AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523
BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY
Batch 70

1. SUBJECT CLASSIFICATION
A. PRIMARY: Food production and nutrition — AF00-0000-0000
B. SECONDARY: Plant production

2. TITLE AND SUBTITLE
Crop indicator lines for agricultural research and production

3. AUTHOR(S)
Leininger,L.N.; Peterson,H.B.

4. DOCUMENT DATE: 1977
5. NUMBER OF PAGES: 16p.
6. ARC NUMBER: ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Utah State

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)

9. ABSTRACT
The worldwide cultivar testing trials conducted each year generate large amounts of information which is not transferable because it is time- and site-specific. This paper suggests a means of solving this problem. It proposes that a systems analysis technique be used to develop mathematical relationships for describing significant interactions among the components of crop production. These relationships would be synthesized into computer simulation models of various crops. The test plants employed would have known genetic sources. Different genotypes would need to be used, but those could be held to a minimum if widely adapted genotypes in each crop are identified, catalogued, and made available. This paper discusses such selection by using two major world crops, corn and soybeans which illustrate two major genetic systems in use for crop production: hybrids and pure lines. Such a consolidation of research efforts would assist in making it more possible to meet world food needs. The paper defines indicator lines, discusses types of indicator lines needed, the types available, the number of indicator lines needed, the use of open-pedigree stock, and the benefits of using indicator lines. One benefit of the proposed research system is that plant breeders and geneticists could predict the value of new genetic combinations without having to grow them in all possible environments.

10. CONTROL NUMBER: PN-AAE-487
11. PRICE OF DOCUMENT:

12. DESCRIPTORS
Environmental factors
Field tests
Indicators
Maize
Plant genetics
Research
Simulation
Soybeans
Systems analysis
Technology transfer

13. PROJECT NUMBER:
14. CONTRACT NUMBER: CSD-2459 211(d)
15. TYPE OF DOCUMENT:

AID 590-1 (4-74)

CROP INDICATOR LINES FOR AGRICULTURAL RESEARCH AND PRODUCTION

Paper developed under partial support from U.S. Agency for International Development under contract AID/csd-2459, and from Utah Agricultural Experiment Station. All reported opinions, conclusions, or recommendations are those of the authors and not those of the funding agency or the United States Government.

Department of Agricultural and Irrigation Engineering
Utah State University
Logan, Utah

CROP INDICATOR LINES FOR AGRICULTURAL RESEARCH AND PRODUCTION[1/]

L. N. Leininger and H. B. Peterson[2/]

INTRODUCTION

Annually many variety[3/] (cultivar) testing trials are conducted throughout the world. Most of these trials generate large amounts of information, but these data are time and site-specific, and hence not transferable. Insufficient plant and sight characterization information is collected systematically in order for the data to have broad utility away from the test site. Previous and current research rational dictates that the only solution to selecting crops and genotypes for any area is through a blanket screening of all genetic material available. This is done in hopes that, by chance, some genotype of a crop will exhibit superior adaptability to the test area.

When field trials are properly designed and the necessary detailed data collected on water, temperature, rediation, soils and crop development, physical and biological models can be used to make the information transferable to many environments. Since large expenditures of time and money are required to conduct the numerous yield trials throughout the world, data transferability would be profitable.

[1/] Paper developed under partial support from U.S. Agency for International Development under contract AID-csd-2459 and from the Agricultural and Irrigation Engineering Department, Utah State University, Logan, Utah 84322.

[2/] Research Collaboratory and Professor, Agricultural and Irrigation Engineering Department, Utah State University, Logan, Utah 84322.

[3/] Underlined words, when they appear for the first time in the text are defined in the glossary, except for words that are normally italicized.

It is proposed that a system analysis technique be used in order to develop appropriate mathematical relationships describing significant interactions among the components of crop production. These relationships are to be synthesized into computer simulation models of the various crops, tested with field data, then utilized as an aid in technology transfer. In the process, significant contributions will be made in directing continuing agricultural research programs as well as organizing available data into a more retrievable format.

All disciplines of agricultural research can use some of the benefits related in this paper that can be generated by the use of test plants of known genetic source. These benefits can be enhanced further by using genetic material for research which is as similar as possible worldwide over[4/]. Obviously, different genotypes will be necessary considering the diversity of the world's climates and soils, but the diversity of genotypes used can be held to a minimum if widely adapted genotypes in each crop are identified, catalogued, and made available. Two things are paramount: (a) all agricultural research must identify the crop and species used in experiments and, (b) a species must be selected whose genetic background is known. This paper discusses such selection using two major world crops, corn and soybeans, since they illustrate two major genetic systems in use for crop production, hybrids and pure lines, respectively.

The greatest void in plant growth research data existing at the present time is in plant-environment interactions. This paper presents rationales for eliminating this void with a minimum of cost and time. Such a consolidation of research efforts would assist in making it possible to more nearly meet the world's food needs in the coming years.

[4/] The idea of selecting genotypes for research should not be confused with the principle of using two or more diverse genotypes as a hedge against environmental vagaries in crop production.

INDICATOR LINES DEFINED

Agricultural research needs at least one common element for continuity between tests conducted in different locations and in different years since each trial is, in reality, in a new environment. Even trials separated by relatively small units of time and space represent different environments and, therefore, need an element of control. Furthermore, biological organisms usually interact with the environment in such a complex manner that simple observations are inadequate to determine the precise reaction or interactions.

Variety testing is probably the most complex type of testing in regard to interaction with the environment. Each variety is a phenotypic expression which, in itself, is the result of the action and interaction of several hundred genes. When this complex organism is placed in a range of different environmental situations, the number of possible phenotypic expressions are enormous. Without a full monitoring of the test environment (2) and a complete set of phenologic data from planting to harvest (1), biological research has little hope of ever elucidating specific nuclear or cytoplasmic reaction to specific environmental properties. Even with as complete a set of environmental and phenologic data as possible, separating specific gene x environment interactions will be difficult; but an agricultural technology transfer system (1) with emphasis upon complete data seems to offer more hope for success than anything yet proposed.

As complex as the interaction of a genotype (variety) with its environment might be, some generalizations can be made. Some varieties are known (by past test performance) to be sensitive to small environmental changes and, therefore, are more adaptable to certain environmental niches. Other genotypes may show a good yield under widely different environments. These later types are said to possess homeostasis.

Some of the control genotypes used in international tests need the highest degree of homeostasis to cover the span of environmental change inherent for trials in temperate, sub-tropic, and tropic climatic zones.

These genotypes are the fundamental base by which all types of agricultural wide area testing can be related to each other, and are known as indicator lines. They can serve to tie a series of variety tests together, such as those for the ATTU project, or to serve as a common reference for separate research with emphasis on water, weather, or soil fertility. The basic difference between controls and indicator lines is not the purpose each serves, but rather, the extent to which the reference line is used to relate experimentation. Controls are used primarily by one or a few investigators; indicator lines can be used throughout all agricultural research to tie together the many unknown properties of the genotype by environment (G x E) interaction.

TYPES OF INDICATOR LINES NEEDED

Ideally, five types of genotypes would be most helpful in agricultural research. The first type would be the universal indicator lines with their broad range of adaptability or homeostasis. These would be lines capable of producing some level of economic yield at all test locations in each of the major climatic subdivisions (3). With a complete set of phenology, weather, soil, and water data, mature grain is not necessary on indicator lines. In fact, if the plant will reach the flowering stage before growth ceases, that line will be useful as an indicator since the remaining growth stages can be generated by reference to that line's growth at other test locations where a complete history is available. This property of being able to computarily complete the life cycle of a test plant applies to the following types of test genotypes as well.

A second useful genotype would be those lines that can be moved within a given latitudinal range with little change in phenotypic expression. These can be called area indicator lines since they tie together a region such as the corn belt. Regional indicators are relatively easier to find, but some lines are more adapted to such movement than others. A third type of lines that can be moved north or south but are more difficult to catalogue. Some of the lines are also capable of producing high yields when moved east-west. Lines of this

type show more reaction to edaphic changes than to climate, but perhaps these properties are inseparable since edaphic properties are a result of climate to a large extent. These lines could also be designated as regional indicator lines.

The fourth genotype that would be useful is one that responds in such a manner to make possible the separation of altitudinal effects. These types are not readily apparent at this stage of biological knowledge. However, as corn production is moved higher and further north, specific altitudinal indicator lines will be available. The fifth and last type of line is highly site-specific. These lines make possible the separation of the largest number of G x E interactions, since they constitute the largest number of selectively occurring genotypes. Each type has a specific reaction to a slight change in environment.

TYPES OF INDICATOR LINES AVAILABLE

Amassing data to select each desired genotype is a lengthy, tedious task, and it would take too long here to go into detail for the selection of each genotype. However, the rationale for the selection of one should be helpful in illustrating the process by which each line is chosen. For this purpose, Hibrido Honduras H-5 is selected for corn.

From the 1971-1972 IMAN[5/] tests, it was learned that H-5 was grown at 35 locations which included the tropics, the north and south subtropics, and a few temperate climates. These tests included planting dates for nearly every month of the year at some test sites, although most test locations with more than one planting date had only a winter and summer planting per site. Elevations ranged from sea level up to 2249 meters. With all this possible variation in environment, H-5 has the following yield record:

a. It yielded statistically highest in 78 percent of the tests, i.e., based upon probability factors, no other hybrid out yielded H-5 at one-half of the locations.

[5/] International Maize Adaptation Nursery conducted by CIMMYT (Centro Internacional de Mejoramiento de Maiz y Trigo), Mexico City.

b. H-5 yielded in the top half of all entries in 31 of the 35 tests, or at only 4 test locations H-5 was lower in recorded yield than the median entry, but never significantly lower statistically.

c. In 34 percent of the test locations, H-5 was either first or second in grain yield; when second, it was not statistically significantly lower in yield.

d. H-5 was highest in grain yield over all entries when averaged over all 35 test locations. Therefore, Hibrido Honduras H-5 would seem to fit the criteria as a universal indicator line.

Following this analysis with other lines from the IMAN tests, INIA H507 was selected. Among other candidates based upon similar data are INIA H-503, OK 34, Diacol H-253, ICA H-207, and ICA HS-209. Zapalote Chico-Oaxaca, selection 179, could be considered due to its early maturity and daylight insensitivity, but it is not a high yielding line. From the U.S.A. lines, A632 x A619 and Mo17 x N 28 are homeostatic and have inbreds from diverse genetic backgrounds.

For soybeans, a self pollinated crop, varieties such as Celland (III)[6/] Williams (III), Woodworth (III), Clark 63 (IV), Columbus (IV), and Forrest (V) have demonstrated the ability to yield well when grown in widely different environments (4). These should serve as universal indicator lines for soybean tests until new lines better suited for this purpose are formulated. As with corn, other lines appear to be more site-specific and can be used to differentiate environmental interaction, such as pest resistance, water utilization efficiency, and aluminum tolerance.

NUMBER OF INDICATOR LINES NEEDED

The number of indicator lines necessary to achieve a reasonable chance of furthering the information on the G x E interaction is speculative and depends upon the type of test being conducted. Enough

---

[6/] Roman numerals in parenthesis indicate maturity zones; the smaller the number, the earlier is maturity.

lines must be utilized so that elucidated gene effects can be verified by comparison in different gene combinations. Conversely, the number of lines needs to be restricted enough so that a thorough set of uniform notes can be recorded by the station scientific staff. Furthermore, the number may be limited by selection of a satisfactory statistical design to fit all or most of the expected indigenous plot variations at each of the various sites.

Each test within each agricultural research discipline has its own unique research design requirements. One of these requirements usually involves the selection of a test crop and at least one genotype within the selected crop. Thus, the number of indicator lines most appropriate for any one test depends upon the emphasis of the test, i.e., whether the differences to be emphasized are between varieties, weather variables, fertility elements, methods of water application, etc.

Variety tests involving most or all of the major climatic areas (3) will need several indicator lines to relate one test to another. Variety tests within a single climatic area will need only one indicator line to tie each test together, although more should be used if available. Thus, the wider the area involved in testing, the more indicator lines will be needed.

Other agricultural research can relate to any variety testing program by selecting a genotype which has been designated and used as an indicator line for specific crops, rather than one that is more readily available. For example, a water by fertilizer study is being designed. There are several crop species from which to choose, but it is desirous to choose one of practical value. Therefore, a crop is selected which is grown on most farms in that area. In selecting the variety or hybrid within the selected crop, a check should be made to find the genotypes designated as indicator lines for that crop. Table 1 lists suggested indicator lines that might be preferred in corn and soybeans at a given time.

If only one genotype is necessary for the experimental purpose and design, select the genotype most adapted to the area of the test. If two or more genotypes are needed, select indicator lines whenever possible. The first genotype selected should be the indicator line best

TABLE 1. Suggested Indicator Lines for Corn and Soybeans Listed in Order of Preference by Reference Climate.*

Typical Area	Reference Climate	Indicator Line Selection Priority					
		1st		2nd		3rd	
		Corn	Soybean	Corn	Soybean	Corn	Soybean
Manaus, Brazil	A_r	Hibrido Honduras H-5	Forrest	INIA H-507	Columbus	INIA H-503	Clark 63
Lajos, Puerto Rico	A_w	INIA H-507	Forrest	Hibrido Honduras H-5	Clark 63	INIA H-503	Williams
Calli, Colombia	D_{bs}	INIA H-507	Forrest	Hibrido Honduras H-5	Williams	INIA H-503	Clark 63
Weslaco, Texas	$C_a(B_s)$	Mo17 x N28	Forrest	Mo17 x B73	Columbus	A632 x A619	Clark 63
Stoneville, Mississippi	C_{af}	Mo17 x N28	Forrest	Mo17 x B73	Columbus	A632 x A619	Clark 63
Ames, Iowa	D_{caf}	A632 x A619	Williams	Mo17 x N28	Calland	B37 x B70	Woodworth
Ft. Collins Colorado	$D_{cb}(B_s)$	A632 x A619	Calland	W64A x SD15	Woodworth	B37 x B70	Williams

* The hybrids and varieties suggested here will change with the release of new genotypes in the immediate future.

adapted to the area of the test site. The next two genotypes selected should be indicator lines best adapted to an adjacent climatic area--one each adapted to a climatic area on either side of the first indicator selected. If no indicator lines are available but are known, select a genotype of open pedigree as close to an indicator line pedigree as possible.

By so doing, the information available for a released genotype is perpetually available. When genotype synthesis and testing is accompanied by a complete set of phenologic and environmental data, other areas of agricultural research will be able to select genotypes more nearly commensurate with their testing rationale.

USE OPEN PEDIGREE STOCK

All indicator lines, regardless of their adaptive properties, must have an open pedigree; therefore all crop entries in agricultural research can be traced genetically to a progenitor to aid in delineating genes or gene combinations in relation to specific environmental measurements. Variety tests conducted by state and federal government research workers in the U.S.A. are quite often open pedigree tests, but these receive only limited distribution in some crops. In corn, for example, open pedigree tests are not only of limited occurrence, but also of limited availability. The more widely distributed corn hybrid yield test results consist of entries mostly from commercial companies with a closed pedigree. Therefore, most corn yield test data has little value in studies on the G x E interaction. Since these same tests record few site characteristics or environmental data, they are of limited use to international agricultural research in general.

Variety tests and other agricultural research involving water, weather, fertilizer, pests, physiology, etc., in which a crop plant is used, will be most beneficial to all agriculture when one or more indicator lines with an open pedigree are used. Conversely, open pedigree variety tests will contribute the most information to agricultural research when all related environmental data are collected and recorded, such as specific site characteristics, temperature, and radiation occurring during the growing season, water and nutrient added, detailed

phenologic statement of plant growth, plant population, along with other applicable data. When all segments of agricultural research discover this simple relationship between each research discipline, all research activities will be intertwined and become available as additional information to resolve the G x E interaction.

BENEFITS FROM USE OF INDICATOR LINES

A universal use of indicator lines in a linked test system may introduce the use of such lines as comparative entities. Using these, plant breeders and geneticists can predict the possible value of new genetic combinations without having to grow them in all possible environments. By testing the new genotypes at a few test stations, say three, in a linked system, the likely adaptability could be predicted at the other locations. In other words, if a new genotype did not out perform the indicator lines at one or more test stations, its chances of doing so at any other environmental site could be closely predicted. The reason is its genetic constitution is known and those specific gene x environment interactions would be predictable.

This property would be of value in the improvement of both self- and cross pollinated crops. The limited amount of testing necessary when a bank of information is available on indicator lines would permit testing for adaptability to be carried out on many more genetic combinations with greater efficiency than is possible today. Consequently, more and better hybrids and varieties will be available for use at less cost.

Careful selection of lines plays a conspicuous role in the overall efficacy generated by any agricultural research endeavor. Genotypes can provide a measure of many possible in situ environments. Proper selection of hybrids and cultivars grown in tests that are fully monitored from beginning to end will lead to successful plant and yield modeling. As modeling becomes more and more accurate, the need to test all genotypes in all environments is reduced since a known genotype will have a predictable reaction with selected environments. When modeling reaches its expected high resolution, most genotype by environment testing can be eliminated; only verification tests will be needed.

SUMMARY

When fully developed, the knowledge available through the extensive use of indicator lines on the G x E interaction will be most useful to all areas of agricultural research and technology transfer. Since information will be available on specific genotypes and their expected reaction to a selected or manufactured environment, research findings on irrigation or drainage, fertilizers, herbicides, fungicides, insecticides, growth stimulators or retardants, or any other plant management tool will have a more precise resolution. Basic research will produce faster results since G x E interaction knowledge will make possible the selection of the genotypes most likely to fit and exhibit the *a priori* hypothesis.

Basic and applied research will be conducted with greater efficiency of time, talent, and funds since many nefarious hypotheses can be eliminated with or without the laborious testing and evaluation which is necessary today.

References

1. Keller, Jack and L. N. Leininger. 1975. An agricultural technology transfer system. Proceedings of a specialty conference conducted by the I & D Director. ASCE, Logan, Utah, August 13-15. pp. 57-65.

2. Leininger, L. N., and H. B. Peterson. 1975. Crop and genotype selection rationale for the ATTU (agricultural technology transformation and utilization) project. Utah State University and AID 211(d).

3. Shaw, R. H., and R. W. Hill. 1975. Reference climate sites for agricultural technology transfer. Utah State University and AID 211(d)-11.

4. Whigham, D. Keith. 1975. Performance of U.S. soybean varieties in the tropics and subtropics in 1973. INTSOY - Universities of Illinois and Puerto Rico cooperating with AID.

Glossary

Area indicator lines -indicator lines that are used to relate similar research material from tests located in a designated climatic area or zone.

ATTU - Utah State University Agricultural Technology Transfer and Utilization research project with a rationale applicable to all Agricultural research involving plants which characterizes the plant and itsenvironment to the fullest extent possible.

Closed pedigree - any variety of hybrid of privately known parentage, e.g., DeKalb XL 45 and Pioneer 3369 corn.

Control - a research unit which has the property of a high degree of repeatability, and whose physical properties are similar to other research units under investigation.

Cross pollinated - the pollination of a plant by pollen from a different plant of the same variety.

Daylight insensitivity - the property of plants to be unresponsive to the effect of light on floral initiation.

Genotype - the identifiable fundamental heredity constitution of a biological organism, i.e., it can be a variety, line, or hybrid.

Genotype by environment (G x E) interaction - the action of the various environmental components upon a variety and the reaction of that variety to these various environmental stimuli.

Homeostasis - the tendency of an organism to maintain within itself relatively stable conditions in reaction to varying environmental elements by means of its own regulatory mechanisms.

Hybrids - the first generation cross between two or more varieties, e.g., Iowa 939, Nebraska 801, Pioneer 3369, and DeKalb XL45 are hybrids of corn.

Inbred line - a relatively homozygous line produced by inbreeding and selection.

Indicator lines - genotypes of crops with the property of producing an economic unit of growth under widely varying and different environmental conditions.

Open pedigree - any variety or hybrid of publically known parentage, e.g., Amsoy soybeans, Iowa 939 corn.

Phenotype - the physical properties expressed by a plant due to the influence of its genetic constitution.

Plant growth and development model - an organized (inter-connected) set of equations which relate plant growth (phenology) progress to daily environmental conditions such as: maximum and minimum temperatures, solar radiation, soil moisture, and day length, among others.

Plant yield model - an additional set of equations coupled to the plant growth and development model which predicts seasonal yield as it may be influenced by a wide range of applicable environmental conditions.

Self pollinated - the pollination of a plant by pollen from the same plant.

Site-specific - an adjective which may be applied to a set of agricultural information, rules, or procedures which are explicit for a given environmental circumstance.

Universal indicator lines - indicator lines that are used to relate similar research material from tests located in widely different environmental conditions.

Variety - a genetic selection within a crop, which is capable of being reproduced in kind by its own seed, e.g., Amsoy, Clark, and Williams soybeans.