

Communication within the organization is not always easy. It can be extremely difficult when key individuals get completely engrossed in pet projects and ignore the rest of the world. And it can happen when management fails to recognize the importance of communication and does not provide channels for it. Walls of silence (failure to communicate) can stop progress on a project as effectively as brick or masonry walls stop people. The best ideas—the ones most likely to work—usually are those which have been cross-fertilized through unrestrained communication.

C. Leadership through communication

Leadership takes effect through communication. Everyone needs to communicate to perform effectively, but communication becomes increasingly important as a man moves up the ladder of

responsibility. The bigger the job, the more the supervisor or administrator must depend on others. He must be able to communicate with these others to tell them what he expects and to motivate them to do it. He also must be able to receive communications—to keep in touch with "rank and file" workers, to elicit suggestions for improvement and support for programs, and to maintain the level of morale needed for good working relationships. Many studies show the effects of good communications programs.

1. National Industrial Conference Board surveyed two plants of the same company in similar size towns whose employees were represented by the same union. The main difference was in internal communications. In the plant with a good communications program, 62% of employees felt they were "part of the company" and 45% said their company was "one of the very best" to work for. In the other plant, which had a poor communications program, the corresponding figures were 29% and 20%.

2. A communications program saved millions of dollars in operating costs for one company. In one plant, it "reduced all manufacturing losses by one-third over a twelve-month period; another (plant) reduced one particularly critical form of loss 50% in three months. The accident record of one department was reduced to one-third of its former record over a three-year period. Within two years another plant reduced manufacturing losses from all causes by well over one-third."

D. Directions of communication

In general, communication in all directions is necessary.

1. Downward communication is vital to tell individuals what is expected of them, to keep them advised of policy changes, to give recognition for noteworthy performances, etc.

2. Upward communication is needed to report progress, problems encountered, suggestions for improvement, etc.

3. Horizontal communication keeps fellow workers informed, provides for a large measure of coordination, and facilitates the hybridization of ideas across disciplinary lines.

Since one communication typically must pass through many links—i.e., from president to vice president to division manager to department head to foreman to plant operator—it needs to start its journey in the clearest form possible. Distortion is to be expected at every level. If the message is unclear at the first link, it may be unrecognizable or meaningless by the time it gets to the operator.

E. Methods of communication

Most techniques and channels of communication are adaptable to use within the organization. Those which are "best" will be determined by the particular situation. In many cases, perhaps the best results will be achieved by employing several techniques. The following are some examples that show the range of possibilities.

1. Informal oral communication—The importance of this type, often on a face-to-face basis, cannot be overemphasized. A basic advantage is that it offers opportunity for immediate clarification of vague information. The informal atmosphere also may be more conducive to full expressions of thought, especially in areas where controversy may exist. Also, informal

oral communication typically lays the foundation for formal communications.

2. Formal oral communication—This type typically involves communication to or within a group of people. It includes all degrees of formality. In some instances the atmosphere may be almost as informal as between two fellow workers, while strict formal procedures are observed in other situations.

   a. The staff conference is widely used to communicate information to key employees. It can be either a formal one-way communication or semiformal with limited two-way communication.

   b. Management-worker committees can be valuable avenues of communication, helping each group understand the problems and aspirations of the other. They also can be used to generate new ideas, suggest improvements, etc. Such groups in TVA are known as "cooperative committees." They are a key tool in labor-management relations and strengthen the entire organization in many ways. Relative informality is essential.

   c. Special work groups may be useful to solve particular problems from time to time. They typically have a clearly defined objective and function for relatively brief periods. This approach is one way to get a team or task force effort since any number of disciplines may be represented in one group.

3. Written communications—This embraces a whole range of communication techniques. Some are directed to very small audiences, while others may closely parallel a mass media approach.

   a. Bulletin boards probably are most universally used. When strategically located, they offer an easy way to disseminate widely limited amounts of information of general interest.

   b. Newsletters of one kind or another are used to communicate with fairly large groups. They may be used periodically to carry a variety of types of information, or to deal with specific topics as the need arises.

   c. Progress and problem reports are especially useful forms of communicating important program information so that all concerned will be kept fairly well up to date.

   d. Trip reports also provide a useful tool for informing coworkers of new developments, problems encountered, trends, etc.

   e. House organs are used by many large organizations to communicate a variety of types of information. They range from inexpensive mimeographed pages to sophisticated printed publications.

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NEW DEVLAND

New Devland is a mythical country used for the study of many fertilizer problems, all of which are not likely to occur in an existing country. Since distances from sources of raw materials used in fertilizer manufacture are needed for some of the problems, New Devland has been given a definite location on the north coast of Africa.

CONVERSION FACTORS

P x 2.29 = P_2O_5	P_2O_5 x 0.44 = P
K x 1.20 = K_2O	K_2O x 0.83 = K
Millimeters x 0.0394 = inches (in)	Inches x 25.4 = millimeters (mm)
Hectares x 2.47 = acres (a)	Acres x 0.405 = hectares (ha)
Kilometers x 0.62 = miles (mi)	Miles x 1.61 = kilometers (km)
Kilograms x 2.2 = pounds (lb)	Pounds x 0.45 = kilograms (kg)
Kg/ha x 0.89 = lb/a	Lb/a x 1.12 = kg/ha

1,000 kilograms = 1 metric ton = 2,204.6 pounds

100 hectares = 1 square kilometer (km)

100 hectares = 1 square kilometer (km)

1 ruga (₨) = $0.05 (U. S.) 1 dollar ($) = ₨ 20

NEW DEVLAND

LOCATION AND SIZE

The Republic of New Devland is located on the northern coast of Africa; it is bounded on the north by the Mediterranean Sea and on the south by Libya. Total land area is 740,016 square kilometers.

PHYSICAL FEATURES AND CLIMATE

New Devland has four geographic areas. The Chama Valley contains the country's richest agricultural areas. This fertile and well-watered valley averages about 190 kilometers wide and extends from the Libyan border to the Mediterranean. The highlands, formed by parallel ridges of the Sangre Cristo Mountains, have some of the highest peaks on the African continent. Undulating foothills extend to the sea. The area is of minor agricultural importance. Narrow mountain valleys, however, provide good pastures for herds of sheep and cattle. The plateau area in eastern New Devland is not fertile and often suffers from drought. The southern plateau is dry, rocky, and known only to the nomadic tribesmen who use the area for grazing.

The climate of New Devland is moderate, with an average temperature of about 30° C. during summer and about 22° C. during winter. The rainy season generally extends from December through March. The dry desert winds of Libya are deflected around New Devland by the Sangre Cristo range. During the summer, the mountains serve as a barrier to the warm moisture-laden winds from the Mediterranean; consequently, frequent showers supply adequate moisture throughout the Chama Valley.

PEOPLE AND CITIES

The population of New Devland is estimated to be more than 32 million (32,000,000) and is increasing at a high rate of 3 percent per year. Average population density is 44 persons per square kilometer but 75 percent of the people live in the Chama Valley.

The capital city of Las Lunas has an estimated population of 2.7 million. Nearly all of the country's exports and imports pass through the excellent deep water port facilities of Las Lunas.

Ports in coastal towns of Moro (4,000), La Junta (12,000), and Los Animas (18,000) can handle only small boats. An excellent deep-water port facility could be built at Los Animas if needed. Dulce (27,000) serves as a trading center for agricultural products. Sapinero (2,000) is remote, isolated, and important only as a provincial capital.

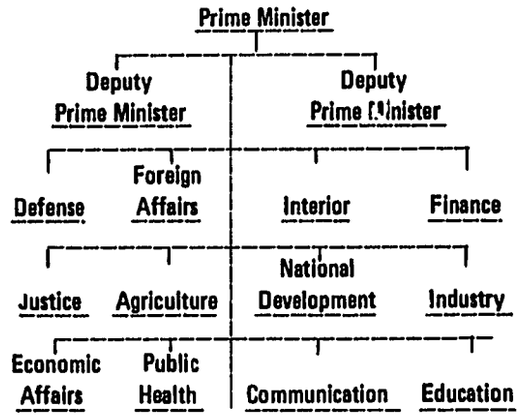
GOVERNMENT

Central

Politically, New Devland is a constitutional monarchy with the sovereign power resting in the elected representatives of the people. Never having been under the domination of a colonial power, New Devland has not developed extreme nationalism and prejudices against foreigners which generally follow colonialism.

New Devland's modern era of government dates from 1938 when a group of Army officers and Civil Service personnel staged a revolution against the absolute authority of the King and were granted a constitution. The government consists of an elected parliament which promulgates national laws and 14 cabinet ministers who perform the executive functions of running the government. The cabinet is headed by a prime minister who is the major government official in the country.

The ministry or cabinet of New Devland is organized as follows:



The Ministry of Agriculture is responsible for promoting and improving the country's agriculture. The Ministry is divided into four departments: Agriculture, Rice, Livestock and Fisheries, and Forestry. The Department of Rice is concerned only with this crop,

while all other crops are the responsibility of the Agriculture Department.

Both departments conduct agricultural research, provide advice and information to the farmer (extension), manage demonstration centers, distribute improved seeds to the farmer, and encourage farmers to use fertilizer and other improved farming practices. (The distribution of limited amounts of free fertilizer to farmers is being done annually.) Both departments perform planning and regulatory activities within their area of specialization.

The Ministry of Industry develops and promotes industries within the country. The Ministry is divided into three departments: Industrial Works, Science, and Industrial Promotion. The Department of Industrial Works operates government industrial factories which include sugar factories and paper and jute mills. The Department of Science conducts scientific research on the best use of the nation's natural resources. This department analyzes foodstuffs and beverages and controls food quality to ensure public safety. An important duty of this department is to train students in analytical chemistry to satisfy the need of government agencies, factories, and other private agencies for practical chemists. The Department of Industrial Promotion undertakes studies and projects for the improvement and promotion of industries.

Provincial and Local

Since 1938, local government in New Devland has consisted of three distinct but closely related levels:

1. *The province*–There are 65 provinces in New Devland. Population ranges from nearly 4 million in Las Lunas province to 18,000 in Sapinero province. Administration of a province is under the authority of a governor who is assisted by a provincial board. Government services in the province are organized into two categories: (a) the provincial office concerned with the general administration of the province, and (b) field agencies established by the ministries of the central government. The provincial government positions are staffed and administered by central government officials and financed entirely out of the national government budget.
2. *The district*–Each province consists of from 2 to 19 districts. There are 499 districts in New Devland; each is headed by a district officer who is directly responsible to the provincial governor. The district officer and the provincial government officials are appointed by the Ministry of the Interior. All government employees, from the director general of each industry to the district officer in each district, are civil service employees. No government office is established below the district level.
3. *The barones and villages*–For administrative purposes, each district is divided into barones, then subdivided into villages. There are 4,750 barones and 20,217 villages in New Devland. Each village elects a headman. The headmen from the villages elect one of themselves to be the headman of the barone. Headmen are not in the civil service but are entitled to wear official uniforms and draw a small salary from the central government.

NATIONAL ECONOMY

Growth of the New Devland economy began shortly after World War II. The gross national product increased from 28.2 billion ruga in 1951 to 73.8 billion ruga in 1967. Allowing for year-to-year price changes, this was a 6.2 percent per annum average rate of growth during 1951-1967. Allowing for rate of population growth, real per capita output increased at an average rate of 3.2 percent annually as shown in Tables 1 and 2.

Per capita income in 1967 averaged 2,278 ruga. The postwar growth of the economy has resulted in significant structural changes. The most outstanding feature of the changing economic pattern has been the

Table 1. Gross national product of New Devland (1951-1967)

Product	1951	1956	1961	1966	1967
	(1,000,000 ruga)[1]				
Agriculture	14,139	16,586	16,962	15,985	16,236
Mining	537	698	979	1,311	1,376
Manufacturing	2,901	4,970	5,352	9,942	10,020
Construction	810	1,732	2,464	4,528	4,526
Wholesale and retail trade	5,085	7,986	11,026	14,788	14,897
Ownership of dwellings	1,049	1,297	3,375	4,383	4,389
	1,890	2,652	2,745	5,261	5,725
Communication and transportation	883	2,210	3,660	6,345	7,209
Public administration and defense	784	2,278	3,006	4,525	5,630
Other	132	680	1,929	2,646	4,007
Net income from abroad	+10	-160	-98	-214	-215
Market price	28,220	40,929	51,400	69,500	73,800

[1]20 ruga equal one U. S. dollar
[2]Includes banking, insurance, real estate, electricity and water supply

Table 2. Per capita income of New Devland (1951-1967)

	1951	1956	1961	1966	1967
Population (in millions)	20.3	23.5	27.2	31.5	32.4
Per capita gross national product at market price (ruga)	1,390	1,744	1,890	2,206	2,278
U. S. dollar equivalent	69.5	87.2	94.5	110.3	113.9

decline of agriculture relative to other industries, as shown by Table 3. From 60 percent of the gross national product in 1948, the agricultural share fell to 25 percent in 1964. At the same time, the combined contribution of manufacturing, transportation, communication, construction, and public utilities increased sharply from 11 percent in 1948 to 35 percent in 1964.

The growing strength of the industrial and service sectors of the national economy is a reflection of the trend toward diversification. A problem of a disparity of income among New Devland's citizens is also occurring with the major problem existing in the agricultural sector. Nearly 85 percent of New Devland's population is engaged in agricultural production, yet this sector of population receives only 22 percent of the national income. Thus, the average annual per capita income in the agricultural sector is only 590 ruga while for the rest of the population the average per capita income is 11,748 ruga.

The central government has recognized this problem and is emphasizing programs that increase agricultural income, such as crop diversification and use of fertilizer. Table 4 shows that total value of "other crops" (maize, tapioca, coffee, tea, citrus, sugarcane, and cotton) has risen much faster than rice in the postwar period.

The changing pattern of domestic production is reflected in the diversification of New Devland's trade pattern. While rice export has fallen sharply in relative importance, exports of tobacco, tapioca, castor seed, and livestock products have increased. All of these were unimportant less than 15 years ago. The combined value

Table 3. Percentage shares of gross national product by industry of origin (1948-1964)

Industry of Origin	1948	1952	1956	1960	1964
			(percent)		
1. Agriculture	60	44	40	34	25
2. Manufacturing, transportation, communication, construction, and public utilities	11	19	22	27	35
3. Other	29	37	38	39	40

Table 4. Percentage shares of the value of major types of agricultural production (1938-1966)

Crop	1938-39	1948-50	1953-55	1958	1961	1963	1966
Rice	62.6	55.5	42.1	40.0	48.8	46.2	43.5
Sugar	8.9	8.8	11.4	8.8	8.0	7.6	7.3
Other	28.5	35.7	46.5	51.2	43.2	46.2	49.2

of these "secondary exports" now accounts for nearly one-half of total exports as shown in Table 5.

Since export goods of New Devland are mostly food, agricultural products, and raw materials, the bulk of its exports goes to industrialized and food-deficient countries. In return, New Devland imports food, drink, manufactured goods, machinery, chemicals, and mineral fuels. Although rising incomes have resulted in a steady increase in the value of all categories of imports, the fastest growth rate has been in the importation of machinery. This reflects the demand for capital goods to meet the need of national economic development.

Table 5. Percentage distribution of exports by commodity (1948-1963)

Commodity	1948	1960	1963	1966
		(percent)		
Rice	45.2	36.0	35.7	15.2
Sugar	20.2	21.3	19.6	16.6
Tin	2.5	6.2	7.6	12.1
Teak	4.1	2.5	1.4	7.4
Tobacco	–	6.0	8.5	8.9
Coffee and tea	–	6.3	3.7	8.9
Tapioca products	–	4.5	4.5	8.9
Other[1]	28.0	17.2	19.0	22.0
Total	100.0	100.0	100.0	100.0

[1]Mainly livestock products

New Devland's balance of payments displays the same characteristics of many other developing countries. Among these are the overriding importance of the trade account, a deficit of goods and services, and a sizable inflow of capital. Since World War II, the total balance-of-payments picture has varied widely. During 1948-1951 the large export surplus accounted for a rise in international reserves. Since 1952, owing mainly to the fast and persistent increase in imports, the trade balance has consistently shown a deficit (Table 6). At the end of 1962, the international reserves amounted to 11,000 million ruga; by 1966 reserves were less than 300 million ruga.

Table 6. Selected import and export statistics (1948-1966)

	1948	1958	1960	1962	1964	1966
			(1,000,000 ruga)			
Total imports	1,747	8,237	10,287	11,504	12,488	14,169
Total exports	2,076	6,447	9,997	9,529	9,731	11,342
Balance of trade	+329	-1,790	-290	-1,975	-2,757	-2,827

EDUCATION

New Devland is making considerable progress in developing a compulsory education program to raise the standard of basic knowledge for all its citizens. School attendance through the fourth grade has been compulsory for all children since 1958. Schools have been established in all areas.

Throughout the Chama Valley, along the sea coast, and in all the cities and larger villages, schools are being established for grades 5 through 7. Attendance is not yet compulsory. The big expansion in these schools started in 1965 so that outside of cities—where such schools have been common for years—few children have completed 7 years of schooling. In 1965 only about 15 percent of the children eligible for grades 5–7 were enrolled in these grades. Of these more than 80 percent were located in cities where such schooling had been common for years.

High schools exist only in the cities of Nebo, San Sol, Moro, La Junta, Los Animas, San Juan, Dulce, Valdez, and Chama. Primarily the sons and daughters of government officials and prosperous businessmen attend high school. More than 75 percent of the high school graduates continue their education at the University of Las Lunas.

Education among the adult population is rare except for government officials. Adult education classes were started in 1959 but attendance was so poor they were dropped in 1962. Adult education now is being offered via television, which reaches most of the population of the Chama Valley. Surveys and general observations indicate that many adults are learning to read and write in the privacy of their homes. Nevertheless, the rural population, even in the Chama Valley, is classed at 90 percent illiterate.

NATURAL RESOURCES

Surveys for mineral and fossil fuel resources have received considerable emphasis. Tin has been mined in the Sangre Cristo Mountains for over 50 years; production was increased moderately after 1964 when the trail to the nearest town, Blanca, was developed into a truck road. Test bores for potash have been made near the Libyan border. Potash has been located in several places, but the deposits appear to be lenticular beds of small area and rarely more than a meter in thickness. K_2O content has ranged from 15 to 20 percent. Cores from test borings in other parts of New Devland also have been examined carefully. No significant mineral

Lignite

In 1946, deposits of lignite were reported in the San Miguel area near the Libyan border. To explore these deposits and develop uses for lignite, the Ministry of National Development established the Lignite Thermal Power Commission in 1947.

From early 1947 until 1950, preparatory work was conducted by the Commission and a deposit of 45 million tons was proved. As a second developmental step, the railway was extended from Dulce to San Miguel and a power plant for generation of electricity from lignite was constructed at Dulce. This plant was placed in operation in 1961. A second power plant is now under construction at Las Lunas.

Phosphate Rock

Deposits of phosphate rock have been discovered in the Sangre Cristo Mountains in the northern highland area. Exploration of these deposits began in 1964.

Because of the remoteness of the area, however, the exploration has been slow and difficult. Extent of the deposits has not been proved, but it has been estimated that at least 70 million tons of phosphate rock can be mined.

The center of the known deposit is 115 kilometers south of San Sol. The phosphorite is an altered limestone of marine origin, formed in beds 2 to 3 meters thick. Depth of the deposit below ground level varies from 30 to 150 meters. The phosphate is relatively soft and requires a minimum of drilling and blasting.

The mine-run rock contains about 33 percent P_2O_5. Beneficiation is not necessary, but screening to remove wall rock and drying before use are necessary. Tests made in the laboratory of the University of Las Lunas show that the rock is low in iron and alumina. Preliminary tests also indicate that the rock can be processed into phosphoric acid or superphosphate using conventional processes.

Oil and Gas

In September 1967, a test well about half way between Los Animas and Dulce showed both oil and gas. In December another test 40 kilometers east of the first boring showed even larger quantities of oil and gas. The Minister of the Interior in March 1968 signed agreements with one European and one American petroleum company for additional exploration.

TRANSPORTATION

New Devland's transportation network radiates from the port facilities of Las Lunas. The western branch of the state-owned railway parallels the Friendship highway along the seacoast into Libya. Most of the imports and exports of northwestern Libya are transported by rail to the port of Las Lunas. The eastern branch of the railway extends to Los Animas. A branch line from La Junta serves the agricultural center of Dulce and the mining area near San Miguel.

The Chama Valley is served by a railway line extending from Las Lunas through Chama and Blanca into Libya. Shipments to and from Libya constitute about 60 percent of the freight hauled over this line. In addition, the Chama River has a navigable channel at least 6 feet deep from Las Lunas to Chama.

When completed, the Friendship highway will extend across the entire coast of New Devland. The highway is now completed beyond Los Animas. The Chama Valley and plateau areas have adequate primary and secondary roads. Many of the smaller towns in these areas are served by regular truck lines.

Transportation in the highlands is poor. Most of the roads—there are only a few—are frequently impassable to motor vehicles. Due to the poor roads, most of the cattle and sheep are driven to railheads at Nebo and San Sol.

AGRICULTURE

New Devland is divided into four main areas: Chama Valley, eastern plateau, southern plateau, and Sangre Cristo mountains and highlands. This division follows lines of agricultural patterns, rainfall, physiography, and other causes. Many agricultural problems are common to all areas. The degree of importance, however, varies with each area. New Devland is an agricultural country. Nearly 85 percent of the population derive their livelihood from the farm or from limited beginnings in crop processing.

The climate is moderate and often described as monsoon-subtropical. Many types of plants will grow in New Devland—more than 80 crop plants have been tested successfully for production. The Sangre Cristo Mountains and the Chama Valley are well supplied with water; rainfall ranges from 375 to 10,000 millimeters per year. Excess moisture is a more frequent problem than a deficiency. The southern plateau has an annual rainfall range from 125 millimeters near the Libyan border to about 500 millimeters near the dividing line between the southern and eastern plateaus. Rainfall continues to increase across the eastern plateau to about 1,150 millimeters near the coast. However, a severe drought occurs in the two plateaus about one year out of five.

Soils

Similar extremes are found in soil and crop conditions. Soils vary from subtropical and rainforest types to temperate climate types. Little progress has been made in soil classification even though a mapping unit was set up in the Ministry of National Development in 1953. It is thought that at least eight major soil groups will be identified eventually.

The Chama Valley consists mostly of alluvial soils, ranging in texture from heavy clay near the Chama River (especially in the lower reaches) to sandy and occasionally gravelly deposits. Soils near the river are quite deep and tend to be morphologically less well developed than those on the second and third terraces.

Soils of the mountainous area generally are not suited to intensive cultivation. High rainfall and steep slopes in this area lead to extreme erosion unless grass or forest cover is continuously maintained. Nevertheless, it is common practice to clear small areas and plant them to crops for two to four years before abandoning them.

The eastern plateau is a level to gently rolling area with much open land. The soils are well developed morphologically, being highly leached and consequently quite acid. Topsoils tend to be sandy, very permeable, and fairly deep. Subsoils often are compacted or impervious.

The southern plateau is an area of savannah and scrub forest. Topographically, the area is similar to the eastern plateau. Little is known about the soils. They appear to be shallow; limestone outcrops are frequent. Some calcareous soils have been found, but it is not known how extensive these are.

Some of the chemical, physical, and morphological properties of New Devland are listed in Table 7. Additional chemical data, from soils on branch experiment stations, are given in Table 8.

Crops

Only two areas are of agricultural importance, the Chama Valley and the eastern plateau. Subsistence agriculture occurs in the southern plateau where there is extensive grazing of sheep and goats by nomadic herders. Grazing in the Sangre Cristo Mountains is somewhat more stabilized. Although sheep predominate, some cattle are produced. There is some cultivated acreage in

Table 7. Chemical, physical, and morphological properties of New Devland soils

Area	Probable soil group	Parent material	Estimated productive potential	pH (surface)	General fertility status: Phosphorus	Potassium	Organic matter
Chama Valley	Alluvial, Low-Humic Gley, Planosol	Alluvium	Good to very good	4.5 - 7.0	Low	Low	Low
Sangre Cristo Mountains	Yellow Podzolic, Latosol	Granite, gneiss	Low	4.0 - 5.5	Low	Low	Low
Eastern Plateau	Red-Yellow Podzolic	Sandstone	Good	4.5 - 5.5	Low to medium	Low	Low
Southern Plateau	Reddish-Brown Lateritic, Red-Brown Earths	Limestone	Fair	5.5 - 7.0	Low	Medium to high	Low to medium

Table 8. Chemical determinations on soils at various branch experiment stations

Location	Depth of sample (millimeters)	pH	Organic matter (%)	Available nutrients P[1]	K[2]	Base exchange capacity (m.e./100 g.)	Soil texture
CHAMA VALLEY							
Chama	0 - 150	6.5	2.04	6	140	16	silt loam
	150 - 300	6.8	2.00	3	180	16	silt loam
Las Lunas	0 - 150	5.5	1.81	5	120	23	clay loam
	150 - 300	5.0	1.97	5	84	24	clay loam
San Sol	0 - 150	5.1	0.53	2	65	4	silt loam
EASTERN PLATEAU							
Dulce	0 - 150	5.3	1.08	6	72	7	sandy loam

[1] < 3 = very low; 3-8 = low; 8-16 = medium; 16-20 = high > 20 = very high
[2] <50 = very low; 50-110 = low; 110-170 = medium; 170-250 = high; > 250 = high

this area where soils are not too steep. These holdings are small and are abandoned in favor of newly cleared areas as soon as the organic matter has been depleted or the topsoil eroded away. Chief crops on these cleared areas are millet and cassava. Several coffee and some tea plantations have been established in the highlands between the coast and the Sangre Cristo Mountains. Pepper also is grown near the coast.

Most soils in the Chama Valley already are in cultivation. Rice, sugarcane, vegetables, and fruit predominate. About 70 percent of the acreage is in rice, 20 percent in sugarcane, and 5 percent in fruit and vegetables. The experiment station near Las Lunas has done most of the work with rice, and the Chama station concentrates on fruits and vegetables. This station has found that mangosteens and rambutan are adapted to the area although bananas, citrus, and papaya are of most importance.

The eastern plateau is sparsely settled but still produces a considerable volume of agricultural products. There are olive groves near the coast, and peanuts or groundnuts are grown throughout the area. Castor beans and sunflower are relatively new in this area but seem to be doing well in the area to the east and south of Dulce.

Cotton is the main cash crop in the eastern plateau, but yields are low. Yams is the staple crop, and large quantities are sold through the agricultural market at Dulce for shipment to Las Lunas, Chama, Buena Vista, and other cities and towns in New Devland. Within the last two years, the experiment station near Dulce has been able to harvest some trial plantings of oranges, tangerines, and other citrus. Yields and quality were remarkably good. Scientists are enthusiastic about the potential for citrus production in the eastern plateau.

Cultivated and open land information for New Devland is listed in Table 9. Table 10 lists crops produced in the country.

Table 9. Cultivated and open land in New Devland (1966)

Area	Total size (hectares)	Cultivated land (%)	Open land (%)
Chama Valley	21,500,000	77	82
Sangre Cristo Mtns. and Highlands	16,700,000	0.5	3
Southern Plateau	11,300,000	1	30-60
Eastern Plateau	24,500,000	5	60-75

Table 10. Hectares, yield, and fertilization of New Devland's crops (1962-1966 average)[1]

Crop	Hectares harvested	Yield (kg./ha.)	Hectares fertilized (%)	Rate of fert. (kg./ha.)
CHAMA VALLEY				
Rice	11,588	2,980	3-5	40
Sugarcane	3,311	31[2]	10	60
Maize	100	1,720	5	30
Cassava	250	17.5[2]	5	75
Mung Bean	126	1,220	0	
Peanuts	100		2-5	60
Cotton	150	860	5	60
Soybean	42	1,238	0	
Tobacco	80	1,320	15	120
Coconut	50	1,950[3]	0	
Banana	2		1-5	300
Lemon	70		1-5	60
Orange	80		1-5	500
Tangerine	50		1-5	600
Mango	20	77,550	1-5	75
Papaya	238	13,000	20	225
Watermelon	31		10	120
Cauliflower	5		10	120
Cabbage	20		1-5	120
Onion	18		5-10	120
Kale	8		1-5	120
Garlic	23		5	120
String Bean	20		1-5	120
Tomato	4		10-15	120
Egg Plant	11		1-5	120
SANGRE CRISTO MOUNTAINS AND HIGHLANDS				
Cassava	500		0	
Millet	500		0	
Tea	200		20	450
Coffee	500		20	450
Black Pepper	50		0	
Chili Pepper	50		0	
SOUTHERN PLATEAU				
No data available				
EASTERN PLATEAU				
Olives	40		0	
Peanuts	200		0	
Castor Bean	10		0	
Sunflower	30		0	
Cotton	800		0	
Yams	1,100		0	
Cassava	950		0	
Millet	1,220		0	
Grain Sorghum	810		0	
Maize	690		0	
Soybeans	50		0	
Tobacco	250		5-10	30
Watermelon	430		0	
Cabbage	280		0	
Kale	260		0	
Onion	230		0	
Garlic	120		0	
String Beans	190		0	
Tomato	190		0	
Apples	25		0	
Peaches	14		0	
Pears	14		0	

[1] Information obtained from 1966 Annual Report, New Devland Ministry of Agriculture
[2] Metric tons
[3] Fruits

Fertilizers

Use of fertilizers in New Devland started after World War II and still is in the initial stage. There is no local production of chemical fertilizers. About 150,000 tons of fertilizer was imported in 1967, compared to only 9,000 tons in 1950. Growth rate of fertilizer use is significant and is increasing at an increasing rate, as illustrated in Table 11. Annual reports are shown in Table 12.

During 1950-1954, imported fertilizers contained primarily nitrogen (Table 12). Some phosphorus but little potassium was used. For the 1954-1959 period, imports of nitrogen doubled over the previous 5-year period while imports of phosphorus and potassium had a 6-fold increase. Since 1960, imports of nitrogen have tripled and phosphorus and potassium imports have increased about five times.

Thus, from basically a nitrogen-using country in the early 1950s, phosphorus and potassium imports now account for over 50 percent of the total plant nutrients used. This has been due mostly to importation in recent years of compound fertilizers containing two and three plant nutrients. Changes in average ratios of imports during three 5-year periods are shown in Table 13. Plant nutrient content of imported fertilizers is shown in Table 14.

Quantities of fertilizers imported in recent years are shown in Table 15. Ammonium sulfate, ammonium phosphates, and mixed fertilizers account for the major portion of imports. Major materials and grades and their primary uses are as follows:

16-20-0, 18-22-0, and 20-20-0: These are the primary ammonium phosphate compounds being used. About 90 percent is being used on rice.

12-12-19 and 12-12-20: These formulations contain potassium sulfate and are used mostly by fruit growers.

13-13-20 and 13-13-21: These formulations contain potassium chloride and are used mostly by vegetable and melon growers.

13-13-13, 14-14-14, and 15-15-15: These formulations are used mostly for sugarcane; small quantities are used for vegetables.

12-8-18: This formulation, introduced in 1962 on the recommendation of FAO, is used only for sugarcane.

6-20-16 and 6-12-18: These formulations are used mostly on tobacco. Other tobacco grades used in small quantities are 10-8-18, 15-15-20, 8-8-5, 14-12-9, and 14-14-8. The last three grades are chloride-free.

Table 11. Imported fertilizer and percent increase by 5-year periods, New Devland (1950-1964)

	1950-1954	1955-1959	1959-1964
		(metric tons)	
Total tons imported during 5-year period	60,834	164,528	379,478
Average tons imported per year	12,167	32,906	75,896
Percent increase during 5-year period	64.5	96.2	108.9
Average percent increase per year	12.9	19.2	21.8

Table 12. Annual import of fertilizers and plant nutrients by years (1950-1967)

Year	Total	Nutrients		
		N	P_2O_5	K_2O
			(metric tons)	
1950	9,354	1,828	162	32
1951	6,465	1,240	108	126
1952	17,465	3,324	552	94
1953	12,164	2,141	758	283
1954	15,386	2,938	379	198
1955	24,280	4,221	1,046	408
1956	23,429	3,912	1,384	681
1957	40,020	6,713	3,021	969
1958	29,170	5,228	1,968	575
1959	47,639	8,004	4,117	1,782
1960	52,163	9,324	3,664	1,958
1961	54,575	10,750	4,621	1,462
1962	66,465	13,211	6,707	1,889
1963	97,375	10,289	10,224	3,011
1964	108,977	19,365	12,775	3,442
1965	122,239	21,561	16,111	6,550
1966	136,021	24,527	19,190	8.096
1967[1]	150,000			

[1] Preliminary estimate

Table 13. Average plant food ratio by 5-year periods, New Devland (1950-1964)

Period	$N - P_2O_5 - K_2O$
1950 - 1954	15.8 - 2.7 - 1.0
1954 - 1959	6.4 - 2.6 - 1.0
1959 - 1964	5.9 - 3.2 - 1.0

Table 14. Plant nutrient content of fertilizers, New Devland, (1950-1966)

Year	$N+P_2O_5+K_2O$
	(percent)
1950	21.6
1953	18.2
1956	25.5
1959	29.2
1962	32.7
1964	32.7
1965	36.2
1966	38.1

Crop Responses to Fertilizers

It was assumed for many years that the alluvial soils of the Chama Valley were quite fertile. Only since 1960 has there been any particular effort to measure crop responses to fertilizers. The four branch experiment stations have done most of their work on variety selection, cultivation and weed control, irrigation, and quality at harvest time. In 1960 the stations were directed to start experiments with fertilizers.

More work has been done with rice than with any other crops because one of the four departments in the Ministry of Agriculture works only with rice. However, the Department of Rice has placed most of its emphasis on the export of rice rather than on production factors. The Las Lunas branch experiment station is the rice station and works only on this crop.

The Chama station works with fruits and vegetables. The station at San Sol also is concerned with vegetables, primarily peppers. The Dulce station, located in the plateau soils, studies general farm crops such as cotton, peanuts, castor beans, sunflower, soybeans, and tobacco.

Rice: The Las Lunas station has completed two detailed field trials with rice. The first test showed that urea was a better source of nitrogen for rice than ammonium nitrate but no better than ammonium sulfate. Rate of nitrogen application was not studied. In the second test an NPK factorial was established on station property. The results showed that rice production was increased by fertilization. In comparison to the nonfertilized plot, paddy yields were increased 28 percent by nitrogen, 25 percent by phosphorus, and 15

Table 15. Fertilizer materials imported into New Devland (1961-1966)

Material	1961	1962	1963	1964	1965	1966
			(metric tons)			
Ammonium sulfate	30,096	28,797	43,028	34,160	25,381	20,007
Ammonium nitrate	465	181	400	2,538	2,777	2,636
Urea	721	1,378	1,425	965	1,356	3,625
Other nitrogen fertilizers	1,956	2,809	1,876	1,775	985	1,121
Superphosphates - single, double, and triple	800	2,828	3,078	2,045	3,091	1,764
Ammonium phosphates	10,550	16,451	24,614	35,359	46,492	55,538
Calcium phosphates	200	–	120	310	200	–
Other phsophorus fertilizers	739	2,049	2,393	736	515	380
Potassium chloride	65	73	54	100	200	300
Potassium sulfate	310	900	952	550	675	832
Other potassium fertilizers	–	630	1,000	132	–	–
Mixed fertilizers	8,865	10,369	18,134	30,307	40,567	48,818
Total	54,757	66,465	97,375	108,977	122,239	136,021

percent by potassium. A combination of N and P increased yields 53 percent, and NPK increased yields 62 percent. Nitrogen, phosphorus, and potassium were each added at rates of 0, 24, and 48 kg/ha in terms of N, kg/ha of 10-5-5 fertilizer for the upper portion of the Chama Valley and 300 kg/ha of 12-8-8 for rice in the lower portion of the valley.

Maize: No fertility research has been completed on this crop. Like many other crops, maize was included in the "simple fertilizer trials" sponsored by the Food and Agriculture Organization of the United Nations. Tests were conducted on farmer fields, using the farmer's variety, management, planting scheme, cultivation, and harvesting facility. Local extension officers supervised and evaluated the tests. Treatments were the same for all tests: three rates of nitrogen (0, 24, and 48 kg/ha) and a single, uniform rate of phosphorus and potassium on all plots.

Responses were varied. Native varieties usually showed some increase in yield. Six hybrid varieties were among the trials. Yields for two of these varieties were tripled by fertilization. All hybrids were located in the Chama Valley.

Sugarcane: This crop generally responded well to fertilization in the FAO trials. About 10 percent of the crop was fertilized in 1966, usually with 13-13-13, 14-14-14, or 15-15-15. A 12-8-18 fertilizer seemed to increase yields even more than the 1:1:1 fertilizers.

Fruit: Fruit ranks third in the amount of cropland occupied in the Chama Valley and is one of the leading contenders for top fertilizer consumption. Leading agricultural officers believe that more than 30 percent of all fertilizers will be used on fruit. This will continue for many years because the industry is growing and fertilizer demands increase as trees increase in age. Other factors favoring increased use of fertilizer for fruit are the managerial skill of the owner or caretaker, the high return on the fertilizer investment, and a year-around demand for the product. Officials say fruit growers are the most progressive of all the farmer groups because of their finances and educational level.

Vegetables: Vegetables probably will rank second to fruit in tons of fertilizers used. Experience shows that a 1:1:1 basal dressing plus nitrogen as a top- or sidedressing produces good crop responses. A 50-percent increase in yield is normally expected from use of fertilizers.

General: The managerial skill of the farmers varies widely. Fruit growers and vegetable farmers in the Chama Valley are the most successful. Managers of coffee and tea plantations are well versed in management. These groups are anxious to use more fertilizers and are obtaining as much as possible of the fertilizer imported into New Devland.

General farmers, including rice and sugarcane producers, have little, if any, education. They are reluctant to make changes. Some are now using small amounts of fertilizer but only because of the pressure exerted by the government to increase fertilizer use.

When the increase in population begins to exert real pressure for development of the eastern plateau, managerial skill will be very important. Soils of this area,

as already detailed, present many problems. The use of fertilizer without other improved practices will not greatly increase crop yields.

RELATION OF RICE FERTILIZATION TO THE RICE PREMIUM

The economy of New Devland is dynamic. Funds available for economic development plans come mainly from export of agricultural commodities. Greater diversification of agricultural products and related industry, therefore, is being promoted to help offset fluctuations in world rice prices. The rice premium and export tax on rice—in effect since World War II—has encouraged product diversification.

The rice premium was started to assess an *ad valorem* tax on the agriculture sector of the economy. There are several advantages to using the rice premium for this purpose: (1) it is easy to collect, (2) by adjusting the premium periodically the government can reduce seasonal fluctuations in the domestic price of rice, and (3) revenue from the rice premium accounts for 10-15 percent of the government budget. The premium's importance as a revenue source, however, is declining.

One effect of the rice tax has been to set the domestic price of rice below the world price. Also, it has been used as a variable tax rather than an *ad valorem* tax as originally intended. Consequently, the tax has varied with production and actually has represented a tax on increased productivity.

Replacing the rice tax with a different kind of tax on agricultural production has been considered. If this source of government revenue could be shifted to a land tax, the result might be an incentive to increase production. A land tax would be a fixed cost whereas the present rice tax acts as a variable cost. While the rice premium has helped stabilize prices, such a price policy is not designed to increase returns to farmers nor provide an incentive to increased production by using more credit, fertilizers, or other improved methods of farming that increase capital outlays.

Very little fertilizer is being used on rice, mainly because the value of the added yield is only slightly higher than the cost of fertilizer. There are three ways to make the use of fertilizer more profitable to the rice farmer: (1) lower the cost of fertilizer, (2) raise the price of rice, and (3) a combination of one and two. Under active consideration of the Ministry of Agriculture is a proposal to subsidize fertilizers using funds collected from the rice premium. Also being discussed is the need to reduce or eliminate the rice premium. No action in this area has yet been taken.

Mr. Goza, in his report *The New Devland Rice Premium,* estimates for two areas of New Devland the increase in the price of rice which the farmer would receive if the rice premium were eliminated. The estimates are for a farm in the upper Chama Valley and a farm near Las Lunas. His analysis is summarized in Table 16.

The assumptions implied in the analysis are: (1) domestic price of rice is equal to export price minus extra costs and taxes associated with exports, (2) the rice trade is perfectly competitive so that changes in the domestic price of rice will be reflected in the paddy price paid to farmers, and (3) elimination of the rice premium will not affect export prices. Goza believed that assumptions one and three were essentially true, but that with regard to assumption two, the more likely effect was an increase in processing costs and middleman profits equal to 10 percent of the rise in paddy prices.

Table 16. The increase in the farm price of rice due to elimination of rice premium

Item	Upper valley[1]	Lower valley[2]
	(ruga per ton)	
Total export value of rice (incl. bran)	1,350	1,714
Total rice taxes	585	664
Processing costs and middleman profits	144	144
Transportation costs	140	30
Price received by farmers (with premium)	481	876
Price received by farmers (without premium)	1,066	1,540
Price received by farmers (without premium[3])	1,013	1.480
Percent increase in farmer price	122%	76%
Percent increase in farmer price[3]	110%	69%

[1] Low quality rice
[2] High quality rice
[3] Assumes processing costs and middleman profits increase by 10 percent of the rise in paddy prices.

The increased profitability of using fertilizer under conditions of no rice premium can be computed for both areas. The yield increases from fertilizer use in the two areas are shown in Table 17. The yield data are from published reports of the Rice Department, Ministry of Agriculture.

Table 17. Yield increases from fertilizer use on rice

Item	Upper valley	Lower valley
	(kilograms per hectare)	
Yield without fertilizer	1,167	1,774
Yield with fertilizer	2,297	2,661
Fertilizer application:		
N	37.5	50
P_2O_5	25	25
K_2O	25	0
Fertilizer cost (ruga/ha.)	597[1]	522[2]

[1]Computed using 179 kg. of 14-14-14 at 2750 ruga per ton and 58 kg. of sulfate of ammonia at 1800 ruga per ton
[2]Computed using 125 kg. of 16-20-0 at 2400 ruga per ton and 143 kg. of sulfate of ammonia 1550 ruga per ton

Economics of rice fertilization with price conditions assuming (1) no premium and (2) a premium is shown in the following table:

Table 18. Economics of rice fertilization

Item	Upper Valley	Lower Valley
With Rice Premium[1]		
Value of rice without fertilizer	561	1,520
Value of rice with fertilizer	1,105	2,331
Added value from fertilizer	544	811
Cost of fertilizer	597	522
Net return from fertilizer	-53	289
Ratio of cost to return	Negative	1:1.55
Without Rice Premium[2]		
Value of rice without fertilizer	1,182	2,625
Value of rice with fertilizer	2,327	3,938
Added value from fertilizer	1,145	1,313
Cost of fertilizer	597	522
Net return from fertilizer	548	791
Ratio of cost to return	1:1.9	1:2.5

[1]Rice price shown in Table 16
[2]Rice price shown in Table 16 assuming middleman profits increase by 10 percent

The data indicate that with the rice premium a farmer in the upper Chama Valley, raising low-quality rice, could not afford to use fertilizer. In fact, even though the yield is doubled, the return from the added yield is less than the cost of the fertilizer. In the Las Lunas area, a farmer raising high-quality rice would receive a return of 1.55 ruga for each ruga invested in fertilizer. With the removal of the rice premium, the return per ruga invested in fertilizer increases to 1.90 ruga in the upper valley area and 2.50 ruga in the lower valley area.

There may be reason to argue that farmers in the upper area can also produce high-quality rice, especially under conditions of adequate water. If farmers in the upper valley can produce high-quality rice, the return per ruga invested in fertilizer would be 1.45 ruga with the rice premium and 2.35 without the premium.

Thus, the return from fertilization in the Las Lunas area closely approximates the return from fertilization in the upper valley area if high-quality rice is produced in both areas. What is significant in both areas is the much more favorable economic environment for rice fertilization when the rice premium is eliminated.

A fertilizer subsidy has been proposed in some quarters in lieu of lowering the rice premium on the premise that farmers not selling rice (consuming total production on farm) will not benefit from a higher rice price. This is true, but it is also doubtful that these same farmers would invest in fertilizer even with a 50 percent subsidy. Probably, farmers now using fertilizer on rice would obtain the major share of the benefits from a fertilizer subsidy. Already familiar with fertilizer use, they would probably increase their level of use per hectare since such a practice would be economical if fertilizer costs are subsidized. Another means to promote rice fertilization is to subsidize fertilizer costs. Table 19 indicates the amount of fertilizer subsidy required for the farmer to obtain the same return per ruga invested in fertilizer as he would receive from the use of fertilizer if there was no rice premium. For a farmer near Chama to use the recommended rate of fertilization and obtain a 1.90 ruga return per ruga invested in fertilizer (rice price with premium), the total fertilizer input of 597 ruga per hectare would have to be subsidized 311 ruga, or 52 percent. For a farmer in the Las Lunas area to receive a 2.50 ruga return per ruga invested in fertilizer (rice price with premium), the total fertilizer input of 522 ruga per hectare would have to be subsidized 198 ruga, or 38 percent.

Table 19. Economics of subsidizing fertilizer costs for use on rice

Item	Upper valley	Lower valley
	(ruga per hectare)	
Value of rice without fertilizer	561	1,520
Value of rice with fertilizer	1,105	2,331
Added value from fertilizer	544	811
Ratio of cost to return fro fertilizer with no rice premium	1:1.9	1:2.5
Cost of fertilizer to obtain same ratio	285	324
Fertilizer subsidy	311	198
Percent subsidization	52%	38%

FOREIGN INVESTMENT

New Devland recently revised its investment law to provide more liberal incentives to private capital, both domestic and foreign. Attracted by the country's basic political stability, sound currency, and growth prospects, an increasing number of foreign firms are exploring business opportunities in New Devland. However, New Devland has reserved utilities, mining, banking, insurance, and some industries (cigarettes, liquor, and most textiles) for operation by the National Economic Development Corporation, which is the public agency for establishing and/or operating economic enterprises.

In 1962, New Devland passed an act called the *Promotion of Industrial Investment*. The benefits granted to "promoted" industries under this legislation are: (1) guarantee against nationalization and competition from government industries, (2) exemption from import duty and business tax on plant, machinery, spare parts, and raw materials, (3) exemption of duty on exported products, (4) exemption from corporate income tax for 5 years, (5) repatriation of capital and remittance of profits abroad, and (6) immigration facilities for managerial and technical staff.

The Board of Investment is the clearinghouse for determination of whether industries will obtain promotional certificates granting the benefits listed above. This board has little autonomy and is also subject to various governmental pressures regarding the establishment of industry. An act is now before the legislation to grant the Board of Investment complete independence in fulfilling its responsibilities.

To a great extent, New Devland is promoting the establishment of industries financed with foreign funds. Plans for fertilizer production facilities, unfortunately, have become involved in internal politics. Several American, European, and Japanese firms have requested promotional certificates to build fertilizer production facilities. These requests have essentially outlined a three-phase program for constructing production facilities:

Phase one—Import nitrogen, phosphate, and potash to be bulk-blended in locally constructed facilities.

Phase two—Construct a sulfuric acid plant and import phosphate rock for the production of superphosphate when a market has been established.

Phase three—Construct granulation facilities for the production of multicomponent fertilizers at a later date.

There are several reasons why plans have not yet been approved. First, local importers are resisting the granting of promotional certificates since they would be put out of business or would be required to buy from the company attaining the right to build a blending plant. Second, fertilizer is considered the key to attaining an accelerated rate of growth in the agricultural sector and the centeral government would like to have direct control over the production and marketing facilities when they are constructed. And, third, a group of New Devland politicians and businessmen are promoting a plan to build an anhydrous ammonia plant which would use the domestic lignite reserves as a feedstock in the production process. Although having considerable merit in terms of using the New Devland natural resources, most engineering feasibility studies have indicated such a plant would be extremely expensive to operate and likely would increase fertilizer costs above present imported prices. Thus, no actions have been taken on developing domestic fertilizer production facilities.

FERTILIZER DISTRIBUTION AND MARKETING

Fertilizer imports are conducted entirely on a private commercial basis. There are no import-export restrictions on fertilizers and no exchange controls, although this does not mean that approval to applications for foreign exchange for import of fertilizers can always be obtained when required. Fertilizers can be imported free of import duty.

Fertilizer Import Companies

The number of companies having licenses to import fertilizers fluctuates greatly. At times there have been more than 40 importers. Even though the number of importers is high, most fertilizer importing and distributing is accomplished by the following companies:

1. *Arriba – Dortmund Company* – This company is licensed as an importer and wholesaler of nitrogenous, phosphate, and other chemical fertilizers. The company is German-owned. It is also an importer and exporter of other products. Arriva-Dortmund imports and distributes a wide range of complete fertilizer compounds from West Germany, as well as a substantial volume of 16-20-0 from Italy. It is the largest company in terms of volume of fertilizers imported and distributed. Company offices are located in Las Lunas.
2. *Devereaux and Company, Ltd.*—This company is licensed as an importer and wholesaler of urea, ammonium phosphate, potassium and nitrogenous fertilizers. It is also licensed as a general importer, exporter, and miner with a U. S. representative in New York; it is also in the banking business. The

company has its main office in Las Lunas and branch offices in Chama, Buena Vista, Valdez, Dulce, San Sol, and La Junta. Under French ownership, it is one of the original importers of fertilizers and has done much to promote the use of fertilizers in New Devland. It handles a rather complete line of agriculture production items.

The company imports a wide range of nitrogen fertilizers from Germany and France and ammonium phosphate from Spain. Devereaux also imports a substantial tonnage of mixed fertilizers.

3. *N. D. Fertilizer Company, Ltd.*-This company is licensed as an importer and wholesaler of phosphate and other chemical fertilizers and also as a general importer. N. D. Fertilizer is American-owned and is the sole distributor for the fertilizers manufactured by U. S. Fertilizer Corporation, its parent company in the United States. Currently, U. S. Fertilizer ships 16-20-0 to New Devland in bulk and operates a small bagging station at Las Lunas. N. D. Fertilizer will assume operation of the bagging facilities this year. N. D. Fertilizer also imports a rather complete range of compound fertilizers for use on fruit and vegetable crops.
4. *Eastern Chemical Company*–This U.S. firm is establishing dealers in New Devland and probably will soon become a major factor in this country's fertilizer industry. It is obtaining a market identification by selling 16-20-0. Eastern will have access to a variety of nitrogen-phosphorus fertilizers from its new plant in Portugal.

Fertilizer Laws and Regulations

There are no functioning laws or regulations in New Devland that guarantee the quality or chemical composition of the fertilizers delivered to the consumer. Weights and measures also are not controlled.

Fertilizer Import Pricing Structure

Fertilizers are imported into the Las Lunas harbor on what is called a CIF price–cost of the fertilizers in the country of origin, insurance, and freight. Thus, CIF price is the price on the steamer in the Las Lunas harbor. There are no import duties on fertilizers, but the following costs must be paid for unloading fertilizer from the steamer into a warehouse:

1. An ad valorem tax to the government computed as 6 percent of the CIF price plus 10 to 15 percent assumed profit.
2. A transportation and handling cost of 50 ruga per ton to ETO (Express Transportation Organization) for transferring fertilizer from steamer to warehouse. ETO is a government-owned transportation firm and has a monopoly on all transportation in the Las Lunas harbor.

Some transportation savings could be incurred by (1) loading directly from steamer to lighters for transportation up-country; or (2) loading from lighters directly into private trucking company vehicles at pier for transportation up-country. This cannot be done at any savings, however, since the 50 ruga/ton still must be paid to ETO. Thus, the cost of imported fertilizers into Las Lunas warehouses is the CIF price plus approximately 7 percent to cover ad valorem taxes and ETO charges.

Product Identification, Bagging, and Storage Costs

All fertilizers except U. S. Fertilizer's bulk 16-20-0 are imported in bags–normally paper and usually 50 kilograms in size. Fertilizer is stored in warehouses until needed to fill orders. The fertilizer then is transferred from the paper bags to jute bags with polyethylene liners. This is done for two purposes: (1) farmers want jute bags for their rice harvest, and (2) rebagging provides for product identification through a brand name. Every importing company has at least one identifying brand and in some cases more than one. For example, several companies are distributing 16-20-0 imported from Italy under as many as three different brand names per company. The company charges a different price for each different brand name.

The cost of rebagging fertilizers by distributors is about 180 ruga per ton. This includes the cost of bags and labor. This added cost of marketing is included in the cost of fertilizers to farmers.

Storage costs are about 5 ruga per ton per month when warehouses are used to at least 50 percent capacity.

Wholesale and Retail Pricing

According to importers, 50 to 60 percent of all fertilizers are used within a 150-kilometer radius of Las Lunas. From 75 to 80 percent of the fertilizers are used within a 300-kilometer radius of Las Lunas. There are two primary reasons for this: (1) a lower transportation cost is reflected in a lower fertilizer cost to nearby farmers, and (2) a lower transportation cost on agricultural production to the Las Lunas market is reflected in a higher net price to nearby farmers.

Table 20 contains a summary of the average fertilizer prices in Las Lunas during 1967. In addition, the following observations on fertilizer marketing are made:

1. The country of origin has some effect on the fertilizer price. For example, 13-13-13 mixed fertilizer imported from Germany is sold to dealers at a higher price than a 13-13-21 mixture imported from Italy.
2. There is little competition among distributors in the sale of mixed fertilizers. Although an extremely high number of mixtures is marketed, only one or two distributors handle any particular mixture. As a result, price competition is not based on nutrient content but on a brand or trademark identity. For example, farmers near Chama can purchase 14-14-14 at the same price as 13-13-13 or 50 ruga/ton cheaper for cash. In another example, 12-24-12 from Germany is priced to farmers by one distributor at 2,350 ruga/ton for cash, 2,600 ruga for credit. A corresponding 12-12-10 mixture from Germany is priced to farmers at 2,400 ruga/ton cash and 2,600 ruga for credit. Since there are 12 more units of phosphorus and 2 more units of potassium in the 12-24-12, the price per ton should be considerably higher. Such a situation obviously reflects a lack of understanding on the part of the farmers as to the relation between price and the nutrient content of fertilizers. This works a hardship upon reputable distributing companies who sell high-analysis fertilizers, since competitors can sell lower analysis fertilizers at approximately the same price per ton.
3. In the case of 16-20-0 (ammonium phosphate) the situation is different. Almost every distributor is handling this product. Although there are some differences in the price to dealers, the farmer price is basically uniform. This is the result of competition among distributors and dealers, as well as a better understanding of the pricing of the product by farmers.
4. Substantial discounts are given at both the dealer and farmer level for cash purchases. Additional discounts are given for quantity purchases.
5. To promote the sale of fertilizers by dealers, some distributors give a bonus for each ton sold.
6. The lack of any regulations or at least enforced regulations in the labeling of fertilizer bags is creating marketing problems for the reputable distributors. The feeling exists that some distributors are mislabeling fertilizer bags and thereby claiming a higher analysis than that actually contained in the bag.

Table 20. Average fertilizer prices in Las Lunas (1967)

Type of fertilizer	Dealer price		Interest rate to Dealers[1]	Farmer price		Interest rate to farmers[2]
	Cash	Credit		Cash	Credit	
	(ruga per ton)		(%)	(ruga per ton)		(%)
16-20-0	2,150	2,300	10.5	2,400	2,800	23.4
20-20-0	2,150	2,350	10.5	2,400	2,800	23.4
13-13-21	2,050	2,200	10.7	2,300	2,800	24.4
13-13-13	2,300	2,500	13.0	2,600	3,200	46.1
14-14-14	2,200	2.350	10.2	2,600	3,200	46.1
15-15-6-4 Mg	2,250	2,400	9.9	2,550	3,100	43.2
12-12-20	2,350	2,450	9.6	2,650	3,000	26.4
12-24-12	2,300	2,450	9.7	2,500	2,900	32.0
15-10-10	2,350	2,500	9.6	2,600	3,000	30.8
Ammonium sulfate	1,400	1,500	10.6	1,550	1,700	19.4
Calcium ammonia nitrate (21% N)	1,450	[3]	–	1,650	[3]	–
Urea (45% N)	2,650	[3]	–	2,800	[3]	–
Superphosphate (20% P_2O_5)	1,155	1,255	12.8	1,400	1,600	27.0
Hyperphosphate (30% P_2O_5)	1,200	1,300	12.5	1,500	1,700	26.6
Potassium chloride (60% K_2O)	1,470	1,600	13.4	1,700	2,000	35.2

[1] Interest per annum, credit terms 8 months
[2] Interest per annum, credit terms 6 months
[3] Sold for cash only

Marketing Margin

There are variations in the pricing of fertilizers to both dealers and farmers. A summary of the information in Table 20 gives the following relationship between cash and credit prices:

Average price to dealers		Average price to farmers	
Cash	Credit	Cash	Credit
1,948 ruga	2,093 ruga	2,211 ruga	2,531 ruga

The average mark-up from the dealer to the farmer for cash sales is 263 ruga, or 13.5 percent per ton. However, dealers normally purchase on credit from distributors and sell to farmers on credit; the average mark-up is 438 ruga, or 20.9 percent per ton. These computations do not reflect the tons of each material sold, compound or mixture. A weighted average probably would show that the average mark-up is slightly lower. The higher volume sale products in general have the narrower margins. Since most fertilizers are sold on a credit basis, the data indicated that dealers are operating on about a 20 percent margin.

Fertilizer Credit Policies

Credit policies of distributors vary. Some distributors allow dealers 10 months of credit; others allow only 4 to 6 months. Average credit period allowed by 18 distributors is 8 months. Information from dealers is not available to the extent it is from distributors regarding the average credit period permitted farmers. Distributors say, however, the usual credit period for farmers is 6 months. In the wholesale published prices of fertilizers, an 8-month period for farmer credit is normally shown. Dealers usually want their money immediately after harvest, however. In fact, some dealers raise the interest rate on outstanding debts after 6 months. A summary of available information gives the following average interest rates paid for credit by farmers and dealers:

Dealer credit		Farmer credit	
Months	Annual rate	Months	Annual rate
8	11.1%	6	29.0%

According to the distributors, 1 percent per month to dealers and 2 percent per month to farmers is the prevailing interest rate for fertilizer credit.

Risk Factor in Fertilizer Credit

Distributors have basically four levels of guarantees which they require from dealers before extending them credit on fertilizers.

1. Bank note
2. Postdated check
3. Land deed
4. History of good repayment

A note through the bank from the dealer is preferred; most dealers have adequate credit rating with banks to obtain such notes. The usual practice is to obtain a postdated check. With some dealers, the distributors require a land deed as security—these are deeds to land which the dealer has obtained as security from farmers for fertilizer credit.

Even with a 1 percent per month interest charge to dealers, fertilizer distributors lose money on extending credit. The normal rate of interest for bank loans to businesses for operating capital is 15 percent per annum. Even if distributors do not need to borrow money to finance dealer credit, they still subsidize dealer credit to the extent of 3 percent per annum because of the alternative investment opportunities for operating capital. Also, the cost of bad loans must be added to the cost of extending fertilizer credit. Bad debts not repaid is a significant added cost of fertilizer credit in New Devland.

The single most detrimental factor to the expansion of fertilizer marketing and promotion in New Devland at the present time, according to distributors, is the credit situation. Most distributors hesitate to establish new dealers because they are not interested in expanding their volume of fertilizer credit.

Extension of credit by dealers to farmers is somewhat different. The fertilizer dealer in New Devland is usually the operator of a small store in a village. He sells almost any consumption or production item needed by local farmers, including fertilizer, food, clothing, pesticides, seed, etc. A land deed is the usual collateral required by a dealer for security against the extension of credit. Not only does the farmer buy fertilizer on credit from the fertilizer dealer-merchant, but he also buys other consumption or production items on credit. When crops are harvested, the farmer pays off his credit in farm produce and usually markets the rest of his crop through the merchant who assumes the role of a middleman. Such trader option agreements insure that the farmer pays off his debts at terms most favorable to the merchant-dealer.

There seems to be little desire on the part of the dealers to acquire the land holdings of farmers for non-payment of loans during years of bad harvest. The more usual practice is one of carrying the farmer in debt from year to year, thereby forcing the farmer to do business with the dealer.

From a fertilizer industry development standpoint, there are several weaknesses in the present dealer

marketing arrangement.

1. Most dealer locations have no storage, thus delivery service to the farmer is slow.
2. Most dealers have little information about fertilizers and cannot give the farmer sound agronomic advice.
3. Many dealers operate on a low-volume and, by necessity, a high-cost basis.

Transportation Costs

No discounts are given for seasonal sales of fertilizers. However, most distributors give a 5 percent discount to dealers to offset transportation costs to dealer locations. The discount is 5 percent regardless of the distance from Las Lunas to the dealer's location. Based on the average wholesale price of 1,948 ruga per ton of fertilizer, the transportation discount would amount to 97 ruga per ton.

There are four methods of transporting fertilizers from Las Lunas to dealer locations. These are by boat, rail, private trucking firms, and ETO or the government-owned trucking firm.

Fertilizers are seldom transported from Las Lunas to other locations by boat or by ETO. Boats are not practical since so many locations are not accessible by water. For those that are, the transportation time is usually excessive. ETO is not used because of exceptionally high rates. Thus, most fertilizers are transported by train or private trucking firms.

Rail rates are published and are the same for all distributors. However, rates of private trucking firms vary according to the tonnage hauled, condition of roads, and longevity of a contract between a distributor and a trucking firm. For example, to locations 50 kilometers from Las Lunas, the rate for a 12-ton truck load is 800 to 1,000 ruga per trip load. However, if only six tons were shipped 50 kilometers—unless the truck had another 6 tons of cargo going to the same location—the rate would be 1,000 to 1,200 ruga per ton, or 50 percent higher.

The truck freight rate is competitive with the rail rate at most locations up to distances of 200 kilometers from Las Lunas. At farther distances the rail rate is considerably cheaper. Truck rates reflect the fact that transportation costs increase in areas where road conditions are bad. A comparison of truck and rail rates is shown in Table 21. Neither trucking nor rail transportation costs for fertilizer is excessively high.

Wholesale prices for fertilizers to dealers at locations away from Las Lunas are in theory equal to the wholesale price in Las Lunas minus a 5 percent transportation allowance, plus loading costs, plus transportation costs, plus unloading costs.

Table 21. Average fertilizer transportation costs by truck and rail

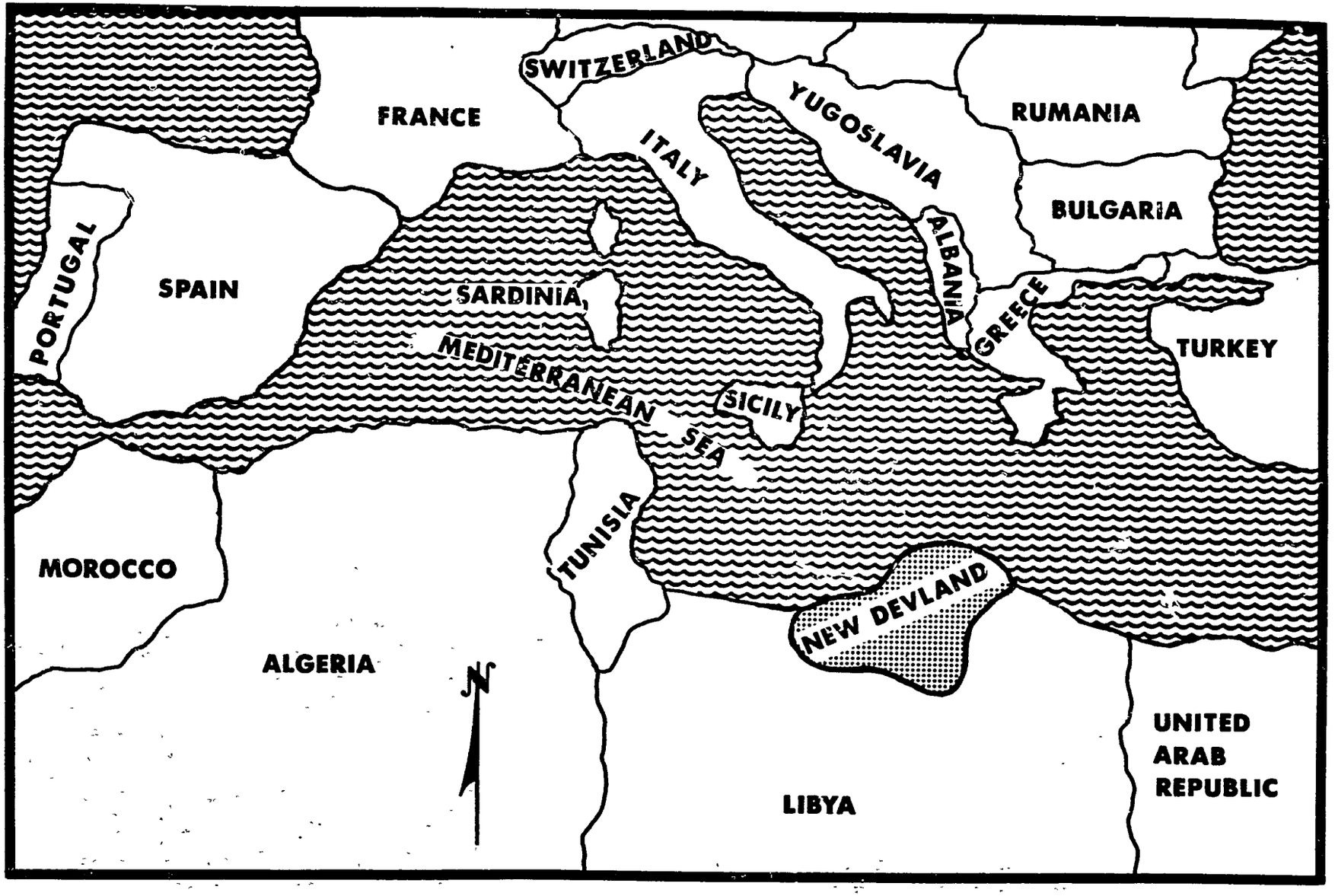
Distance	Freight rate/ton		Freight rate/ton/kilometer	
	Truck	Rail	Truck	Rail
	(ruga)			
1-200 km	80	87	.400	.435
200-1000 km	130	100	.216	.166
Over 1000 km	183	136	.092	.068

Farmer prices for fertilizers in outlying areas fluctuate considerably. The reason is that little fertilizer is sold at any distance from a rail head or truck terminal on an improved road. Distributors say they sell almost no fertilizer to dealers in these areas for cash and that dealers in these areas in turn sell to farmers almost entirely on a credit basis. Average mark-up by these dealers is 24.1 percent. This is slightly higher than the dealer margin in the Las Lunas area. This higher marketing margin is needed for two reasons: (1) Dealers in these areas handle less volume and thus their marketing costs per ton are higher, and (2) the 5 percent transportation allowance does not cover the costs of transportation when the distance from Las Lunas exceeds 200 kilometers.

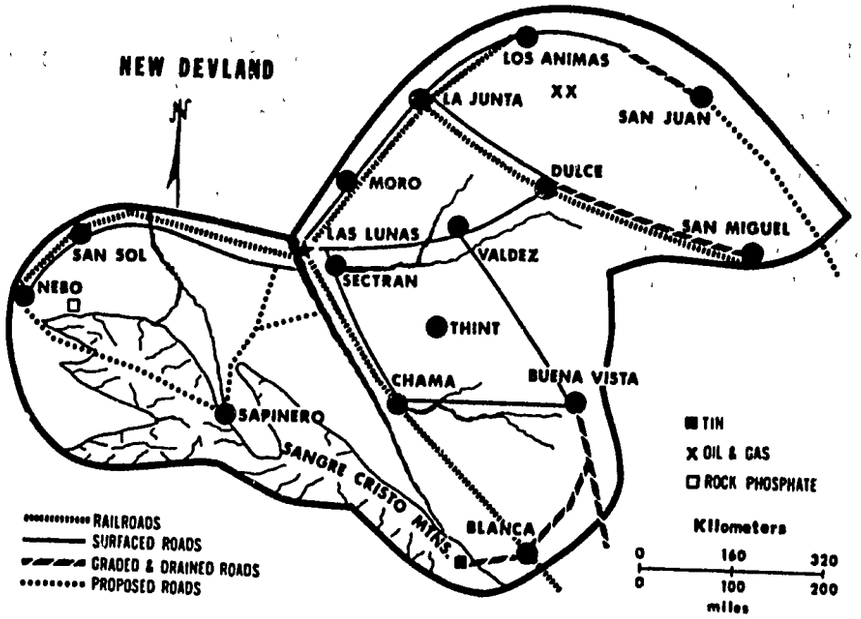
There are areas in New Devland where road conditions are extremely bad or where roads are almost non-existent. In such areas, transportation costs may be as high as 800 ruga/ton; such costs are reflected in the price farmers must pay for fertilizer.

Comments on the Structure of the Fertilizer Marketing System

Any assessment of the marketing system is confusing. The functions of money-lender, product buyer, processor, and distributor are often integrated under single management. Such vertical integration in isolated markets permits collusion among traders through a reduction of alternatives to the farmer. Since the trader has made loans to farmers, repayments are made with the marketing of the farmer's harvest through the trader. Interest rates are said to be high from collusion among traders; as a result, growers are constantly in debt to the traders and a permanent relationship develops, with the trader reaping the benefits from the association.

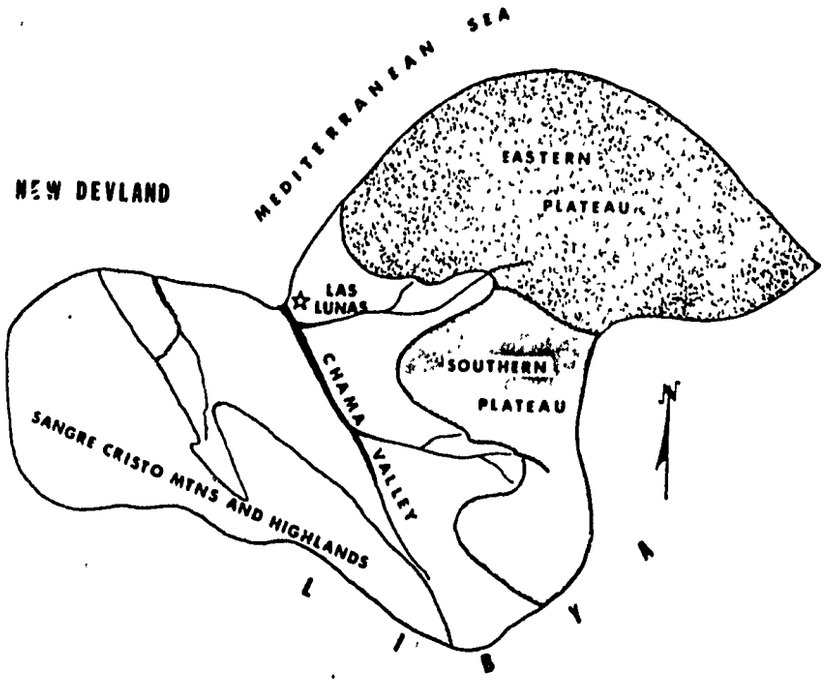


Location of New Devland



Transportation System

Geographic Areas



CRITIQUE QUESTIONNAIRE

Third Multination Training Course

During the past 8 weeks, you have participated in an international training course conducted by the Tennessee Valley Authority. This course was developed to provide an opportunity for participants to make an intensive study of the technology and economics of fertilizer production, distribution and use.

The Tennessee Valley Authority wishes to conduct the best training course possible. In this regard, we ask your cooperation in answering the attached questionnaire as a basis for improving the course content and presentation of material.

Do not feel compelled to give answers to questions on which you have no opinion.

A. Professional status:

1. Check the profession that is closest to your interest and/or training:

Agronomy _____ Economics _____ Engineering _____

B. Objectives of the training course:

1. Briefly stated, the objectives of the training program were:

a. Examine problems involved in establishing and operating a fertilizer program in a developing country.

b. Study developments in fertilizer production, marketing, and use in the United States and relate these developments to needs and resources in those developing countries represented.

c. Show the interrelationship and interdependence among chemical engineering research on fertilizer development and production, agronomic research on fertilizers and economics of their use, and educational programs for fertilizer introduction and use.

2. In your opinion, indicate whether the objectives of the training program were accomplished.

Objective	Was Accomplished	Was Not Accomplished
a		
b		
c		

C. Program format:

1. The following general format was followed during a training day. Considering the entire course, indicate your evaluation of the daily format.

		The time allowed for this item was			This item should have been eliminated.
		Too much	About right	Too little	
8:30 - 9:30	Topic of the day				
9:30 -10:00	Break				
10:00-10:45	Professional topic				
10:45-11:30	Professional discussion				
11:30-11:45	Multination time				
11:45-12:45	Lunch				
12:45 - 1:30	Professional topic				
1:30 - 2:15	Professional discussion				
2:15 - 2:45	Break				
2:45 - 4:00	Panel problem				

2. Explain changes which you feel should be made in the training day format--such as, addition or deletion of items, rearrangement, or changes in allocation of time.

_____

_____

_____

D. Topic of the day:

1. Listed below are the topics of the day, usually discussed from 8:30 to 9:30 o'clock. Your evaluation should relate only to the topic of the day, not to the professional discussions that followed. Check your opinion.

Day No.	Topic	The time devoted to this topic was			This topic should have been eliminated
		Too much	About right	Too little	
1	TVA orientation				
2	Fertilizer potentials				

Day No.	Topic	The time devoted to this topic was			This topic should have been eliminated
		Too much	about right	Too little	
5	World fertilizers				
6	Raw materials				
7	Phosphorus fertilizers				
9,10	Nitrogen fertilizers				
11	Ammonium phosphate fertilizers				
12	Nitric phosphate fertilizers				
14	Potassium fertilizers				
15	Mixed fertilizers				
16	Bulk blends and liquids				
17	Physical properties				
19	Storage and distribution				
20	Fertilizer pricing				
21	Capital and credit				
22	Research and development				
23	Factors impeding fertilizer use				
24	Education and promotion				
25	Communications				
26	Statistical data				
27	Fertilizers for developing countries				

2. With regard to the topics of the day discussed from 8:30 o'clock, check your opinion on the following questions:

Day No.	Topic	The speaker(s) did not cover the following areas adequately:			The topic should have been presented by:	
		Production	Marketing	Use	Fewer speakers	More speakers
1	TVA orientation					
2	Fertilizer potentials					

Day No.	Topic	The speaker(s) did not cover the following areas adequately:			The topic should have been presented by:	
		Production	Marketing	Use	Fewer speakers	More speakers
5	World fertilizers					
6	Raw materials					
7	Phosphorus fertilizers					
9,10	Nitrogen fertilizers					
11	Ammonium phosphate fertilizers					
12	Nitric phosphate fertilizers					
14	Potassium fertilizers					
15	Mixed fertilizers					
16	Bulk blends and liquids					
17	Physical properties					
19	Storage and distribution					
20	Fertilizer pricing					
21	Capital and credit					
22	Research and development					
23	Factors impeding fertilizer use					
24	Education and promotion					
25	Communications					
26	Statistical data					
27	Fertilizers for developing countries					

3. Which of the following topics should have been substituted for a topic listed in D-1? For each topic checked in the following list, be sure that you have indicated that an item is eliminated in number 1 under Section D.

World sulfur supplies _____
Rice fertilization _____
Safety in fertilizer plants _____
Farmer cooperatives _____
Fertilizing high pH soils _____
Farm service centers _____
Analytical procedures for quality control _____

Other topics (specify) _____ _____
_____

Crop insurance _____
Superphosphoric acid and polyphosphate fertilizers _____
Micronutrient fertilizers _____
Establishing fertilizer distribution systems _____
Fertilizer literature (agricultural and chemical) _____
_____ _____

4. Comment on any further changes you would make in the discussions of the topics of the day.

_____
_____
_____

E. Professional topics and discussion:

1. Agronomy discussion section (to be completed by all participants):

a. Was the agronomy information presented too academic? Yes _____ No _____

b. The time devoted to professional topics on agronomy was: too much _____, about right _____, too little _____.

c. If the amount of time devoted to agronomy topics were increased, how should the time be used? more topics _____, slower presentation of the same amount of material _____, more details in presentations (such as, statistics, experimental design, analytical procedures, etc.) _____, more exposure to local soil conditions through field trips _____, other _____; explain _____
_____
_____
_____

d. Printed material supplied as a supplement to the discussions on agronomy was: sufficient _____, inadequate _____, if inadequate, what type of additional printed material would have been most helpful? _____
_____
_____

e. Did the discussion leaders in the agronomy sessions give adequate consideration to: agronomic considerations? Yes _____ No _____; economic considerations? Yes _____ No _____; engineering considerations? Yes _____ No _____.

f. Which of the professional discussions on agronomy should receive less time or more time? (limit 3).

Less time	More time
(1) _____	(1) _____
(2) _____	(2) _____
(3) _____	(3) _____

g. Visuals used by the discussion leaders were: poor quality _____, satisfactory _____, too few in number _____.

h. When visuals were of poor quality, the reason was : too much data on the visuals _____, the visual design was too complicated to understand quickly _____, significant points on the visual were not easily determined _____, the screen was poorly located _____.

i. What type of visuals did you prefer? 2 x 2 slides _____, 8 x 10 overhead projections _____, no preference _____.

2. Economics (to be completed only by economists and marketing specialists):

a. Arrangements were not made for economists to meet as a professional group. What topics would have been particularly valuable for economists to have discussed separately from agronomists and engineers? _____

_____
_____
_____
_____
_____

b. Even though there were not enough economists for a full schedule of separate discussions, would it still have been desirable for them to have had a few separate sessions? Yes _____ No _____.

3. Engineering (to be completed only by engineers):

a. Arrangements were not made for engineers to meet as a professional group. What topics would have been particularly valuable for economists to have discussed separately from agronomists and engineers? _____

_____
_____
_____
_____
_____

b. Even though there were not enough engineers for a full schedule of separate discussions, would it still have been desirable for them to have had a few separate sessions? Yes _____ No _____.

F. Panel Problems:

1. Were the panel problems useful as a teaching technique? Yes _____ No _____

2. Panel problems were designed as a teaching technique to reinforce lectures, to apply lecture information to practical problems, to give practice in communications, and to provide experience in working together as teams. Indicate whether these objectives were accomplished.

Objective	Accomplished	Not Accomplished
Reinforce lecture		
Apply theory to practice		
Communications		
Teamwork		

3. The amount of time devoted to panel problems during each course-day was: too much _____, too little _____, about right _____.

4. How much time did you use in preparing the solution to your panel problem? hours _____ (Use the average of the time spent for each of your problems).

5. The special writeups for each problem personalized the solution, gave some of the social and political background, and frequently suggested misleading solutions. In your opinion the panel writeups should contain:

   a. Political and social background; Yes _____ No _____

   b. Personalization of the problem situation; Yes _____ No _____

   c. Possible solutions (misleading or factual) Yes _____ No _____

6. The number of individuals assigned to each panel problem should be: a set number for each problem _____, a variable number depending on the nature of the problem _____. If you checked a set number, what is the most efficient panel size? _____.

7. Panelists for a problem should be: from a single country _____, from different countries _____.

8. When the panel problem is primarily engineering, the panelists should be: all engineers _____, engineers agronomists, and economists _____, assigned without regard to profession _____.

9. Should participants be assigned to more than one panel problem? Yes _____ No _____.

10. In the following table, check your opinion of the panel problems:

Problem No.	Topic	This problem should be			
		Subdivided into two or more problems	Included with problem No.___	Unchanged	Eliminated
1	Assessing fertilizer needs				
2	Import or domestic manufacture				
3	Rock phosphate mines				
4	Monetary returns from fertilizer use				
5	Ammonia facilities				
6	Nitrogen fertilizers				
7	Irrigation				
8	Soil testing laboratory				
9	Phosphorus fertilizers				
10	Potassium fertilizers				
11	Import vs. domestic production				
12	Bulk blending				
13	Final manufacturing facilities				
14	Field application				
15	Transportation				
16	Capital for fertilizer facilities				
17	Credit systems				
18	Wheat production and education				

11. List panel problems you would have substituted for any of those listed in question 13 (limit 3).

   a. _____

   b. _____

   c. _____

12. Panel problems should be based on the topic of the day. Yes _____ No _____

13. Panel problems should be presented _____ days after the topic of the day.

14. TVA personnel were used only to moderate the panel presentations and to comment on the solutions. Should one or more TVA representatives be assigned to each problem to work directly with the panelists? Yes _____ No _____.

15. Panelists had 30 minutes to present their problem solution. This was about the right amount of time. _____ 45 minutes was needed. _____ 60 minutes was needed _____.

16. About forty-five minutes was provided for group discussion of panel problem solutions. This was the correct amount of time. _____ 60 minutes was needed. _____ Only 30 minutes was needed. _____

17. Discussions by the group of the panel problem solutions were frequently quite unorganized. More control should have been exerted by the moderator. _____ The audience should be limited to one question per person until all have had a chance to ask questions. _____ No changes in the method of panel presentations or discussions are needed. _____ Other _____ (Explain) _____

G. Communications

1. During the course one-half day was spent in an audiovisual workshop (Day No. 3 or 4), one day on communication theory and application (Day No. 26), and about one-fourth day with panel problems (Day No. 27). The amount of time spent on communications was: too long _____ too short _____ about right _____.

2. The portion of the communications session most useful was: lectures _____, audiovisual workshop _____, communications problems _____.

3. Indicate your opinion on the following portions of the communications sessions:

Item	Was helpful	Could be improved	Should be eliminated
Lectures			
Audiovisual workshop			
Communications problems			

4. The amount of time spent on communications in developing countries was: too long _____, too short _____, about right _____.

5. For communications in developing countries, more time should have been spent on: equipment _____, comminications techniques _____, examples of successful communications programs _____.

H. Multination time:

1. The amount of time allotted for multination time was: too long _____, about right _____, too little _____.

2. Multination time should be scheduled: at 8:30 a.m. _____, just before lunch _____, at the end of the day _____, in two separate periods _____; these periods should have been at _____ a.m. and _____ p.m.

I. Field trips:

1. Field trips for engineers, economists, and agronomists should: always be separate _____, always be together _____, some together and some separate, depending upon nature of the trip _____, makes no difference _____.

2. If all professionals do make the same field trip: they should go at the same time _____, they should go at separate times _____, they should be divided into professional groups even though they travel together _____.

3. The number of field trips (at TVA) was: too many _____, about right _____, too few _____.

4. Field trips (TVA) most and least useful were:

Most useful	Least useful
a. _____	a. _____
b. _____	b. _____
c. _____	c. _____

5. Field trips which should be added to the training course are:

a. _____

b. _____

c. _____

J. Library time:

1. Time allowed for use of the library was: about right _____, too much _____, not enough _____.

2. Library time should be scheduled: 30 minutes each day _____, one hour each day _____, one-half day each week _____, several hours during the first week and then only an hour or so each week thereafter _____, only an hour or so per week at the beginning but several hours per day during the last week _____.

3. It would have been helpful for TVA to have provided: a list of available reprints _____, a complete list of TVA publications _____, a special list of the latest publications dealing with fertilizer technology and use _____.

4. Photocopies (Xerox) of out-of-print materials or of non-TVA articles are expensive--$.10 per page. TVA has only limited funds to provide photocopies of materials to participants in training courses. In your opinion, photocopies should be provided to all who ask for them at no cost _____, photocopies should be provided at actual costs of reproduction _____, each participant should have a limited number of photocopy pages free, and pay actual reproduction cost for the rest _____.

5. Should TVA make different arrangements for ordering books by participants in the training course? Yes _____, No _____. How? _____

6. Participants should be provided with a suggested list of reference books on fertilizer technology and when they reach Washington, D. C. Yes _____ No _____.

K. Visual aids:

The use of visuals was about right. _____; All speakers should have used more visuals. _____; Some speakers should have used more visuals. _____; The quality of all visuals was good. _____; Some visuals were of poor quality _____.

L. Seminars:

1. Participants from each country should be required to present a seminar. Yes _____ No _____.

2. Participants in a training course should be: limited to one country at a time _____, drawn from several countries _____, makes no difference _____.

3. Would it be advisable to have some time set aside each week for participants to work on special assignments from their sponsors or to consult with TVA staff members? Yes _____ No _____. If you answered "yes", how many hours per week should be allowed? _____

4. When a recognized authority on a particular subject is not available to present a lecture, would you prefer: the lecture to be pre-recorded on tape by the authority and used during the lecture period _____, the lecture to be presented by someone else with the paper being prepared by the authority _____.

5. How would you rate the information presented at TVA by subject matter areas? (All participants should complete the table.)

Subject matter	Too elementary	Too general	Too technical	About right
Agronomy				
Economics				
Engineering				

6. Please make suggestions for using time after hours and on weekends in which TVA could be of assistance.

_____

_____

_____

_____

_____

_____

_____

7. What part of the training program was of most benefit to you? _____

_____

_____

_____

_____

_____

8. Other criticisms or suggestions for improvement. _____

_____

_____

_____

_____

_____

Name (optional) _____

Country (optional) _____