PN-AAD-995

AGENCY FOR INTERNATIONAL DEVELOPMENT

SPRING REVIEW
OF
THE NEW CEREAL VARIETIES

May 13 - 15, 1969

MAJOR PHYSICAL INPUTS

MAJOR PHYSICAL INPUTS - WITH EMPHASIS ON FERTILIZER AND WATER MANAGEMENT FOR CROP PRODUCTION *

I. INTRODUCTION - FERTILIZER

1. The rapid improvement in the yield of the major cereals--corn, wheat, and rice--in some of the developing nations has been so remarkable that it has been termed "The Green Revolution." A look at what is causing this rapid improvement in yields reveals that institutional, social, and economic changes, as well as the introduction and use of new and improved physical agricultural inputs, are playing important roles.

2. It is the purpose of this paper to consider some of the major physical inputs, looking in depth at fertilizers, and to a somewhat lesser degree at pesticides, machinery, and seed production, in the roles they have played and must play in the future to assure continued success. It should be kept in mind that individual inputs--be they variety, fertilizer, pesticides, or any other major component of yield--seldom, if ever, give maximum results unless they are utilized in the right combination with other inputs.

3. Information utilized to develop this paper comes only from a few sources. A complete review of this broad subject was not possible in the time allotted. The evaluation of the developing nations' general

---

*Prepared by the International Fertilizer Development Staff of TVA, Omer Kelley and James M. Blume of A.I.D.

fertilizer situation and their estimated needs comes primarily from TVA's report entitled "Estimated World Fertilizer Production Capacity as Related to Future Needs" 1968 edition, and from the President's Science Advisory Committee report entitled "The World Food Problem." Data on the effect of the new varieties of the crops on fertilizer requirements and estimated use, as well as data on the use of other inputs, comes primarily from the world crop papers, and from the individual country crop papers as furnished through this study.

4. The advent of new high-yielding varieties that greatly improves the overall yield potentials of these crops opens up a whole new opportunity for the use of other agricultural inputs. This new yield potential greatly alters the economics of using these various inputs, and improves the attitudes and enthusiasm of governments, industries, and the producers of these crops. The need for, as well as the results from, the package approach gives new hope to all facets of industry and government that were once quite pessimistic on the possibilities of producing adequate food.

II. FERTILIZERS

5. Fertilizers are selected for major attention in this paper not to imply that they are all important, but because of the problems of overall cost and logistics that will be involved in furnishing this input in the quantities that are indicated.

6. A. Total Fertilizer Demand

To even maintain the present inadequate dietary levels it is estimated that the developing Free World, that is Asia (excluding Japan

and Communist Asia), Africa, and Latin America must by 1975 be using over 13 million metric tons of plant nutrient as compared to 6.2 million metric tons in 1967. To improve the average diet in these regions by 10 percent would require the usage of about 19 million metric tons of plant nutrient. TVA estimates that by 1975 a slight increase in diet may create a demand for approaching 15 million metric tons--about 2-1/2 times the amount of fertilizer that was used in 1967.

7. This means that whereas these countries had difficulty in furnishing, distributing, and utilizing average yearly increases of 0.6 million metric tons of plant nutrients during the 1962-1967 period, they must now somehow find a way to increase fertilizer availability, distribution, and usage by an average of 1.3 million metric tons per year over the period 1967-1975--a formidable and expensive task to say the least.

8. Overall estimates of fertilizer consumption and demand by 1972 for the selected individual countries included in this study are shown in Table 1. These data are total fertilizer use for each country, and include the fertilizer to be used by the crops included in this study.

9. To give an indication of the probable costs of producing these fertilizers in the LDC's the generalized cost of $500 per metric ton of annual plant nutrient capacity, including all facilities necessary for production, storage, transportation, and distribution, that is used in the President's Science Advisory Committee Report should be used. This would mean; for example, that the country of Kenya, if it were to

produce its own fertilizers, by 1975 might require a total capital investment of $40,850,000. Pakistan would have seven times this amount, or about $293 million, invested.

B. Consideration of Domestic Production vs Importation

10. The problem of whether a LDC should import finished fertilizers as opposed to domestic production is complex and changeable. No simple solution can be fitted to all situations. Major considerations are foreign exchange requirements, availability of raw materials, and level of demand for fertilizers. Production of fertilizers by importation of intermediates is economically feasible in many situations. Few of the LDC's have natural gas for ammonia and mineral deposits that are economic to mine for phosphate and potassium fertilizers. By directing attention only to the LDC's that have no presently usable raw materials, some generalities can be formulated.

11. Importation of finished products requires a continuing high expenditure of foreign currency and is normally used only as an expedient until domestic production is possible. Importing finished products serves to supply needed fertilizers during construction of local fertilizer plants and also to "seed" the marketing and distribution systems so that they will be functioning when local production is initiated. However, in small and less populated countries with low fertilizer needs, importation of finished fertilizers will remain more economic than domestic manufacture. Generally, countries with a demand

for less than 100 tons per day of P_2O_5 and less than 200 tons per day of N should import finished products.

12. Importation of intermediates is attractive for LDCs because continuing foreign exchange costs are lower than for importation of finished products, and capital costs and plant construction time are lower than for manufacture from raw materials. Generally, importation of intermediates is economically attractive for countries with P_2O_5 demands of about 100 to 300 tons per day and nitrogen needs of about 200 to 400 tons per day. By utilizing intermediates, some of the advantages of scale and location near the sources of basic raw materials should be realized by the importing country. By carefully planning and locating a fertilizer industry based on intermediates, a country can begin to establish its industry; when demand increases sufficiently other components can be added until a full-fledged industry results.

13. Production of finished fertilizers from raw materials is most attractive for the LDCs with comparatively large fertilizer demands, and relatively high degrees of industrial sophistication. This requires the largest initial expenditure of foreign exchange for capital investment, but the smallest continuing expenditure for raw materials, as compared with importation of finished products or intermediates. Generally, a good case can be made to install domestic capacity when the P_2O_5 demand exceeds about 300 tons per day, and the nitrogen demand is in the range that will utilize the major part of a modern ammonia plant with a capacity of 600 tons per day.

C. Impact of High-Yielding Varieties on Fertilizer Consumption

14. New and higher yielding varieties of rice, wheat, and corn have been introduced in various countries during the past decade. It is important that their impact be recognized, not only on supplying additional food, but also on fertilizer use. The following is a study on three crops, rice, wheat, and corn as to the rate new high-yielding varieties have been accepted and the effects they may have on fertilizer use by 1975.

1. Rice

a. Outlook before Introduction of High-Yielding Varieties

15. The impact of high-yielding varieties of rice on fertilizer consumption can be illustrated by comparing the 1964 fertilizer use-yield relationships of three high-yielding rice countries--Japan, Republic of Korea, and Taiwan--with those of India, Philippines, and Thailand (Table 2).

16. First reaction to this data is to recommend increased use of fertilizer to improve the rice yields in the low-yield countries. There was a reason, however, why rice farmers in India, Philippines, Thailand, as well as other southeast Asian countries, were not using fertilizers and were not able to obtain high yields. The rice grown in these countries was entirely different in its response to heavy fertilization to that grown in Japan, Republic of Korea, and Taiwan. Whereas the native varieties of rice grown in the high-producting countries could respond to heavy fertilization, the use of fertilizers

on the rice being grown in the low-yielding countries could not be encouraged. Even small applications of fertilizer, especially nitrogen, were not generally economical, and in some cases caused actual reductions in yield due to excessive growth of foliage and early lodging. The outlook for heavy use of fertilizers under these conditions was not encouraging.

b. Outlook after the Introduction of High-Yielding Varieties

17. By 1965, short-strawed, fertilizer-responsive varieties of rice adapted to southeast Asian conditions were becoming available primarily from the International Rice Research Institute. These varieties were highly responsive to the application of fertilizer; former yield barriers in these countries were broken. The potential for fertilizer use on rice in these countries also took on a new dimension until today. It is almost uniformly accepted that rice in these countries can respond to at least 200 lbs. of plant nutrient per acre. The average rate of 100 lbs. N, 60 lbs. P_2O_5, and 40 lbs. K_2O is being recommended in most southeast Asian countries and is highly profitable at present prices when the new varieties are used along with adequate levels of other inputs including pesticides, water control, and proper cultural practices.

18. To estimate fertilizer demand for rice in the countries included in this study, one must establish the rate of adoption of the

new high-yielding varieties. Four years after introduction of the new varieties it is estimated that nearly one-third of the 42 million acres of rice grown under irrigation in India, Pakistan, The Philippines, and Thailand are already planted to the high-yielding varieties. It is reasonable to assume that this shift toward new varieties will continue until virtually all of the rice grown under irrigation is planted to high-yielding varieties. Since high-yielding varieties appear to be responsive only to a total package of improved practices, including water control, it may be questioned how much of the nonirrigated rice will be planted to these varieties. For the present it appears doubtful if more than 10 percent of the available nonirrigated land should be planted.

19. If we would assume that by 1975 the 42 million acres of irrigated rice, plus an additional 9 million acres of nonirrigated rice, in the above mentioned four countries were planted to high-yielding varieties and fertilized at the average recommended rate of 200 lbs of plant nutrients per acre, this would require about 5.2 million metric tons of plant nutrient for the high-yielding rice alone. If this same acreage were seeded to native varieties and fertilized according to recommendations no more than one-fifth of the amount of fertilizer would be used. This is without a doubt an unrealistic figure due to the fact that markets for this much rice do not exist in these countries, and the possibility for export sales is not promising. It does, however, illustrate the potentials.

20. Experience has shown that a 40 percent achievement of the ideal may be more realistic. This would mean that by 1975 rice alone in these countries might be using as much as 2.04 million metric tons of plant nutrients. This would roughly break down into 1.05 million metric tons of N, 0.62 of P_2O_5, and 0.41 of K_2O. An indication of how this would break down in the four mentioned countries is shown in Table 3.

21. Estimates of demand for plant nutrients on rice are not included for South Vietnam and for the other countries of the study. South Vietnam--should hostilities cease--could almost immediately become a major user of new varieties and associated inputs, including fertilizer; projections under present conditions are not attempted. The other countries in southeast Asia and Africa are minor users of fertilizer on rice; so far new varieties have not been accepted. However, the above comparisons illustrate the potential impact new varieties of rice could have on fertilizer consumption.

2. Wheat

a. Outlook before Introduction of Semi-dwarf Varieties

22. Prior to the introduction of semi-dwarf varieties, wheat production was much the same in most of the LDCs reviewed. Only a slight increase in production per unit area was actually recorded over the past few years. The total production was almost entirely dependent on the climatic conditions for a particular growing season. Where production was increased, as in the case of India, this was due primarily

to improved cultural practices that were being used on the local varieties rather than any sizeable increases in acreage.

23. Relatively high fertilizer usage combined with the use of improved varieties was apparently responsible for the high yields of wheat grown in Mexico, Japan, and the United States. These yields were more than double those of areas where neither fertilizers nor improved varieties were used extensively (Table 4).

24. By 1964, a limited but economical response to fertilizer improved local varieties was beginning to be reported. This was particularly true for India and Turkey. West Pakistan and Morocco, however, remained static until 1966, at which time some improvement due to improved cultural practices and added fertilizers were noted.

b. Outlook after the Introduction of Semi-dwarf Varieties

25. Today, only two years after their introduction, Pakistan and India have about 17 percent of their wheat land planted to the new varieties; Morocco has about 3 percent and Turkey has less than 1 percent of its total planted to the new varieties.

26. With the introduction of semi-dwarf varieties, the fertilizer potential changed dramatically on wheat. Recommendations for nitrogen doubled and tripled; phosphate application rates tripled, and for the first time use of potassium became profitable in many areas. An average rate of fertilization for the new semi-dwarf varieties is about 80 lbs. of N, 60 of P_2O_5, and 35 of K_2O (Table 5). This increase

in fertilizer recommendations, coupled with the rapid acceptance of the semi-dwarf varieties in a number of areas, has suggested substantial demands for additional fertilizer. This is particularly true in India and Pakistan where wheat occupies a high percentage of the irrigated and rainfed areas. The semi-dwarf varieties, although very responsive to fertilizer in areas where rainfall is adequate in Turkey and Morocco, show less response and promise of acceptance in the semi-arid regions of these two countries. Little or no wheat is grown in irrigated lands of Turkey and Morocco; whereas, wheat has a high priority for irrigated land in India and Pakistan.

27. About 27.5 million acreas of land appear to be adapted to the semi-dwarf varieties of wheat. This is about one-third of the total land now devoted to growing wheat.

28. Almost 2.4 million metric tons of fertilizer nutrients would be needed if all of the areas adapted to the semi-dwarf varieties of wheat of the four countries under study were fertilized according to top recommendation. This is about 1.6 million metric tons more than if the local varieties had been fertilized according to recommendation. These goals are theoretical and indicate the maximum utilization of land adapted to semi-dwarf varieties in the four countries under study. Based on past experience 40 percent of this goal will probably be achieved by 1975. Therefore, fertilizer by 1975, due to the introduction of semi-dwarf varieties, will probably be 0.96 million metric tons of plant

nutrient. This is still almost 0.7 million metric tons more than if all of the adapted area had been planted to local varieties and fertilized at the recommended rates. The break down according to nutrient and country appears in Table 6.

3. Corn

a. Outlook before Introduction of High-Yielding Varieties

29. Although corn has been a staple crop in a number of countries, particularly in North and South America, major increases in yield per acre have been restricted primarily to the United States and Japan. Very little fertilizer has been applied to corn grown in the study countries.

30. Yields very nearly reflect fertilizer usage with the greatest strides being made in the United States where a complete package of fertilizer, hybrids, herbicides, and pesticides, has been used along with a multitude of other factors including row spacing, date and rate of planting, and efficient harvesting. The average yield and use of fertilizer on corn appears in Table 7.

31. Fertilization of many of the unimproved varieties developed in the local country appears impractical. Responses to nitrogen and phosphate are slight and often will continue to be uneconomical under existing price structures. Therefore, the outlook for fertilization of existing unimproved varieties in many countries is not encouraging.

b. Outlook after Introduction of High-Yielding Varieties

32. The introduction of high-yielding hybrids alone does not appear to be very effective in increasing yields of corn. Hybrid corn has been available in Mexico for 18 years, but occupies only 10 percent of Mexico's corn acreage. Yields have not increased greatly over this period of time. This is a real disappointment since over a similar period in the United States hybrids have come to be used on 98 percent of the corn land and yields have tripled. Mexico does, however, have nearly one-third of its corn land in improved varieties of corn. These are less responsive to fertilizer and have less potential than the hybrids.

33. Brazil has 50 percent of its corn acreage in new hybrids. Nevertheless, little fertilizer is being used and yields have not changed greatly in the past 10 years.

34. Kenya and Thailand, on the other hand, two countries new to corn production, have accepted the improved varieties at a fast rate and have had considerable success. The flint varieties of corn introduced to Thailand from Guatemala less than 10 years ago are now grown on more than 85 percent of the land devoted to corn production (Table 8). Similar acceptance of new varieties has occured on large scale farms in Kenya.

35. There are specific reasons for the success in Kenya and Thailand as well as the United States. Considerable emphasis is given cultural practices, such as plant population, pest control, and

possibly most important, time of planting. Research from Kenya has revealed that a 6-week delay in planting can nullify any benefits from nitrogen.

36. When the package approach is used--including new hybrids, pesticides, population, and time of planting--nitrogen rates of 130 to 150 lbs. per acre are profitable. This is true for hybrids grown in Kenya, Mexico, and Brazil. Nitrogen rates of up to 60 lbs. per acre are profitable for the special flint varieties grown in Thailand.

37. Best results are achieved when 30 to 60 lbs per acre of P_2O_5 and up to 40 lbs. of K_2O are also applied--again when the improved or high-yielding varieties are grown in a system. In Kenya sulfur is as important as phosphate to satisfactory yields.

38. At the present time it is difficult to establish the impact improved varieties have had on fertilizer consumption in recent years. The best records exist for Kenya where high-yielding varieties were estimated as being responsible for increasing N consumption by 4,350 tons, and P_2O_5 by 3,800 tons. No K_2O is currently being recommended on corn in Kenya. However, sulfur requirements are probably equal to those for P_2O_5.

39. Prospects are dim for additional increases in fertilizer consumption for corn through 1975. This is due to the complexity of the package system, and most importantly, the fact that corn is in surplus in all of the four countries where comparisons were

made. Some improvement in usage could occur provided a livestock industry is developed within or near the producing country.

40. Projections for Kenya suggest that 1.5 million acres of improved varieties when properly fertilized will provide a surplus of corn four times the level currently experienced for that country. This could free land to livestock production and thus create a market for the projected surplus.

41. Fertilizer use on the 1.5 million acres could be as high as 85,908 tons of N and 21,600 tons of P_2O_5. Sulfur, rather than K_2O, appears to be the next important plant nutrient in Kenya. However, 21,600 tons of K_2O will probably be used by 1975 or shortly after because of new stress on the soil (Table 9).

42. The theoretical increase in fertilizer consumption will be 280,000 nutrient tons for Mexico, 25,000 tons for Thailand, and 330,000 metric tons for Brazil. This represents a total nutrient consumption of 764,028 metric tons. This is assuming that the respective countries fertilize at the anticipated rate on the land adapted to the high-yielding varieties of corn. Based on progress to date these estimates are too high and should be reduced by 50 percent. Thus, a total nutrient increase on corn, as a result of new varieties, when incorporated in a complete package, will more nearly be about 381,000 metric tons of plant nutrient. About 231,000 tons will be as nitrogen and 75,000 tons each will be as P_2O_5 and K_2O.

43. Again, even these increases are highly dependent on the development of enterprises that will use this additional corn production, since surpluses exist in all four of the countries studied. It is probable that considerable reduction in land devoted to corn will occur, but that devoted to corn will be grown with the entire package of inputs.

44. Land made available as a result of this shift could probably be devoted to livestock enterprises that would utilize the surplus of corn or devoted to other crops that would improve diets in these countries.

D. General Observations on Fertilizers

45. To estimate fertilizer consumption for a given crop one must have a firm estimate of the cost-price relationship. This relationship on the new varieties of wheat and rice has been quite favorable. Corn has been erratic, but generally less favorable. As self-sufficiency of these grains is attained the cost-price relationship may be altered--prices of grain may drop and the need for subsidies on fertilizer will be discontinued. Any estimate of fertilizer demand must recognize that these countries have the potential to reach self-sufficiency. This may, however, not mean a reduction in input needs. Under ideal conditions shifts in crops that would improve the diet might continue to create an increased demand for fertilizer.

46. The need for food and generally favorable cost-price ratios has created a sellers market for fertilizers in most countries. With

more domestic production capacity being built, and imports available, a buyers market in some cases is evolving. Fertilizer salesmanship is being required for the first time. No doubt unavailability of fertilizer has in cases somewhat limited production, but transport, storage, and marketing facilities for grain have also been seriously taxed by the large yields over the past two years. Storage, distribution, and marketing facilities for both fertilizers and grain should be given high priority if the gains in fertilizer use and grain yields are to be maintained.

47. Fertilizer production capacity, although not being built in all cases as rapidly as planned, is becoming available in those countries where investment climate and market seem to justify private industry's attention. Possibly more of AID's limited funds and effort should be focused on improving production from existing facilities, on improving the market, the infrastructure, and the investment climate, and on investment guarantees so that non-AID money can be attracted to build justified additional capacity.

48. Fertilizer imports have played an important role in the success of high-yielding variety programs to date. AID-financed fertilizers (about 3.4 million metric tons of fertilizer material in 1968) have been especially important to India, Pakistan, and South Vietnam. About 94 percent of AID-sponsored fertilizer in 1968 went to these three countries with 79 percent going to India alone.

49. High ocean freight rates, especially U.S. flag ships that cost two and one-half to three times as much as foreign flag ships, seriously influence the competitive position of the United States in the world market. (The Cargo Preference Act of 1954 requires that 50 percent of AID-financed purchases be shipped in U.S. flag ships if available.) In 1968 ocean freight costs were over 50 percent of the f.o.b. value of the fertilizer. These high rates have been overcome somewhat by shipping higher analysis fertilizers where available. Still greater savings might be possible if some means were found to finance and ship the ultra high-analysis intermediates, such as anhydrous ammonia, urea-ammonia solutions, phosphoric acid, and elemental phosphorus. This would further encourage those countries that do not have basic raw materials to base their industry on low cost intermediates, thus greatly reducing their capital investment requirement.

50. To keep the green revolution moving, additional loans undoubtedly will be required for fertilizers and other inputs. Care should be taken that these loans are not detrimental to normal trade or to the marketing of domestically produced fertilizers. These loans should be made normally to help countries to produce their basic food supplies. Once a country is able to export grains it should be able to obtain their fertilizers and other inputs on a barter basis or from foreign exchange generated from this trade.

III. PESTICIDES

51. When man creates ideal conditions for the multiplication of pests, he must also create efficient means for combatting them. Introduction of the high-yielding varieties and the associated use of fertilizers and improved water control have altered the environment. Increasing the vegetation as well as extending the time that vegetation covers the ground, plus improving the fertility and soil moisture may favor not only the crop being grown but also weeds, insects, disease,nematodes, parasite predators, birds, rodents, and other pests. Unless methods of control are available and used the advantages of other inputs may not be fully realized.

52. It appears that the use of high-yielding varieties of wheat has not led to substantially increased requirement for plant protection chemicals, since the growing crop is not usually subjected to extensive insect damage. Small amounts of fungicides are used for treatment of seed before planting and increased stocks of wheat in storage will require larger supplies of materials and more equipment for fumigation.

53. In contrast, pesticides are an important part of the rice production package. The high-yielding varieties are susceptible to stem borer, gall midge, and leaf hoppers, and the use of pesticides is universally recommended in connection with them. With the advent of the new varieties the use of pesticides increased by 20 percent in The Philippines. In India some 9.7 million acres were treated for insect control in 1967-68.

54. Information on the use of pesticides on corn is not readily available. Spraying for the control of stalk borers in some of the African countries is highly recommended. Weed growth can be, and often is, stimulated by the addition of fertilizers and the weeds must be controlled either chemically or manually if optimum yields are to be obtained.

55. Herbicide use on rice and wheat is not now widely practiced. Growing the dwarf varieties under heavy fertilization will almost inevitably increase weed problems and the use of herbicides will become an economic necessity even in cheap labor situtations. Herbicides may also effect savings of other inputs. For example, to properly control weeds in rice it sometimes is necessary to maintain six to eight inches of flood water. When herbicides are used one to two inches of water is sufficient.

56. Estimates of pesticide use are based on projections made for acceptance of new and improved varieties of corn, wheat, and rice by 1975. The potential consumption appears in Tables 10 and 11.

57. In the countries studied, improved varieties could create a total demand for pesticides of as much as 71.6 million lbs. for corn, 28.0 million for wheat, and 818.2 million for rice. A more realistic estimate is that 40 percent of the goal set for wheat and rice and 50 percent of that for corn will be realized by 1975. This means that in the countries studied about 458.9 million lbs. of pesticides will be used as compared to a 917.8 million lbs. potential should all the land

suited for production of high-yielding varieties receive the proper treatment.

IV. MACHINERY

58. Perhaps the most controversial of the inputs associated with the high-yielding variety programs is machinery. The controversy arises because many people mistakenly equate all machinery inputs with labor saving. In fact, the purpose of the machinery introduced into the high-yielding variety programs has been to perform an essential job that would otherwise not get done, or to perform it faster or better. Labor saving, if any, has not been important.

59. To date, the lack of machinery has not seriously hampered the green revolution nor can the introduction of machinery be credited with much of the yield increase in the high-yielding variety programs in most of the countries covered by this study. The one main exception to this is the role that machinery has played in the phenomenal increase in wheat yields in Morocco. It appears that proper seedbed preparation is one of the most important--if not the most important--inputs under Moroccan conditions. Deep plowing that replaces traditional shallow plowing with a stick plow may over the short run double wheat yields. Overcoming this limiting factor is essential for any major increase in yield and the response of other inputs, such as improved varieties, fertilizers, pesticides, etc., can be greatly enhanced.

60. The semi-dwarf wheats are more sensitive to depth of planting than the traditional varieties, and the use of grain drills is therefore

more essential. Because of this fact, the introduction of new wheats into Turkey has led to the development of substantial local industry which manufacture grain drills copied from American models. Before corn yields can be improved, machinery that properly place and space corn seed will be necessary.

61. For those countries that have the possibility of multiple cropping on the same soil, probably the greatest contribution of mechanization is "timeliness." When one is trying to produce maximum yield from a given land area and available sunlight energy, anything that will speed up the removal of one crop and the rapid establishment of the next becomes very important. Thus, mechanization of harvesting as well as seedbed preparation is proving quite effective, even where labor is abundant. For those areas that do not have assured water, either from rainfall or from irrigation, one of the advantages of the new wheat and rice is their short growing period. The time saved is often sufficient to allow an additional crop, providing the grain can be harvested and the land prepared promptly.

62. Also, drying equipment that eliminates field drying in some cases may gain 10 days to two weeks in the establishment of the next crop, and permit the utilization of residual moisture that would otherwise be lost. Rapid harvest and artificial drying can also greatly reduce losses from weather, rodents, and birds. Shattering losses also may be greatly reduced.

63. Dryers are also proving particularly important where the new rice varieties are being grown. These varieties are not photo periodic and may mature before the end of the rainy season. Since they also are not subject to dormancy periods, the new grain will sprout unless it is promptly dried.

To overcome these conditions, India and South Vietnam are finding it necessary to introduce artificial dryers.

63. To increase in yield from the use of the new varieties gives farmers more grain than they can thresh by traditional methods. Here the use of threshing machines is becoming important. For example, it is estimated that 60 to 80 percent of the wheat in the Ludhiana District of India will be machine-threshed this year. Most of the machines to accomplished this are being made locally. In this same district many of the Persian wells are being replaced by tube wells pumped by electric motors or diesel engines. This provides a more adequate and a more dependable source of irrigation water.

64. Equipment to apply other inputs is also coming into the picture. Grain drills to assure proper depth of seeding have been mentioned. Knapsack sprayers to apply pesticides mechanically are necessary.

V. SEED PRODUCTION

65. Most of the new high-yielding varieties of grain had their origin foreign to the developing countries where they are being grown, although in some cases foreign varieties have been modified within the country of use.

66. The normal pattern of varietal spread to date has involved the inter-country movement of only small quantities of seedstock, which then is tested and multiplied within the importing country. This seems to be the way the new hybrid and synthetic varieties of corn have spread and generally the same has been true of rice--the one exception being that 2,000 tons of IR-8

seed moved from The Philippines to South Vietnam in 1968.

67. In contrast, the high-yielding varieties of wheat were introduced into several countries through massive imports (table 12). The 80,000 plus tons of seed shipped from Mexico to India, Pakistan, and Turkey during the 1966-67 and 1967-68 crop years was probably the largest inter-country movement of seed the world has ever known.

68. For the most part, spread of new varieties of wheat and rice within a country has taken place through farmer-to-farmer sales. This brings about rapid acceptance, but it is anticipated that varieties of these grains may have to be changed for best results as often as every four to five years. This may also be true of nonhybrid improved varieties of corn. Some organized method of doing this will be needed. It appears the major countries may be recognizing this and are creating governmental appartus to assure seed purity of established varieties and to increase and introduce supplies of new introductions. In India, the National Seed Corporation grows foundation and certified seed and, in addition, multiplies all promising selections prior to their formal release. In Turkey, seed increase of the 1,770 tons of Mexican plus 400 tons of U.S. varieties was handled by the State Seed Farm Directorate which largely carries out the multiplication through contracts with private growers. In Pakistan, the Department of Agriculture and the Agricultural Development Corporation both help serve these functions. Public sector control seems, so far, to be the method of serving these needs. Private sector participation is only beginning.

69. The solution for providing corn seed appears to be quite different. Generally, private firms seem best suited to provide the seed. This is especially true with corn hybrids. Continued annual markets are more assured because seeds should not be utilized more than one year to maintain uniformity

and top yields. On-farm production of hybrid seed and farmer-to-farmer seed exchanges are not possible. Private industry appears particularly well suited to serve this need.

70. In general, the procedures and organization that will be required for the maintenance of seeds seem to be evolving. In actual practice, however, their performance often leaves something to be desired. Additional technical assistance would seem to be indicated. AID has furnished consultants on seed propagation and regulations to a number of countries and now has five specialists from Mississippi State University working in India helping to develop and encourage a private sector seed industry.

71. Since the efficient use of fertilizers and pesticides is highly dependent on the use of high quality seed, AID support should be directed to insure the quality of this input. The potential demand for new seed will be high, as indicated in table 13.

VI. INTRODUCTION - WATER MANAGEMENT

72. The developing world has the basic natural resources of water, soil, climate, and labour, for abundant food production. High production results only when combinations of water, soil and crop management are adapted to local conditions and are skillfully applied by individual cultivators. High capital costs for irrigation and drainage works are rarely returned unless the water is well controlled and unless fertilizers, good seeds, and other appropriate cultural practices are also used. This principle of combined practices--of fitting the various practices together as adapted to each kind of soil--is the very cornerstone of any successful programme for water and soil conservation that gives efficient, sustained production at a high level.

VII WATER MANAGEMENT

73. The importance of adequate moisture in the life cycle of crop plants is well understood by agriculturists and irrigation engineers. If plants are to live and grow, there must a continuous passage of water through their roots and leaves. The World Food Problem Panel 1/ reports that of an estimated 7.85 billion acres of arable land 4.58 billion acres suffers from moisture deficiencies during all or part of the growing season. Most of the arable land suffering from moisture deficiency lies in the vast tropical and sub-tropical savannas and deserts where long or full-year growing seasons are available and where there are the greatest potentials for photosynthetic energy. The Panel states:

1/ President's Science Advisory Committee, The World Food Problem (The White House, May 1967).

> In Asia, a shift to increasing crop production by intensifying agriculture and using modern methods to improve annual yields on land under cultivation will be mandatory. Even in Latin America and Africa, the cost of clearing additional land may well make it more economical in many regions to concentrate on elevating yields rather than expanding cultivated areas.

74. Even where only single crops are grown, sporadic periods of drought during the growing season can make substantial inroads on production. The traumatic food shortages in India in 1966-67 testify to the impact of variable rainfall. When these occur, new and costly inputs of fertilizer, etc. may have been largely futile.

75. But moisture deficiency is only one aspect of water management. Almost as difficult are the problems of moisture excess. Widespread flooding, a continuous phenomenon in tropical rain forests, can occur anyplace but is particularly characteristic of the vast wet-dry savannas at the onset of the rainy season. Water excess occurred in the American Midwest a century ago and recurs now as waterlogging in arid irrigated regions and wherever too much rain prevents cultivation during certain periods of land preparation, planting and harvesting. Every farmer understands the importance of timeliness in cropping operations and American farmers particularly appreciate the importance of high-energy input and of mechanical means to assure critical operations at the right time. Excess moisture conditions can be controlled to a large degree by surface and subsurface drainage, as the success of agriculture in the U.S. Midwest testified; further, management of moisture by tillage and cropping practices has often been very effective in advanced countries.

76. In arid and sub-humid regions, problems of salinity are invariably associated with inadequate water management practices. Water logging resulting from poor drainage or excess irrigation concentrates salts in the soil root zone and evapotranspiration increases sodium ion concentrations. Most of the ancient productivity of the lower Tigris-Euphrates basin has been destroyed by salinity, and until reclamation based on ground water development both to provide drainage and augment water supplies became effective about 1964, land in the Indus Basin was going out of production due to waterlogging and salinity at the rate of between one hundred thousand and one hundred fifty thousand acres per year.

77. While one man, with his family and an ox, may till a piece of ground by himself, water management problems invariably require some kind of group action. Drainage cannot be accomplished if there is no way to pass through a neighbor's fields and construction of an irrigation canal or a diversion dam is usually impossible, except through group action. Frequently water management problems are massive. Unless large-scale actions are taken their solution is impossible. The larger these become, the more complex must be the organization.

78. When rainfall is insufficient a part or all of the time, it is necessary to pay particular attention to the conservation of the rainfall that is available, and where economical, to develop irrigation

for increasing crop production. In many of the LDCs, expensive dams and distribution systems have been built and at the present time are in operation. In others, the construction of dams and distribution systems are in progress or are being planned. Almost without exception, there has been insufficient effort to develop on-farm water management systems for efficient use of water. This involves leveling, farm ditching and irrigation structures. Drainage generally has been neglected. Information on when to irrigate, how much water to apply and when to apply the water has not received the attention that is necessary. Gains in crop yeilds made possible through irrigation are not being realized. In many cases irrigation serves only as some kind of insurance against drought. Insufficient effort has been made to capitalize on the tremendous production potential that is available through the proper use of irrigation water combined with fertilizer and good cultural management practices when used with high yielding varieties.

79. Nearly all countries have at least two organizations concerned with water--one responsible for water development and the other responsible for water and soil conservation. For example, in the U.S. the Bureau of Reclamation is connected with water development and the Department of Agriculture with soil and water conservation, and in Turkey, DSI is responsible for water development and Topraksu is responsible for soil water conservation. As a general rule, in the LDC's the Agency responsible for water development, has a staff of relatively well trained

civil engineers and receives a large portion of the country's resources[1/] for the development of irrigation works including dams, canals etc. The Agency responsible for water and soil conservation, usually has a relatively small budget and few, if any engineers. These engineers generally are not trained to supervise or carry out land leveling practices, contouring, terracing, irrigation lay-out, development of drainage systems etc. Furthermore the two agencies generally do not cooperate and neither one tends to work in the other's area of responsibility. Therefore, the inter-relation of water and soil receive little or no attention. Consequently, in nearly all of the developing countries, the problems associated with on farm water management, are not given adequate consideration in the national schemes relating to agriculture production. Likewise the universities and colleges seldom have educational or training programs in subject matters relating to these specific kinds of problems. Nor have the research centers and institutes been involved in research relating to these problems. Hence, they are few if any people available who are trained to work in this area.

80. The AID Missions have sent many people to U.S. universities for training in water and soil management. But this effort has not significantly affected the problem to date. Therefore it appears A.I.D. programs too have not given sufficient importance to water management in the developing countries. The recent survey and response by the Missions to querries concerning the green revolution make only casual reference to on-farm water management. The India report spends some time on certain aspects of water management in the general text, but does not include them in the major summary comments of the document. Most of

---

1/ In Mexico for example - Freebarn - states that "Irrigation Investments have been over ninety percent all direct public investments in agriculture" (Freebarn, Donald K. - The Dichomany Prosperity and Poverty in Mexican Agriculture, Land and Economics, February 1969, pp.36)

the other countries either touch on them with a few sentences, or do not mention them as problems of importance. The lack of recognition of water management as fundamentally importanc t in crop production is not due to the fact that studies have not been made. In India for example, many studies have been made, all of which point out concisely and forcefully that these problems are among the most important to Indian Agriculture development.

81. A Study Team in 1967 concerned with Prospects For Turkish Agriculture found the lack of on-farm water management and conservation practices, in the short run second only to the introduction of high yielding wheat varieties, and probably the most important in the long run to Turkey's Agriculture's potential. India has made an effort to do something about this, even though it has been at very low level. The Soil Conservation Service now has some 13 people in India. Five are located in New Delhi at the national level giving advice to the Indian government, and two teams, four people each, are located in Mysore and one in Punjub. They are expecting to put another team at Utter Predash sometime this year. In terms of the over-all AID input and the importance of these problems to the Indian government, this is hardly measurable. In Turkey, there was an assignment of 3 USDA people to help train Turks and develop guidelines for solving these problems, but it is understood that their tour is to be terminated in the near future. In the Turkey study referred to above, it was estimated by the Study Team that it would take 200 teams, 4 men each, about 15 years to develop adequate on farm water and conservation practices. The training of this number of people is no small job. Each team would be giving advice and technical

assistance to the Turkish farmers. While India and Turkey are given as examples, the same situation and need occurs in practically every L.D.C. Over history there are examples of good water management in most if not all countries. But these are exceptions and not the rule.

VII WATER AND NEW VARIETIES

82. The countries which have successfully adopted the new varieties have all attempted to assure that plantings are concentrated on areas where they can be expected to be most profitable. In many cases, the availability of an adequate and assured supply of moisture during the growing season has been the most important single determinant in choice of location. For example, the 32,000 acres in India selected by the government for the high-yielding varieties program were chosen mainly on the basis of assured water supply. Generally the same inadequate on-farm water management practices were used. Even though significant increased yields were obtain they were much below the maximum potential of these new varieties.

83. An adequate supply of water may be based on either rainfall or irrigation. In both India and Pakistan the semi-dwarf wheats are nearly all produced on irrigated land. In Turkey only a small percentage of the new wheat area is irrigated. However, the winter rainfall in the Mediterranean and Agean regions is well-timed and sufficient for wheat production. In Morocco the rain season coincides with the growing season and wheat is irrigated only during abnormally dry years. In Mexico, 100% of the new varieties are grown on irrigated lands. For the most part, use of the new rice varieties has been restricted to irrigated lands, although some is being grown during the monsoon season in unirrigated areas which receive

heavy rainfall.

84. For both wheat and rice, the lack of assured water supply sets one of the limits for profitable expansion of acreage of the new varieties. Heavy expenditure for fertilizer involves too much risk if timely and adequate water is not assured, and, fertilizer may decrease crop yield in times of drought.

MAJOR PHYSICAL INPUTS - WITH EMPHASIS ON FERTILIZER AND WATER MANAGEMENT FOR CROP PRODUCTION

SUMMARY

1. The developing world has the basic resources of water, soil, climate and labour for abundant food production. High production and maximum economic returns results only when the right combinations of water, soil, crop management, good seeds, fertilizers, pesticides and other appropriate practices are used.

2. High-yielding varieties increase the potential for fertilizer use on grain crops by four to five times as compared to traditional varieties.

3. Short run demand for fertilizers are markedly increased. Long run demand to produce a given quantity of food may require less land permitting other crops that will also increase fertilizer demand.

4. Fertilizer prices to farmers are high. As much as $300 per ton of N, $260 per ton of P_2O_5, and $100 per ton of K_2O. To reduce these costs more efficient methods of transport and handling must be devised. Production costs in the developed areas in modern plants are already low in light of the worldwide overcapacity. Improving efficiency of plant output in the LDCs would lower costs.

5. Estimated rate of increase in fertilizer use in the subject countries for the years 1967-72 is generally between 12 and 20 percent compounded annually. Fertilizer use on cereals may exceed this.

6. Consideration of the best way to furnish the LDC's fertilizer needs should include importation of finished fertilizers, importation of intermediates produced in modern large scale production plants at low cost, and finally the manufacture of fertilizers in the LDCs from imported raw materials.

7. In general, a country should have demand to justify modern economically scaled production facilities before production from imported raw materials should be considered.

8. Intermediates might be a means of starting the domestic fertilizer industry at less demand and at less capital outlay. Importing of finished fertilizers should best serve the need from an economic as well as a foreign exchange position of the low fertilizer using countries.

9. Financing for fertilizer production facilities in countries that have adequate demand and favorable investment climate appears to be available from private sources and lending agencies. Direct loar of AID money for production facilities may generally be questioned. Other uses, such as improving efficiency of established capacity, improving parts and infrastructure, improving distribution and marketing systems, and furnishing fertilizers to "seed" markets may be a better use of limited AID funds.

10. Other inputs, especially machinery to speed up cultivation and harvest, special drills and seeders to place seed and fertilizer to improve yields, dryers to preserve the crop and to permit earlier harvest, and storage capacity to protect and preserve the increased yields should be encouraged. Mechanization should be aimed at improving yields and efficiency and not at reducing labor.

11. Pesticidies are an important component of the production package, especially for rice and corn. Wheat may not be so dependent. Fumigation materials will be important for storage. Herbicides are important for corn and will become more important for short-strawed varieties of wheat and rice.

12. Organization of seed certification and production organizations that can rapidly increase and introduce new varieties will be essential. Combinations of government agencies that maintain standards and purity and private producers may be the best solution.

13. For the forseeable future, some 60 to 80 percent of the world cultivated land in the LDC's must continue to depend upon natural precipitation. Most rainfall is seasonal and highly intensive resulting in considerable water run-off and resulting in serious flooding and sediment damage.

14. In rain-fed areas, increased in food production from 50 to 200 percent are possible, when improved water management practices such as contouring, terracing, fallowing and water spreading are used with other improved inputs. More attention should be given to water management on rain-fed areas.

15. Many of the countries have major ground water resources (Indus basin in Pakistan and India, the Indo-Gangetic Plain in India etc.), where tube well development has taken place during the past years. The real extent and dependability of these water resources while largely unknown, need to be studied and rapidly developed to their maximum economic sustained limit. Research and technical assistance in the proper use and management of water from these wells is an urgent need in most LDC's.

16. In much of the irrigated areas in the developing world the climate is suitable for year around farming. Two to three crops a year could be produced with the proper combination of fertilizer, good seed, soil and water. Thus making possible a three to five fold increases in crop production.

17. Waterloged soils and alkali conditions are developing in many irrigated projects of the LDC's, particularly in large areas of India and Pakistan. The Adana area of Turkey, it's most productive land, is now beginning to show symptoms of these problems. Knowledge and application of good water management practices and program for waste-water and rain disposal is imperative to the solution and prevention of these conditions.

18. Throughout the developing world essentially no research on the interrelationships of soil, water, and plants has been carried out. The Universities and Colleges of the LDC's provide practically no instructions or research in agriculture water management either in their engineering or agriculture courses. There is a tremendous need in all of the LDC's for an ever increasing ability to train, educate, conduct problem solving research and get results of the research into practice.

19. Water resources, water management and water conservation practices and research should receive equal importance and be coordinated with data pertaining to soils, fertilizer, seeds, pesticides and other agronomic practices if technical reports by Governments, AID missions and international technical groups are to be most useful in program analysis and effectiveness.