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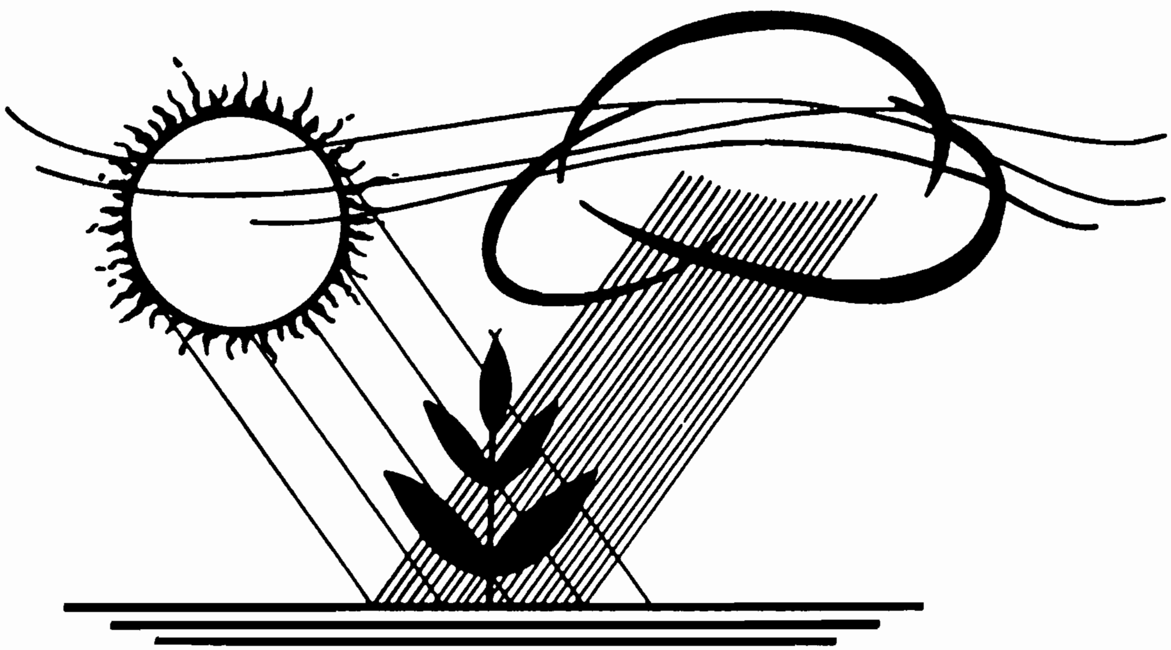

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CONFERENCE REPORTS

ROOTS

WATER MANAGEMENT AND IRRIGATION SYSTEM PERFORMANCE

PLANT NUTRITION AND SOIL FERTILITY

HAS REMOTE SENSING COME OF AGE?

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If this paper is to provide an adequate answer to the question that is posed in its title, we must begin by defining certain terms in the specific sense in which they will be used throughout the paper.

The term "remote sensing" as used here pertains not only to the acquisition of data (e.g. through the use of cameras, line scanners and other sensor systems, when operated from aircraft or spacecraft) but also to the analysis of such data in order to obtain desired information. In this paper it will be presumed that the information sought is that pertaining primarily to the vegetation and associated resources of agricultural lands. This narrowing of our focus is justified by the enormity of the overall field that is encompassed by remote sensing and by the fact that the session of which this paper is a part deals specifically with applications of remote sensing to "agronomy and natural resources".

We are all conversant with the concept of "coming of age" as applied to a person. Therefore, in order to clarify the term "to come of age" as applied to remote sensing, we may find it helpful to use the following analogy between our perception of a person and of a technology:

Our perception of a person (e.g. a teenager) over a lengthy period of time may eventually prompt us to proclaim that this person, whom we previously regarded as somewhat immature and unreliable, has at last "come of age". Because this person has undergone a gradual developmental process that has progressed beyond a certain point, we can henceforth have a high degree of confidence in his or her ability to perform important tasks consistently and in a very acceptable manner. Hence we can routinely regard this person in the future as one who can be beneficially employed in the solving of certain problems.

Similarly, our perception of a technology (e.g. remote sensing) over a lengthy period of time may prompt us eventually to proclaim that this technology, which we previously regarded as somewhat immature and unreliable, has at last "come of age". Because this technology has undergone a gradual developmental process that has progressed beyond a certain point, we can henceforth have a high degree of confidence in its ability to perform important tasks consistently and in a very acceptable manner. Hence we can routinely regard this technology in the future as one that can be benefically employed in the solving of certain problems.

The foregoing analogy highlights the fact that we need to answer two questions, when considering either a person or a technology, as we seek to determine whether or not it has "come of age". (1) Has it shown significant growth and improvement over the years, thereby reaching an adequate degree of maturity? (2) Is there, as a result, general acceptance and beneficial use of it at the present time?

Most of the remainder of this paper is devoted to the answering of these two questions with respect to modern remote sensing technology and with special reference to its usefulness in agronomy and closely related fields. It is to be emphasized, however, that even though a strong affirmative answer might be indicated with respect to these two questions (and therefore to the basic question, "has remote sensing come of age?") this does not preclude the possibility and desirability of bringing about still further improvements.

I. Has Remote Sensing Technology Shown Significant Growth and Improvement Over the Years, Thereby Reaching an Adequate Degree of Maturity?

From time to time, treatises have been written aimed at answering this question either directly or indirectly (American Society of Photogrammetry, 1952, 1960, 1975, 1983; Colwell, 1952, 1954, 1955). Collectively, they provide a highly impressive chronological list of improvements that have taken place over the years in our ability to acquire and analyze remote sensing data (See Table 1).

Whether from a mere reading of this list or from a critical delving into the significance of each achievement, the following answer to the question posed here seems warranted: Generally speaking, remote sensing technology has, indeed, shown a significant growth and improvement over the years, and thereby has now reached an adequate degree of maturity to permit it to be routinely and beneficially employed in the solving of certain problems. Within the limited context of this paper, remote sensing technology can be regarded as having reached an adequate degree of maturity only when it has repeatedly been demonstrated that farmers and other managers of agricultural resources can use it beneficially, and on a routine basis, for the inventory, monitoring and management of vegetation, soils, water, crop-damaging agents, etc. on agricultural lands. When these individuals are given such information in a timely manner, and with a sufficiently high degree of accuracy, there are now numerous instances in which it can be shown conclusively that they can and do manage agricultural crops and related resources far more efficiently than would otherwise be possible. A primary example of such use of modern remote sensing technology (of the many examples that might be cited) will be found in the paper that immediately follows mine, entitled, "Inventorying Lands and Estimating Crop Acreages from Landsat Imagery", by Sharon Wall. Numerous other examples are provided, in lantern slide form, in the oral presentation of this paper.

II. Is There General Acceptance and Successful Use of Remote Sensing at the Present Time in Those Aspects of Human Endeavor Where It Can Be Beneficially Applied?

The question here is not one of technology capability but of technology acceptance. Furthermore, the emphasis is on general acceptance rather than on the acceptance of a few highly successful and widely publicized uses of the technology. As it turns out, the answering of this question is more in the domain of a research sociologist than of a remote sensing scientist. One highly competent research sociologist who has addressed this question, and with specific reference to modern remtoe sensing technology is one of my colleagues at the University of California, Dr. Ida Hoos. Much of the material that appears in the remainder of this section is based on information contained in her various publications regarding this matter (Hoos, 1976, 1979a, 1979b).

In Table 2 I have attempted to categorize that information under five concepts that commonly are of importance in gaining the acceptance of almost any new technology. They are of particular relevance when the objective is to gain the general acceptance and beneficial use of remote sensing for the inventory, monitoring and management of agricultural resources.

If, in the light of Table 2, one reflects on the actual vs. potential uses of modern remote sensing technolgoy in agronomy and related fields, a few impressive examples come to mind in which it is being used routinely, and with great success. Further reflection suggests, however, that there are far more examples in which such technology could be used by these people but, as yet, is not being used by them. On the basis of this reflection, therefore, it seems that, overall, a negative answer must be given at the present time to the question posed above. That is to say: At the present time, in agronomy and related fields there is not a general acceptance and successful use of remote sensing in those aspects where it can be beneficially applied, a few well-publicized "success stories" notwithstanding.

III. Summary and Conclusion

In addressing itself to the question "has remote sensing come of age" this paper has considered two aspects, the first of which suggests a strong affirmative answer and the second, a qualified negative answer. Therefore, even allowing for the possibility of further improvement after "coming of age", we conclude that remote sensing has not fully come of age in agronomy and related fields and will not do so until there is a more general acceptance and use of it in these fields. One of the better ways to increase the acceptance of this technology is through the holding of symposia on the subject such as the one of which this paper is a part.

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TABLE 1. SOME HIGHLIGHTS IN THE EVOLUTION OF MODERN REMOTE SENSING TECHNOLOGY (With Special Reference to Agriculture and Related Fields)

1830-1850 Development of the first photographic processes and of the term "photography", meaning "to write with light".

1850-1890 Acquisition of the first aerial photographs, by using captive balloons, kites and homing pigeons as the camera platforms. Production of color photography from multiband black-and-white photos, using an "optical combiner".

1890-1910 Development of roll film (replacing glass plates) and of navigable, heavier-than-air vehicles. Patenting of the "radial line plot" process.

1910-1920 Under the impetus of World War I, improvement in the ability to acquire and analyze aerial photos. Documentation of the high accuracy of military photo interpretation.

1920-1930 Demonstration of the potential applicability of aerial photographic interpretation to the inventory, monitoring and management of natural resources.

1930-1940 Systematic acquisition of the first aerial photographic coverage of the United States. Demonstration of its usefulness in determining farm acreages and as a "road map". Total loss of appreciation in the U.S. of military photographic interpretation, but increased appreciation of it in Germany.

1940-1950 Under the impetus of World War II, rediscovery in the U.S. of the importance of military photo interpretation. Extensive recruitment, training and use of agriculturists and other civilian professionals for the performance of military photo interpretation, and subsequent transfer of this technology as they later returned to their civil pursuits. Development and use of improved aerial cameras. Use of spectral reflectance data in deriving "multiband tone signatures". Development and use of (1) natural color aerial photography (but with little success) and of (b) a color infrared film known as "camouflage detection film", used to detect foliage. (Exploited the unique "660 dip" and "880 blip" of healthy green vegetation). Development and successful use of photo interpretation keys, including the first dichotomous "two-branched" key.

1950-1960 Under impetus of the Korean War, establishment of the Interservice Committee on Photo Interpretation Research Keys and Techniques. Further development of photo interpretation keys for military and/or civil purposes. First use of infrared aerial photography for detecting diseases in plants. Outstanding performance of the International Training Center for Aerial Survey. Establishment of Commission VII (Photo Interpretation) of the International Society for Photogrammetry. Inclusion in the MANUAL OF PHOTOGRAMMETRY--SECOND EDITION, of a full chapter on "Photographic Interpretation for Civil Purposes". Early development of sensor systems for producing photo-like images in the ultraviolet, infrared and microwave spectral regions. Dawning of the space age, with the launching of Sputnik I in October, 1957. Publication of the first comprehensive book on photographic interpretation for civil purposes, viz. the prize-winning, 1000-page MANUAL OF PHOTOGRAPHIC INTERPRETATION. Establishment of the National Photographic Interpretation Center.

1960-1970 Coining and adoption of the term "remote sensing". Establishment of the NASA Earth Resources Survey Program and designation of its three "Remote Sensing Centers of Excellence" (Purdue; Univ. of Michigan; and Univ. of Calif., Berkeley). Establishment of NASA Remote Sensing Committees on (1) sensors, (2) disciplines and (3) geographic test sites. Acquisition of space photography and high altitude aerial photography of vast areas. Highly successful performance of the first multiband photographic experiment from space (SO 65) using photography acquired by the Apollo IX astronauts. Development of "crop calendars" and of the "multi" concept, including aspects dealing with the multiband, multidate and multistage acquisition of imagery, the multi-enhancement and multidisciplinary analysis of it, and the multithematic presentation of results obtained from it. Development of capability for making computer-assisted analyses of digital remote sensing data based on "scene brightness".

TABLE 1. SOME HIGHLIGHTS IN THE EVOLUTION OF MODERN REMOTE SENSING TECHNOLOGY (With Special Reference to Agriculture and Related Fields) (Concluded)

1970-1980 The "Landsat" era. First acquisition of near-global, highly uniform imagery from space. Extensive acquisition and use of "high flight" photography. First acquisition of radar imagery of a large cloud-infested area (Project RADAM). Implementation of two major agricultural remote sensing programs, viz. LACIE (Large Area Crop Inventory Experiment) and AgRISTARS (Agricultural and Resource Inventory Surveys Through Aerospace Remote Sensing). The making, by six campuses of the Univ. of Calif., of an "Integrated Analysis of Earth Resources in the State of California Using Remote Sensing Techniques". Publication of the MANUAL OF REMOTE SENSING--FIRST EDITION. First definitive analysis of "technology acceptance" in relation to remote sensing. Continued improvement in sensors and in digital data-analysis techniques.

1980-Present The "Space Shuttle" and "Thematic Mapper" era. Development of the capability for space vehicles to make graceful re-entries and landings (in contrast to the previous "splashdowns"). Major effort to transfer remote sensing initiative and funding from the federal government to the state and private sectors. Publication of the MANUAL OF REMOTE SENSING--SECOND EDITION. Implementation of the National High Altitude Photography (NHAP) Program.

TABLE 2. SOME CONSIDERATIONS INVOLVED IN GAINING THE GENERAL ACCEPTANCE AND BENEFICIAL USE OF MODERN REMOTE SENSING TECHNOLOGY

1. The Concept of "Appreciation vs. Adoption". In any given organization modern remote sensing technology has not been adopted until the following condition exists: The top level decision makers are sufficiently convinced of the potential usefulness of that technology for solving certain resource-related problems that (a) they routinely consider using it, as each resource inventory/monitoring/management problem arises, and (b) they then forthrightly direct that it be used in each appropriate instance.

2. The Concept of "Requirements for Adoption". If a particular aspect of modern remote sensing technology is to be adopted in any given instance, the decision maker needs to be convinced of its simplicity, direct applicability, continuing availability, and economy. In many instances, the timeliness with which the desired information can be obtained through its use is also a very important consideration.

3. The Concept of "Progression Toward Adoption". Remote sensing technology will not transfer itself. If the top level decision maker is to become convinced that he should actually adopt modern remote sensing technology, he ordinarily must progress toward that viewpoint through the following succession of steps: awareness, interest, evaluation, trial, and adoption.

4. The Concept of "Deterrents to Adoption". The primary deterrents to the adoption of modern remote sensing technology by an organization's top level decision makers are (a) Oversell, (resulting in the raising of user expectations to levels beyond what current capabilities can deliver); (b) Overkill, (as when the user is urged to use elaborate techniques of computer-assisted analysis when the desired information could have been derived quite adequately through the use of simple, inexpensive, manual interpretation techniques); (c) Undertraining (most commonly exemplified when a novice who has just completed an "appreciation" course in remote sensing is required to plunge directly into the demanding tasks that are involved in making operational use of modern remote sensing technology); (d) Underinvolvement (as when the user agency, plagued by a lack of qualified and/or motivated personnel, turns over the bulk of the work to consultants or others who lack familiarity with the user agency's resource problems, information needs, and perhaps even the resource itself); (e) Spurious Evaluation (as when the user agency, forced by higher authority or others into a "rush to judgment" produces premature, incomplete, incestually-validated, and overly-optimistic appraisals), (f) Misapplication (resulting in part from the sheer glamour of the shiny new tool known as remote sensing, and perhaps best metaphorized by the saying "give a small boy a hammer, and he soon discovers that everything needs pounding"), and (g) the "Not-Invented-Here" syndrome (exemplified by the reluctance of a top-level executive to admit that some other person or organization came up with a great idea, before he or his organization did).

5. The "Maintenance of Momentum" Concept. Too often a resource manager or his boss is given only a superficial exposure to the marvels of modern remote sensing technology through an "appreciation" type of course from which he graduates with great enthusiasm. Almost always there is no follow-up to ensure that his organization will begin to put this technology to practical use. Consequently, only a short time later he likely will have lost all of the momentum that had been instilled in him during the course. The key to solving this problem often is as follows: By prior arrangement, each attendee brings with him to the course a specific unsolved resource-inventory/management problem of importance to his organization. Also by prior communication with the instructional staff for the course, he brings with him (or the staff procures for him) the Landsat MSS or TM data tapes and/or aerial photography covering his problem area. During the concluding phases of the course, under supervision of the staff, he applies to this specific problem the data-enhancement and data-analysis techniques that have been dealt with earlier in the course. In this way he leaves the course having "solved" the problem. Almost invariably he can scarcely wait to field check his analyses, refine and correct them as necessary and then implement the management measures that are dictated by such analyses. From this success he can then progress to additional remote sensing-related problems. Thus his momentum is maintained. If procedural manuals and technical assistance also are made available to the recent attendee of the course these can be factors which will aid him still further in maintaining this momentum, once he encounters difficult remote sensing-related projects while on the job.

INVENTORYING IRRIGATED LAND AND CROP ACREAGE FROM LANDSAT

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The level terrain, productive soils, well developed irrigation system and long growing season have combined with California's innovative farmers to make the state the most productive in the U.S. A University of California task force studying agriculture in the 1980's as a competitor for resources projected that, of the essential inputs for farming--including water, land, energy and labor--"water will be the most scarce during the next decade (if not longer) and is most likely to limit food and fiber production in the state" (Univ. Calif., 1978). Currently, the California Department of Water Resources (DWR) estimates that 9.9 million acres (3.8 million ha) are irrigated at least once during the growing season. Agriculture is the prime recipient of the available water in the state utilizing about 85% of the developed supply (DWR, 1974).

Given agriculture's importance to California's economy and it's overwhelming total demand for water, DWR has, since the late 1940's, been performing a continuing survey to monitor land use changes as input to state water planning. Approximately one-seventh of the state is mapped during a given year with 35mm color aerial photography supplemented with field inspections. Recognizing the limitations of an area-limited, single-date survey system, DWR has been cooperating with the National Aeronautics and Space Administration (NASA) and the University of California (UC) in addressing the applicability of Landsat (an earth orbiting resource observation satellite) imagery and computer compatible digital data to aid water management decision-making. These decisions are based partly on information that a Landsat-aided inventory system should be able to provide: (1) the proportion of the total area of the state that is irrigated in a given year, and (2) the distribution and area of specific crop types.

Irrigated Lands Estimation - Manual Analysis

A procedure for the estimation of irrigated land using full-frame, simulated color infrared Landsat imagery and a sample of ground data was demonstrated statewide in 1979. Relatively inexpensive manual (human as opposed to computer) interpretation of three dates of Landsat enlargements was used to produce a map of land irrigated at least once during the growing season. Maps of irrigated land based on a ground survey of 1 x 5 mile sample segments allocated over ten hydrologic basins in the state were also obtained. The Landsat and ground maps were then linked by regression equations to enable precise estimation of irrigated land area by county, basin and statewide.

Land irrigated at least once in California during 1979 was estimated to be 9.86 million acres, with an expected error of less than 1.75% at the 99% level of confidence. This figure was within one-half of one percent of a corresponding acreage estimate developed by DWR. Most hydrologic basin acreage estimates were within 2 to 6.5 percent of the true values 95 times out of 100. To achieve the same level of error with a <u>ground-only</u> sample would have required a minimum of 3 to 5 times as many sample segments statewide and cost 1.5 to 2.5 times that of a corresponding <u>Landsat-ground</u> system.

The Landsat-ground estimation procedure was designed to complement the current DWR mapping program described earlier. The Landsat system's role is to enable inexpensive, <u>statewide</u> estimation of land irrigated in a given year, broken down by county and basin. As such, the Landsat procedure represents a new capability for obtaining near-real time data on changes in agricultural water use throughout the state.

Irrigated Lands Estimation - Digital Analysis

A technique for computer classification of irrigated land has also been developed. Classification results are based on a "vegetation indicator' which is derived from Landsat digital data. The vegetation indicator is calculated by ratioing spectral reflectance values from the red and near-infrared bands of the electromagnetic spectrum as received by the satellite. For each of the dates used, a ratio value (called a "threshold"), above which land is labelled as irrigated and below which as not irrigated, is set by an analyst while viewing the area on a television monitor. Repeated tests by U.C. and NASA using the digital data and ground sample segments have shown that in those agricultural areas that are fairly large, well organized and contiguous (for example, the Central Valley and the Imperial Valley) the computer-aided classification technique performs approximately the same as the manual analysis procedure. One advantage of using the computer-aided technique where it performs in a cost-effective manner is that the data is in a form suitable for manipulation with computer-driven geographic information systems.

Crop Type Analyses

Ultimately, DWR as well as agricultural agencies such as the California Crop and Livestock Reporting Service (USDA) would like to use Landsat data as an operational tool in producing estimates and maps of specific crop types. Pilot tests conducted over sites in Sutter, Kern and Fresno counties were promising and showed that when a crop occupied greater than 10% of the area crop type labelling accuracies were generally 85 to 97 percent correct. Currently, a cooperative agreement among USDA, Statistical Reporting Service, DWR, NASA, U.C. Berkeley and the California Department of Food and Agriculture is researching the complex issues surrounding the utilization of satellite data in the diverse California agricultural environment. The major topics being addressed include: (1) classification and labelling methodologies--testing well-used algorithms against newly developed and potentially less expensive techniques, (2) statistical sampling questions involving stratification and sample allocation (for classification/labelling as well as area estimation), (3) the definition and production of useful maps, (4) the development of relatively low cost microcomputer based image analysis and display systems for agency use, and (5) the organization of a mutually beneficial relationship between DWR and USDA's California Crop and Livestock Reporting Service to support the use of satellite data. The development of techniques as well as large-areal tests taking place over the next several years should help answer many of the questions that are pressing today.

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LOW ALTITUDE AERIAL PHOTOGRAPHY FOR AGRICULTURAL MANAGEMENT

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Large format (23 x 23 cm) aerial photography has been used for more than half a century for mapping, engineering, and large scale projects in agriculture, forestry, and mineral exploration. But small format (35 and 70 mm) aerial photography has been slow to catch on as a routine tool for soil and crop management on individual farms (Flowerday, 1982). Reasons for this include the high cost of obtaining photography from established mapping firms, lack of aerial photographers prepared to specialize in small agricultural jobs, and a dearth of information on how to interpret aerial photos for farm management. But aerial photography need not be expensive when compared to other inputs in crop production. Most of the photos shown with this presentation were taken with 35 mm cameras from a moderate performance, two or four seat single engine airplane. Depending on scale and coverage, per-acre costs for farm photography can range from a few cents to a few dollars per acre. If the information gained from the photos contributes to improved soil or irrigation management, pest control, or crop planning, the returns can far outweigh the costs.

The advantages of aerial photography in crop production are (1) the overall perspective of entire fields at one glance, (2) repeated coverage within a season or from year to year, and (3) the use of color infrared film to enhance visible differences.

The overall perspective allows one to see the interior of a field easily and on an equal basis with the edges. Patterns of non-uniform growth which may not be visible from the pickup window while driving around the field are easily seen on an aerial photo. The photo gives a better idea of the size and shape of problem areas and may convince the grower that the problem needs remedial attention.

The use of 35mm cameras and relatively inexpensive airplanes makes it easy to obtain photos on short notice. Critical timing and repeated coverage may be necessary to intercept pest infestations or to monitor irrigation effects. For other purposes, photos once a year may be sufficient.

Color infrared film gives one the increased ability to make distinctions between healthy and unhealthy vegetation. This is probably largely due to the fact that the film has more contrast than color film, and small differences in visible color are enhanced on the infrared film. It is not very often that one observes a difference due solely to the fact that infrared film is recording plant reflectance that the eye cannot see.

AERIAL PHOTO EXAMPLES OF CROP PROBLEMS

The following problems were illustrated by slides at the California Plant and Soil Conference.

Soil texture and waterholding capacity differences

Soil differences, and their effects on crop water availability, are perhaps the most frequent cause of plant growth differences within individual fields (Wildman, 1982). Timely aerial photography can readily detect these kinds of differences, and can be used to help define management changes necessary to improve the plant condition. For example, just before harvest grapes on one side of a vineyard growing on sandy loam soil tested 26% sugar, while those on the other side in clay loam soil tested only 18%. Aerial photos showed that vines on the low waterholding capacity sandy loam were defoliating, while those on the clay loam had full green foliage. In later years, the crop maturity was made more uniform by changing irrigation management to supplement the vines on the low waterholding capacity soils.

In another case, a claypan soil supporting alfalfa was photographed to aid soil investigation prior to planting vineyard. On the basis of the photo and soil examination pits, the land was deep ripped to improve the uniformity of root depth for grapevines. An aerial photo taken nine years later shows that the resulting vineyard has much more uniform growth than did the alfalfa preceding it.

Irrigation problems and management

Irrigation problems are often very evident on aerial photos. Uneven distribution of water can occur for a variety of reasons, and shows up either as a soil moisture difference or a crop growth difference. In one case, a photo of contour check irrigation taken when the lower portions of the checks were still wet emphasized the non-uniform distribution of water by that system. In another case, a full section alfalfa field was irrigated from one end in one mile long border checks. The color photo suggested lesser growth in low spots along the runs, but the infrared photo gave a much more accurate picture of the areas of poor growth. The problem was phytophthora root rot aggravated by wet soil conditions. Shorter and steeper runs would alleviate the problem.

Center pivot systems seem particularly susceptible to uneven water distribution. In one interesting photo a wedge-shaped section of better growth extended from the center to each of the four corners of the field. More water was applied to the corners because the main sprinkler arm slowed down at each corner to compensate for lowered line pressure as water was provided to the swing arm in the corner. Adjustment of the timer on the main arm was needed to make water application more uniform.

Drainage problems

Poorly drained areas usually depress or kill a crop. In citrus orchards in a San Joaquin Valley area, water tables rose after reservoir water replaced pumped water. Mature citrus and olive trees were killed in the lowest areas, and afflicted in varying degrees in other places. Color infrared film particularly shows gradations from bright red healthy trees through purplish sick trees to blue-gray dead trees. The area obviously needs tile drainage.

Salinity

Partially reclaimed fields of cotton and alfalfa show striking patterns of excellent crop growth immediately adjacent to areas so saline that no growth at all occurs. The differences are related to the ability to leach salts through soils of varying texture or depth over restricting subsoil layers.

Nutrient deficiencies and fertilizer problems

Nitrogen deficiencies and excesses are evident from the air every year on fields that have been unevenly fertilized by aerial or ground application. A wheat field in Madera County was unevenly fertilized because the pilot flew too low to get the proper spreading, and the flagman advanced to far at one point. In the color infrared photo under-fertilized grain appears blue, properly fertilized grain is red, and over-fertilized, lodged grain shows a pink color.

Iron chlorosis in pear trees is a continuing problem in fine-textured, calcareous soils with seasonal high water tables in Lake County. Severely stricken trees show up as yellow on a color aerial photo, but are almost pure white on color infrared. The greater contrast between dark soil, healthy red trees, and unhealthy white trees makes detection of iron chlorosis much easier with the infrared film.

Disease and insect detection

Routine aerial photography for pest and disease detection has not advanced as fast, at least in agriculture, as the early champions of the technology had predicted. Part of the reason lies in the critical timing necessary to catch a transcient infestation in time to effect a treatment. Much more research needs to be done to develop specific interpretations of aerial photos for pest management. Nevertheless, diagnosing infestations of phylloxera insects and monitoring their annual rate of spread in vineyards is proving to be useful in planning the orderly removal and replanting of vines on phylloxera resistant rootstocks. Aerial photos from 1978 to 1981 in a Napa Valley vineyard showed an annual increase of 255% in vines stunted or killed by the insect (Wildman et al. 1983). Now that phylloxera has invaded the new vineyards of the Salinas Valley, experience gained in Napa Valley is particularly useful (Wildman, 1984).

Slide set available

The slides shown with this presentation are part of a larger set developed by the author. The set is No. 83-102 and is entitled "Color Infrared Aerial Photography for Agricultural Management". It is available for loan or purchase from Visual Media, University of California, Davis, CA 95616.

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USE OF RADAR IMAGERS FOR VEGETATION AND SOIL STUDIES

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Many vegetation resource managers have used aerial photography and Landsat Multispectral Scanner System (MSS) images to aid them in mapping and assessing crops, forests, and other vegetation. To expand the capabilities of remote sensors, scientists have studied visible- and infrared-region sensors that have higher spectral and spatial resolutions than those of photography or of the MSS. More recently, however, they have considered radar sensors that respond to different plant and soil characteristics than those of visible and infrared sensors. This overview presents the state of radar remote sensing for plant and soil surveys as compared to visible and infrared sensors.

Visible and Infrared Remote Sensing

The most familiar form of remote sensing is human vision in which one senses a scene with visible light reflected from scene objects. We identify scene objects by their spectral (brightness and color) and spatial (texture, shape, size, shadow, and location) characteristics. A closely related form of remote sensing is panchromatic and ordinary color photography in which, with photographic films, we make permanent images similar to those that we see with our eyes and brain. With these that we obtain from aerial platforms, we can use the same spectral and spatial characteristics that we use with human vision to identify scene objects. Also, we can quantify the areal distribution and size of objects through photogrammetry and cartography (Avery, 1977).

With special films and filters, we can extend our perceptions to regions beyond the visible into the near infrared (NIR). The most common form of extended remote sensing is color infrared (CIR) photography. Another is the multiband sensing by the MSS.

With either of these, we can use NIR brightnesses and their associated spatial characteristics to enhance our knowledge of plant and soil types and of their condition. Healthy green leaves exhibit large NIR reflectances and low red-light reflectances. Bare soils exhibit lower NIR reflectances and higher red-light reflectances (Swain and Davis, 1978). These fundamental properties have led scientists to develop extensive uses for CIR or MSS images for plant and soil surveys (Avery, 1977). For one to discriminate different plants from each other, one requires that the subject plant objects have distinctly different green leaf area indices (GLAI) at the time of sensing. The visible and NIR reflectances of soils are a function of soil type, organic matter content, and surface soil moisture condition (Swain and Davis, 1978). For the MSS data, scientists have developed mathematical transformations that define features such as the green vegetation index (GVI) or soil brightness index (SBI) that they can use to discriminate plants or soils in a more robust fashion than with the raw MSS data (Kauth and Thomas, 1976). Since different plants may have similar GVI on a given date, scientists have used the sensor's ability to monitor growth and senescence of plants through the growing season to form a basis for identification (Badhwar et al., 1982). This requires multidate data sets that are registered spatially with each other.

Problems with Visible and Infrared Remote Sensing

Even with these extended remote sensors and analysis techniques, users have encountered significant problems. First, these sensors must have clear skies and daylight. This is a problem in many regions where clouds are present at critical times. Also, clouds can interfere with the ability of the sensors to collect a reasonable sequence of multidate data for multidate feature extraction. Second, even with adequate cloud-free data sets, one may find that some plants appear the same throughout the season. Examples of these are the small grains, corn and sorghum, and some types of similar deciduous and coniferous trees. Third, with CIR or the MSS, one can not detect changes in some desired plant conditions such as plant water content or changes in plant structure that are related to plant stress.

To address the limitations of CIR and the MSS, scientists are considering other visible and infrared sensors and radar sensors. I will only discuss the radar sensors.

Radar Remote Sensors

As demonstrated by the Seasat Synthetic Aperture Radar (SAR) in 1978 and the Shuttle Imaging Radar (SIR-A) in 1981, engineers can produce high spatial resolution radar images of Earth scenes from spacecraft platforms (Ford et al., 1980 and 1983). These images have an appearance similar to that of panchromatic photography in that they represent only one wavelength band. In the future (with the SIR-B in 1984 and SIR-C in 1986), radar sensors will acquire radar images with two or more combinations of wavelength, sensor look angle, and/or polarization combination. Thus, one will be able to form color images of radar data and will be able to analyze radar data as multichannel data. Multidate radar data will probably be available in the 1990's.

Radars present several advantages or differences with respect to visible and infrared sensors. Radars penetrate clouds and produce their own illumination so one can use them day or night, with or without cloud cover. With longer wavelengths and sensor look angles near nadir (but, not less than 15 degrees from the nadir since one can not form SAR images for these angles), radar waves penetrate some vegetation canopies to view the underlying soils. Radars respond to canopy water-containing elements and their sizes and orientations, not just to green leaves as do visible and infrared sensors. In fact, in some cases, the primary sources of backscattering in canopies are the trunks, stalks, stems, and branches of plants as opposed to the leaves (Ulaby et al., 1982). Some scientists have found that radar backscattering continues to change with increasing plant biomass even when the GLAI is greater than 8, a condition that led to saturation of visible and infrared reflectances of some vegetation canopies. Different approaches yield different results. With two or more polarization combinations, one can isolate characteristics related to plant-part orientations (Paris, 1983). Also, with the use two or more sensor viewing angles, one can isolate plant and soil background characteristics. In addition, with two or more wavelengths, one can isolate characteristics related to plant part sizes. With respect to soil properties, radars respond to changes in surface soil moisture content and surface roughness. When combined with visible and infrared sensing, radar can add significant capabilities for monitoring vegetation type and condition and soil type and condition.

Problems with Radar Remote Sensors

At the present time, the major disadvantages of radar remote sensing are (1) the existence of high spatial variability in the brightness of radar images due to coherent interactions among backscattered waves, (2) the expense and excessively long time required for processing SAR data to produce iamges, and (3) the incomplete knowledge that we have of the precise information content of radar image data.

In time, these disadvantages should be overcome so that by the 1990's, vegetation resource managers will have the opportunity to use these data for their plant and soil survey needs.

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THERMAL INFRARED STUDIES OF SOILS

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Remotely sensed data in conjunction with environmental site variables have been used to characterize soil properties for soil survey for over 50 years. Since 1929 when the first soil survey was conducted with the aid of black-and-white panchromatic aerial photography, the advancing aerospace technology has continued to provide soil surveyors with an important tool for stratifying natural landscapes into soil taxonomic units [1,2]. The major regions of the electromagnetic spectrum used to conduct soil investigations range from the visible through the microwave. The visible-reflectance infrared region (0.4 µm - 2.5 µm) is used primarily in operational soil survey activities to characterize surface features which can be correlated to subsurface soil profile properties used to classify soil individuals. The regions encompassing the thermal infrared and microwave regions of the spectrum are used to detect emitted and backscattered radiation, respectively, for measuring specific soil properties critical to intensive agricultural and forestry operations. Most research has focused on estimating soil moisture and its availability in individual agricultural fields [3]. Little research has been conducted on the use of thermal infrared remote sensing for supporting soil survey operations in both agricultural and forested environments.

Two important properties which are estimated in every soil survey are soil moisture and soil temperature regimes [4]. These properties define critical soil profile properties both for the classification of soil units at various taxonomic categories and for the soil survey interpretations required for optimum vegetation management. Regional soil temperature and moisture regimes are often based on data extrapolated from a network of weather stations. In the West, this network is sparse and the climatic data vary widely over relatively small geographical areas. These two factors result in soil temperature and moisture regime boundaries which are too broad for formulating resource management alternatives on site-specific planning units. A source of spatial data that has been minimally exploited for stratifying landscapes into critical soil climate regimes is a multispectral record of reflected and emitted radiation detected by either an aircraft or spacecraft.

A sensor which holds great promise for detailed, synoptic, and repetitive acquisition of thermal infrared data is the Thematic Mapper (TM) on board the Landsat-4 spacecraft. The TM sensor detects reflected energy in six narrow bands in the visible and reflectance infrared region, and emitted energy in one broad band in the thermal infrared region of the spectrum. This energy is detected from a ground area of approximately 30 meters square (120 meters square for the thermal data) over a 185km swath every 16 days; and encodes this energy into 256 gray levels [5,6].

Our research objectives are to investigate the usefulness of TM thermal infrared data and other environmental site variables for stratifying agricultural and forested landscapes into specific soil climate regimes and for mapping areas suitable for site rehabilitation programs [7,8].

To accomplish these objectives ground data and low altitude aerial photography are collected coincident with the acquisition of spectral data from either the U-2 aircraft (TM simulated data) or the Landsat-4 spacecraft at study sites in the Central Valley and northern Sierra Nevada. Ground data collection includes: (1) sampling the soil surface for field and laboratory characterization of selected soil properties; (2) sampling the vegetation for documenting type, growth, stage, density, and condition of cover types and native vegetation, and (3) measuring environmental site variables such as elevation, slope inclination, slope aspect, wet and dry bulb temperature, and wind speed.

Results to date indicate that the data acquired by the TM6 thermal band is the highest quality thermal data acquired by an Earth orbiting land remote sensing satellite. This high quality is measured in terms of spectral resolution (10.42 - 11.66 μm), spatial resolution (170.0 μr IFOV; or 120 meters ground resolution) and radiometric resolution (NEΔT - 0.11^{o}K @ 300^{o}K). Photographic examples of these thermal data showing the discrimination of radiant temperature differences of both agricultural and forest cover types in relation to soil properties are presented. The actively growing crops and other features under high moisture conditions appear as dark tones on the imagery as a result of the low radiant temperature of the cover type at the time of the Landsat overpass. Conversely, those cover types with high radiant temperatures (dry, bare soil, deciduous orchard canopies) appear as light tones on the imagery. In forested areas, the high radiant temperatures of bare soil, dry meadows, rock outcrops, and mine tailings are easily discriminated on the TM thermal images. Dense forest canopies and wet meadows are represented in dark tones due to their relatively low radiant temperature resulting from the cooling effect of evapotranspiration. In addition, use of diurnal differences in the radiant temperature of surface features has also improved our ability to discriminate major soil and vegetation units. The effects of reduced surface litter cover and limited soil moisture are detectable and mappable on diurnal temperature difference and diurnal temperature sum images. Mapping these areas is needed for developing and implementing forest site rehabilitation programs.

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PUTTING IT ALL TOGETHER IN A GEOGRAPHIC INFORMATION SYSTEM

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There are many techniques available for analyzing remotely sensed data as we have already seen in this conference. We observed that ancillary data, such as surface observations, soil maps, and weather measurements, can be combined with remotely sensed data. Correlation of this information in an orderly format, such as that geographically arrayed by computer, is referred to as a data base.

Example of the use of a data base would be the combination of elevation data with Landsat data. In mountainous terrain, certain tree species exist within certain elevation ranges. Therefore, digital geographically oriented topographic data can be merged with Landsat data to separate species that appear similarly spectrally.

Data bases also permit more feasiblilty in the use of remote sensing data as well as ancillary data. Weismiller and his colleagues spacially registered Landsat data at a scale of 1:24,000 and overlayed this digitized township, watershed, and physiographic boundaries. This enabled separation of soil associations by three landscape positions. With this data base, one can also deliniate, by categories, the acres of soil and vegetation by slope and by watersheds. This greatly increases the accuracy of runoff estimates in watershed analysis.

With the addition of temporal remote sensing data and additional ancillary data, one could determine land cover by soil type, provide soil interpretations, determine erosion hazard areas, chart land use changes, and carry out a variety of applications. Some of these data base applications can be obtained without direct use of remote sensing data.

Geographic Information Systems

The correlation of remotely sensed data with other data or information in an orderly format involves the use of a data base. A data base can be a table of data such as soil chemical data, sales tax collection, deaths due to heart attacks, etc. To be most useful to remote sensing, a data base needs to have a geographic or locational attribute.

The development of data bases will ultimately lead to the need for geographic information systems. A geographic information system is a formal process for gathering, storing, analyzing and disseminating information about natural resources and social economic data. These type of systems are very expensive to establish but are extremely cost effective for planning, developing, managing, and conserving natural resources if one has the cooperation of some key agencies who originate the data.

Currently there are 24 states who have some type of geographic information systems for providing information on resources within the state (Mead, 1983). At least one state has discontinued the system while a few others are wondering why they got into it. On the other hand, there are some real success cases such as those found in Texas and Minnesota. It is not my intent to go into the pros and cons of a G.I.S. but to at least give a caution that while they are extremely useful, they also require interested people and financial resources to keep them operational.

Specific Applications

There are many different examples that one could illustrate the use made of remote sensing data with ancillary data. Sometimes, remote sensing may only play an indirect role. Recently, in Missouri, digitized soil maps for Butler County, Missouri were made on aerial photography at a scale of

1:24,000. We also digitized land ownership maps which were at a scale of 1:400. The ownership maps were overlayed on the soil maps in the computer as the assessor wanted a listing of parcels showing the acres of different soils and the assigned soil assessment grade for each soil.

The temporal aspect of Landsat and other remotely sensed data is also extremely useful in geographic information systems. In Missouri, if one compares Landsat scenes from 1982 or 1983 with scenes of five years previous to that, one can document the acres of pasture that have been plowed up in the northern part of the state and planted to soybeans. In Atchison County, Missouri, it was shown that 70% of the land area is now in row crop where estimates from five years earlier show less than 47% of the county in row crops. When one combines this information with soils data, and industry can quickly determine how much fertilizer and chemicals as well as seed need to be ordered within a trade area. Soil Conservation Service can look at the locational aspects of what soils now have soybeans grown on them and the need for conservation practices. In locating severely eroded areas in targeted counties, this can mean writing the most return for limited financial land and manpower resources.

Missouri's Department of Conservation can look at the same information and check the ratio of pasture areas to row crop in evaluating the survival of pheasants or observe the decrease of the deer population with change in timber area within the county. The point is that everyone sees a different use or makes a different interpretation of the same data. It is also important to note that accuracy of the classification result and the merger with other ancillary data calls for important financial decisions to be made by a variety of users.

Summary and Conclusion

Many applications of remote sensing depend upon the resource managers' access to information, correlation of this information with current ancillary data, the type of analytical equipment available, and the managers' training or that of their staff people in remote sensing. Using, understanding, and accepting this technology takes time, money, and patience.

The need for technology transfer in remote sensing is ever-increasing. Colleges and Universities, as well as state and federal agencies, are attempting to meet this need, and resource managers should not hesitate to seek assistance. Prototypes of second generation Landsat systems and operational uses will further be demonstrated for many disciplines during the coming decade even though we may have to rely on foreign sources. Remotely sensed data applied to natural resources, especially when combined with ancillary data, such as soil maps, topographic information, and watershed boundaries can be of enormous value to resource managers.

ADVENTURES IN NO-TILL, NORTHERN CALIFORNIA

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SISKIYOU COUNTY COOPERATIVE EXTENSION

No-Till farming in Northern California offers some advantages to our area farmers and ranchers: these are, (1) Reduced preparation time. (2) Avoid working rocky ground. (3) Save Moisture on shallow soils. (4) Avoid turning up new weed seeds. (5) Plant later in season. (6) Interseed exsisting stands, pastures, and alfalfa.

In northern California the no-till drill was originally brought in for dryland range seedings and dryland wheat. By the end of the first season the drill had been used on 700 plus acres that varied from range, pastures, alfalfa, oats and turnips.

No-till was used to interseed pastures that had inadequate stands of either grasses or legumes. The pasture seedings were successful in some seedings and others were a complete flop.

The range seedings that received a treatment of one pint Roundup + 6oz. X-77, in 10 gpa water were good. A range seeding that had broadleaf weeds received 2,4D at 1/2 lb./A in 10 gpa water, essentially failed.

The irrigated pastures had a varied response. Growers that irrigated properly got a good take of legumes, but the grasses did not have the ability to withstand the exsisting competition.

In one case the clover was so competitive that the grass did not have a chance.

One of the crowning achievements was a 90 acre dryland seeding of alfalfa. The field had been in alfalfa for years. It was seeded to grain one year and then reseeded to alfalfa. This seeding failed.

The stand that was seeded in 1982 had old plants anywhere from one foot apart to several feet. The field was sprayed with one pint Roundup + 8oz. x 77 at 15 gpa. The stand was an outstanding success with a 2.75 ton first cutting in 1983. At no time did we observe stand thinning from the old plants.

The no-till observation that Daniel Drake and I have made results in a list do's for success.

1. Weed control with an adequate rate of Roundup is mandatory.
2. Do not seed when the soil is too wet or soil will glaze over on sides of opening.
3. Do not cover the openings with soil.
4. Do not seed too early as no-till soil temperatures are too low.
5. Use a low rate of Roundup to set permanent pastures back for interseeding.
6. You can seed later with no-till with weed control because you do not lose the soil moisture with tillage.

CONSERVATION TILLAGE IN DRYLAND SEEDING

Nick G. Pappas (1)
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Russell M. Christensen (3)

Conservation tillage is happening in the Sacramento Valley and a cooperative effort between growers, ASCS, SCS, and Cooperative Extension is making it happen. This report will deal specifically with Tehama County. Three things brought this about; first there was already experience with the equipment and winter cereals, second was the proper equipment availability in the area, and third was a cost sharing program through ASCS. The cost sharing program of ASCS was the incentive to get growers to try this new practice.

Winter cereals were chosen for the initial test for several reasons. The major reasons were start of the ASCS program shortly before planting time, the equipment was available and adaptable and there was experience planting winter cereals with this equipment.

Winter cereals are normally planted from the first of October through mid-December, water being supplied by winter rains until spring. If insufficient rains occur in the spring, which often happens, grain does not fill properly and yield is reduced. Fertilizer for dryland cereals is usually 50 to 80 pounds per acre of nitrogen. A small amount of a phosphorous fertilizer is often added when seed is drilled in. Early weeds are controlled by normal preplant cultivation. Later germinating weeds are controlled in late winter by post emergent materials. An application of nitrogen may be made in late winter. Harvest time is early June.

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It was decided to try and establish many smaller, varied tests to gain as much practical knowledge as possible in one winter crop season. The idea was to develop general guidelines so growers could make use of the practice and fine tune the system in coming years. It was felt this would be the method most useful and meaningful to local growers likely to stimulate the program.

Seven separate tests were setup and monitored from planting to harvest. All were dryland. Three were wheat following wheat, two were oats following oats, one was oats on grazing land and one was a winter forage mix following the same. All were planted with a Duncan Multi-seeder drill supplied by a local dealer.

Conditions ranged from very little to excessive straw, soil fairly dry to wet, and moderate to high amounts of nitrogen in the drill with and without phosphorous. Primarily there was no cultivation but in one test the whole was field disked once and another a portion chiseled prior to drilling.

One of the major problems that occurred in some tests was not enough time to apply preplant herbicide for existing weeds. It was evident from these tests that existing weeds must be controlled at planting time. In some cases competition was severe.

Some other problems involved wet soil and wet straw. In wet soil the sides of the seed trench were slickened by the double disk openers and seed was not covered, significantly reducing germination. Wet straw was not cut by the coulter but stuffed into the seed trench and seed dropped on top of the straw, also significantly reducing germination. Excessive straw was also a problem, such as windrows from harvesters without spreaders. Harvesters with straw choppers and spreaders are strongly recommended for minimum or no-till planting. Where yield comparisons of tests could be observed, only one wheat field had an estimated reduction.

Enough knowledge was gained during the past season to develop some general guidelines for growers using minimum and no-till planting in this area. In coming years as minimum and no-till plantings increase more testing will be necessary to develop more precise information and guidelines.

PRODUCING NO-TILL GRAIN SORGHUM UNDER IRRIGATION

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Minimum tillage is a farming practice that has become quite popular during the last decade outside of California. Growers and researchers have found that crop residues not plowed protect topsoil from water and wind erosion. In addition, minimum tillage farming uses less fuel and labor. Soils are improved from less compaction and increased organic matter. Water infiltration and storage may also be increased. The grower can receive many of these benefits, often without reducing yields.

The terms 'minimum tillage' or 'reduced tillage' are fairly new words for farmers involved with irrigated agriculture in California. However, this is not a completely new practice for them. Field operations are often eliminated to save time and lower production costs. This is especially true when double cropping. One example of this is the burning of wheat or barley stubble prior to double cropping corn, grain sorghum or blackeyes. Without burning, it would require at least 3 extra discings, delay planting, and often briefly tie up nitrogen for the next crop.

Conventional sorghum plantings use 6-12 lbs of seed on 30-40 inch row spacings or 12-25 lbs per acre drilled. Under irrigated conditions as the distance between rows decrease, yields generally increase. A plant population of 100,000 plants per acre is usually optimum.

An experiment was conducted during 1982 to evaluate different seeding rates of grain sorghum under no-till conditions. Seed rates evaluated were 9, 14, and 18 lbs per acre. Plot size was 70' by 1320' and was replicated 4 times.

The grain sorghum variety, NC+161, was planted following a 3 ton/A wheat crop. The 4½ tons of wheat straw left behind was not burned nor was the field prepared in any way. A 9½ foot Duncan 734 no-till seeder with disc openers spaced 6 inches apart was used to plant through the heavy straw accumulation into the hard, dry soil. The planter is much heavier than a conventional drill. Its wheels can be hydraulically raised so that the entire weight of the planter is over the triple disc openers for maximum penetration. The drill was easily pulled with a 65 h.p. tractor at 4-5 m.p.h.

The planter cut through the straw and into the soil leaving the seed at a depth from 0-1½ inches. The biggest problem planting was the driver's inability to see clearly the prior pass. Pulling a drag or disk marker might have eliminated the overlaps and skips. Planting on beds would have alleviated this problem also. Wheat straw that bunched in windrows also affected planting performance. Levees had to be reshaped after planting because the heavy planter, with wheels up, destroyed them.

The sorghum was irrigated up. The straw prevented crusting and weed competition but also delayed emergence and inhibited early plant growth. Plant emergence ranged between 52-67%. This is about 25-35% lower than what would be expected with pre-irrigation and conventional planting. A straw chopper used when harvesting the prior wheat crop would have facilitated planting and emergence.

Approximately 20-45 units of nitrogen as NH_3 were applied with each irrigation except the first, resulting in a total of 178 units of nitrogen. The sorghum showed nitrogen deficiency symptoms during the early part of the crop season, undoubtedly lowering yields somewhat. The first application of nitrogen should have been run in the first irrigation.

Sorghum plots were harvested December 20, 1983, about 3 weeks later than normal. This was due partly to delayed emergence and also because a late maturing variety was used.

The 18 lbs/A seeding rate produced the highest yield in this trial (table 1) at 4,059 lbs/A. This yield was about 0.3 ton less than the grower normally expects to receive.

The grower sold his sorghum at $90 per ton. The 0.3 ton yield reduction with no-till resulted in a loss of $27 per acre; however, there were no land preparation or cultivation costs. Land preparation, including labor and equipment, cost $36 per acre. Cultivating 3 times would have cost $23 per acre. Seed costs at 18 lbs/A would be about $4 higher with no-till if compared to a commonly used 12 lb seeding rate for conventional planting. The no-till planting method saved $55 per acre. Subtracting the $27 due to the loss in yield, the no-till method netted $28 more per acre than the grower's conventional sorhum planting. However, with sorghum at $90 per ton, the grower lost money with both methods of planting but lost less with no-till.

Table 1. Yield Results for Different Seeding Rates of No-till Grain Sorghum

Treatment Seed Rate Lbs/A	Plants/A	Plant Emergence %	Yield @ 14% Lbs/A	Bu. Wt. Lbs	Harvest Moisture %
9	71,327	52%	2,951	48.0	21.0
14	137,089	67%	3,088	47.8	19.4
18	158,840	59%	4,059	47.6	18.1
*33	---	--	3,464	46.3	22.4
LSD .05			325	N.S.	N.S.

* The 33 lb seeding rate was not replicated but was the rate used for the remainder of the field.

Role of Irrigation Scheduling in Efficient Water Use

by

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Since the ultimate objective of irrigation is crop production, irrigation efficiency for our purposes is defined in terms closely associated with crop yield as an output. Many studies have shown that seasonal total evapotranspiration (ET) meets this criterion when used in the sense that water supply is the limiting factor in crop yield. Thus, irrigation efficiency can be defined as the ratio of the seasonal quantities

$$\frac{\text{ET}}{\text{Applied water.}}$$

Efficiency of irrigation can be assessed at different levels. For our purposes, we need to consider only two — the farm level and the basin level. Basin level irrigation efficiencies are higher than on-farm efficiencies because of recycling — possibly high enough in California that effective water savings potential is rather small.

Increasing on-farm irrigation efficiency is still important because of recycling costs, energy conservation, and water quality degradation during multiple use.

Crop plants in general have a given total ET requirement. Provided with less there usually is reduction in yield; any excess applied is wasted. To meet the requirement closely means that the first requisite of efficient irrigation is accurate scheduling.

Rational irrigation schedules are based on either water balance (budget) or on soil water monitoring. Both have advantages and disadvantages in widespread use.

Rational irrigation schedules are vital, but they must be implemented to be effective. In practice there are limitations stemming from the farm water supply — either in timing of delivery or in quantity available — or from irrigation systems employed. Thus, scheduling assistance must be supplemented with help in overcoming these limitations if efficient on-farm irrigation is to be a general reality.

Most aspects of irrigation management are site-specific with considerable variation within a field and vary in time as well. Highly efficient irrigation demands knowledgeable and intensive management. Much remains to be done in providing education, information, services, and some additional research. The efforts of the entire agricultural community, both private and public, are needed.

DIAGNOSIS AND MANAGEMENT OF WATER INFILTRATION PROBLEMS IN CALIFORNIA SOILS

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A recent survey of California farm advisers indicated that over 2.5 million acres of irrigated land had slower water infiltration than was considered desirable. Slow water infiltration may result in longer irrigation time, or additional irrigations. If a suitable irrigation management program is not developed, yield may be reduced due to water stress, and for permanent tree and vine crops, health, and long term vigor and productivity of the plants may be reduced. Ponded water, due to application rates in excess of infiltration may cause increases in disease or death of sensitive trees and vines. On sloping ground, ponded water will runoff, causing erosion. These ultimately add to the cost of production. This paper discusses the causes of slow soil water infiltration and some management strategies for avoiding, reducing, or ameliorating the problem.

Water flows through soil pores as it does through a pipe. The major differences being that soil pores vary greatly in size, tortuosity, and continuity. Large pores transmit water rapidly. Few pores are straight. Rather, they bend and twist around the solid soil matrix. This tortuosity slows the movement of water. Pores tend not to be long continuous tubes. When they are, water is transmitted rapidly. In most soils, many pores are "dead ends" or are connected to other pores by narrow passages. The sizes, tortuosity, and continuity of pores is determined by natural soil forming factors and by management.

Accumulation of clay and of cementing substances such as silica, iron, and calcium carbonate plugs pores and reduces water flow. Clay (B_t) pans, si-cemented duripans, Fe-cemented ortsteins, and carbonate-cemented petrocalcic horizons are products of pedogenic processes. These horizons have very slow water transmission rates because the pores are small and/or filled with clay or cementing material. Such horizons are found in well developed soil profiles throughout California.

Alternating layers of fine and coarse textured layers also reduce soil water flow. A clay rich horizon holds water tightly because the pores are small, and water will not flow freely into an underlying coarse textured horizon unless the soil is saturated. Such stratification is found in young alluvial soils.

Excessive traffic, or traffic over the soil when the soil is wet changes the arrangement of soil particles and reduces pore numbers and size of pores. The soil zone in which this occurs is called a traffic or tillage pan. These pans are common management induced problems throughout California. Surface sealing and crusting occurs when rainfall or irrigation water causes dispersion of clays and rearrangement of sand and silt particles, which plug pores in the surface few millimeters of the soil.

Low organic matter, poor aggregate stability, low content of shrink-swell clays, and sodium on the soil exchange complex are soil properties which predispose a soil to crust formation and compaction. It is impractical to manage soils to change their clay content or mineralogy. In arid and semi-arid areas of California it is difficult to increase soil organic matter through amendments. However, soil chemistry, particularly sodium content can be managed through appropriate applications of amendments.

Water penetration through clay pans, and hardpans, is improved by disrupting the limiting layer. Explosives, rippers, backhoes, and slip plows have been used for disruption. Properly spaced ripping or slip plowing improves water movement through soils. Water movement through stratified soils is improved by mixing or other disturbance of the stratification.

Management created layers are less easily ameliorated. Compacted layers may be disrupted in the same way as natural pans, but continued traffic will cause the compact layer to reform. Reduced traffic or lighter equipment are two possible solutions to the problem. Of particular importance is improved timing of operations. Equipment traffic on wet soils must be reduced or eliminated if compaction is to be reduced.

Crust formation can be reduced by improving aggregate stability, modifying the cation composition of the exchange complex, and protecting the soil from water drop impact. Organic matter and synthetic soil conditioners have been used to improve soil structure. Both work to some degree, but most synthetics are too expensive for general field use. Gypsum has been shown to improve water penetration by reducing clay swelling and dispersion. When applied to the soil surface it increases the infiltration rate. Straw is an effective mulch which absorbs energy from rainfall or sprinkler irrigation. It helps to reduce crusting from direct impact.

PRESENT AND FUTURE CHANGES AFFECTING FERTILIZER USE AND EFFICIENCY*

The manufacture, marketing, and use of fertilizers tend to undergo evolutionary change rather than the revolutionary adoption of new practices and technology. In the future, fertilizer production and fertilizer use will continue to rely on the same basic technology and materials now available. However, manufacture, analysis, and methods of distribution will be modified to meet changes in raw material costs and supply and customer preference.

For example, the expanding practice of reduced or minimum tillage which results in soil, water, and energy conservation may necessitate the modification of fertilizers and their methods of application to better suit this cultural practice. In California, drip irrigation is being adopted on high-value crops and in areas where water costs are high. This presents an effective and economical method of applying nutrients to a growing crop. Fertilizers for these systems are modified to make them highly acidic, thus avoiding the potential for precipitation of impurities in the drip lines. Other changes are occurring in response to the need to increase fertilizer efficiency, conserve energy and raw materials during manufacture, and reduce transportation and handling costs.

Nitrogen Receiving Much Effort

Much of the effort expended by engineers, agronomists, and others concerned with fertilizer use efficiency has been directed at nitrogen. Of the three major fertilizer elements, nitrogen is the one on which farmers spend the most dollars and it is also the one most mobile after it is applied to the soil. It can be

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either leached through the downward movement of water, or denitrified and lost to the atmosphere under flooded or anaerobic conditions, or lost as ammonia gas with some fertilizer materials.

Today, urea is the most widely used solid nitrogen material, and its use is expected to expand. The goal of much development work is to extend urea's versatility as a base for N-P solid and fluid fertilizers and to improve its efficiency under conditions conducive to nitrogen loss. By reacting urea and phosphoric acid, a relatively pure urea phosphate can be produced. This crystalline product can be used to make urea-ammonium polyphosphate solution, such as 17-28-0 containing more than 5 percent polyphosphate.

In urea phosphate, the phosphate portion is unneutralized; therefore, the product is very acidic. When applied to the soil, urea is hydrolyzed by the enzyme urease. This results in free ammonia which may be lost, particularly when urea is broadcast on the soil surface under conditions of neutral to high pH and high temperatures. By cogranulating urea and urea phosphate, the environment in the immediate vicinity of the granule tends to be acidic, resulting in reduced potential for ammonia loss. Reduced evolution of free ammonia also makes a cogranulated urea-urea phosphate material attractive for banding near or with seeds. This group of compounds may show particular promise in minimum-tillage situations where a once-through weed, feed, and seed operation would be advantageous. Under this tillage regime, placing fertilizer at or very near the seed would take advantage of urea phosphate's unique characteristic.

The process for producing straight urea is being modified and promises to substantially reduce the energy required for granulation. This process, termed the falling curtain process, can produce a wide range of granule sizes so that the granules can be more closely matched to usage. For example, size can be closely matched to that of diammonium phosphate and other materials used in bulk blending, resulting in less segregation of blends. By closely controlling the size of urea granules, it may be possible to provide a more uniform distribution from centrifugal spreaders, produce a wider swath, and decrease the amount of overlap in application--permitting further reduction in the energy required for application. The falling curtain process has the flexibility to produce a whole range of granule sizes; for example, a large marble-size material that may find wide use in the forestry trade or other uses.

Quality Phosphate Is an Issue

Major efforts are underway to assure the farmer of a continued supply of high-quality phosphate fertilizers, despite a declining raw material quality and increasing energy costs. The cornerstone of the phosphate industry is the production of wet-process phosphoric acid from phosphate rock and sulfuric acid. This phosphoric acid is the phosphate source for most of the fertilizer materials shown in table 1. The domestic use of these materials reveals that a high percentage of the phosphate fertilizers used in 1981 were used in mixtures of one form or another as shown in table 2. The pattern of use is not necessarily closely matched to the variety of products manufactured due to the strong influence that exports have on our domestic phosphate industry. Among the various phosphate materials produced in 1981, diammonium phosphate accounted for the largest share, around 48 percent.

Table 1. Share of Phosphate Material Supply in the United States, 1981

Material	Percent of Total P_2O_5
Triple superphosphate	14
Diammonium phosphate	48
Monoammonium phosphate	6
Ammoniation-granulation	15
Other dry products	5
Fluid products (solutions and suspensions)	12
Total	100

Source: Inorganic Fertilizer Materials and Related Products, Series M28B, Bureau of the Census, U.S. Department of Commerce, Washington, D.C., Annual and Monthly Reports, and TVA estimates.

Table 2. Use Pattern of Phosphate Fertilizers in the United States, 1981

Methods of Use	Percent of Total P_2O_5
Direct application materials	19
Dry mixtures	65
Ammoniation-granulation	17
Bulk blends	48
Fluid mixtures	16
Solutions	8
Suspensions	8

Source: Commercial Fertilizers (Consumption for Year Ended June 30, 1982), SpCr 7(11-82), U.S. Department of Agriculture, Crop Reporting Board, Statistical Reporting Service, Washington, D.C., November 1982, and TVA estimates.

Since 1950, the types of phosphate fertilizers in the marketplace have changed considerably because of the following factors:

1. Quest for higher analysis materials
2. Changes in process technology
3. Agronomic factors

Development of higher analysis materials appears to have hit a plateau with the development of monoammonium and diammonium phosphates for dry materials and ammonium polyphosphates for fluid materials. Superphosphoric acid and wet-process phosphoric acid may represent the natural upper limits for high-analysis inorganic liquid phosphate fertilizers. Changes in process technology need to be viewed within the context of developing a new class of products or of altering the manufacturing methods used to make the products we have today.

Wet-process acid plays a dominant role in the phosphorus fertilizer industry and will continue to play that role in the foreseeable future. The pattern of current and projected use, however, indicates that over 90 percent of the phosphate used in the U.S. for fertilizer is combined with nitrogen and/or potassium before use. This means that alternative routes of processing phosphate rock other than those where phosphoric acid is an intermediate are possible. A recurring theme along this line has been the nitric phosphate process. Because of the large quantities of sulfur required to produce phosphoric acid by the wet-process method, interest in the nitric phosphate process has been coinciding with the fluctuating prices of sulfur. Other factors having a bearing on this cycle include: the cost of energy, environmental problems and costs associated with phosphoric acid production, and possible modification of the nitric phosphate process that could make it competitive with the wet-process route.

As mentioned earlier, urea phosphate may have a bright future when cogranulated with urea to minimize possible nitrogen loss. Urea phosphate technology also provides a means of removing most of the impurities from wet-process phosphoric acid while preserving its content of latent chemical heat for possible use at a destination point. The costs of shipping and handling solids are usually less than the costs of shipping and handling liquids. Urea phosphates are suitable for making clear N-P liquids, for ammoniation-granulation products, and for producing liquids with high-polyphosphate content.

Recently, TVA developed and patented an energy-efficient process for producing ammonium polyphosphate fluid fertilizers from merchant-grade orthophosphoric acid. The nominal grade of the ammonium polyphosphate product made by this process is limited to 9-32-0 so that the fluid in process contains no crystals at 80°F. This allows the fluid to be cooled in conventional evaporative coolers which are the type commonly used in existing pipe reactor plants producing 10-34-0; thus, existing TVA pipe reactor plants can be modified to produce 9-32-0. The process involves feeding merchant-grade (53-54 percent P_2O_5) wet-process ortho-phosphosphoric acid and ammonia through separate heat exchangers which use heat generated in the process to preheat the feed acid and vaporize the ammonia. These preheated materials are then fed into an enlarged pipe reactor to produce an ammonium polyphosphate melt containing about 20 percent of its P_2O_5 as polyphosphate. The melt discharges into a reactor surge tank where water of formulation is added to produce the nominal 9-32-0 grade fluid. After the fluid passes through a cooler, 2 percent by weight of attapulgite-type clay is added. The clay suspends any ammonium phosphate crystals or impurities that might precipitate during low temperature or long-term storage and provides extra clay for cold blending 9-32-0 with other materials.

As the quality of phosphate ore continues to decline, the level of impurities in wet-process acid will increase. This may cause shifts in product mixes, but it is not likely that any new products will be made. The net effect of lower quality phosphate rock is the accumulation of a new commodity called sludge acid. The acid is created by allowing impurities in wet-process acid to settle out in holding tanks. The top layers are decanted off and shipped or used for making diammonium phosphate for the export market. Part of the sludge acid is being converted to monoammonium phosphate rather than to triple superphosphate. This trend is largely due to the higher cost of shipping P_2O_5 in triple superphosphate compared with the cost of shipping P_2O_5 in monoammonium and diammonium phosphates. Grades of monoammonium phosphate, following no set standard, are varying from 48 to 55 percent available P_2O_5. As the impurity level increases, the tendency toward monoammonium phosphate as a sump for this sludge acid will become entrenched, resulting in product with declining water solubility. The whole question of water solubility will need to be reevaluated since the water-insoluble constituents of the monoammonium phosphate made from sludge acid are not of the dicalcium phosphate type.

Conclusions

It does not appear that the fertilizer industry will see the introduction of large numbers of new products within the next 20 years. Modification of the present product mix will occur in response to the need to become more energy efficient in fertilizer production, to produce materials with the potential for improved agronomic efficiency, and to respond to declining supplies and quality of raw materials and to world trade factors as the industry responds more and more to the international marketplace.

PLANT BREEDERS AND THEIR ROLES IN EFFICIENT CROP PRODUCTION SYSTEMS

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The science and art of modern plant breeding as a recognized profession and its impact upon agriculture is widely recognized throughout the U.S. even though the profession will not celebrate its 100th birthday until the year 2000. This appreciation of the value of plant breeding as a means of obtaining new or improved plant forms takes on novel and different dimensions with each advance in any one of the many sciences that are regularly applied in plant breeding. Plant breeding today is a science made possible through the application of the body of knowledge from a rather large number of other basic plant and physical sciences. To be sure, the science of genetics is the central core of the scientific disciplines which the plant breeder employs. The body of knowledge that makes up each of the important basic sciences, as well as the most appropriate methods of application, is expanding so rapidly that breeding methods are in use only a few years before becoming obsolete. Likewise, breeders find the challenge of keeping abreast of new knowledge and developments a substantial demand on their time. In fact, plant breeding literature has become so voluminous and overwhelms most plant breeders if they try to keep abreast of all phases of it.

It has long been recognized that the primary purpose of plant breeding programs is to obtain or produce varieties, hybrids and/or clones that are efficient in their use of plant nutrients, give the greatest return of high-quality products per unit of area in relation to cost of production and that accommodate both the producer's and consumer's needs. Although most of our important food plants were domesticated and brought under cultivation centuries ago, there remains today virtually unlimited opportunities to improve and in many cases to substantially modify the characteristics of the varieties of plants available for agricultural uses. Traditionally, new varieties have not only had to be more productive but able to withstand extremes of temperature and/or soil moisture, attacks of pathogens and/or insects, and exhibit stability of performance.

Defining objectives of plant breeding programs has become more and more complicated mainly because more, as well as, a higher level of complex factors must be considered. Of the multitude of considerations in identifying objectives of plant breeding programs, the efficiency of the crop production system in which any new variety will be utilized is certainly at the forefront today.

Until recently plant breeders could develop a consensus regarding the optimum or ideal efficient crop production system for most crop species. This certainly is not the case today due principally to the wide differences of opinion about the effects and interactions of many of the production inputs and the wide-ranging philosophies about the whole ecosystem relative to agriculture. In addition, the farmers of today are not of one mind relative to the desired characteristics of new varieties. This is by way of pointing out that the plant breeder has a most formidable challenge in identifying what his client will want and need a few years hence.

Based upon the continually expanding impact of plant breeders and their products upon agricultural production over the period 1900 through 1983, it is certain that even more significant influence will be the circumstance during the remainder of this century. Concurrent with this larger direct involvement is an equal, but more subtle, concern of most professional plant breeders reference to the awareness of the dimensions of the responsibilities that are concommitant with the release of new varieties to consumers. Plant breeders' roles in crop production systems through the remainder of this century can be characterized as a further expansion of the solid base of performance evolved in the recent past. These roles can be divided into two general categories - (1) improving the efficiency of the land (soil) resource and (2) improved efficiency of production/use of non-land resources.

Improving the efficiency of land use through plant breeding will, for example, involve the development of new crop varieties more specifically adapted to less productive sites and take the form of increased animal carrying capacity rangeland species, shorter growing season corn hybrids, higher level of pest resistance, more stability of performance under variable moisture conditions and resistance to air pollutants to name a few.

Major progress will be forthcoming in the development of varieties specifically suited to problem soils such as high salt, aluminum tolerance and increased production in soils deficient or in excess of various minor elements. Plant breeding programs on crops commonly produced on highly productive soils and environments will undoubtedly continue to concentrate on higher yield per se with a major result being the reduction of land area necessary to produce the desired amount of the crop. At the same time the plant breeder will be directly involved in evolution of new systems for utilization of the land resources that become available and thus require a change in cropping patterns. This whole area of involvement will have far-reaching implications, such as, people interactions ranging from public policy decision makers to consumers and farmers. The multitude of areas of concern that must be considered, not the least of which is maintenance of a productive land resource, will require that the professional plant breeder become an active participant in as many dialogues as possible to assure that his forthcoming products meet the legitimate concerns of the time.

Increased efficiency of production or use of non-land resources will be characterized by new varieties that produce equal or superior yield or have increased value per unit plant material produced, all being made possible with decreased production inputs. A number of examples include: breeding for insect, disease or nematode resistance which would result in reduced pesticide use; quicker drydown in corn, sorghum or sunflower hybrid which results in decreased artificial drying costs; ameniability to machine harvest/direct seeding with reduced labor costs plus potential higher crop recovery; increased heterois/modified plant architecture with the result that the more competitive plants will grow faster with reduced cultivation, irrigation, herbicide costs and more successful no or low-till; higher quality forage species resulting in increased available nutrients per unit of forage; improved N_2 fixation/utilization on the part of the plant as well as the bacterium resulting in decreased N costs plus possibly increased crop quality (protein) and increased residual N for the succeeding crop in the rotation; manipulation of the plant-mycorrhizae association with increased phosphorous uptake resulting in reduced phosphorous fertilizer costs; lodging resistance through dwarfing or stiff stalks resulting in higher recovery of crop at harvest; manipulation of the harvest/index (weight of harvestable product/weight of total plant) resulting in improved utilization of all inputs; improvement of crop quality resulting in reduced amount of crop needed and thus resulting in improved overall efficiency.

It would be a major understatement to suggest that plant breeders will be alone in designing the crop plants that will be needed. Likewise, it would be foolhardy to assume that all attempts are going to meet with success. However, the plant breeder's role will most certainly require the best training and experience that our educational systems can provide in order that the successes will be even more numerous.

MOVEMENT OF NUTRIENT IONS THROUGH THE SOIL TO ROOTS

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It is now widely recognized that the absorption of some of the essential mineral nutrients by plants is limited by the movement of ions through the soil to roots. For example, even in well-fertilized, "good" agricultural soils, phosphate absorption is limited by factors controlling delivery to the roots rather than by the inherent capability of root cells to absorb this nutrient. This implies that the selection or breeding of cultivars with increased capacity for metabolic uptake of phosphate would not lead to a significant improvement in phosphate absorption by roots. For phosphate, maximum uptake by plants depends on the growth rate and surface area of the root systems (Barber and Silberbush, 1983) and on optimum symbiosis with soil-borne mycorrhizal fungi (Carling and Brown, 1982).

The delivery of nutrient ions to the root cortex is by the processes of simple diffusion and mass flow, and for certain ions by the intervention of mycorrhizal fungi (Clarkson and Hanson, 1980). The purpose of this paper is to describe these mechanisms and to identify which seems to be most important for the various essential mineral nutrients.

Simple Diffusion

Nutrients in the soil solution can move to roots from regions of higher concentration by the process of simple diffusion. The speed of this process varies for each nutrient ion, depending on its characteristic diffusion coefficient. For certain nutrients, this process is quite slow relative to the rate of absorption into root cells. This leads to the development of a depletion zone around roots where the concentration of some nutrients is very low compared to that in the soil solution just several millimeters away from the root. Among the various nutrients, phosphate, zinc, manganese, and copper have particularly low diffusion coefficients (Nye and Tinker, 1977).

Mass Flow

Nutrient ions may also move to roots with the mass flow of soil solution that occurs because of rainfall (or irrigation) and in response to water loss from plants by the process of transpiration. The nutritional significance of mass flow depends on the plant demand for a given nutrient, its concentration in the soil solution, and on the amount of convective water movement. In general, the process of mass flow can deliver sufficient quantities of nutrients like nitrogen, sulfur, calcium, and magnesium which occur in fairly high concentration in well-fertilized soils. For nutrients needed in high quantities but which occur in low concentrations in the soil solution (e.g., phosphate), delivery by mass flow is not sufficient to meet the nutritional needs of the plant (Clarkson and Hanson, 1980).

Mycorrhizal Fungi

Most crop species normally form a symbiotic association with soil-inhabiting, mycorrhizal fungi. In this symbiosis, the fungal hyphae extend from the soil to the root. This allows fungal-mediated delivery of certain relatively immobile mineral nutrients to the cell wall space of the root cortex. In return, the fungus gains access to organic nutrients (e.g., sugars, amino acids, and organic acids) produced by the plant. The result is that plants infected with mycorrhizal fungi usually grow much faster and larger than their nonmycorrhizal counter parts. The enhancement in plant growth is generally attributed to mycorrhizal-mediated delivery to roots of nutrients such as phosphate, zinc, manganese, and copper; that is, those nutrients which are not delivered to roots by diffusion and mass flow in quantities sufficient to meet the nutritional needs of the plant (Rhodes and Gerdemann, 1980).

The Essential Mineral Nutrients

There are thirteen mineral nutrients which are considered to be essential for the growth and development of most plant species. In well-fertilized soils, mass flow and diffusion are adequate to supply the plant demand for nitrogen, sulfur, chloride, calcium, magnesium, molybdenum, and boron. A well-developed mycorrhizal association can supply phosphorus, zinc, manganese, and copper. The demand for potassium and iron is adequately met by mass flow and simple diffusion if the plant has a vigorous and well-developed root system.

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EXOGENOUS HORMONE PRODUCTION IN SOIL-ROOT SYSTEMS

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Microbial production of plant growth regulating substances have been demonstrated in both culture media and soils. Researchers have reported microbial synthesis of auxins, gibberellins, cytokinins, trisporic acids and ethylene. Although the effects of exogenous hormones on plant growth have not been well established, stimulatory and inhibitory effects have been observed depending on the concentration of the hormones, microbial populations, uptake by plants, and the stage of plant development.

Until recently, identification of specific growth regulators produced by microorganisms has primarily been accomplished by using partition chromatography followed by a bioassay. The lack of specificity of these bioassays often yields results such as "auxin-derivatives" or "gibberellin-like" effects. High performance liquid chromatography (HPLC) provides a precise, sensitive, and a highly specific method for isolating these hormones with subsequent characterization by mass spectrometry (Frankenberger and Brunner, 1983).

Root exudates contain tryptophan and related compounds that act as precursors for the biosynthesis of indole-3-acetic acid (IAA). Microbial production of IAA in the root zone may provide an exogenous source of auxin affecting plant growth. Auxins in soil are believed to be produced by autochthonous microflora as they decompose carbonaceous materials. Typical concentrations of auxins in soil have been reported to range from 5 to 50 ug/g soil (Chandramohan and Mahadevon, 1968).

Gibberellins are isoprenoids, synthesized from mevalonic acid (Lynch, 1974). Over 35 similar GA_3-like substances are known to occur in plants. Gibberellins have been detected in a wide range of rhizosphere fungi, bacteria (most notably Azotobacter), and in blue-green algae (Darbyshire and Greaves, 1970). Jackson et al. (1964) reported that an exogenous source of gibberellin was taken up by tomato seedlings during the critical stage of development when vegetative and reproductive primordia differentiate. Tomato plants, however, are very sensitive to growth regulators and the same effect could not be reproduced on axenic barley seedings.

Cytokinins are aminopurines linked to phosphate esters of sugars to form nucleosides and nucleotides. They occur as tRNA bases in various species of plants, animals, and microbial cells. Free cytokinins have been reported to be synthesized by bacteria, fungi, algae and insects. Isopentyladenine (iP) is the most common form of cytokinin produced by micoorganisms. The micorrhizal fungus Rhizopogon roseolus, is thought to produce cytokinins since hypertrophy of root cortex cells, common to ectotrophic associations, resembles the hypertrophy that results when roots are treated with an exogenous source of kinetin (Miller, 1967).

Abscisic acid (ABA) has not yet been reported as a metabolite of soil microorganisms. Mucoraceous fungi produce trisporic acids during sexual reproduction which are structurally similar to ABA (Lynch, 1976). Although trisporic acids have ABA-like activity on seed germination and pea growth, they are fully conjugated molecules and extremely unstable. The breakdown products of trisporic acids are suggested to be responsible for this ABA-like activity (Lynch, 1976).

Ethylene is an olefin gas produced by plants, microorganisms, and free soil enzymes. Methionine is believed to be the major precursor for ethylene synthesis. Anaerobic soils are known to accumulate large quantities of ethylene. Values as high as 75 ppm have been recorded in the field (Smith and Dowdell, 1976). Several investigators believe that ethylene production in soil may be an important factor in causing injury to crops under waterlogged conditions.

Microbial produced plant growth regulators should be recognized in having a potential influence on plant growth and development. Plant response would be governed by the rate of hormone uptake, the active concentration of regulators in the rhizosphere and the modification of the plants own pool of growth regulators due to the addition of exogenous supplies. Futher studies are needed to investigate factors affecting production of plant growth regulators, their distribution and stability in soil, and their specific sources.

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ALLELOPATHY AND WEED MANAGEMENT:

THE POTENTIAL AT THE ROOT/SOIL INTERFACE

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A very important component of the aggressive nature of weeds is allelopathic interference, or the release of naturally produced plant toxins by the weed which can inhibit the growth of nearby crop plants or other weeds (Rice, 1979; Gliessman, 1983). Considerable research has been done in order to determine the mechanisms of release of such phytotoxins into the environment (Rice, 1979), with most work concentrating on the above-ground plant parts giving off chemical products through rain or fog wash, actively produced volatiles, or decay products from the breakdown of plant parts. Very little work has concentrated on the below-ground release of toxins from plant roots.

The purpose of this paper is to review the pertinent literature on allelopathy involving the release of toxins from roots and propose areas of future research on the subject. The possible role of allelopathy for weed management is also discussed.

Field Observations

Our studies have focused on determining which weeds are of major significance on the soils and with the crop systems commonly employed in the coastal Santa Cruz County region. From different crops planted at different times of the year, the following list of species commonly occur:

Table 1. List of weed species commonly occurring in crop systems in Santa Cruz County

Scientific Name	Common Name
Brassica campestris	wild mustard
Spergula arvensis	corn spurry/snake weed
Amaranthus retroflexus	red root pigweed
Chenopodium album	lambsquarters
Medicago polymorpha	California burclover
Sonchus oleracoous	milkthistle
Stelaria media	chickweed
Sillene gallica	catchfly
Montia perfoliata	milerslettuce
Avena fatua	wild oat
Bromus mollis	softchest brum
Sonchus spp.	sowthistle
Convolvulus arvensis	field bindweed
Erodium cicutarium	redstem filaree
Festuca spp.	fescue
Plantago lanceolata	plantain
Malva parviflora	cheeseweed
Polygonum aviculare	knotweed
Solanum tuberosum	potatoe
Anagallis arvensis	scarlet pinpernel
Taraxacum officinale	dandelion
Portulaca oleraceae	purslane
Solanum nodiflorum	black nightshade
Vicia spp.	vetch
Laminum unplexicale	henbit
Heterotheca grandiflora	telegraph plant
Amaranthus album	tumble pigweed
Euphorbia maculata	prostrate spurge

Allelopathy Trials

Most of our trials for allelopathy involved the collection of mature plant parts, which were then either tested fresh or dried in a convection oven at 50° C for 48 hours. Fresh material was soaked for 2 hours in distilled water, 1 part plant to 10 parts water. Dried material was soaked the same, but usually only 1 part plant to 20-30 parts water. The soak was filtered and used to irrigate a seed bed of quartz sand in petri dishes where seed of test species (crops or weeds) were planted. Distilled water was used as a control. Percent germination and initial radicle elongation were measured after 72 hours. Results of some of our trials are seen in Table 2.

Table 2. Percent radicle length of germinated seeds 72 hours after planting in extracts (10%) of several of more common weeds in vegetable crops in Santa Cruz County, California[a]

	Plantago lanceolata	Chenopodium album	Spergula arvensis	Raphanus sativa
Sweet corn (Golden Bantam)	57.5	35.3	64.1	72.4
Radish (White 252)	42.3	4.9	19.1	47.4
Lettuce (Great Lakes 118)	0	0	0	21.2
Alfalfa (Iroquois 513)	25.9	0	0	61.6
Oats (Johnny's 506)	16.8	3.1	3.0	6.8

[a]N = 30 for corn and oats. N = 45 for the others. Controls (100% response) planted in distilled water. All means significantly different from controls at 1% level.

Results and Discussion

The weeds present in agricultural systems of Santa Cruz County are representative of weeds which occur in annual cropping systems in many temperate regions of the world. Our bioassays are showing that chemical inhibition, or allelopathy, is one of several important mechanisms through which these weeds can interfere with crop development. Each weed expresses a different inhibitory potential, just as each crop shows a different degree of susceptibility. Experiments of allelopathic interactions between weeds themselves, as well as the effects of crops on weeds, offer possibilities for alternative weed management strategies. How much of these interactions take place at the root/soil interface is yet to be seen.

Conclusion

Allelopathy offers considerable potential for the design and application of weed management systems. As our knowledge of the intricacies of plant/plant chemical interactions becomes more complete, we will become better able to incorporate the chemical interactions of plants into weed control. Through a more thorough understanding of the ecological basis for plant dominance, especially where weeds are involved, we will become better able to incorporate such knowledge into agriculture. This is especially true as the economic and ecological limitations on weed control practices used currently in modern agriculture become more restrictive.

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INFILTRATION UNDER SURGE AND CONTINUOUS IRRIGATION

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Introduction

Soil serves a dual role of water conveyance and infiltration as water spreads across the field during surface irrigation and both factors contribute to nonuniformity of water distribution. In the first case, time is required for the advancing front to travel the field length (advance time) hence, during advance, opportunity time for water to infiltrate at the inflow point is greater than at points downstream. Nonuniformity of opportunity time translates into nonuniform water distribution. Unequal opportunity time has long been recognized as a cause of nonuniformity, but only recently has the magnitude and structure of spatially varying infiltration been investigated in this context.

This study was conducted to statistically describe blocked furrow and ring infiltration measurements in the context of estimating water distribution under continuous and surge irrigation.

Materials and Methods

Treatment Description

Infiltration methods were tested on Yolo clay loam during the summer of 1983. To prepare the area for testing, grain sorghum was planted to extract water from the soil profile. Soil was sampled at each blocked furrow and ring site before testing and water contents on a mass basis were 9.6 and 12.2% for the 0-30 cm and 30-60 cm intervals, respectively, with standard deviations of 1.8 and 1.7%, respectively. Because the soil was dry when cultivated and furrowed (76 cm spacing), the effect of wheel compaction was minimized and all furrows were treated as one population.

Four methods were tested sequentially 30 times along a furrow transect to give 120 measurements. Tests were spaced on 2 m centers in a single 240 m furrow. First in the sequence of four was a 1-meter blocked furrow section with continuously flowing water, the second was a .457 m ring, followed by another blocked furrow test with stagnant water, and finally blocked furrow surge flow. Infiltrated volume was measured for 180 min except for the surge flow where three 40 min surges, separated by 40 min off times between surges, totaled 200 min. Water depth was maintained between 6-7 cm in the furrows and ring. Flow rate was 0.5 lps in the continuous and surge flow tests.

A statistical summary, assuming a normal distribution function, of volume infiltrated and steady infiltration is given in Table 1. Mean comparisons were not calculated because, as will be shown later, the assumption of independence is not valid in all cases.

Table 1. Statistical summary of infiltration tests

Infiltration	Ring	Blocked furrow stagnant	continuous	surge
Volume, ℓ				
Mean				
180 min	42	115	178	-
40 min surge 1	-	-	-	131
120 min surge 2	-	-	-	146
200 min surge 3	-	-	-	155
S.D. (CV,%)				
180 min	36(86)	50(44)	95(53)	-
40 min surge 1	-	-	-	84(64)
120 min surge 2	-	-	-	93(63)
200 min surge 3	-	-	-	92(59)
Uniformity, CU				
180 min	32	65	57	-
40 min surge 1	-	-	-	49
120 min surge 2	-	-	-	49
200 min surge 3	-	-	-	53

Volume infiltrated for ring tests is lower than for blocked furrow or two point tests due in part to the smaller wetted area. More water infiltrated when surface water flowed as compared to stagnant conditions which is congruent with Nance and Lambert's findings (1971). Flowing water may reduce surface sealing. Under surging, the majority of water infiltrated during the first surge and total volume, corrected for opportunity time, was almost the same as for continuous flow tests. Volume infiltrated during 180 min was corrected by extending steady infiltration from 120 to 180 min to give 168 ℓ.

Dispersion, expressed in standard deviations, is lower for rings than blocked furrows, but when it is divided by the mean and expressed as the coefficient of variation, the coefficient is greater for the ring data than for all the other tests (Table 1). Soil cracking likely contributed more to variability in the case of rings because with a small area, fewer of the cracks are self-contained within the ring. The greater coefficient of variation for flowing tests compared to stagnant tests may be attributed to the water opening or maintaining cracks in the soil. Surging did not reduce the coefficient of variation as would be expected if furrow dewatering between surges homogenized the surface layer.

Finally, CU (Christiansen, 1942) expressed as a function of coefficient of variation, CV, (Hart, 1961), is given in Table 1.

$$CU = 100\ (1 - 0.798\ CV/100)$$

Calculated CU does not include other sources of nonuniformity in surface irrigation but can be used to compare uniformity estimated from other infiltration measurement methods.

The preceding analysis was based on the assumption that each realization is independent or samples are not correlated in space. Variograms of volumes infiltrated in Fig. 1 show that samples are correlated because semivariance is less than the variance (open circle) and it decreases as separation between samples decreases. In the case of ring infiltration, as lag distance increases, semivariance approaches the variance. Samples separated by 24 or more are not spatially related, and thus, independent. This implies that fewer samples would give an adequate estimate of variance. As a note, the number of lags should not exceed one-quarter the number of samples (Davis, 1973), thus, 30/4 or 7 lags (56 m) are shown in Fig. 4.

Structure is less well defined in the variogram for blocked furrow stagnant flow infiltration and spacing of 16 m or greater would assure independence of sampling. Under continuous flow, structure is more defined and when the continuous flow and stagnant results are combined the effect is reinforced. Infiltration after three surges (200 min) shows structure 40 m (Fig. 2). Structure for the first surge is similar to the total but for the second and third surges structure decays to the pure nugget effect and variance decreases for infiltration contributed by each surge. The decrease in variability and its spatial structure corresponds to a decrease in infiltration rate.

Conclusions

Water distribution uniformity in furrows can be estimated using a transect of infiltration measurements. For the soil tested, flow conditions (stagnant, continuous, or surged) do not significantly affect estimated CU.

Variograms can be used to find the sample separation to insure independence. If the sampling objective is to assess spatial variability without consideration of spatial structure, the variogram shows the minimum sampling separation where each sample gives maximum new information. A strong case can be made for this strategy in that most fields are managed without differential control within the field.

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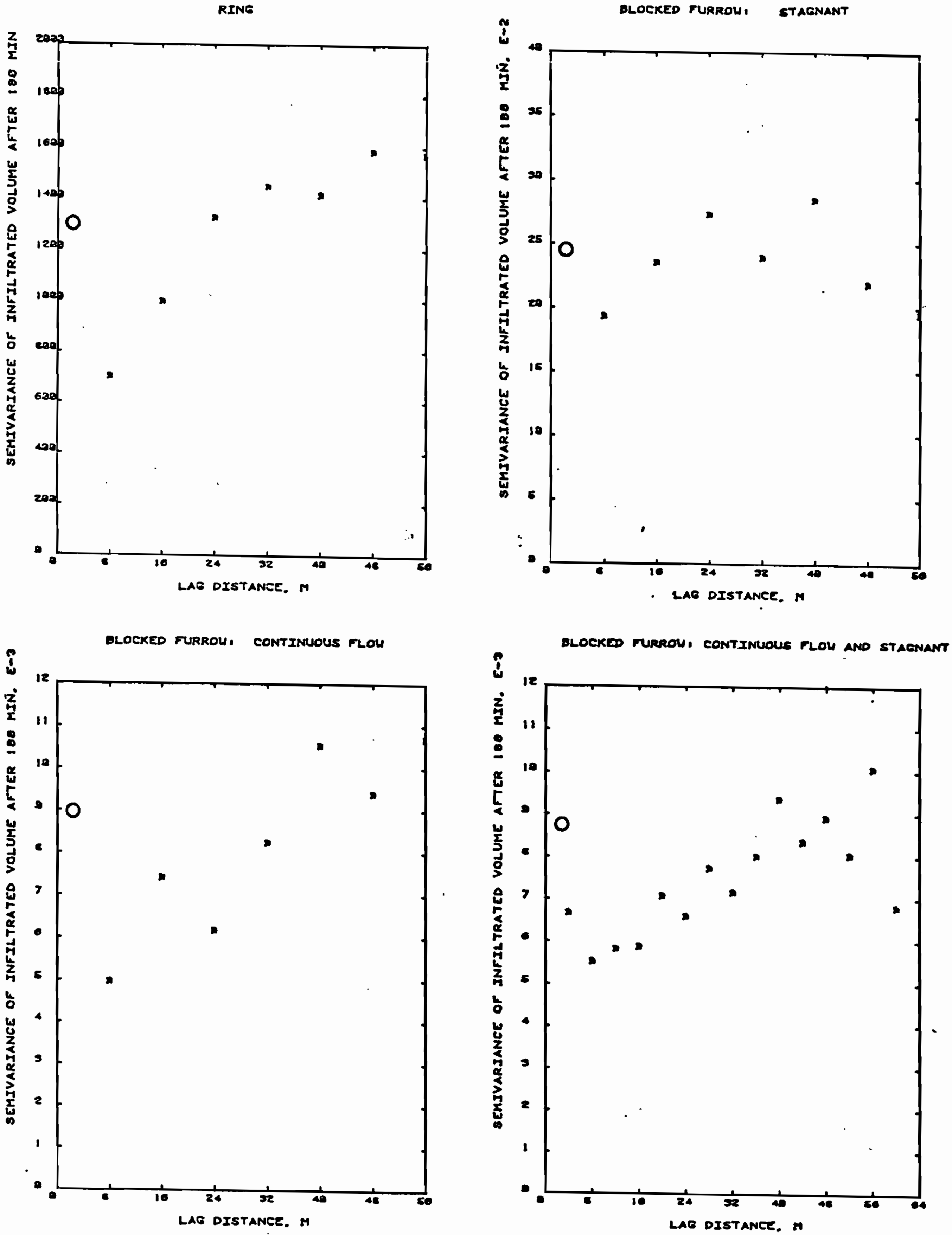

Figure 1. Variogram of volume infiltrated after 180 min for ring and block furrow: stagnant, continuous, and continuous and stagnant flow tests.

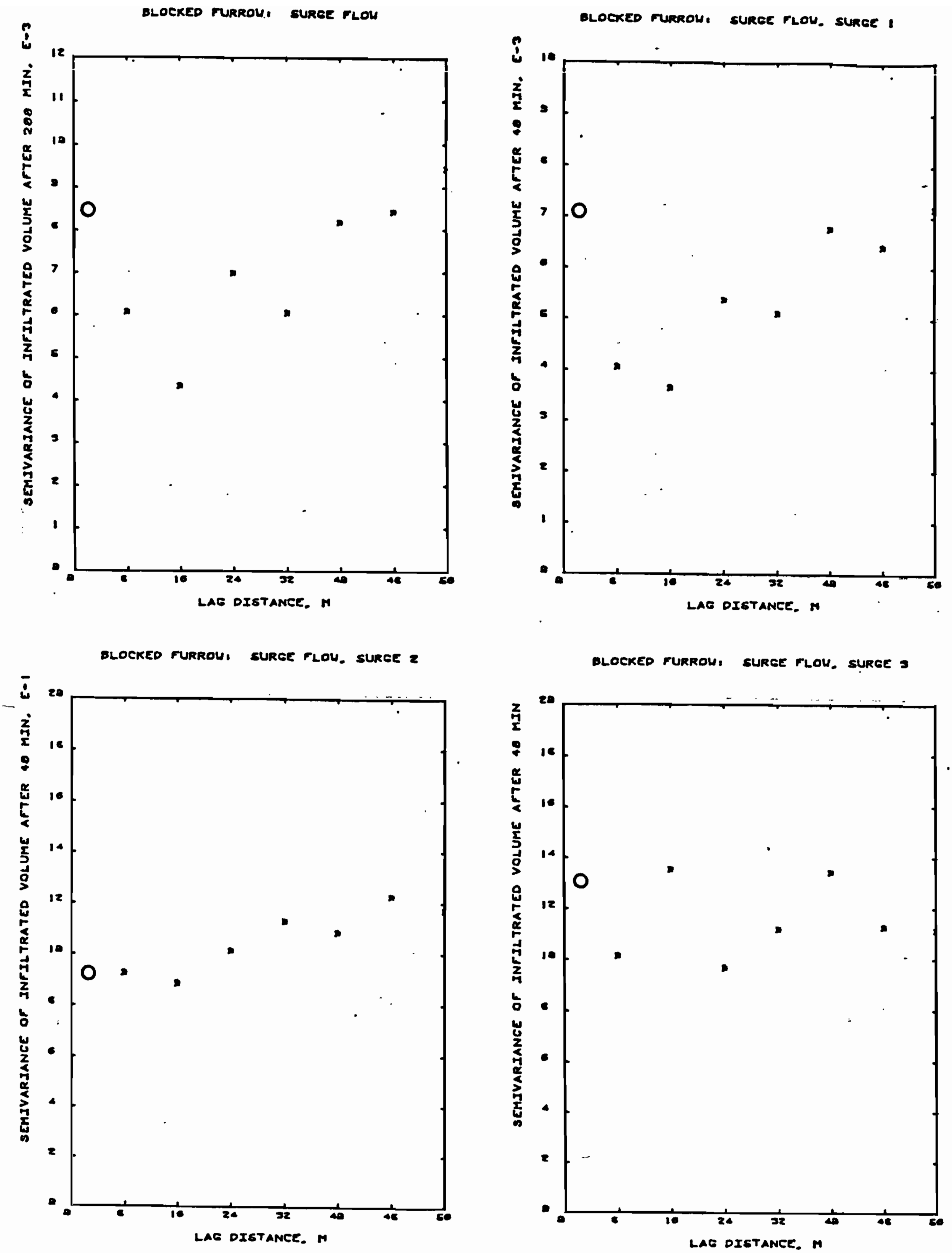

Figure 2. Variogram of volume infiltrated from three surges and of volume infiltrated during each surge 1, 2, and 3.

RESPONSE OF PISTACHIO TO SEVERE WATER STRESS

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Pistachios have a reputation for being drought resistant. This indicates the existence of mechanisms to avoid and/or tolerate water stress; avoidance associate with responses that limit plant water loss and tolerance involving adjustment of intercellular composition to allow plant survival. The relative importance of these adaptations in pistachio is unknown. The objective of this study was to compare tree and crop behavior under both optimal and limiting soil water conditions.

METHODS

The experimental site is located in a commercial orchard south of Kettleman City. In the well watered block, eight pistillate trees (9 year old "Kerman" on P. atlantica) were each instrumented with three neutron access tubes. Soil water status was assessed twice weekly throughout the growing season with readings taken every 12 inches to a depth of 10 feet. The surface soil water status was evaluated by collecting gravimetric samples. Irrigations with hand move sprinklers began on May 1 and continued until August 17, generally being applied avery 18 days. Care was taken to insure that these trees were adequately supplied with water.

A group of 120 trees located 11 rows away was used for the water stress evaluation. Three trees were instrumented with access tubes, mostly to a depth of 15 feet, and weekly soil water readings recorded. These trees (hereafter referred to as the stressed trees) were not irrigated throughout the growing season, and thus, relied entirely on winter rainfall stored in the soil profile to meet their water requirements.

Leaf water potential (ψ_ℓ) was evaluated throughout the season from measurements of xylem pressure potential with a pressure chamber (PMS Model 600). Concomitant measurements of leaf stomatal conductance (g_ℓ) were made on both sides of exposed, sunlit leaves with a steady state diffusion porometer (Licor Model 1600). Hourly recordings of ψ_ℓ and g_ℓ were frequently conducted. These diurnal measurements began before dawn and continued until at least one hour after sunset.

Tree trunk radius changes were measured to an accuracy of 0.01 mm with a Karlberg microdendometer periodically on 15 trees in each block.

Nut development was evaluated based on sampling begun in early June. Twice a week, 40 nut samples were collected from each of four randomly selected trees in each block. Nut sampling continued after the September 26 harvest from four trees in each block that remained unharvested.

The nuts were immediately removed to the laboratory where hull (mesocarp), shell (endocarp) and kernel (embryo) weights were determined. Composition of each sampling in terms of split, nonsplit and blank nuts (embryo abortion and vegetative parthenocarpy) was also evaluated.

Commercial harvesting equipment was used to determine yields of 40 randomly selected trees in each block. Detailed analysis described above was made of 200 nut samples taken from both the harvested nuts and those remaining in the tree after shaking on eight trees in each water regime.

RESULTS AND DISCUSSION

Winter rainfall amounts stored in the root zone were not nearly enough to meet the water requirements of trees in the stressed block. Therefore, rather than follow the typical bell-shaped ET pattern associated with adequately irrigated crops, water use decreased with time during the season in the stressed block. This is illustrated by the soil water extraction patterns presented in Figure 1 for two 15 day periods; one early in the season and the other midseason. Soil water depletion measurements, which represent water uptake by roots, for the May 16 to 31 period show that the bulk of extraction took place in the upper six feet of the profile. A total of 1.48 inches was used in the 15 foot profile over this 15 day period. On the other hand, total water use in the stressed block from July 18 to August 2 totalled only 0.42 inch and occurred mostly in the lower parts of the root zone. The difference in extraction patterns is consistent with previously reported data that shows that when deprived of adequate irrigation, trees will first deplete the upper layers of the profile before extracting water from deeper zones. Of greater interest in Figure 1 is the large disparity in tree water use, especially in view of the relationship between indicated ET and evaporative demand, the soil water status measurements strongly suggest the presence of severe plant water stress.

Figure 2 shows seasonal stomatal behavior as indicated by midday

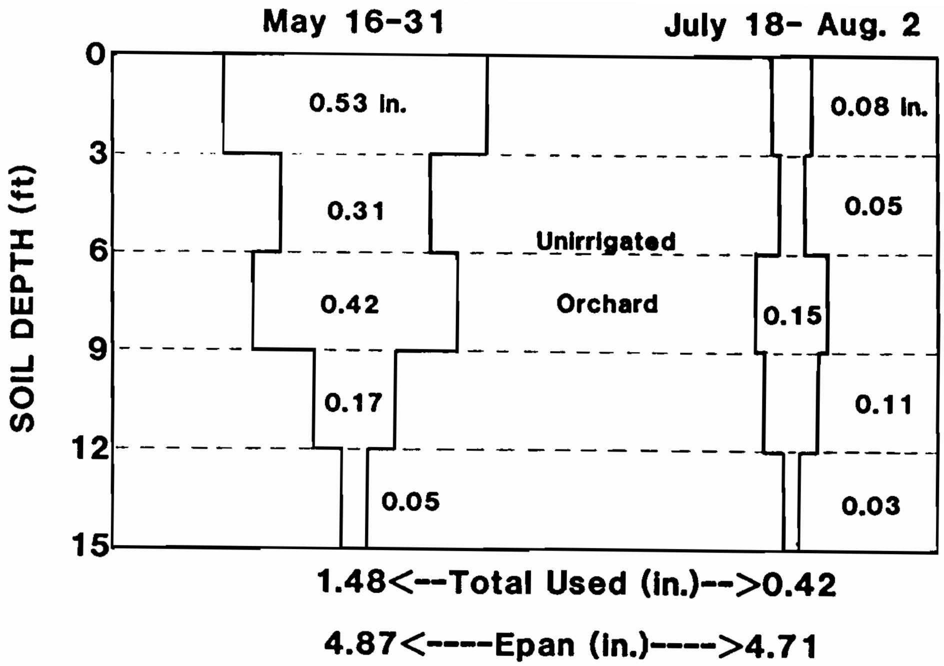

Figure 1. Soil water extraction patterns and amounts in the stressed block for early and midseason 15 day periods. Depletion values are averages of measurements taken at one ft intervals from six access tubes.

(solar noon) g_ℓ measurements for both stressed and well watered trees. Midday g_ℓ increased steadily in both well watered and stressed blocks from mid April to early June most likely in response to progressively higher levels of solar radiation. At that point, g_ℓ in the stressed trees declined rapidly attaining a minimum value of 0.09 cm/sec on September 6. Subsequent modest increases in stomatal aperture reflect the occurrence of some late season rainfall. Well watered values, on the other hand, continued to increase to approximately 0.85 cm/sec in mid June and maintained this level with moderate variation until the end of september. At that point, leaf senescence and lower net solar radiation resulted in a fast rate of g_ℓ decline.

The stressed trees' efforts to conserve water was also mainfested in the diurnal pattern of g_ℓ, in addition to midday magnitudes. Figure 3 presents a comparison of well water and stressed g_ℓ measurements taken hourly from 0500 to 2200 on July 11. Note that in the well watered trees, g_ℓ increased after sunrise, reached a maximum (0.75 cm/sec) by 1000 and remained relatively constant until 1700. This contrasts sharply with the stomatal activity of the stressed trees, that showed maximum aperture

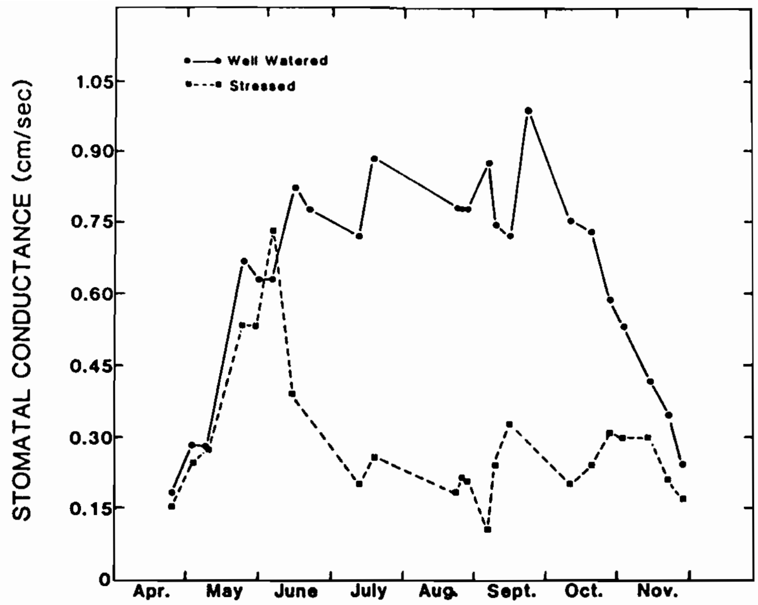

Figure 2. Seasonal midday (solar Noon) values of stomatal conductance for well watered and stressed pistachio. Each point is the average of two measurements taken on four trees.

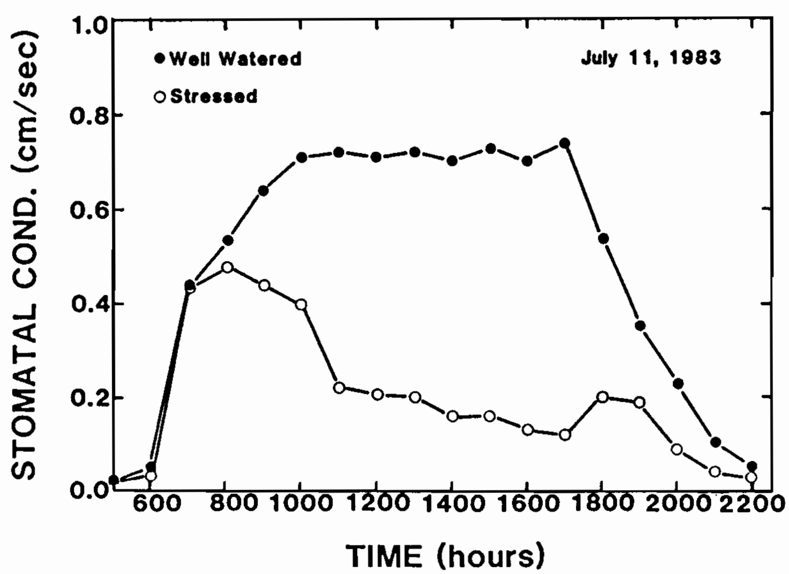

Figure 3. Hourly measurements of stomatal conductance taken on July 11 in well watered and stressed trees. Each point is the average of two measurements taken on four trees.

($g_\ell \cong 0.44$ cm/sec) at 0800 that declined thereafter, except for slight increases at 1800 and 1900. Thus, the stomata remain partially open for only a short time during the early morning hours when environmental conditions are less severe and begin to close rapidly when evaporative demand increases. In the late after noon stomatal opening also slightly increases. This pattern of stomatal opening allows the tree to assimilate the maximum amount of CO_2 while losing the minimum amount of water. It's interesting to note that the well watered trees do not show any evidence of the partial midday stomatal closure associated with other deciduous trees, including almond and walnut, under non-limiting soil water conditions. It appears, therefore, that even though pistachio can effectively control transpiration when deprived of adequate water, it consumes water at a high rate when it's in abundant supply.

The data presented in Figure 2 show that midday stomatal response did not vary between the different water regimes until early June. Nearly equivalent midday g_ℓ values obtained on June 6 were associated with ψ_ℓ of -16.9 and -27.9 bars, respectively, for the well watered and stressed blocks. The precipitous drop in g_ℓ thereafter was not accompanied by an equivalent change in ψ_ℓ. Apparently, only a slight ψ_ℓ decrease in excess of -28 bars resulted in a large concomitant decrease in guard cell turgor that translated into a large reduction in g_ℓ. It's recognized, however, that a unique relationship between g_ℓ and ψ_ℓ of -28 bars does, most likely, not exist. In other words, a ψ_ℓ of -28 bars may not always signal the beginning of stomatal closure. As with other species that undergo osmotic adjustment, the ψ_ℓ associated with stomatal closure depends on the tree's immediate stress history.

The significant stomatal differences represented in Figures 2 and 3 indicate reduced transpiration rates for the stressed trees, and indeed, their seasonal water use totaled only 7.15 inches based upon soil water depletion measurements. So by controlling stomatal aperture, pistachio makes the best of an unfavorable situation. It limits water loss while at the same time, unavoidably limiting CO_2 assimilation. Since photosynthesis depends upon CO_2, stomatal closure has been shown to decrease dry matter accumulation, which consequently affects tree growth and crop yield.

Expansive growth has long been considered a more sensitive indicator of plant water stress than stomatal behavior. Figure 4 shows accumulated

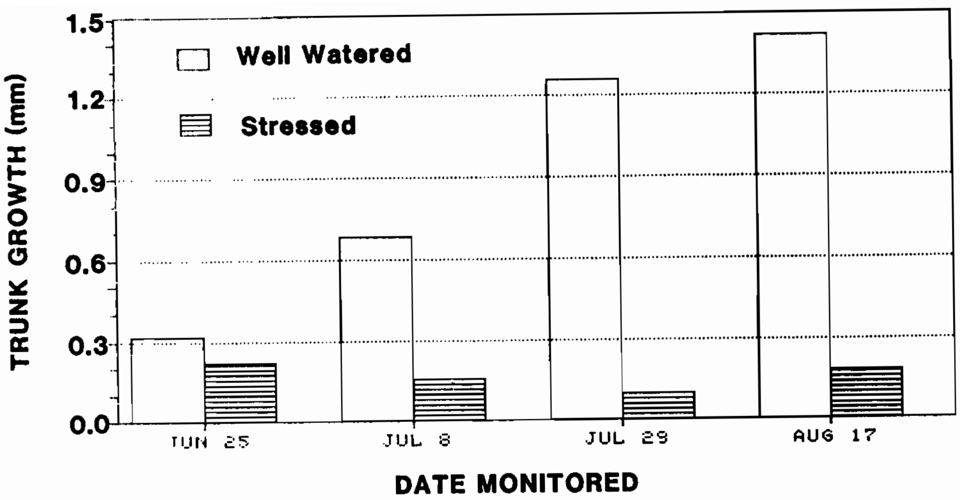

Figure 4. Accumulated expansive radial trunk growth from late June to mid August in well watered and stressed trees. Data represent averages of 15 trees per block.

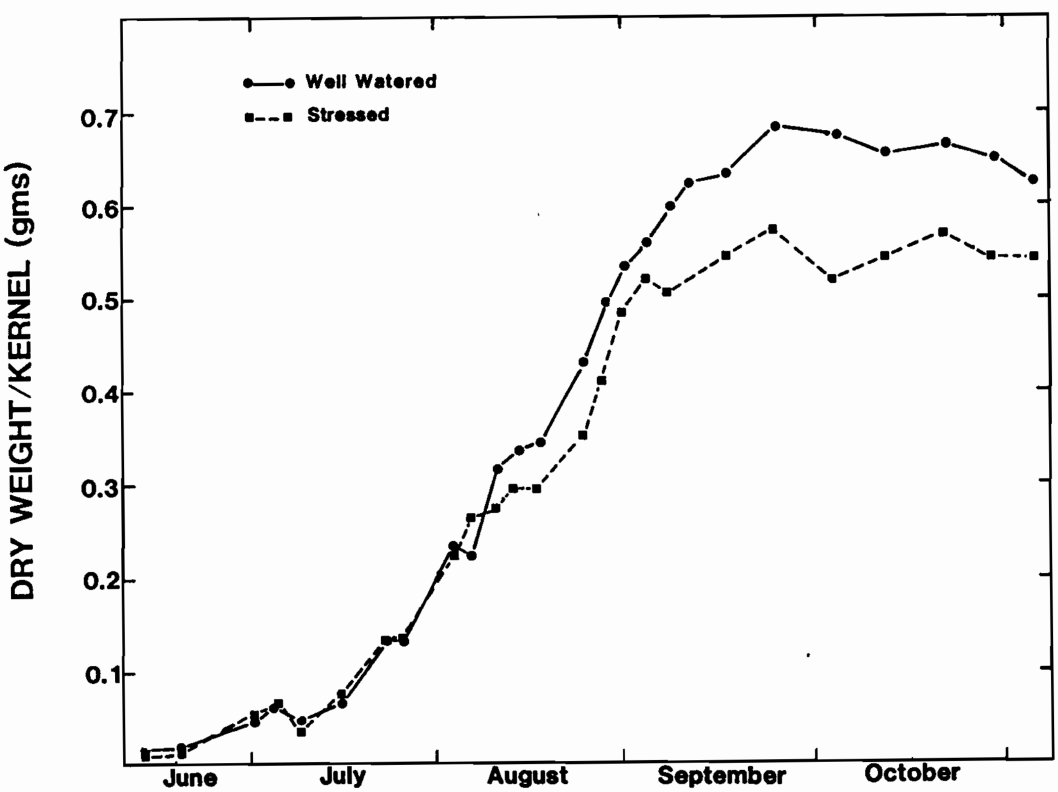

Figure 5. Developing kernel dry weights in filling nuts in both well watered and stressed trees. Data points are based on 40 nut samples collected from each of four trees.

radial trunk growth assessed from the end of June through mid August in both blocks. It clearly shows than, while overall trunk growth was relatively low even in the well watered trees, the severe water stress resulted in trunk contraction (negative growth) during July.

Kernel development expressed as dry matter accumulation in filling nuts under both stressed and well water conditions is presented in Figure 5. This data shows that there was relatively little difference in dry weight gain through the end of August. Remember that significant disparity of g_ℓ and presumably net photosynthesis began in early June. This clearly illustrates that the developing nuts are strong photosynthetic sinks. Figure 5 shows that maximum kernel weight occurred in late September and decreased slowly thereafter. At harvest, stressed kernels weighed about 16% less than well watered (0.58 vs. 0.69 gms/kernel) on a dry weight basis. Lower kernel weights were the result of smaller nut size in the stressed trees, rather than incomplete killing. This is evidenced by the dry weight percentage of kernel to nut in harvested, split nuts; 53.2 and 54.9% in the well watered and stressed trees, respectively. Direct measurements of longitudinal and radial nut size verified the existence of smaller nuts in the stressed trees. This is somewhat surprising in that it's been reported that ultimate shell size is attained in May, well before significant differences in stomatal behavior was observed. On the other hand, since shell enlargement is an expansive growth process, it should be sensitive to mild plant water stress that occurs before stomatal changes are observed.

Rather than dry weight accumulation in the filling kernels, the biggest difference in nut development between the well watered and stressed trees occurred in the relative percentages of split and unsplit nuts. Figure 6 illustrates the fate and composition at harvest of the average overall tree nut load, on a numerical basis, in the well watered trees. Of the total load, 79.8% was removed by the harvest, leaving 20.2% in the trees - most of these were blanks. The harvested nuts consisted of 69.0% splits, 21.4% non-splits, and 9.6% blanks. This contrasts sharply with equivalent data for the stressed trees shown in Figure 7. Only 59.7% of the nuts were removed by shaking and of these, a much smaller number were splits (39.4%). Similarly, a much larger percentage (44.8 vs 19.4%) of nuts that remained in the tree were also non-splits. The total amount of blanking in both water regimes was similar.

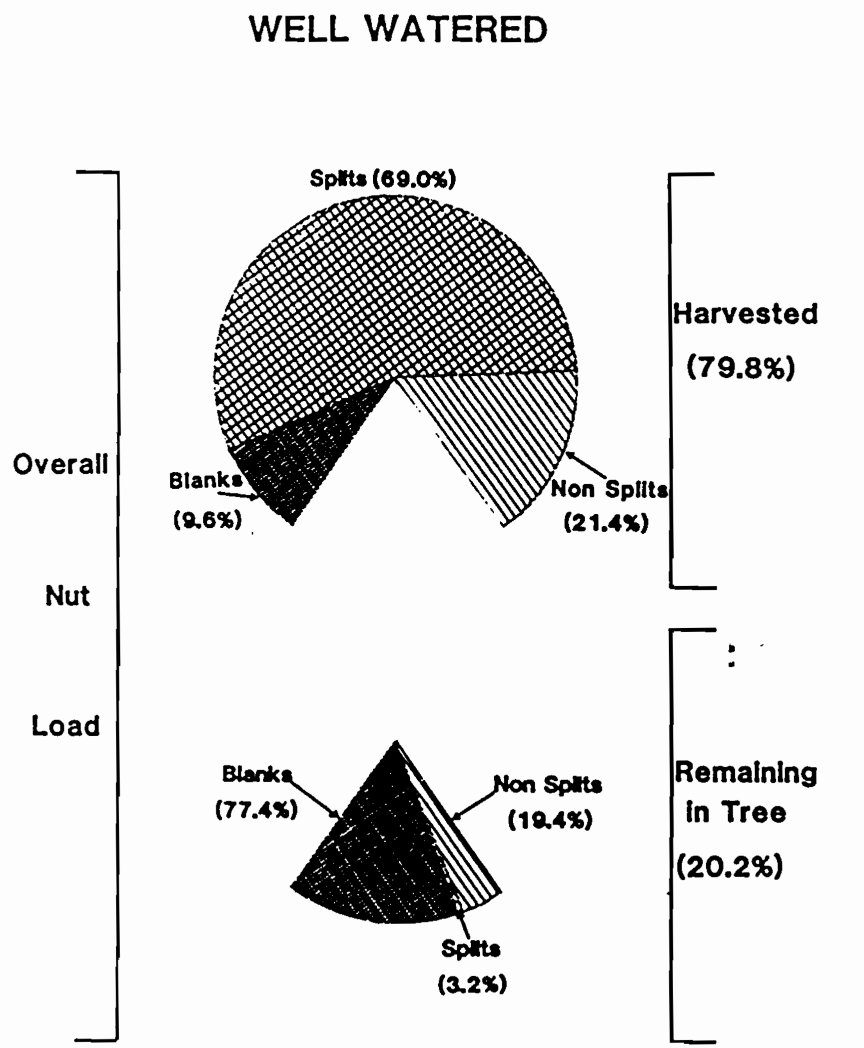

Figure 6. Fate and composition at harvest, on a numerical basis, of crop load on a well watered pistachio. Values in parenthesis represent averages of eight trees, 200 nut samples taken from both harvested nuts and those remaining in the tree after shaking.

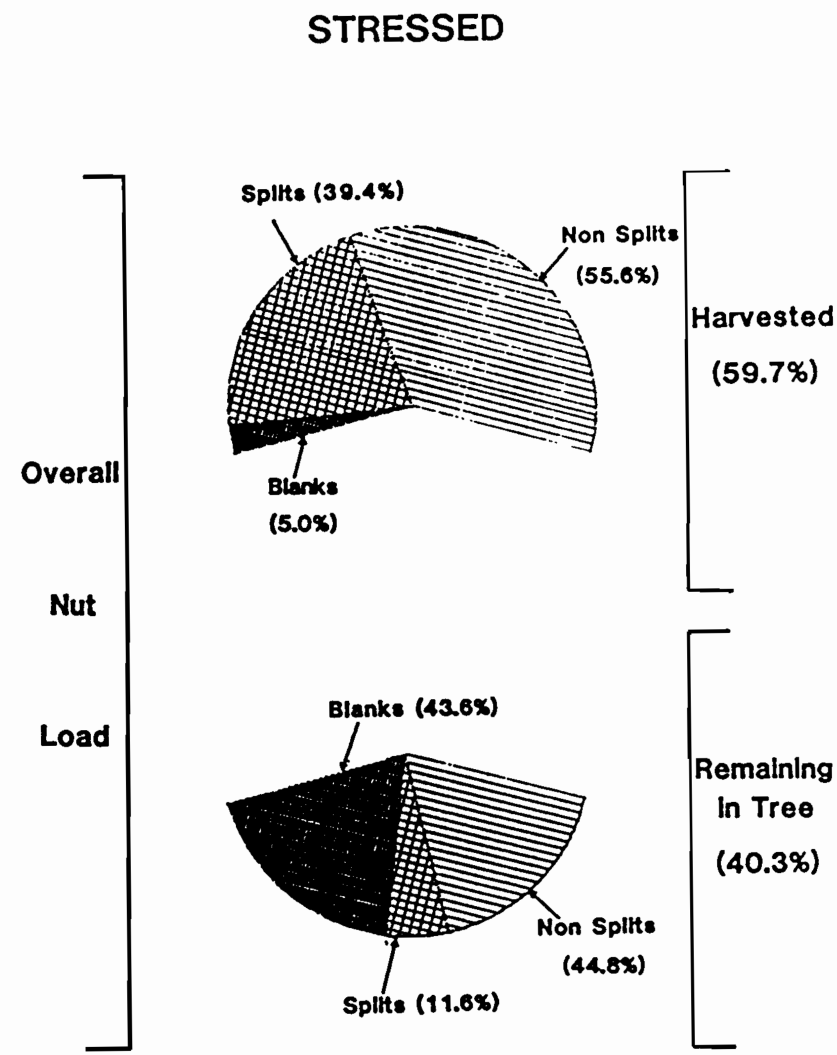

Figure 7. Fate and composition at harvest, on a numerical basis, of crop load of stressed pistachio. Values in parenthesis represent averages of eight trees, 200 samples taken from both harvested nuts and those remaining on the tree after shaking.

The large amounts of non-splits in the stressed trees was most likely due to the fact that shell splitting is a biochemical reaction associated with kernel growth and development. Therefore, lower net photosynthesis not only reduced dry matter accumulation in the nut but delayed the biochemical processes necessary for shell splitting in a large percentage of the crop. Data (not shown) indicated that shell splitting continued in the stress nuts through the last sampling (November 11). It should also be noted that the hulls of the stressed nuts generally remained tightly bound to the shells through harvest (September 26), and only from mid October on did a majority of the nuts attain "physiological maturity" as defined as easy separation of the hull from the shell.

Table 1. Harvest yields and quality expressed at five percent moisture content for well watered and stressed trees. Numbers in parenthesis are percentages of total yield. Total yields are each averages of 40 trees and components are average of 200 nut samples from eight trees.

	Total Yield	In-Shell Splits	Splits	Blanks	Hulls
	lbs/tree				
Well watered	36.7	22.4 (61.2)	6.8 (18.4)	2.2 (6.0)	5.3 (14.4)
Stressed	21.8	7.0 (32.1)	11.0 (50.5)	0.7 (3.2)	3.1 (14.2)

Table 1 presents harvest data expressed on a weight per tree basis for the different yield components. It shows that gross yields in the stressed trees were 40.6% less than the well watered trees. Of greater importance, the yield expressed as dry, in-shell was 68.8% lower in the stressed trees. It's important, however, to make the distinction between harvested amounts and total nut production. Our measurements show that when considered in terms of total biomass produced in the nuts, both those remaining in the tree and harvested, there was only 14.7% less production in the stressed trees. This, again demonstrates that nut development is the preferential carbohydrate sink, but also indicates that one of the other sinks, most like tree storage, will suffer. Since loral bud differentiation, maintenance, and retention requires carbohydrates, serious effects on next year's growth and yield are possible.

CONCLUSIONS

Imposing severe water stress on mature pistachio trees resulted in significantly reduced ET, seasonal stomatal conductance (and presumably net photosynthesis), leaf water potentials, tree growth and crop yields. Lower crop yields resulted from two factors; lower dry matter accumulation in the nut (the stressed nuts filled completely, but the reduced shell size dictated a smaller kernel), and a higher proportaion of nuts remaining in the tree after shaking. However, total nut biomass produced in the stressed trees was only marginally less than that of the well watered trees. Harvested nut quality decreased sharply due to the higher percentage of unsplit nuts caused by stress-induced delay in the biochemical processes involved in shell splitting. Indeed, stressed nuts at harvest appeared to be physiologically "younger" than well watered nuts, especially in terms of hull slippage.

It's remarkable that mature trees grown on a relatively low water holding capacity soil that remained unirrigated throughout the season did not significantly defoliate and produced a modest crop. We are not suggesting, however, that top performance can be obtained if trees are subjected to water limiting conditions. Because of the indicated reduced net photosynthesis in the stressed trees, it remains to be seen which carbohydrate-requiring process will be most adversely affected next season.

IRRIGATION OF THE IMPERIAL EAST MESA WITH SALINE GROUND WATER

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The 500 km^2 on the Imperial East Mesa, California is one of many arid areas of the world which remain undeveloped because of dry noncohesive course textured sands that move readily with frequent high winds. Experimental farms established in the 1940`s utilizing Colorado river water concluded that nutrient and irrigation requirements would be higher and yields lower in the East Mesa than in the nearby Imperial Valley [Storie et al., 1957]. The leasing of large tracts of this area for geothermal energy development in the mid 1970`s and recent innovative irrigation techniques prompted a reassesment of the agricultural potential of the area. A study initiated on the Republic Geothermal, Inc. lease area in March 1979 utilized 0.001 ha basins to grow tamarisk, date palm, asparagus, sugar beets, and alfalfa [Robinson et al., 1980,1981]. Groundwater [1,430 mg\L total dissolved solids [TDS]] and geothermal water [2240 mg\L] were compared for irrigation. A flat culture was used because wind rapidly leveled beds and furrows. Hay bales were placed around the basins to protect them from blowing sand. Following the successful growth of sugar beets, tamarisk, asparagus, and date palm with groundwater, the experiment was expanded to include 0.4 ha of spitter, 0.4 ha of biwall and 0.4 ha of sprinkler irrigation in March of 1982. In this study only the ground water was used. Of particular interest was the 730 mg\L chloride contained in this water supply which compares to 140 ml\L in the Colorada river.

Similar experiments to this on sands of the Yuma Mesa in Arizona were initiated by Roth [1972] and Roth et al. [1974] with a lower salinity Colorado river water [875 mg\L TDS]; and experiments of this level of salinity [1350 mg\L TDS] were conducted in the Imperia Valley on heavier textured soil [Robinson et al.1980]. However, the combined problem of course textured sand substrait and higher salinity water presented a different challenge.

METHODS

Samples of the sand taken 24 hours after a saturating irrigation showed a field capacity of 8.1% by weight, a bulk density of 1.61 for a volumetric percentage of 13.0% moisture. Examination of the first crops of cotton, sorghum, and sugar beets showed the roots to be confined to the upper foot. Subsequent trials with chiseling to 56cm showed that rooting could be extended to that depth.

In the absence of any climatic data for this desert area a class A Weather Bureau Pan was set up and recorded for three years. The method of utilizing this data to estimate the irrigation need for crops begins with a daily mean for each month as is shown in the table. The first trial tested the assumption that the need of the crops would be the same as pan evaporation i.e. a 1:1 ratio of irrigation to pan evaporation.

To evaluate the effectiveness of this ratio soil chloride was checked periodically to see if it was increasing or decreasing. An increase would indicate that the ratio was too low for adequate leaching, a decrease that it was too high. The table presents the daily control data estimating the number of days that the soil moisture storage could supply water to plants in each given month. This is given for both a 30 and a 60cm rooting depth. Also shown is the time to run our biwall and sprinkler systems to compare a 0.75 to a 1.0 pan to irrigation ratio. The sprinkler system consisted of 2.78mm nozzles on 9 x 12 m spacing run at 331 kPa.The sprinkler timing was ajusted to account for a 34.5 kPa increase in pressure when the 0.75 treatment was turned off. The biwall system was run at 138 kPa with each tape supplying a strip 50cm wide, and the pressure was maintained constant when the 0.75 treatment was turned off.

RESULTS

A weighted mean soil chloride concentration of a guayule planting in the biwall plots from 3 to 60cm depth July 14,1982 was 35.0 meq\L in July 22,1983 it was 31.1 meq\L at a distance of 30cm perpendicular to the biwall. This planting remained in place the full time and received a 1:1 pan to irrigation ratio the full time.

The sprinkler area also received a 1:1 ratio and showed a 47.0 meq\L weighted mean soil chloride concentration in a grid of nine samples from 0 to 60cm depth on August 16,1982. On July 22, 1983 the mean was 42.0 meq\L in a second cotton crop.

Since both of the systems showed a slight reduction in the soil chloride level a 0.75 pan to irrigation ratio will be evaluated along with a 1:1 ratio this year while also recording the moisture level with a neutron probe and plant temperature with an infra red thermometer.

CONCLUSION

This study points out the utility of pan evaporation for controling irrigation in an area which has no history of agriculture and no backlog of climatic data. The pan evaporation serves as a marker against which a researcher can begin,and then ajust with other measurements or with the most recent data.

The author gratefully acknowledges continuing support from Republic Geothermal Inc. Terry R.Thomas Manager of Administration, Daniel J.Scherer Staff Research Associate, and Doyle D.Freeman Senior Agricultural Technition.

ESTIMATED MINUTES TO RUN SYSTEMS FOR 0.75 AND 1.00 PAN TREATMENTS

DAILY PAN EVAPOR-ATION CM	ROOT DEPTH WATER STORAGE IN DAYS 30CM	60CM	B I W A L L RUN 0.75& 1.00 DIALY	RUN 1.0 ONLY DAILY	S P R I N K L E R RUN 0.75& 1.00 DAILY	RUN 1.0 ONLY DAILY
NOV .386	7.5	15	32	11	37	12
DEC .391	7.5	15	32	11	37	12
JAN .282	10.6	21	23	7	27	8
FEB .384	7.8	15.6	31	11	36	11
MAR .561	5.3	10.6	45	15	53	16
APR .932	3.3	6.4	75	25	88	27
MAY 1.14	2.6	5.2	92	31	108	33
JUN 1.42	2.1	4.2	113	38	133	38
JLY 1.50	2.0	4.0	120	40	141	43
AUG 1.30	2.3	4.6	104	35	123	38
SEP 1.06	2.9	5.8	85	28	100	30
OCT 0.73	4.1	8.2	59	20	67	23

SOIL CALCULATIONS BASED ON 13%FIELD CAPACITY AND 3% PWP

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IRRIGATION SCHEDULING AND VERTICILLIUM WILT INTERACTIONS IN COTTON PRODUCTION

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Irrigation scheduling provides a unique opportunity to control cotton plant growth and biomass partitioning in regions dependent on irrigation for an adequate water supply. Successful water management and irrigation scheduling requires observations of the water status of soils and plants and an understanding of the associated plant responses and climatic interactions (2, 3, 4). Canopy development and microclimate respond directly to water management; as a result, irrigation scheduling may interact with pest and disease dynamics. With adequate understanding, water management and other cultural components of the production system may serve to minimize the impact of economic crop damage in such cases.

Verticillium wilt (Verticillium dahliae Kleb.) is a soilborne fungal pathogen that invades the vascular system of cotton, or other host plants, and triggers a series of events that result in yield loss. Fungal activity in the conducting vessels is associated with reduced leaf water potential, increased stomatal resistance, and a proportionate growth inhibition (1). Some pathotypes of V. dahliae cause plants to defoliate. Generally, the greatest yield losses occur when plants are infected early in the plant growth cycle.

Verticillium wilt severity is favored by cool air temperature, a factor that, to some extent, is controlled by irrigation scheduling (3). This report discusses some interactions of irrigation scheduling and plant density with Verticillium wilt and their potential to minimize yield loss from this pathogen.

Materials and Methods

Field studies were conducted at the University of California West Side Field Station on Panoche clay loam in 1982 and 1983. In 1982, ten contrasting irrigation regimes, described in Table 1, were replicated three times in a randomized complete block design. Planting time and climatic conditions were near normal in 1982. Five irrigation regimes, ranging in intensity from no postplant irrigation to three irrigations scheduled to achieve maximum productivity in the absence of Verticillium wilt, were combined factorially with three planting densities in 1983. The 15 treatments were replicated three times in a randomized complete block design. The 1983 season was characterized by cool and wet spring conditions. Tests were conducted in the same field block both years to take advantage of the high inoculum density present in the soil at this site.

All plots were preplant irrigated to rewet the soil through the maximum rooting depth possible. Water was delivered to individual plots through gated pipe and measured by a time-volume technique. Plots were sufficiently large (8 or 10 m X 90 m) to allow isolation from horizontal water movement, accommodate plant sampling for treatment characterization, and provide a representative yield determination by mechanical harvests.

Defoliation and infection observations were made on 100 plants in the two center rows of 8-row plots. Ten consecutive plants in each of 10 separate positions were selected for observations.

Results and Discussion

Foliar wilt symptoms were strongly related to the timing of the first season irrigation with maximum infection for the earliest irrigation. The most pronounced effect of initial irrigation timing is illustrated by examining defoliation severity of the 1982 study shown in Figure 1. The earliest and most severe defoliation was observed on treatments irrigated in early- to mid-June. In the absence of Verticillium wilt, an initial postplant irrigation is required in mid-June on these soils to achieve maximum yield (2). Table 1 shows the yield loss associated with treatments (T-1 through T-5) reflecting the most defoliation. The onset of defoliation is observed approximately three to four weeks after the initial postplant irrigation. The rate of increased defoliation over time is relatively constant for all treatments, however, late season water stress (T-5 and T-7) tends to moderate the effect. The yield loss associated with early water stress represents a trade-off with moderating the impact of Verticillium wilt defoliation.

Delaying the first irrigation of the growing season in the 1983 study showed a similar effect of moderating defoliation intensity as was observed in 1982 (Figure 2). However, the overall impact of irrigation scheduling was strongly related to plant population level. Higher plant densities increased defoliation severity at high irrigation input levels. However, with a single summer irrigation (JD = 220 or 228) the increase was insignificant.

Figure 3 shows highest productivity to be associated with treatments that moderate the severity of defoliation. Total water (W_t) of 60 to 75 cm (one summer irrigation plus soil stored water at planting) gave highest seedcotton yields and the impact of increased defoliation from higher plant densities was minimal at this irrigation intensity. Plant densities of 50,000 per hectare were required for high productivity.

Minimizing the impact of Verticillium wilt defoliation by increased water stress and reduced plant densities clearly represents a trade-off situation with the reduced yield potential resulting from lower inputs of these factors. It is possible to examine the magnitude of this trade-off. A water-yield function (3) for the San Joaquin Valley indicates that about 75 percent of the maximum yield possible (1500 kg lint per hectare) is expected for a single irrigation on this soil. The 1438 kg per hectare yield of treatment T-9 is only four percent below that expected for this irrigation level in the absence of Verticillium wilt. Assuming that a lint yield of 2,000 kg/ha is possible in a good climatic year in the absence of wilt, the T-9 treatment yield is 72 percent of the maximum possible yield. Treatments T-1 through T-5 averaged 1168 kg lint per hectare or 58 percent of the maximum. With the 1982 results a 14 percent advantage (275 kg lint per ha) exists in favor of using water stress to minimize the loss from Verticillium wilt. Reduced water addition also lowers variable production cost.

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Table 1. Irrigation variables and cotton yields, cv. 'SJ-2', in 1982. U. C. West Side Field Station - Panoche clay loam.

102 cm rows Treatment		Irrigation Date 1st	Last	No.	Water Amt. (cm) Post-plant	Total	Lint yield (kg/ha)
T-1	Excessive wet	6/10	8/18	5	68.8	114.0	1103*d
T-2	Wet	6/17	8/18	4	57.4	102.6	1173c
T-3	Max. yield	6/17	8/11	3	49.3	94.5	1198c
T-4	Max. yield	6/17	8/11	3	47.2	92.5	1210c
T-5	Stress (late)	6/17	7/14	2	33.3	78.5	1154cd
T-6	Unif. (stress)	7/8	8/11	2	32.5	77.7	1410a
T-7	1-irrig. (early)	6/17		1	17.8	68.1	1218c
T-8	1-irrig. (med.)	7/8		1	18.5	63.8	1347b
T-9	1-irrig. (late)	7/21		1	17.5	62.7	1438a
T-10	No postplant				0.0	45.2	935e

*Values not followed by the same letter differ at a 0.05 probability level.

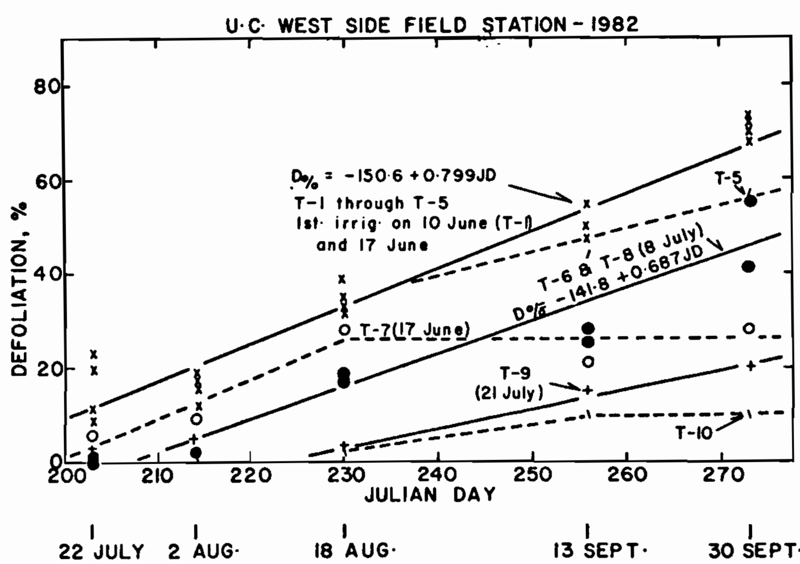

Figure 1. The relationship of defoliation severity to controlled water stress in early season.

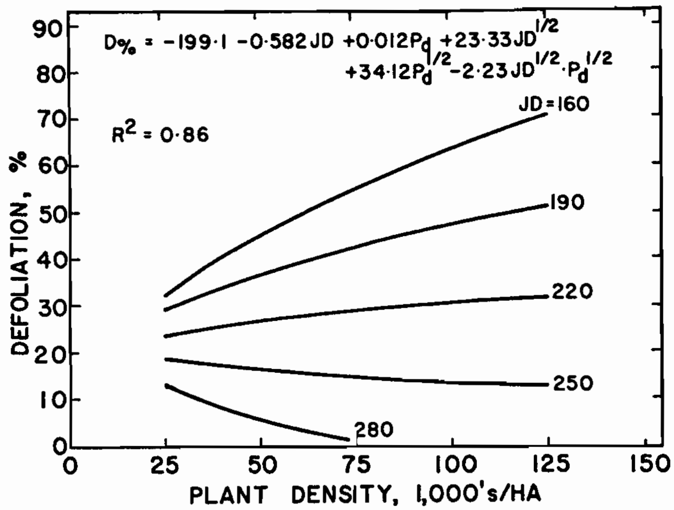

Figure 2. Relation of defoliation percent, evaluated on Oct. 10, 1983, to timing of a 1st irrigation (JD) and plant density.

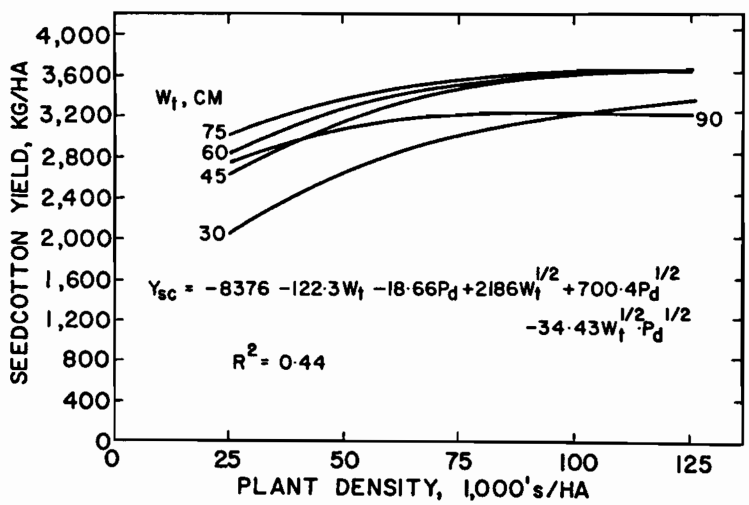

Figure 3. Seedcotton yields in 1983 from water (W_t, cm) and plant density (P_d) variables.

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EVALUATING SPATIAL VARIABILITY IN IRRIGATION SYSTEMS

by

B.R. Hanson, S.W. Kite and D.L. Lancaster

Traditional methods for evaluating spatial variability of applied water in irrigation systems include distribution uniformity, Christiansen's uniformity coefficient and coefficient of variation. These methods provide a measure of variability in the system which can be related to some standard but provide no information on how the variability occurs.

Correlograms, variograms, and spectral analysis can help describe spatial variability in an irrigation system. Correlograms show the correlation structure with distance between samples while variograms show the variance structure. Spectral analysis shows the variance distribution with frequency thus identifying possible patterns causing the variance in the data. Nielsen et al (1982) discusses these methods in some detail. This study used spectral analysis to evaluate spatial variability of water advance in a furrow irrigation system and of applied water by a center pivot sprinkler system.

System Description

Water advance in one basin was measured at the 1/4 and 1/2 distances in a level basin irrigation system with furrows in all irrigated furrows (alternate furrows only). Penetrometer measurements and furrow-bottom elevations were also obtained at the same distances as the water advance.

Catch can data of a center pivot (water driven) was obtained along a transect starting at 40 m from the pivot point and extending to 419 meters. Can spacing was 3 meters. The sprinkler system consists of 10 spans, each 40 m long, with six impact sprinklers per span. Nozzle discharges were also measured at each sprinkler head.

Results

Water advance data at the 1/4 distance (Figure 1) generally showed a pattern of two furrows with relatively small advance time followed by two furrows with larger times. The spectral analysis (Figure 2) verified this periodicity. Spectral analysis showed that much of the variance in the data is attributed to this periodic behavior. The penetrometer data clearly showed a periodic pattern of two high readings followed by two low ones. The high readings occurred in the wheel furrows. No obvious pattern existed in the elevation data (Figure 3) but the spectral analysis (Figure 4) showed the same pereiodicity as in the water advance.

Differences between wheel furrows and non-wheel furrows caused this periodicity of four irrigated furrows due to faster water advance in wheel furrows than in non-wheel furrows. The penetrometer periodicity reflect lower infiltration rates in wheel furrows and the furrow elevation periodicity reflects a larger depth of flow in the wheel furrows, both which contribute to faster advance times.

Catch-can data (Figure 5) showed peaks at 40 and 170 meters but no definite patterns for the remainder of the transect, although some valleys appeared to exist. The spectral analysis (Figure 6) showed a periodicity occurring every 40 meters or one span length. The nozzle discharge data also showed the same periodicity. A modification made by the grower to the system to increase the volume of water applied appeared to cause this behavior. All nozzle diameters except those adjacent to the water drive units were increased by the grower. The valleys in the data, which appeared to cause some of the periodicity, resulted from a smaller depth applied in the vicinity of the water drives. We recommended that those nozzle diameters be increased to reduce this periodic effect since much of the variance in the data was due to this periodicity.

Conclusions

Periodic behavior in water advance data of a furrow system and in catch-can data of a center pivot was identified with correlograms and spectral analysis. The periodic behavior was related to grower practices.

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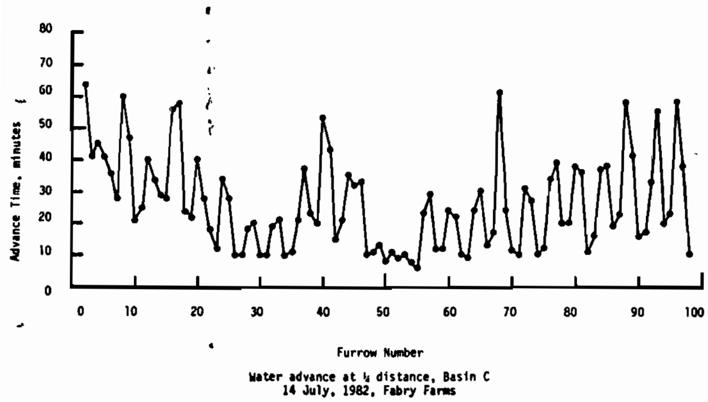

Figure 1

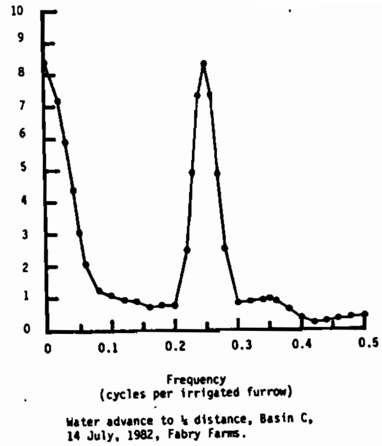

Figure 2

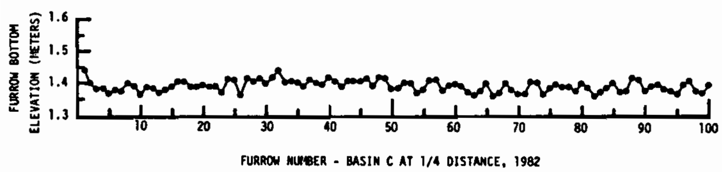

Figure 3

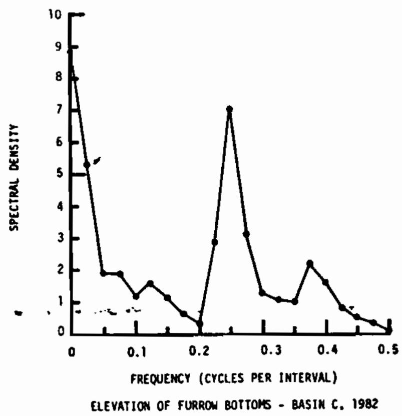

Figure 4

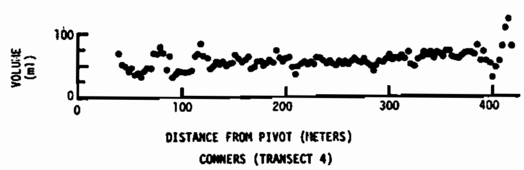

Figure 5

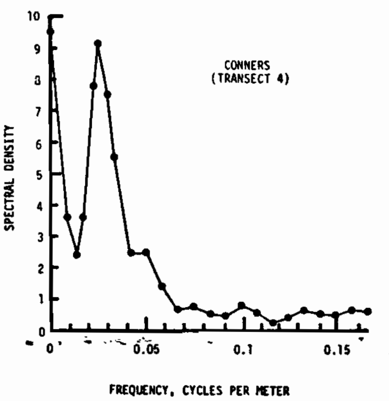

Figure 6

Use of NH_4HCO_3-DTPA soil test for determination of elemental availability and toxicity indices

P.N. Soltanpour[1]

Soltanpour and Schwab developed the NH_4HCO_3-DTPA soil test in 1977 for determination of availability indices of nitrate, phosphorus, potassium, zinc, iron, copper and manganese. Since then it has been shown that this test can be used for determination of availability and toxicity indices of cadmium, lead, boron, selenium and molybdenum. The list of elements that can be determined with this test is expanding. When used in conjunction with an inductively-coupled plasma spectrometer, this test becomes even more efficient and will enable laboratory personnel to evaluate the fertility and other problems of soils rapidly. This test is currently being used by the Colorado State University Soil Testing Laboratory and University of Wyoming Soil Testing Laboratory and several commercial laboratories.

The test involves shaking a 10-g soil sample with a 20-ml aliquot of NH_4HCO_3-DTPA for 15 minutes at 180 oscillations per minute followed by filtration and analysis. The following references should be consulted for the details.

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[1]Professor of Agronomy (Soils) and Director of the Soil Testing Laboratory, Colorado State University.

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PRINCIPLES OF SOIL TESTING

P.N. Soltanpour[1]

Introduction

Soil testing is defined as accurate, simple, and relatively rapid physical and chemical tests for determination of indices of acidity, salinity, sodicity and elemental availability and toxicity. The process of soil testing involves sampling; sample preparation, extraction and analysis; interpretation of results and recommendations. In this paper, determination of elemental availability indices for the purpose of making fertilizer recommendations will be discussed.

Soil Sampling

Farm fields should be sampled in a manner to obtain a representative sample. Fields with different soil types, crop rotations and management practices should be sampled separately. Our research data show that nitrate distribution in irrigated fields of Colorado is not random, and that the "row" and "column" effects on soil nitrate levels cannot be predicted. Therefore, a systematic sampling plan should be followed in these fields. These sampling studies in Eastern Colorado irrigated fields have shown that obtaining a relatively small number of cores per field will result in a relatively large sampling error. Therefore, one should consider the level of sampling error that can be tolerated and obtain a sufficient number of cores per composite sample to attain the desired sampling error. Sampling depth is dictated by the nutrient mobility and the crop rooting depth. For immobile nutrients such as phosphorus usually a plow layer sample is adequate. However, for mobile nutrients such as nitrate, deeper samples should be obtained for deep-rooted crops. Field sampling studies should be conducted in different agricultural areas to determine the most appropriate sampling plan, intensity and depth.

Soil Preparation, Extraction and Analysis

Sample preparation is also important. Our research work has shown that excessive grinding will change extractable levels of iron in soils to a large extent and manganese to a lesser extent. Therefore, grinding force and time should be standardized.

Shape and size of extracting vessel may also affect the extractable level of elements. Shaker speed will affect these levels and should be standardized. The soil to extracting solution ratio and time of shaking will also affect these levels and should be standardized.

Analytical methods that are accurate and rapid should be adopted. Quality control methods should be used to check analytical results.

Use of a check sample that has been analyzed many times to spot any gross error in analysis is recommended. In addition use of blind duplicates and interlaboratory comparisons are recommended.

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Factors Affecting Nutrient Availability

Availability of any nutrient is determined by its concentration in the soil solution (intensity factor), by the amount of labile nutrient present in the soil (quantity factor) and by the slope of the regression line relating quantity factor to intensity factor (buffering capacity factor). It is assumed that this relationship is linear over a limited range of practical interest. Other factors such as root volume, mycorrhiza, diffusion rate, soil temperature, soil moisture, transpiration rate, placement method of fertilizer, plant species and varieties will also affect availability. At this time our knowledge of soil-plant-environment relationships is not advanced enough to enable us to predict nutrient availability accu ately. For this reason measurements of nutrient availability in soils are called "availability indices".

Attributes of a Good Soil Test

A good soil test should extract nutrients from the same labile pool as the plant roots. It should separate deficient from nondeficient soils. It should be accurate, rapid and economical. Some data indicate that the intensity factor is the most important factor determining availability and a good soil test should determine the intensity factor. However, some researchers claim that a good soil test should measure intensity and quantity factors. Of course for a fertilizer recommendation the buffering capacity (fixation capacity) should be used when applicable and this involves a knowledge of both intensity and quantity factors.

Selection and Calibration of Soil Tests

Extracting solutions should first be evaluated under greenhouse conditions to save time and money. In these experiments, the moisture level and levels of other nutrients should be kept near their respective optimum levels. The yield response to the nutrient of interest should be measured. The Cate and Nelson method may then be used to evaluate different soil tests. If a soil test does not separate deficient from nondeficient soils under greenhouse conditions then it should be discarded.

The next step is the field calibration of a soil test for a specific crop. In field experiments the yield response to a nutrient should be measured. The Cate and Nelson method may be used to determine the critical levels. In addition the "Chi Square" method of Keisling and Mullinix may be used to define deficiency, marginal and sufficiency zones. When field experiments are carried out, soil factors such as moisture, clay, organic matter, pH, etc. should be measured. When enough data are available for a number of growing seasons regression equations of fertilizer requirement as a function of soil test level, yield, pH, clay content, organic matter and any other appropriate "independent" variable should be developed. These regression equations should be verified and when proven accurate be used to make fertilizer recommendations.

Comparison of Fertilizer Recommendations

Many soil test recommendation comparisons have shown that different laboratories recommend different levels of fertilizers based on the results of the same soil sample taken from a given field. These studies have shown that the problem of over-recommendation is indeed prevalent in this country.

Reasons for this discrepancy in recommendations are many and not all are known. But the main reason may be lack of adequate field calibration data or in some cases when field calibration data are available, misuse or lack of use of these data. Four main factors affect the interpretation of soil test results. These are the soil test used; other soil properties such as clay type, clay level and pH; the crop variety and the environment. When a soil test is calibrated for a given soil in a given environment and for a specific crop, the results cannot be extrapolated to other soils, crops and environments. As an example, Illinois and Michigan data indicate that the hot-water soluble boron in the range of 0-0.5 or 0-1.0 ppm respectively, is deficient for alfalfa crops. However, recent results have shown that a hot-water-soluble boron level of 0.1 ppm in Colorado soils is not deficient for alfalfa crops. Unfortunately some laboratories are using Illinois and Michigan results for Colorado soils.

Summary

Principles of soil testing have been discussed. The main problem (challenge) facing us today is the development of adequate field calibration data for soil tests for the purpose of fertilizer recommendations. Soil tests should be field calibrated for major soil series, and major crops grown in these soils. At this time our knowledge is not advanced enough to be able to quantitatively relate economical fertilizer requirements of specific crops to soil test levels, other soil properties, environmental factors, and crop species and varieties. Future research should address these problems in order to advance the science of soil testing and fertilizer recommendations. Obviously this advance depends on the progess made in areas of weather forecasting, economic forecasting, soil chemistry and plant nutrition.

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Alfalfa: How to Hit the Mark

by

Roland D. Meyer, Extension Soils Specialist

Part of "Hitting the Mark" is defining the goal or target that we are striving to achieve. When speaking of alfalfa, this goal may be an eight, ten, twelve or greater ton per acre forage yield. To attain this mark, a grower must integrate a number of important aspects of crop production. These include providing adequate supplies of nutrients, water, and the control of insects and diseases after selecting and planting a variety capable of producing high forage yields. Other management considerations such as time interval between cutting, forage removal, amount of traffic affecting soil compaction during the harvesting operation and irrigation to provide water for the new crop and cutting schedule become extremely important in producing top quality yields. In my discussion, the major concern will be to address the availability of adequate supplies of plant nutrients. To gain some appreciation for the quantity of nutrients contained in eight tons of alfalfa hay let us evaluate the amounts given in Table 1.

Large quantities of nitrogen are utilized to produce high yields and the desired protein levels. The major source is nitrogen from the atmosphere as fixation occurs through the mutually beneficial relationship between the alfalfa plant and the nitrogen fixing rhizobia bacteria located in the nodules on the roots. Current research with Roger Benton indicates little if any response to applied nitrogen can be expected, particularly when adequate amounts of phosphorus and potassium are avail able (Table 2). These results reaffirm previous studies indica ting the response to nitrogen is usually small and seldom economical.

In so far as the quantity taken up by alfalfa is concerned, potassium and calcium are next in their relative amounts removed by alfalfa. In most situations the potassium supplied by soils is quite adequate to insure necessary quantities for maximum production. However, in some sandy soils and perhaps others, this may not be the case and response to added potassium can be obtained. Calcium likewise is adequately supplied by most soils. Nutrient supplies of calcium very seldom limit yields unless soil pH levels drop somewhat below 5.0 throughout a major portion of the soil profile.

Table 1. Nutrient quantities contained in 8 tons of alfalfa hay.

Nutrient	Chemical Symbol	Pounds
Nitrogen	N	480
Phosphorus	P205 (P)	94 (42)
Potassium	K20	350 (290)
Calcium	Ca	256
Magnesium	Mg	53
Sulfur	S	32
Iron	Fe	3
Manganese	Mn	2
Zinc	Zn	0.3
Copper	Cu	0.2
Chlorine	Cl	2
Molybdenum	Mo	0.02
Boron	B	0.5

Although a smaller quantity of phosphorus is taken up, perhaps it is the nutrient which most often limits alfalfa hay production. The immobility and low solubility of phosphorus in the soil require that the reservoir of 'fixed' phosphorus be kept at a rather high level so that adequate supplies are available to the plant. Ongoing investigations with Daniel Marcum indicate the importance of phosphorus and potassium (Figure 1). Even though all plants including alfalfa showed striking potassium deficiency symptoms, very little response to applied potassium alone was observed. Response to phosphorus alone was marked and combinations of phosphorus plus potassium showed a highly positive interaction particularly as greater quantities of potassium were applied.

Sulfur is another nutrient responsible for increasing yields of alfalfa, particularly in the intermountain areas of Northern California. Sulfur availability to the plant is reduced when wet, perhaps even water-logged soil conditions, along with cool temperatures limit the bacterial oxidation of

Table 2. Alfalfa forage yields as influenced by seed inoculation, fertilizer and lime treatments in 1982 and 1983. Leavers Ranch - Siskiyou County.

Treatment						Yield, Tons DM/A		
		Application Rate*						
No.	Seed Inoculated	N	P_2O_5	K_2O	Lime	1982	1983	2 yr. Total
		---- lbs/A ----			Tons/A			
1.	No					4.56	4.27	8.83
2.	No		80			4.44	4.55	8.99
3.	No		80	200		4.70	4.59	9.29
4.	No		80	200	2	4.85	4.59	9.44
5.	No	300	80	200	2	4.82	5.00	9.82
6.	No	600	80	200	2	5.06	4.98	10.04
7.	No	900	80	200	2	5.04	5.25	10.29
8.	No	1200	80	200	2	4.76	4.69	9.45
9.	Yes					3.99	4.12	8.11
10.	Yes		40			4.06	4.18	8.24
11.	Yes		80			3.97	4.49	8.46
12.	Yes		160			4.49	4.64	9.13
13.	Yes		80	200		4.10	4.40	8.50
14.	Yes		80	200	2	4.30	4.62	8.92
15.	Yes		160	200	2	4.55	4.39	8.94
16.	Yes		160	400	2	4.76	4.43	9.19
17.	Yes	300	80	200	2	4.50	4.29	8.79
18.	Yes	600	80	200	2	4.60	5.03	9.63
19.	Yes	900	80	200	2	4.53	4.35	8.88
20.	Yes	1200	80	200	2	4.74	4.78	9.52
21.	No	600**	80	200	2	4.96	5.01	9.97
22.	Yes	600**	80	200	2	4.68	4.88	9.56

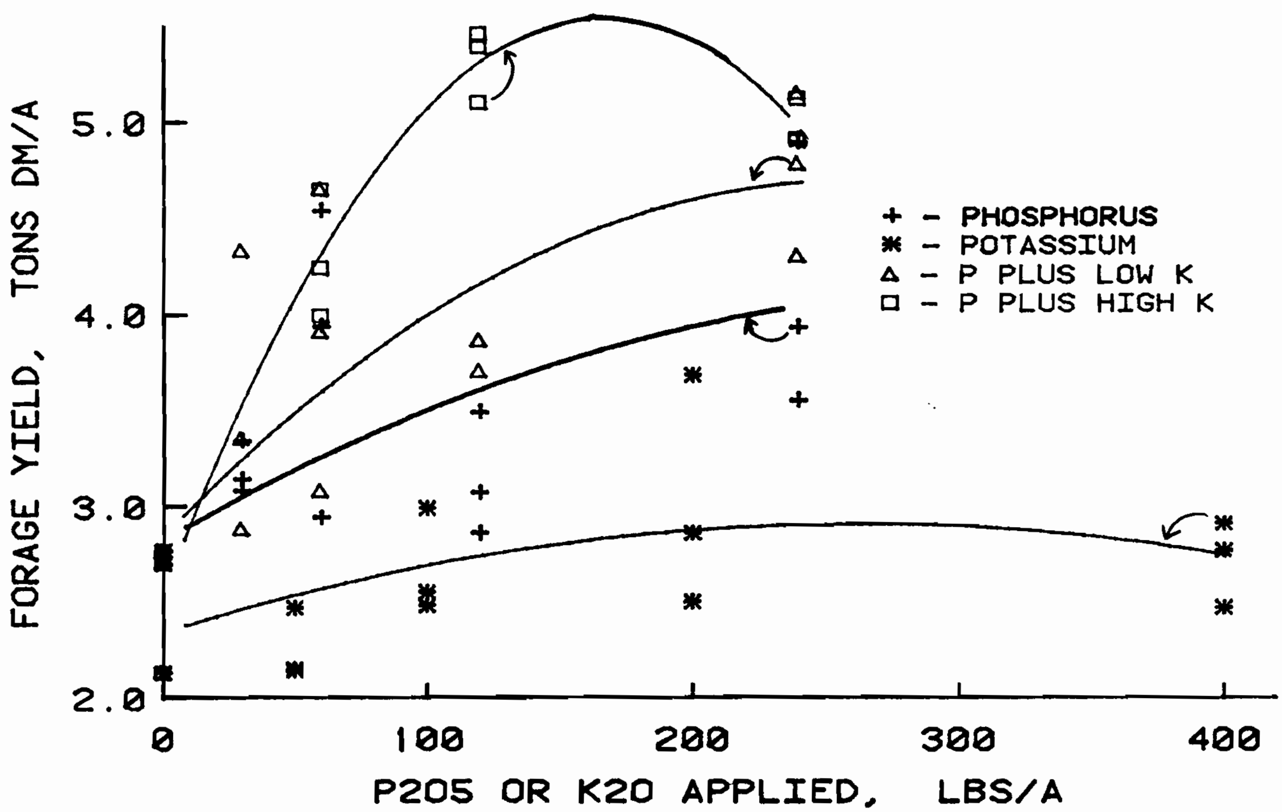
All plots fertilized and seeded on June 4 & 5, 1981.

*NH_4NO_3 was applied 3 times/year, P_2O_5 applied as 0-45-0, K_2O applied as 0-0-60, lime applied as 100% $CaCO_3$ equivalent.

**$Ca(NO_3)_2$ was applied 3 times/year.

sulfur to the sulfate form needed by plants. The degree to which micronutrients such as boron, molybdenum and perhaps zinc affect alfalfa yields is rather small. Maintaining adequate levels of boron becomes very important in the production of seed crops, particularly alfalfa.

Figure 1. Alfalfa yield response in 1982 to fertilizer applied on the soil surface on June 24, 1981. Bosworth Ranch - Shasta County.



Diagnosing the nutritional status of alfalfa can be effectively carried out by the use of a combination of soil testing, plant tissue testing, observing plant symptoms and the use of carefully marked fertilized and unfertilized strips to determine yield increases.

RICE: SELECTING THE BEST FERTILIZER MANAGEMENT PROGRAM

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Fertilization accounts for about 44 percent of the annual yield of rice in California as measured in Statewide soil fertility experiments. Thus the need of farmers to accurately diagnose the nutrient supplying capacity of the soil and the nutritional status of the crop during its life-cycle is important in obtaining maximum economic yields. Soil and plant analyses are recognized as valuable diagnostic tools for estimating fertilizer needs. Considerable effort has been devoted to develop correlations between test results and known field responses. Critical values once established and used in an intelligent interpretative manner can be very useful in maximizing crop yields and obtaining maximum fertilizer use efficiency.

Soil tests have been evaluated for the major plant nutrients likely to be deficient in California rice soils. For P, K, and Zn we are able to predict the degree of deficiency with good success. Unfortunately, N which is the most common deficiency, has not been a useful soil test to date and is complicated by the fact that N availability is dependent upon the rate of microbial activity which is affected by temperature, moisture, aeration, type of organic matter, pH and other factors and also because of the various losses to which N is susceptible.

The currently recommended soil tests for California rice are as follows: P - sodium bicarbonate extraction, critical value 6 ppm extractable P; K - ammonium acetate extraction, critical value 60 ppm extractable K; Zn - DTPA extraction, critical value 0.5 ppm Zn, except where irrigation water HCO_3^- concentration exceeds 2-3 meq. per liter and itself induces zinc deficiency in rice.

Diagnostic plant analysis techniques have been developed for N, P, K and Zn for the new short-statured California rice varieties. Recently released cultivars which are less susceptible to lodging and have a higher yield potential than earlier varieties are more fertilizer responsive. They can profitably utilize up to 20 percent higher N fertilization than the taller traditional varieties without danger of lodging.

The most recently fully matured leaf on the rice plant has been found to be the most sensitive indicator of the plants nutrient status. The recently matured leaf, separated at the leaf collar, is suitable for N, P and K analyses. Zinc evaluation must be made on whole seedling plants collected up to 21 days after planting and on whole plant shoots.

Because critical nutrient concentrations change with the stage of plant development, it is desirable to collect a series of samples preferably at the (1) mid-tillering stage (35-40 days after planting (DAP) in early cultivars and about 10-12 days later in late rice cultivars), (2) maximum tillering stage (55-60 DAP in early cultivars); and (3) panicle initiation (60-70 DAP in early cultivars). A satisfactory procedure used to minimize sample variability is to collect about 60 leaf blades from about 30 sits in a sample field of about 20 acres. If fields are not uniform, atypical areas should be sampled separately. After oven drying at 60°C samples ground to a 40 mesh are suitable for chemical analysis.

The best correlations between critical nutrient concentration, plant growth and grain yields have been obtained with Kjeldahl-N or

Orange-G dye absorption, 2 percent acetic acid extractable P(PO_4-P) and K. The Kjeldahl method is a standard A.O.A.C. procedure and the 2 percent acetic acid extraction is that described by Ulrich (1983). The Orange G-dye absorption determination of protein N correlates very well with Kjeldahl N and is rapid and inexpensive. The Orange G method is described by Hafez and Mikkelsen (1981).

Recent evaluation of critical and adequate concentrations of N, P and K has been made of newly released California short and medium-grain rice cultivars (Table 1). Variety of rice apparently has no significant effect on critical nutrient concentration in comparison of plants with and without an adequate supply of a nutrient. Critical concentrations of nutrients change with stage of plant growth and they characteristically decline with plant maturity. Nutrient concentrations may be changed slightly by conditions which affect plant growth, but in flooded rice culture only phenoxy-type herbicides appear to slightly depress nutrient uptake. The application of MCPA does not appear to significantly affect the interpretation of critical values. In sodic soils, the uptake of Na may compensate in part for K requirement of rice and both elements may need consideration.

The ultimate aim in growing rice is to produce the maximum economic yield of grain at the lowest unit cost of production. Yield is determined by suitable climate, varieties with genetic yield potential and optimum crop management practices. With these factors integrated grain yield is basically determined by four components: (1) Number of panicles per m^2; (2) number of grains per panicle; (3) percent of field grain and (4) weight of individual grain or grain size. Each of these yield components is determined for a variety at a different stage of growth by various external factors. The number of panicles per m^2 is largely determined by events occurring shortly after germination and influenced most during the active tillering stage. Early maturing cultivars (140 days) have a 40 day tillering period while late maturing (160 day) cultivars tiller for about 55 days. Panicle formation starts after maximum tillering and is greatly affected by growing conditions existing from panicle differentiation to the terminal stages of reduction-division which occurs about 5 days before heading. The number of grains per panicle is determined over a relatively short period of about 27-32 days after panicle initiation. The number of unfilled grains is influenced most during the reduction-division stage and is finally determined in a 5 to 10 day period just before head exsertion. The percentage of filled grains produced is determined over a 30 to 50 period depending on varietal growth duration. Filling is affected by a variety of post-harvest environmental conditions such as rates of carbon assimilation, respiration, translocation of CHO and sink capacity of the grains to receive CHO supplied by leaves and culms. Carbon assimilation for example is affected by solar radiation, the N content of the leaves, day-night temperature relations, plant type, efficient light utilization and general health of the plants. With good field conditions 85 to 95 percent grain filling may be obtained. Under adverse conditions, particularly with low temperatures after jointing, grain filling may be severely reduced. Seed weight is strongly correlated with the percentage of filled grain but practically speaking seed weight shows the least variation among all the yield components.

Examination of the above yield components in the rice crop to be harvested significantly reveals why high or low rice yields are obtained (Figure 1). Some problems associated with low grain yields are not related to plant nutrition, but frequently the diagnosis and elimination of nutrient deficiencies provide better guarantees of high yields and lower unit production costs.

References

1. Soil and Plant Tissue Testing in California. 1983. University of California Bulletin 1879. H. M. Reisenauer, Editor.
2. Hafez, A. and D. S. Mikkelsen. 1981. Calorimetric Determination of nitrogen for evaluating the nutritional status of rice. Commun. in Soil Science and Plant Analysis 12:61-69.

Table 1. Critical and adequate N-P-K concentrations in California short-statured rice cultivars.*

Growth Stage	Critical	Adequate	Critical	Adequate	Critical	Adequate
Mid-Tillering	4.6	4.6-5.2	1000	1000-1800	1.4	1.4-2.8
Maximum Tillering	4.0	4.0-4.6	1000	1000-1800	1.2	1.2-2.4
Panicle Initiation	3.3	3.3-4.2	800	800-1800	1.0	1.2-2.4
Flag Leaf	2.6	2.6-3.2	800	800-1800	1.0	1.2-2.2

* Analyses based on dry-weight basis of recently matured leaves for Kjeldahl-N, 2% HAc extractable PO_4-P and K.

** Critical zinc values shoots rice seedlings, 20 ppm total Zn; whole plant shoots 15 ppm Zn.

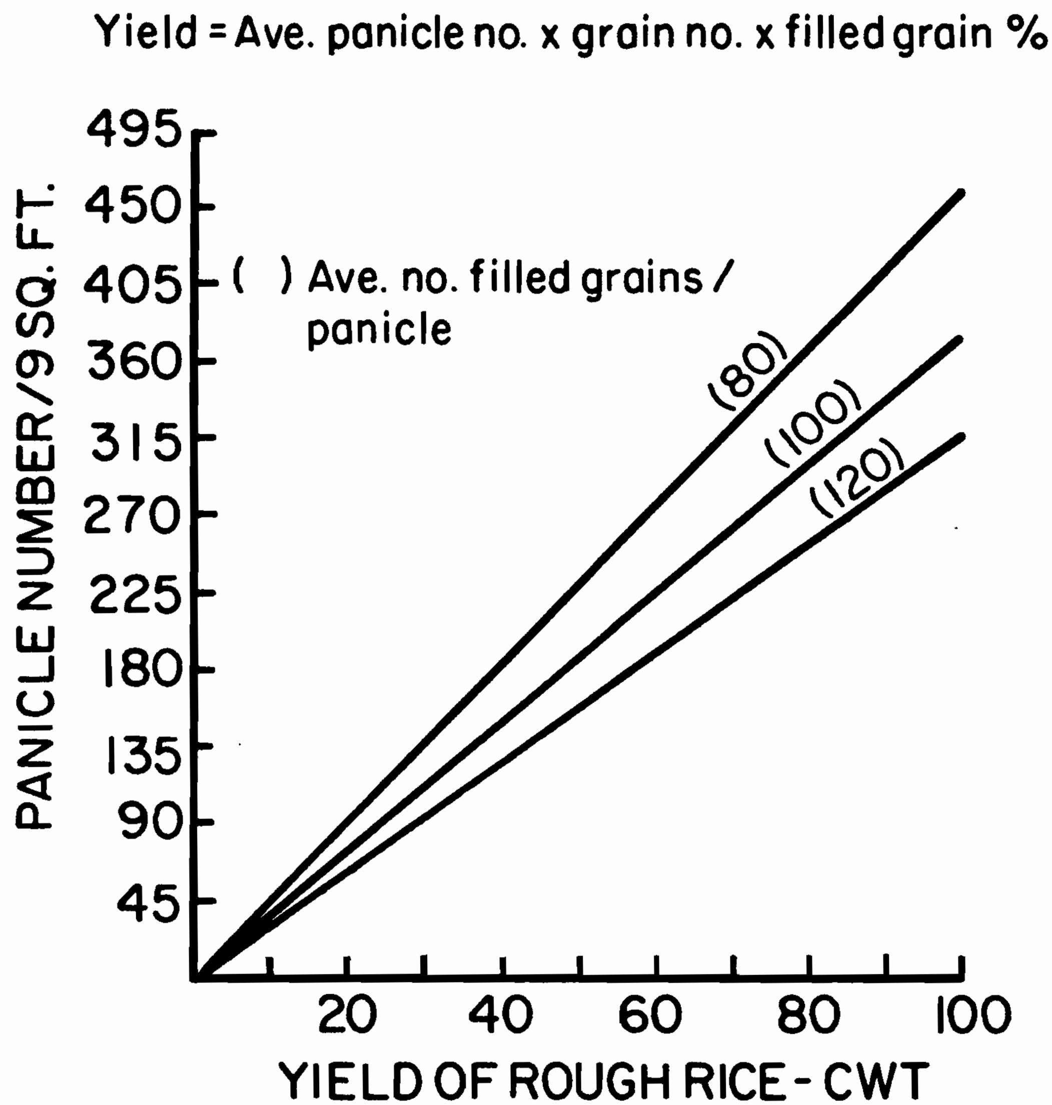

Figure 1. Effect of yield components on grain yields of rice.

FERTILIZING VEGETABLES AND STRAWBERRIES IN CENTRAL COAST AREA OF CALIFORNIA

Norman C. Welch, Kent Tyler, Dave Ririe and Francis Broadbent

In the Central Coast vegetable producing areas of California the main crops grown need an abundant supply of available nitrogen close to harvest. This is needed to produce a bright green, eye appealing product and because the leafy crops common to this area absorb 2/3 of its nutrients and produce 2/3 of it growth both in dry and fresh weight during the last 30% of its growing cycle.

Often in the first 1/3 of growing period only minor amounts of nitrogen sometimes less than 5# per acre are absorbed into the plant. This represents less than 1/20 of total nitrogen needed to produce a crop.

Nitrogen fertilizer applied to the soil soon becomes very mobile through the oxidation action of soil bacterial. To apply nitrogen to maximize its benefit to the crop and to minimize cost and pollution, several factors need to be taken into consideration. The most important consideration is the growing practices of the farmer. His method of irrigation as to frequency and duration will need to be carefully evaluated. The more water applied beyond the ET of the crops, usually the more nitrogen will need to be applied because of the loss of nitrates leached below the root system. The type of root system a plant develops will help determine the fertilizer placement. A direct seeded lettuce will have a more extensive root system than a transplanted one. We have found that lettuce roots to a depth of 2-1/2 feet or more with direct seeded crops in a Watsonville loam to clay loam soil. With transplanted lettuce in the same soil series, roots are seldom found below 18". Cauliflower, cabbage and celery roots develop along similar patterns.

Soil texture has a major effect on water and nutrient retention. Sandy soil can be difficult to manage because of its poor water holding capacity while clay soil in our district often has a high perched water table that encourages nitrogen losses due to denitrafication. Soil type also has a mark effect upon how extensive roots will explore soil profile. Again, grower practice in soil tillage will affect root growth. Restricted root growth in compacted soil or in soils with high perched water tables results in reduced top growth and makes plants susceptible to a wide range of problems from which neither field men nor growers can benefit. We find in the Central Coast district a need to fertilize lettuce crops with higher rates of nitrogen in spring than during the summer. Although some of this is due to winter leaching by rain, restricted root growth in cool soil is believed to be a significant factor as later planted fields require less nitrogen. Low soil oxygen and poor soil structure have a significant effect on ability of plants to pick up nutrient.

Crop rotation needs to be considered in determining fertilizer rates. Lettuce following a well-managed strawberry crop is difficult to fertilize adequately with nitrogen because of the depleted soil nitrates. In some of our tests, we applied three times the amount of nitrogen that the crop would absorb and still did not obtain maximum yield of acceptable size lettuce in fields with less than 5 ppm nitrate in upper 12" of the soil.

With financial support of California Iceberg Lettuce Research Program and the Environmental Protection Agency 208 program, we have just completed a 4-year nitrogen fertilizer experiment in lettuce. The treatments were repeated in the same location of the experiment for 8 crops of lettuce. Ammonium sulfate was used in these experiments. Nitrapyrin, an anti-bactericide that inhibits the nitrosomas bacteria for a short period of time from oxidizing the ammonium ion to the readily leachable form of nitrate was used at the rate of 1 qt/acre in part of the treatments. This chemical was applied as an aqueous spray over the fertilizer as it was being sidedressed into the bed just prior to planting. Some of the treatments were such that one half of the N was applied preplant and the remainder was applied after thinning. 15 N depleted ammonium sulfate was used in one of the experiments. This material helps distinguish between residual soil nitrogen and fertilizer nitrogen applied for that crop.

Preplant and post-harvest soil samples were taken from each of the plots in one foot increments to a depth of three feet. Leaf midribs were sampled at approximate two-week intervals after thinning and analyzed for nitrate N. Whole top samples were taken during the season and analyzed for total N and ratios of isotopic N. Measurement of the isotopic composition of these forms of N in whole top samples permitted calculation of the amount of fertilizer-derived N present in the crop.

The lettuce was harvested on June 26 for the spring crop, taking 10-foot length of bed to obtain 24 heads, or one carton. Each head was trimmed to a uniform number of wrapper leaves before weighing.

Leaf Midrib Analyses

The NO_3-N levels in the midribs provided a basis of differentiating between part of the fertilizer treatments (Table 1). The NO_3-N levels in sample from the ON plots were significantly lower than all others for both preheading and cap leaf samples. The midrib NO_3-N levels for 30 + 30 N rates were not significantly different from 60-pound N + nitrapyrin and 120-pound N rates. Midrib analyses did not effectively separate treatment with acceptable lettuce head-weight from heads too small for the market. The NO_3-N levels in samples from a treatment producing too large heads were not significantly different from those from desirable head size treatments. Large size lettuce is undesirable because of the extra cost of shipping and the increased damage to lettuce packed in bulging cartons.

TABLE 1.

Leaf Midrib Nitrate-Nitrogen - Spring Lettuce

N Treatments lb/Acre	Preheading	Cap Leaf
0	5350 a **	3875 a **
30 + 30 ***	7800 ab	7965 b
60 *	10735 bc	8285 b
120	12480 c	9180 b
120 *	10965 bc	7870 b
60 + 60	11975 c	11015 c
180*	14325 c	10690 cd
180	12765 c	10855 cd
90 + 90	13885 c	11935 cd
120 + 120	11980 c	12120 d

* Nitrapyrin at one-quart per acre.

** Figures not connected by common letter are significant at the 5% level.

*** Double figures indicate ammonium sulfate applied before planting and after thinning (about six weeks later) in equal amounts; single figures--all nitrogen applied preplant.

Fertilizer N lbs/A	Spring Tonnage Harvested tons/A	Spring Weight in Pounds per 2-dozen heads
0	23.3 a **	31.0 a
30 + 30 ***	28.0 b	43.0 b
60 *	32.0 c	48.4 c
120	31.5 c	48.0 c
120 *	35.7 d	52.4 d
60 + 60	33.5 c	51.4 d
180 *	39.1 e	59.8 e
180	31.4 c	48.0 c
90 + 90	35.7 d	55.6 d
120 + 120	36.5 d	54.6 d

* Nitrapyrin at one quart per acre.

** Figures not connected by common letter are significant at the 5% level.

*** Double figures indicate ammonium sulfate applied before planting and after thinning (about 6 weeks later) in equal amounts; single figures--all nitrogen applied preplant.

Nitrogen Uptake

The ability of the lettuce crop to utilize soil N is clear. Even at the highest rates of applied N, the amount of residual soil N in the crop exceeded that derived from fertilizers (Fig. 1). Uptake efficiency of applied N in lettuce was low, ranging from 12 percent for 180 pounds N in a single application to 25 percent for 60 pounds N in split applications. The nitrapyrin treatments resulted in a significant increase in total N uptake over the comparable single or split N applications (Fig. 2). However, nitrapyrin use did not result in a significant increase in uptake of fertilizer N at comparable rates of N (Fig. 3).

Yield

Yields as measured by fresh weight in tons per acre and pounds per 2-dozen heads are summarized in Table 2. The plots receiving nitrapyrin out-yielded both single and split applications of comparable rates. The single preplant applications without nitrapyrin produced lower yields than split N applications. Sixty pounds N + nitrapyrin, 60 + 60, 120, 120 + nitrapyrin and 180 pounds of N plots produced lettuce heads of acceptable sizes and weight for market. Nitrogen rate of 180 + nitrapyrin, 90 + 90 and 120 + 120 produced unacceptably large heads for shipping.

Soil Nitrogen

Soil sampling before and following each crop suggests N is not being leached readily in this soil, as levels of NO_3-N in the one to two feet and the two to three feet levels are generally higher before N fertilizer is applied in N-treated plots, than after the crop has been grown (Table 3). A fairly impervious layer three feet below the soil surface helped to form a perched water table. This may have increased the potential of denitrification, as 51 to 70 percent of the labeled N could not be accounted for after adding crop removal and N residual in the soil.

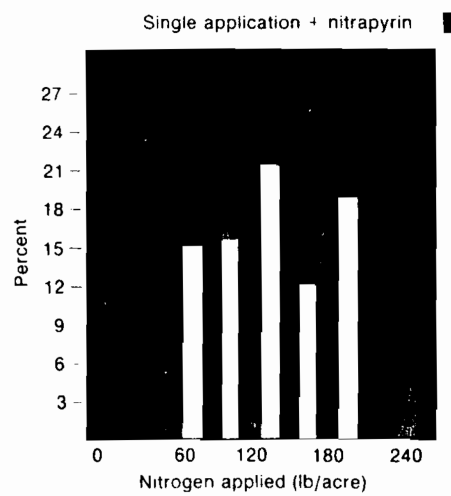

Fig. 1. Lettuce efficiency in uptake of applied nitrogen was low, ranging from 12 to 25 percent.

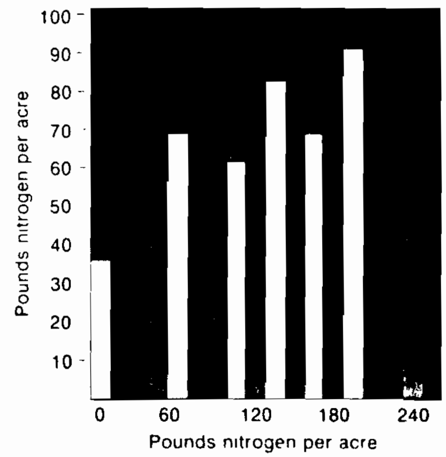

Fig. 2. Nitrapyrin treatments resulted in greater total nitrogen uptake, compared with single or split applications.

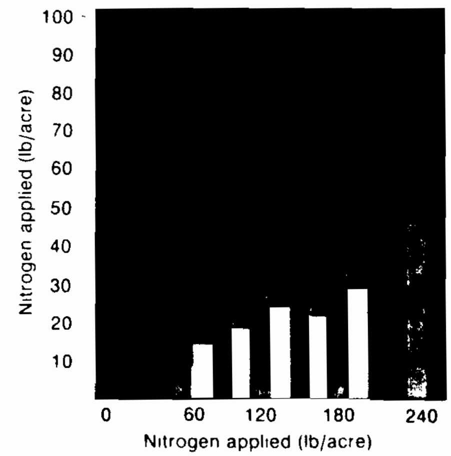

Fig. 3. Nitrapyrin did not significantly increase fertilizer nitrogen uptake at comparable rates for split application.

Most of our soils are supplied with sufficient phosphate and potassium. In a few soil series, root growth is so poor that proper placement of phosphate fertilizer is important. In general, we do not have soil that ties up phosphate. Since these two nutrients move very little in the soil profile there is no experimental evidence that they need to be applied more than once per crop for maximum yield or quality so long as there is normal root growth and adequate amounts applied. Generally, addition of phosphate and potassium fertilizer to soil help maintain soil levels well beyond deficient levels. Zinc can be deficient in only a few of our soils. Most other nutrients are available in adequate amounts with a few isolated exceptions. Over 90% of minor element problems I run into are a result of poor root growth, soil compaction or pests attacking the root system.

There is not enough time to cover fertilizing strawberries. However, we have found slow release fertilizer is very useful in this crop because of it's rather uniform constant demand for nitrogen. These materials help reduce problems of salt damage and leaching. Nitrapyrin is now registered in this crop and has proven to be helpful.

Summary

Lettuce has a low efficiency in using fertilizer nitrogen. However, this crop needs adequate nitrogen near harvest to produce acceptable head size with dark green color. Nitrapyrin proved beneficial in helping grow this crop with reduced rates of ammonium sulfate. Single application of 60 pounds N + nitrapyrin or 60 + 60 pounds N per acre produced maximum yields, as measured by market-acceptable head weights.

If sufficient phosphate, potassium or zinc is applied before planting to supplement residual amounts found in soil, there is no evidence that multiple applications or excessive amounts improve shipping quality.

Mostof our crops could be grown for some time without application of these nutrients as many soils are well supplied with them. In early cold soils or soil with compaction problems, this will not be true because of limited root growth. Occasionally boron and molybdenum in coastal sandy soil will be deficient. We have not observed any response to foliar application of minor elements in extensive tests which were conducted over a number of years.

We have collected similar data for cauliflower, celery and cabbage. These three crops respond to rates of nitrogen and use of nitrapyrin about the same as lettuce.

Time does not permit discussing potassium, phosphate and zinc responses in coastal soils.

Few of our soils are deficient in these nutrients. Since they do not move readily with water and we do not have soil that ties up phosphate, fertilizing with these materials presents little challenge.

Time alloted me does not permit covering our work in strawberries with slow release fertilizer and nitrapyrin with ammonium type fertilizer. This crop requires a steadier supply of nutrients than vegetables over its growing season. Where slow release fertilizer has not worked well in vegetables, they have been very useful in strawberries.

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GRAPES: ACCURATELY PREDICTING FERTILIZER RESPONSE

Peter Christensen

Accurately predicting fertilizer response in grapes involves several important steps, beginning with a proper assessment of needs, followed by suitable fertilizer applications and follow-up evaluations for continued treatment. I will go through these steps based on current research information on grapes and how they relate to the nutritional characteristics of grapevines.

Assessment of Fertilizer Needs

This should be based on field observation, preferably supported by laboratory analysis. With grapevines, as with other permanent-rooted crops, tissue analysis is the most useful and accurate laboratory diagnostic tool. The usefulness of soil analysis is mostly limited to the determination of soil chemical problems such as excessively low or high pHs and excess sodium, salts, or boron.

It is recommended that growers begin by surveying their vineyard blocks with bloom time petiole tissue sampling, being careful to keep varieties, soil areas, and management differences separated. This establishes a starting base, along with recent fertilization records.

Follow-up sampling can be performed in questionable or problem areas in midsummer of that same year. This follow-up is particularly helpful with potassium (K) which may have questionable levels at bloom time and then fall into a deficient range by mid to late summer when the demands of ripening fruit for K become particularly high. Adjustments in fertilizer programs are usually not practical or warranted until that autumn or winter unless some serious or solvable problems are detected, such as deficient zinc (Zn) or boron (B) levels. Supplementary nitrogen (N) treatment the same year as the petiole sampling is possible but would only be recommended where a well-confirmed N deficiency could be diagnosed and treated by early to mid June. Otherwise, elevated N levels and late season vegetative growth could interfere with fruit and wood ripening.

Another possibility is to apply N to a recently diagnosed deficient vineyard immediately post-harvest. Recent studies in California and South Africa indicate that vines pick up and store N in the fall if it is applied early enough to take advantage of a still functioning leaf area. However, this should only be considered in weak to moderately vigorous vineyards on sandy soils. This practice may be hazardous in fine-textured soils where late season N applications could stimulate late growth.

It is important to remember that critical tissue nutrient levels are not the same for all varieties. This is particularly true for nitrate-nitrogen (NO_3-N), for which critical levels have only been established with the Thompson Seedless variety. It is now well recognized that varieties can vary widely in N assimilation and utilization. This is at least partly influenced by their inherent nitrate reductase enzyme activity level. Varieties of lower nitrate reductase activity tend to accumulate higher levels of nitrate; high nitrate reductase activity varieties more readily convert nitrates to ammonium and ultimately to amino acids. Thus, they typically contain lower levels of nitrates.

One could also say that at least some of the low NO_3-N varieties are actually more efficient users of N. Examples are French Colombard, Flame Seedless, and Perlette. They may contain NO_3-N levels known to be deficient in Thompson Seedless but the vines may be quite vigorous and show no signs of N deficiency. Thus, it could be very detrimental to fertilize on the basis of tissue analysis alone with these varieties, as an already vigorous vineyard could become excessively vegetative by increased N applications.

We are now beginning to group grape varieties according to their comparative NO_3-N levels as follows:

Relative NO_3-N Level Group	Grape Variety
High	Zante Currant Petite Sirah Merlot Tinta Madera Emerald Riesling Chenin blanc Queen Grenache
Intermediate-High	Sauvignon blanc Muscat of Alexandria Ruby Seedless
Intermediate	Ruby Cabernet Thompson Seedless Rubired Emperor Semillon Cardinal Cabernet Sauvignon Zinfandel Carignane Chardonnay Pinot noir
Low-Intermediate	Calmeria Exotic French Colombard Barbera Italia
Low	Ribier Flame Seedless Perlette Salvador

This does not necessarily mean that a low NO_3-N variety needs more N fertilizer. More importantly, they probably convert NO_3-N more rapidly.

Petiole tissue NO_3-N analysis of varieties other than Thompson Seedless may still be useful to monitor year to year changes and to detect high or excessive levels of N and avoiding overfertilization with N. The final criterion of N fertilization should always be based on observation and judgement according to vine vigor.

The critical petiole tissue levels for other nutrients, such as P, K, Zn, and B, appear to fit most grape varieties but needs continued refinement. For example, Perlette and Ruby Cabernet appear to have lower critical petiole Zn levels than most other varieties.

Vines have not shown response to P, K, Zn, or B unless there is some evidence of at least a mild deficiency. Thus, proper diagnosis with these nutrients is important. Confirmation can be determined by a combination of tissue analysis, observation, and trial applications.

Some growers prefer to apply maintenance treatments to prevent deficiencies. This can be inexpensively accomplished by adding Zn to foliar sprays or B to herbicide or foliar sprays. However, it is much more expensive with K, for example. Also, a higher percentage of K becomes fixed by the soil if it is applied in light, annual treatments. It is more efficient and effective to apply K in larger quantities less often and only to areas of need.

Proper Fertilizer Treatment

Nitrogen Important factors in efficient N usage include evaluation of need by observation and tissue analysis, timing of application, and differential spot treatment.

N promotes growth. Thus, annual assessment of vine vigor will determine which areas require less, the same, or more N. Summer observations on rate of growth and winter, pruning-time assessments of fruiting wood quality should be used.

Most vineyards have differing soil types which affect vine vigor and N availability. These areas should be fertilized differently, according to need, for greatest efficiency. Sandy soils and areas with root problems should receive more N than the more fertile, finer textured soil areas. Split applications are also preferred in these areas to reduce leaching losses.

The advantages of split applications of N or applying smaller increments more frequently is well demonstrated with drip irrigation. Many growers are experiencing highly efficient N treatments through drip and are now using no more than 20 to 25 lbs. of N per acre each year where 60 lbs. of N per acre was used under furrow irrigation. It is recommended to begin N fertilization through drip shortly after bud break and to apply 2 to 4 lbs. N/acre each week. This should be continued until mid to late May in vineyards of average vigor and until late June in below average vigor vineyards. Vineyards of high to excess vigor should receive no N or only a total of 4 to 6 weekly applications.

N should not be applied until late winter to early spring to avoid leaching or denitrification losses from winter rains. Recent studies have shown that most of the N applied in early winter can be lost from the top 3 to 4 feet, even in a fine sandy loam hardpan soil.

Potassium K should only be spot-treated with concentrated placement of high rates of K for greatest benefit. Applying relatively low, annual rates over the entire vineyard may not correct the deficient area and wastes K in non-need areas.

Zinc The most efficient treatment is to apply a basic or neutralized zinc sulfate product (50-52% Zn) at two weeks prebloom to full bloom in a full wetting, dilute spray. Concentrate sprays or those with lower zinc analysis compounds may contribute to "maintenance" programs but compromise maximum effectiveness in cases of confirmed deficiency.

Boron Deficiencies are limited to rather specific geographic areas on the east-side of the San Joaquin Valley and coastal valleys. It is the easiest and least expensive deficiency to correct. Two thirds to one ounce per vine of B fertilizer, depending on analysis, is all that is needed to correct a deficiency.

About 5 lb./acre of B fertilizer per year is all that is needed for maintenance. This can be applied every year in a foliar or herbicide spray or once every 2 to 3 years, 10 to 15 lbs./acre respectively, in an undervine, preemergence herbicide spray.

Follow-up Evaluation and Treatment

A tissue analysis program should be continued for several years to follow and to make possible adjustments in fertilizer practices. Petiole tissue nutrient levels are also affected by seasonal weather differences which can cause them to vary widely from year to year. Thus, only one year of tissue sampling may be somewhat misleading. At least 3 consecutive years of bloom time petiole sampling is recommended to avoid the reliance on one year's information. Year to year variations can be particularly great with NO_3-N, which can fluctuate over 100% between years with no change in the fertilizer program. K levels can also vary widely from season to season, but not to the magnitude of NO_3-N.

Some growers may wish to continue annual petiole sampling following the first three years. This is not necessary with the nutrients P, K, Mg, Mn, Zn, or B which need only be rechecked every three years or so. However, more consistent petiole sampling may be useful with N. It is leached with rainfall and irrigation water and most often requires annual application.

Never rely completely on laboratory analysis for fertilizer recommendations. Erroneous results or inaccurate interpretations sometimes occur. These are most easily avoided by choosing a good, reputable laboratory. Ask for a recheck of some analyses or get a second opinion if there is any question. Above all, the grower and field representative should rely most heavily on their observations and good judgement in the field, especially with N.

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ECONOMICS OF RISK REDUCTION

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Farming is not a riskless venture. Risk and uncertainty present special problems and opportunities. Without risk, there would be little, if any, profit. By taking risks, farmers may obtain greater profits.

Managers cannot eliminate all risk and uncertainty from their businesses. They can reduce their risk exposure, i.e., manage their risk; but they cannot eliminate risk. The goal of risk management is to optimize income after considering the sources of risk, the methods of reducing risk, the ability and willingness to take risks, and the income potential of the different alternatives. The goal of risk management is not necessarily to minimize risk except in the use of a "safety-first" criterion to meet a minimum level of gross income for short-run survival.

There are three sources of risk for the producer: production risk, marketing risk, and financial risk. Production risk is the uncertainty of the physical yield or response. Marketing risk is the uncertainty of the product price. Financial risk is due to increased borrowing against the same net worth causing an increased chance of losing more of that net worth.

For the fertilizer recommendation problem, let us consider only production and marketing risks. Specifically, I will discuss how to reduce these risks and then how to make decisions in the face of these risks.

Reducing Production and Marketing Risks

It is foolish to risk more than is actually necessary. Here are several methods to reduce these risks.

1. Crop Insurance involves paying another person or institution (e.g., the government) to absorb risk. The decision to buy insurance depends on the premiums, the potential loss, the chances of a loss, and the impact of a loss on the business.
2. Commodity contracts and hedging on the futures market reduce the uncertainty of future prices and thus income. They also eliminate the chances of greater income or losses.
3. Flexibility - Managers can reduce risk by keeping their plans flexible so new information can be used. Flexibility is hard to define; here are some examples of flexibility:
   a. Buildings which can be used for livestock, grain storage, machinery with only minor adaptations.
   b. Machinery which can be used on several crops.
   c. Fertilizing throughout the growing season so new information on price and yield expectations can be used to adjust the fertilization rate.
4. Diversification - Since prices and yields of different crops sometimes do not fluctuate together, diversification may be one method of reducing both production and marketing risks.
5. Environmental control by irrigation, frost protection, and hot caps may reduce production risk.

These methods can reduce risk, but they do not eliminate risk. The choice between risky alternatives still remains.

Developing A Decision Tree

The basic framework for decision making with risks involves choosing between alternatives which have returns which depend upon events which we do not control. There are several methods to arrange these alternatives, events, and returns. When dealing with both production and marketing risks, the easiest method is to utilize a decision tree.

A decision tree consists of branches and nodes; it grows on its side. Square nodes are used to denote decisions or alternative actions, and circular nodes denote the events which that depend on chance. The decision tree framework is illustrated by the fertilization decision for a dryland wheat farmer (Figure 1).

The decision tree is drawn in chronological sequence from left to right with the alternative acts (level of fertilizer application) branching from the decision node denoted by a square and the events (level of rainfall) branching from events or chance nodes denoted by circles. The net returns are indicated at the terminal branches. At the decision node, it is the manager's choice whether to follow the "lightly," "moderately," or "heavily" branch. For each of these three action branches there are three event branches corresponding to "low," "average," or "high" rainfall. The net returns estimated for each decision (e.g., $20, $25, and $27.50 for "fertilizer lightly") are used to aid the manager in the fertilization decision. Probabilities are used to decide the alternative with the greatest expected return. (This procedure is discussed later.)

The decision tree approach can be used to represent more complicated situations. Suppose that the manager has to make two fertilizer decisions, one prior to planting and the other, a top dressing decision, after emergence of the crop. These could be represented in the decision tree with intervening rainfall levels and subsequent price levels (Figure 2). It might also be possible for the manager to purchase a long-range weather forecast. The "purchase" or "no-purchase" alternatives could be represented as a decision

Figure 1. A Simple Decision Tree

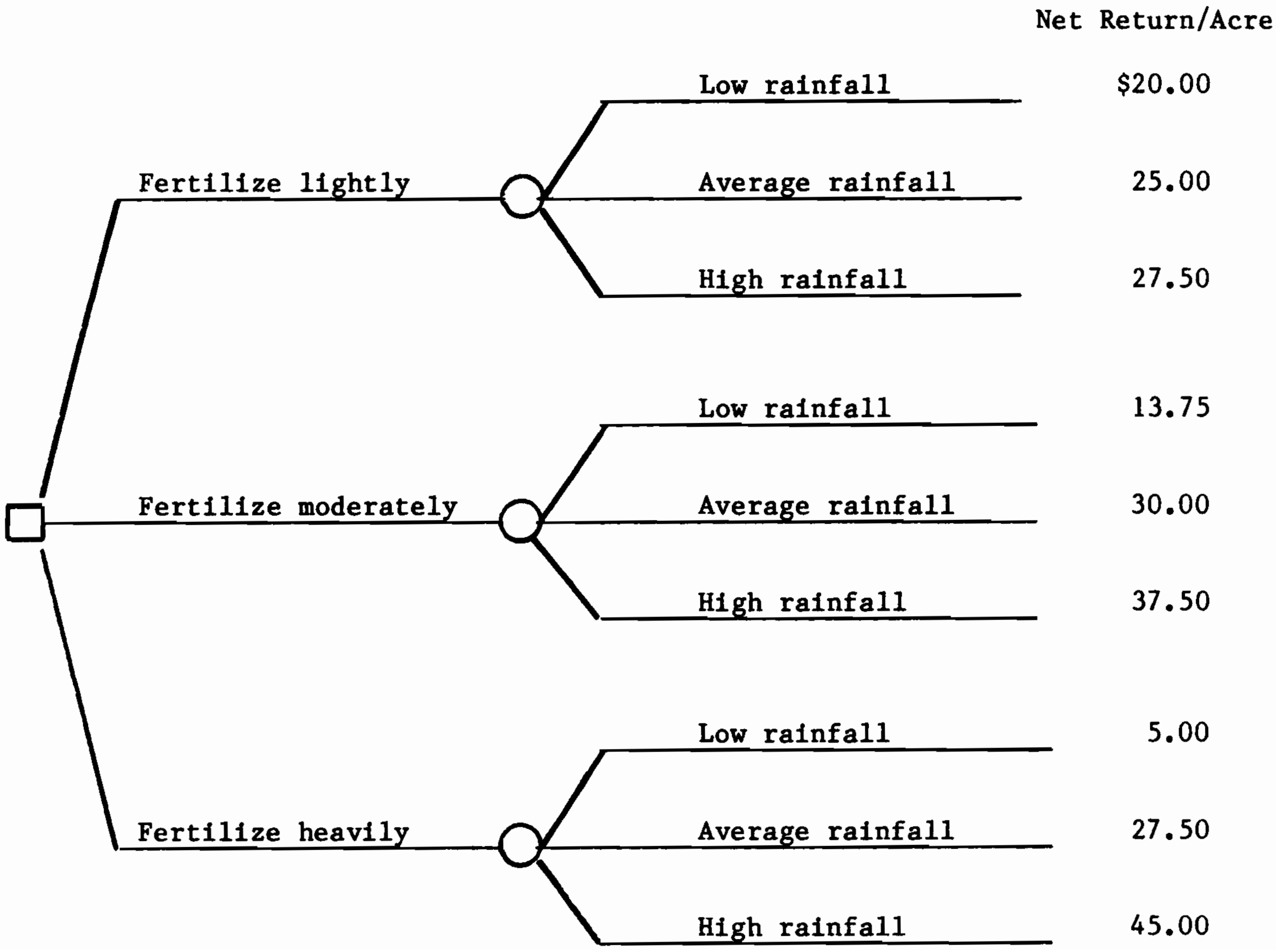
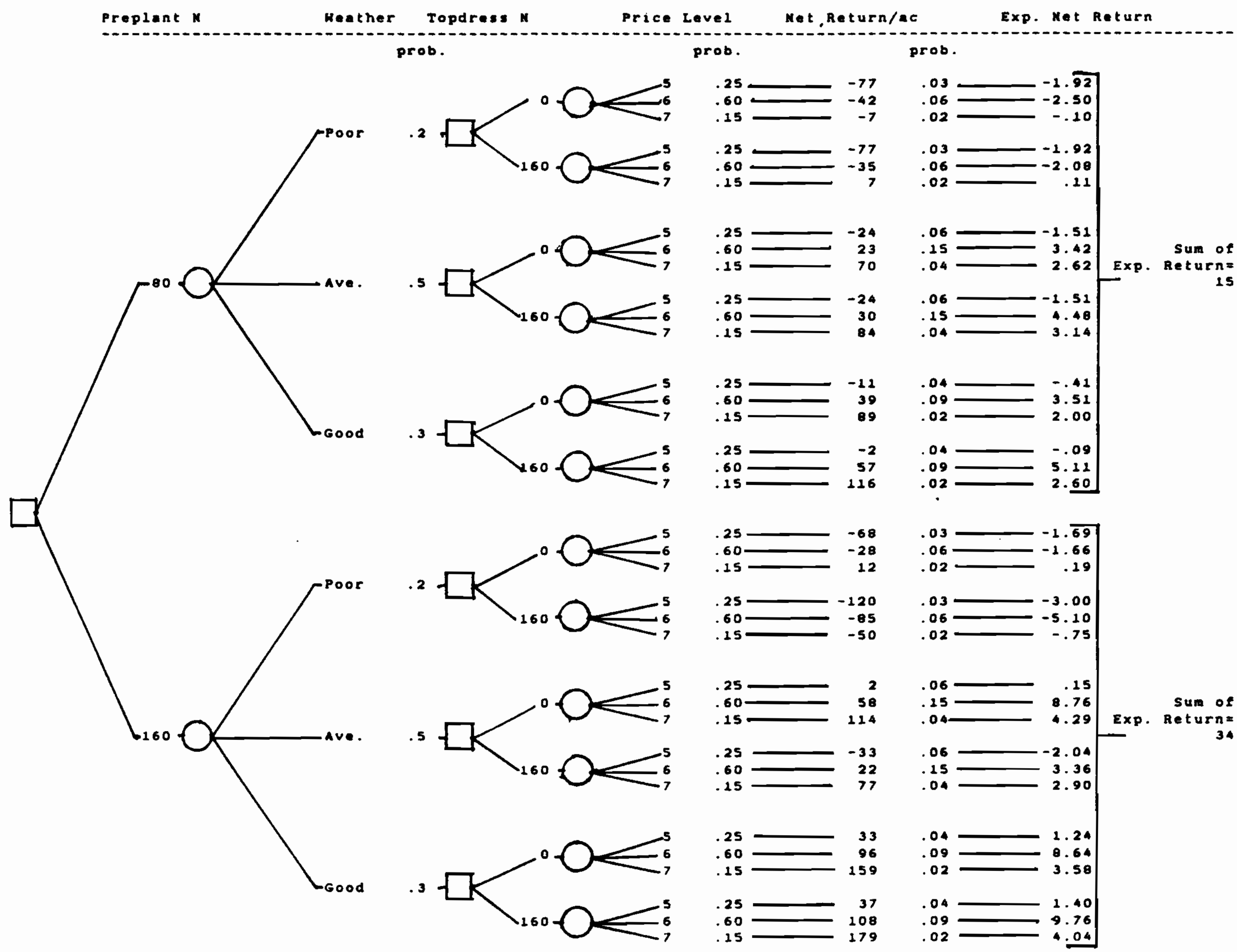


Figure 2. A Decision Tree for Wheat Fertilization



node with an event node representing the outcome of the forecast. With these alternatives, the decision tree becomes more complicated.

As further complexities are added to the decision problems, the decision tree can become a "bushy mess." When the number of nodes, alternative actions, and number of events multiply, the tree explodes rapidly. It is best to begin with a rather coarse tree specifying only the major branches; checking and lopping off the inferior actions and insignificant events; developing the unlopped branches in further detail; and repeating the cycle.

Drawing an adequate decision tree is not often easy and first attempts can be frustrating. It is even more difficult when the decision problem is not well specified before beginning with the analysis. The advantage of the decision tree approach is that it allows the components of the decision problem to be laid out in an orderly system and thus showing the chronological interaction of alternative actions and events.

Incorporating Probabilities

So far we have developed a decision tree for a wheat farmer which includes the major decision and events. Now, by estimating the probabilities of the events, we can calculate the expected returns from each alternative with the greatest expected return.

There are several ways to develop probabilities; mean and variance, frequencies, cumulative distribution, "conviction weights," direct estimation, Anderson's sparse data method, and a few others. For a discussion of these methods see Nelson, et al (1978) and Anderson (1973 and 1974).

Once they have been developed, the probabilities are placed in the decision tree next to the appropriate event. If more than one event leads to a terminal branch, or result, the joint probability of that result needs to be calculated. For example, if there is a 20% probability of low rainfall and a 20% probability of a low price, there is a 4% chance of having both low rainfall and low price (i.e., 20% x 20% = 4%).

The probabilities of the results after each decision are used to estimate the expected returns from that decision. For each decision, the sum of the probabilities of the potential results must be equal to 1.0. In complex decision trees, this rule should be checked closely to eliminate errors in multiplication and in decision tree development. In wheat fertilization (Figure 2), the probabilities have been assigned to each event and the joint probabilities of the returns have been calculated. The manager now selects the alternative which will maximize expected returns and not violate any "safety-first" rule.

Conclusions

Farming involves risk. We can not eliminate it, so we must incorporate it into the decision process. As professionals, we must supply farmers with information on price and yield variability and educate them on how to use it in their decisions. As farmers, we must realize that there will be risk, look for ways to reduce risk, evaluate our ability and willingness to bear risk, and make decisions with risk incorporated. Failure of either group could result in loss of potential income due to alternatives not chosen or business failure.

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ALFALFA CANOPY ARCHITECTURE, LIGHT INTERCEPTION AND PHOTORECEPTIVITY

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Solar tracking, the phenomenon of sun-following by leaves, occurs in many cultivated and native plant species (Ehleringer and Forseth, 1980). Two types of leaf movements have been described in solar tracking plants. Diaheliotropic movements maintain the leaf surface, perpendicular to the direction of incident radiation. Paraheliotropic movements result in a leaf orientation parallel to the direction of incident radiation.

The question arises whether solar tracking is beneficial to crop productivity. Diaheliotropic leaf movements may be beneficial since leaves oriented perpendicular to the plane of incident radiation will maximize energy interception, and hence photosynthesis (PS), for most of the daylight period. Nontracking leaves will reach maximum interception only during that period when the sun passes directly over the leaf surface. Estimates of the level of enhancement of daily light interception of single leaves attributed to solar tracking are on the order of 30 to 40% (Mooney and Ehleringer, 1978). In a canopy, however, the effect could be counter productive if the upper exposed leaves remain above their light-saturation point while shading the lower leaves (Fukai and Loomis, 1976).

Paraheliotropism is reportedly drought related (Shackel and Hall, 1979). It reputedly reduces leaf temperature and increases water use efficiency when the leaf water potential is low.

The purpose of this paper is to describe the solar tracking characteristics of a closed alfalfa canopy and to evaluate those characteristics relative to photosynthetic productivity. Part of this study was published elsewhere (Travis and Reed, 1983).

Materials and Methods

Plant Materials - A one-year-old stand of alfalfa, var. Lahontan, irrigated on a 10-day cycle and harvested at approximately 4-week intervals was used for the tracking study.

Solar Tracking Measurements - Solar tracking measurements (leaflet angle and leaflet azimuth) were taken at 2- to 3-h intervals between 0600 and 1700 True Solar Time. Solar tracking is quantitated by the following equation:

$$\text{Cosine I} = \text{Cos}\ (\Delta\text{leaf and sun angles}) \times \text{Cos}\ (\Delta\text{leaf and sun azimuths})$$

Values for sun angle and azimuth were taken for the Smithsonian tables. For a leaflet that tracks the sun perfectly, the Cos I would be 1.0.

Water Potential Measurements - Xylem water potential was measured on three to five adjacent branches with a Scholander pressure chamber.

Gas Exchange and Light Measurements - Photosynthesis was measured in the field using a portable double-isotope porometer. Light measurements (PPFD) were taken with a calibrated LI-COR quantum sensor.

Results and Discussion

The general pattern of daily solar tracking activity by alfalfa leaflets in a closed canopy is shown in Fig. 1A. The average Cos I was relatively high during the morning hours indicating that most leaflets were tracking the sun. By late morning tracking activity began to decline. That response was due to leaf cupping (paraheliotropism). Solar tracking activity increased again during the late afternoon. The onset of midday cupping was apparently not related to water stress (Fig. 1B). In each variety cupping began between 0900 and 1000 h, several hours prior to the midafternoon decrease in water potential, and in 3 of the 4 varieties solar tracking activity resumed prior to the decrease in water potential. Tracking in the fourth variety (Norsman) resumed prior to the late afternoon recovery from moisture stress.

The relationship between tracking activity and leaflet age and location in the canopy is shown in Fig. 2. At 0822 h the frequency of leaflets with Cos I greater than 0.8 was greatest in the lower strata of the canopy. The percentage of leaflets with Cos I of 0.8 or greater was 90% at the sixth-to-eighth positions, as opposed to less than 60% of the second-to-fourth positions. At 1422 h, the Cos I values for leaflets in all strata were distributed between 0.2 and 1.0. The return of tracking activity was evidenced by the leaf position data at 1652 h, at which time about 65% of the sixth-to-eighth position leaflets had Cos I values equal to or greater than 0.8 compared to only 48% for the second-to-fourth position leaflets. These results indicate that during the morning and afternoon hours a gradient of increasing tracking efficiency occurs with depth in the canopy. In simple terms, the upper leaflets are more randomly oriented than the lower leaflets. This arrangement suggests an enhanced light penetration into the lower strata which should benefit the lower or older leaves. To test this hypothesis light measurements were made at 10-cm intervals throughout the canopy (Fig. 3). Measurements were taken with the photocell positioned perpendicular to incident radiation (Cos I = 1.0) and with the photocell parallel to the soil surface (Cos I = 0.57). The latter position was selected to represent the average nontracking leaf. At each level in the canopy, down to approximately 30 cm above the soil surface, significantly more light was available to tracking leaflets than to nontracking leaflets.

To evaluate the potential carbon gain resulting from enhanced light interception by lower strata in the canopy one must assess the effect of light dose and leaflet age on PS. Figures 4 and 5 present those data. The carbon gain benefit can be estimated by comparing these figures with the light penetration data (Fig. 3). Most of the leaflets in the upper stratum of the canopy should be at or near the light saturation level for PS regardless of orientation. However, leaflets in the lower stratum (e.g. sixth position) are under less than optimum conditions. The PPFD value (750 μmoles m^{-2} s^{-1}) obtained for tracking leaflets at position six is sufficient to support PS to about 85% of maximum. Assuming that leaflets at that age photosynthesize at 75% of the level of recently developed leaflets, their contribution to canopy PS may be on the order of 60 to 65% of the of the upper leaflets. Conversely, in the absence of tracking, leaflets in the sixth position would receive about 45% of the PPFD necessary to saturate PS resulting in about 30% of maximum PS. Since most leaflets at that level track relatively effectively the overall contribution of older leaflets to canopy PS is likely near the higher estimate.

A valid estimate of the potential carbon gain on a daily basis will require an integration of the canopy depth effect over the entire day with a correction for the limitation placed on the system by the absence of tracking during the midday hours. The ultimate potential carbon gain may then be assessed by integrating the average daily gain over the length of the regrowth cycle and subsequently the growing season.

Conclusions

The solar tracking characteristics of alfalfa apparently provide the crop with a mechanism for maintaining photosynthetic productivity in older leaves. Current research is directed toward characterizing tracking in several varying germplasm sources. Preliminary results indicating tracking differences between germplasm sources will be discussed.

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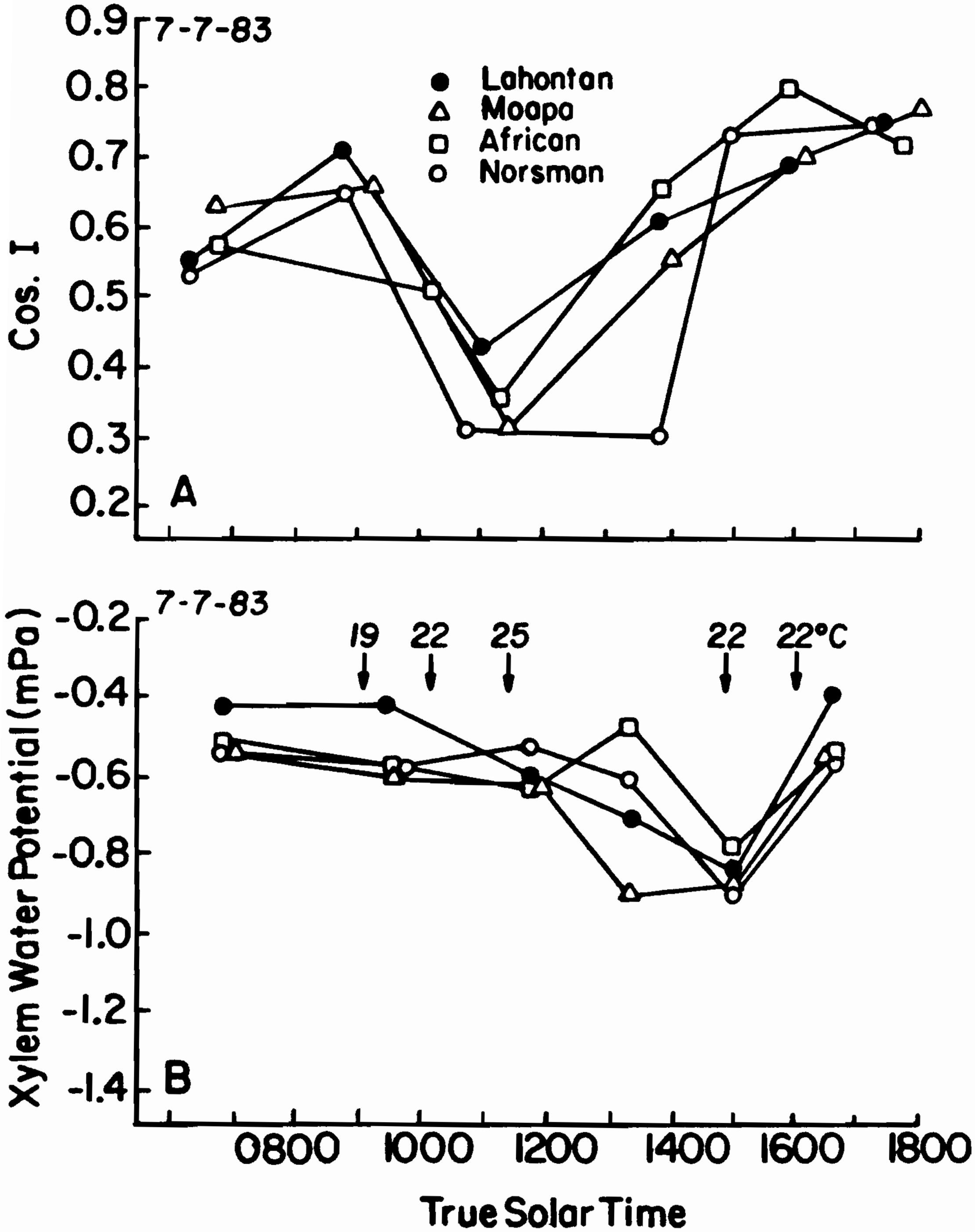
Figure 1. A: Daily solar tracking pattern (A) and xylem water potential pattern (B) for four alfalfa varieties.

Figure 2. The efficiency of solar tracking as a function of leaflet age and time of day.

Figure 3. Photosynthetic photo flux density values at 10 cm intervals within the canopy. ( ), Photocell perpendicular to incident radiation. ( ), photocell parallel to soil surface.

Figure 4. Effect of PPFD on apparent photosynthesis.

Figure 5. Effect of leaflet age on apparent photosynthesis.



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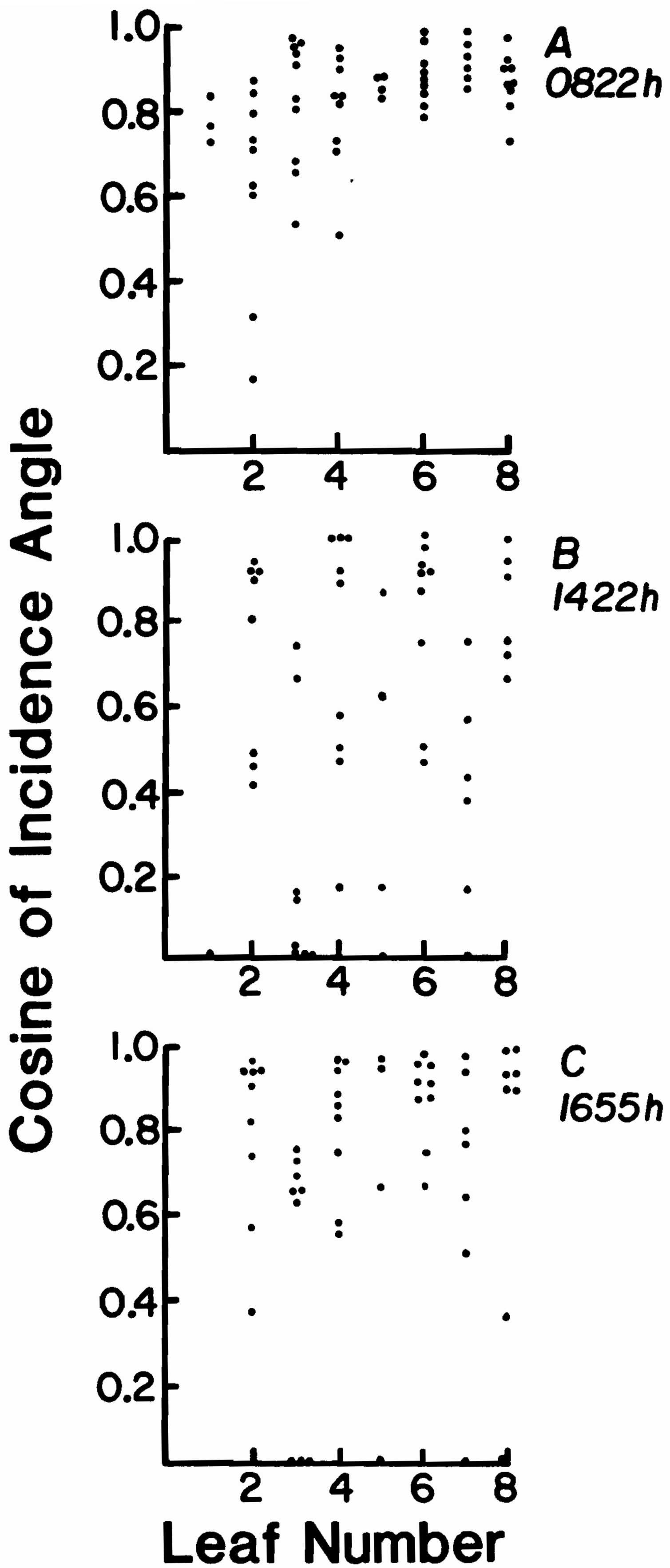

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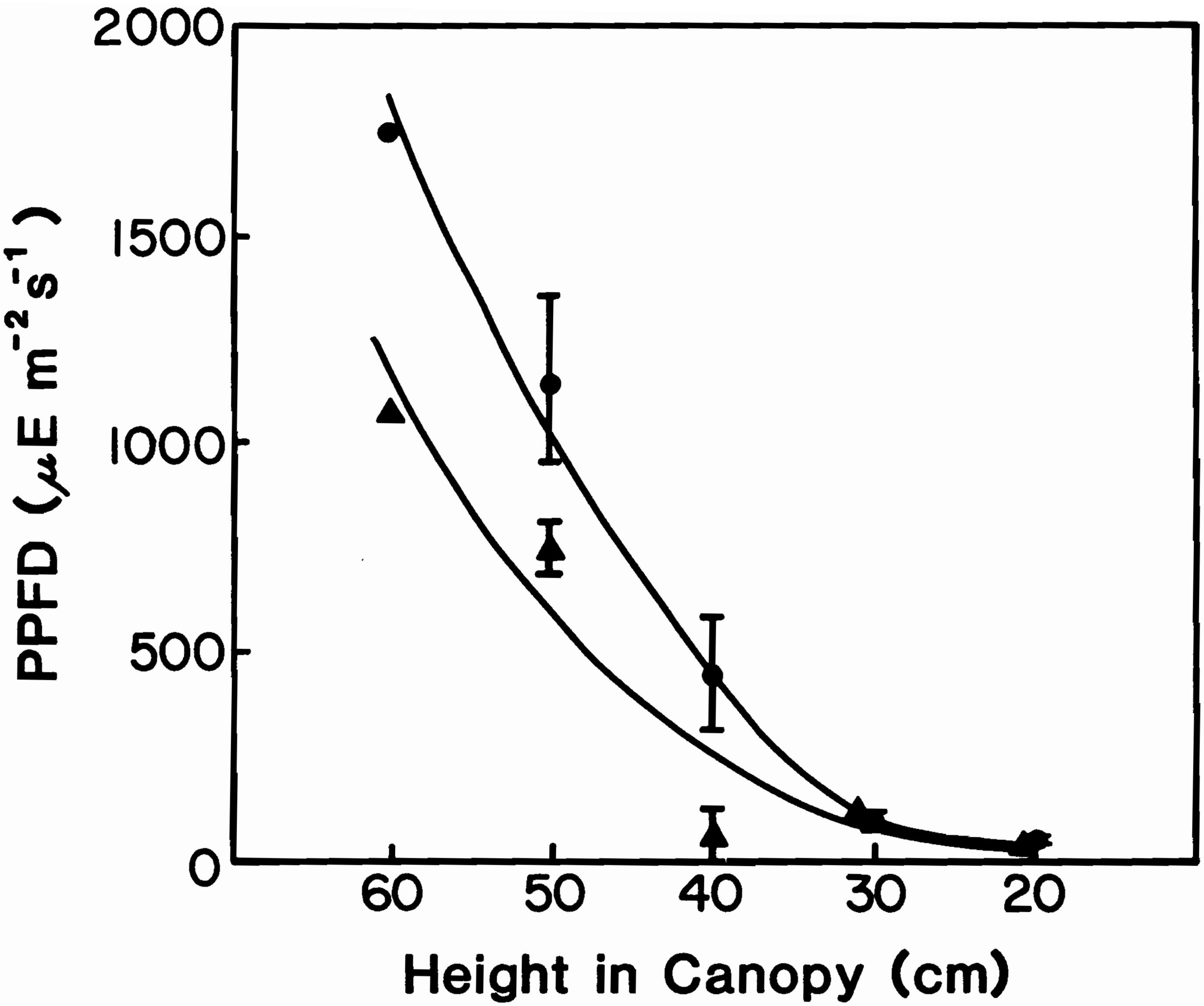

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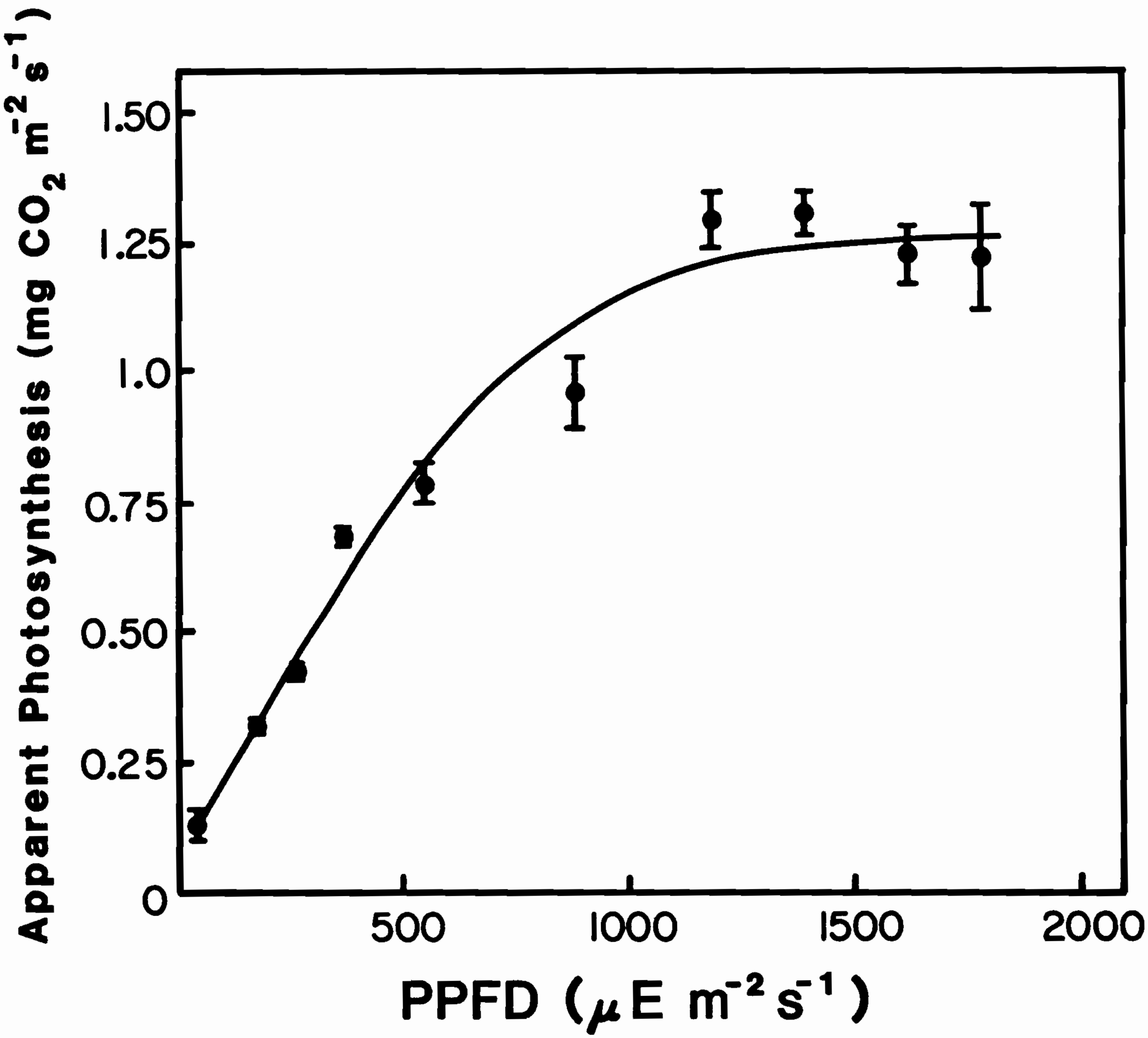

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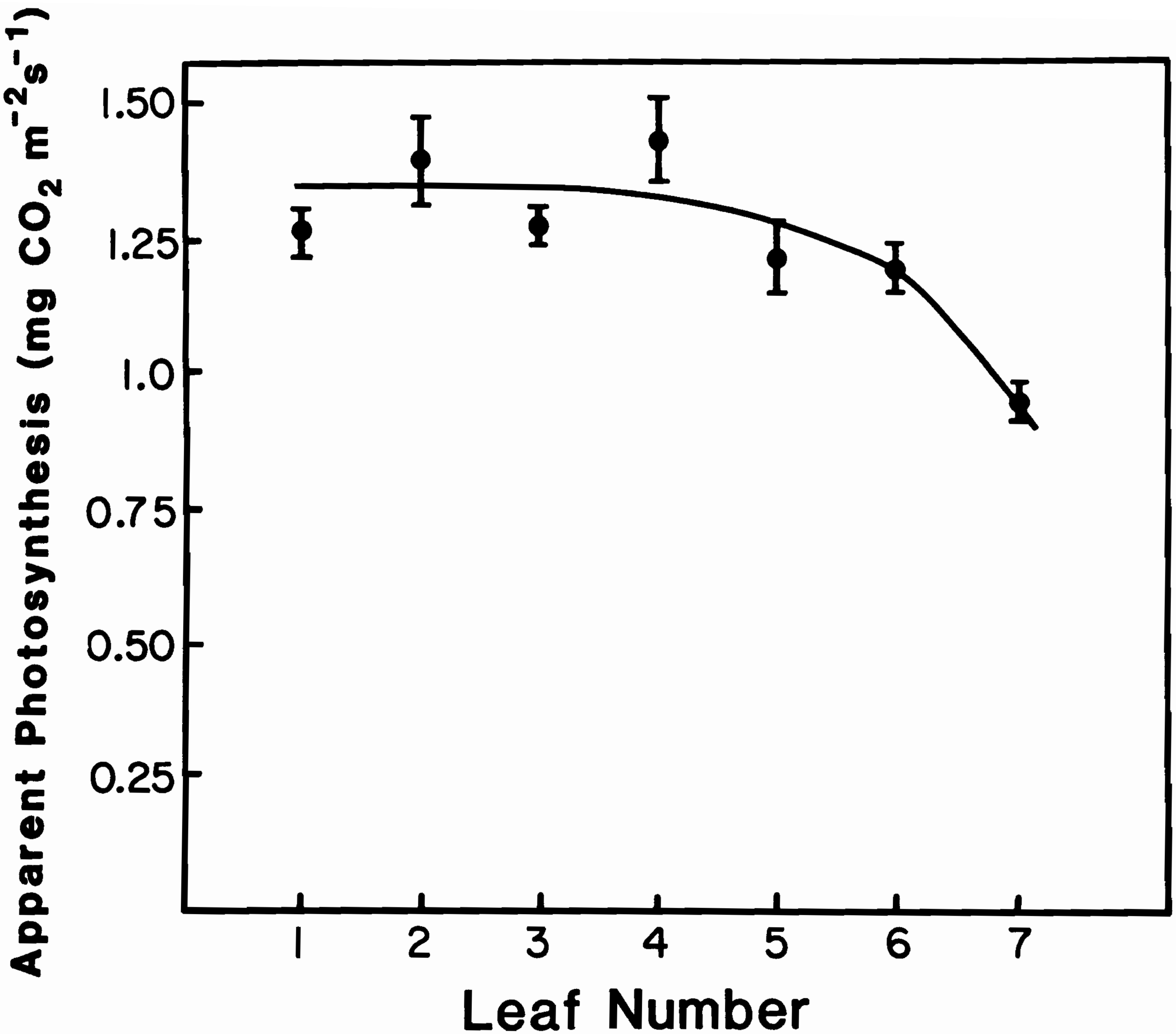

Figure 5. Effect of leaflet age on apparent photosynthesis.

BREEDING SEEDLESS RAISIN GRAPES FOR MECHANICAL HARVEST

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The San Joaquin Valley of California produces essentially all of the raisin grapes grown in the United States. Approximately 95% of the raisins are made from the 'Thompson Seedless' variety and about 80% of these are sun-dried in the field. 'Thompson Seedless' makes a very desirable, high quality raisin when picked at the proper sugar content. This is usually the last week of August or the first week of September. After picking, it takes from 2-4 weeks for the grapes to dry into raisins. The longer the grower waits to pick his crop to obtain high quality (high in sugar) raisins, the greater the chance for rain and poor drying conditions. Therefore, the grower needs to be able to pick his crop as quickly as possible when it has reached the desired maturity.

Labor is not always available to pick the entire raisin grape crop as quickly as desired to obtain the highest quality raisins without risk of rain damage. Therefore, it is desirable to develop mechanical means to harvest this crop. 'Thompson Seedless' fruit is severely damaged when harvested mechanically and does not make an acceptable dried product. When fruiting canes are cut 1 week ahead of harvest, the fruit is easier to harvest; however, specially trained crews are needed to cut the canes. The development of grape varieties that could be mechanically harvested with a minimum of fruit damage and without cutting canes would make it easier to harvest the raisin grape crop.

The objective of our raisin breeding program is the development of several seedless grape varieties that can be mechanically harvested, that ripen in a sequence and as early or earlier than 'Thompson Seedless'.

Method and Field Trials

Several early-maturing seedless grape selections which existed in our breeding program and generally shattered easier than 'Thompson Seedless' were planted in 1979 so they could be harvested mechanically and fruit removal studied. In 1979 'Thompson Seedless', with and without canes cut, and 'Fiesta' without canes cut were mechanically harvested to determine the kind and amount of fruit damage. In 1981 and 1982 the selections were mechanically harvested and evaluated for damage. In 1982, laboratory tests were devised to determine desirable berry and cluster characteristics for mechanical harvest. We devised the 'Jensen shatter test' to approximate mechanical harvest. Berry damage and fruit removal was determined after dropping the fruit cluster 6 feet. The percent of berries that pull off with the cap stem, the force to remove the cap stem and the force to break the berries were also measured. Various proportions of berries from 'Thompson Seedless' were damaged by cutting and shaken 30 times in a gallon jar to simulate mechanical harvest. This was done to determine the maximum amount of damage that could be inflicted on the grapes without affecting the appearance of the raisins.

Results and Discussion

'Thompson Seedless' and 'Fiesta' harvested mechanically had 34 and 14% moderately damaged berries, respectively, and over 10% severely damaged berries. The 'Thompson Seedless' that were cane cut 5 days before harvest had 4% moderate and 3% severe damage. This indicates that even 'Fiesta', which shatters easier than 'Thompson Seedless', is not as good as cane-cut 'Thompson Seedless'. Therefore, types easier to harvest must be developed to make mechanical harvesting more feasible.

When 'Fiesta' and the 4 early-ripening selections were mechanically harvested in 1981, all had over 10% severe damage and 15% moderate damage. There were significant differences among varieties for the amount of moderate damage but not for severe damage. There were also significant differences between varieties for berries removed with stems. The percent damage in the dry raisins for all selections averaged 1% for hand harvest and 3% for mechanical harvest. Both were below the 5% maximum allowable. However, one selection averaged 6% damage when mechanically harvested. All selections harvested mechanically in 1982 showed greater than 5% damage while hand-picked showed 0-2%. The selection P54-3 had the most damage both years. This showed us that variability existed among the grapes for ease of harvest and for berries removed with stems. Retaining the stems on the berries likely would reduce mold injury that might occur on the berry stem scar.

The Jensen shatter test closely approximated the mechanical harvest tests for the 5 selections tested. Using this test, 2 selections (C21-151 and B73-167) were identified that had much less damage than 'Thompson Seedless' or the selection (C61-126) considered best in the mechanical harvest test. C21-151 and B73-167 had 41 and 12% damaged berries compared to 52 and 51% for 'Thompson Seedless' and C61-126, respectively. More berries of C21-151 and B73-167 were pulled off with the cap stem than of 'Thompson Seedless'; the former also required more force to break the berries. These desirable characteristics should make C21-151 and B73-167 more suitable for mechanical harvest than 'Thompson Seedless'.

When 'Thompson Seedless' was damaged by hand and shaken to simulate mechanical handling in the harvester, it was found that an unacceptable sticky product resulted if more than 5% of the berries were damaged. The stickiness was caused by juicing of the damaged berries. The marketing order states that natural raisins before processing may contain no more than 5% with mechanical damage. Therefore, the raisin varieties for mechanical harvest must have fewer than 5% with damage to meet inspection requirements and to produce acceptable raisins.

Conclusions

Differences were found among grape genotypes for amount of damage during mechanical harvest and simulated tests, for percentage of berries removed with cap stems, force required to remove cap stems and force required to break the berries.

Using laboratory tests, 2 genotypes were identified having desirable characteristics for mechanical harvesting. They will be tested to see if they respond as well in the field under actual mechanical harvesting conditions.

BREEDING SUGARBEET FOR CROP EFFICIENCIES

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The title in the program is purposely vague because a precise topic had not been chosen when it was due. A more appropriate title would be: Population Improvement in Self-fertile Sugarbeet.

When hybrid cultivars are the end product of a breeding program, the program will have several distinctive phases: (1) Divergent populations will be developed with maximum genetic variation; (2) The populations will be improved or modified for genetic structure, for example, in sugarbeet for multigerm (MM) or monogerm (mm), for nonrestorer types (type-0), for self-sterility ($\underline{S}^s\underline{S}^s$) or self-fertility ($\underline{S}^f\underline{S}^f$), etc; (3) Major population defects will be corrected or moderated, for example, for adaptation, bolting tendency, disease reaction, etc. (Examples will be presented demonstrating the improvements made against major diseases.); (4) Hybrid performance will be improved by various intra- and inter-population improvement methods; and (5) Superior parental lines will be extracted from the improved populations.

Contemporary sugarbeet cultivars grown in the western U. S. A. are primarily 3-way hybrids. The pollinator or male parent has usually been derived from obsolete, open-pollinated ($\underline{S}^s\underline{S}^s$), multigerm cultivars. The female or seed bearing parent is usually a cytoplasmic male sterile (CMS), F_1, monogerm hybrid between two self-fertile ($\underline{S}^f\underline{S}^f$) inbred lines.

Thus, sugarbeet breeding populations are separated into two major categories depending primarily upon whether they are destined to be used as pollinators (MM, S^sS^s) or as seed bearing parents (mm, S^fS^f, type-0). To maintain as much heterotic potential as possible, breeders have attempted to maintain maximum genetic diversity between these two parental types.

The population improvement program in sugarbeet has largely been confined to self-sterile sources in which random mating among selected plants or lines is readily accomplished after each cycle of selection. Within self-fertile sources, rates of out crossing are unpredictable and usually low and breeding procedures have mimicked the traditional methods used for autogamous crops (e.g., wheat, lettuce, soybean, etc.) to obtain inbred or pure lines.

At Salinas, genetic male sterility (a_1a_1) has been introduced to obtain random mating within the self-fertile sources and relatively broadbased, self-fertile, monogerm, type-0 populations have been developed. These sources are sometimes referred to as male-sterile facilitated, random-mating populations. Within these sources, population improvement of all types can be practiced. One of the methods that can be used that was not previously possible with sugarbeet is S_1 progeny recurrent selection. Because of the success of this method in other crops (e.g., corn), it is of interest to evaluate the efficacy of S_1 evaluation in sugarbeet.

Two cycles of S_1 progeny recurrent selection have been completed within a population referred to as 790. This paper will summarize the results of S_1 progeny evaluation within 790 and compare it to corresponding test-cross progeny evaluation as a means of identifying and sorting genotypes for high and low performance.

Materials and Methods

The self-fertile, random-mating source population designated 790 was developed from bulk crosses involving a large number of self-fertile breeding lines. These inbreds had been developed in the curly top and virus yellows resistance breeding programs and were adapted to California. After a cycle of selfing and selecting for monogerm, the population was advanced by random mating. Randomly selected pollen-fertile ($\underline{A}_1\underline{a}_1$) S_o plants were selfed to produce S_1 progeny and simultaneously crossed to a common CMS tester. Thus, after each cycle of evaluation, the plants produced from remnant S_1 seed of selected families would segregate $3\underline{A}_1\underline{\ }:1\underline{a}_1\underline{a}_1$ and could be recombined through the male sterile segregates.

After the test-cross (TX) and S_1 progeny evaluations, a 20% selection intensity was used and synthetics based upon S_1 or TX progeny performance for high and low sugar yield were produced. Synthetics based upon selection for high and low sugar concentration for the S_1 progeny evaluations also were created. The selected S_1 families were represented by an average of 22 plants, and approximately 400 plants were intermated to form the C1 synthetics. An unselected synthetic check (CO) was produced by intermating S_1 plants from each of the 90 S_1 and TX families that were evaluated.

For the second cycle of selection, 144 S_1 families extracted from the C1 synthetic for high sugar yield were evaluated. A C2 synthetic based upon a 20% selection intensity for sugar yield was subsequently produced.

After the first cycle of selection, the CO and C1 synthetics were evaluated in five randomized complete block tests at Salinas and Brawley in 1978 and 1979. After the second cycle of selection, the C0, C1, and C2 synthetics were evaluated in three tests at Salinas and Brawley in 1982.

Results and Discussion

The C1 synthetics derived on the basis of S_1 selection for high and low sugar yield were significantly (P=0.05) higher (10.7%) and lower (-10.0%) for sugar yield than the C0 synthetic check. These differences were due to changes in root yield with sucrose concentration remaining essentially unchanged. The selection for high sugar yield based on TX performance also produced a significant increase in sugar yield (7.1%) and root yield (6.6%), but the selection for low sugar yield did not greatly influence the performance of the derived synthetic in comparison to the check. The divergent synthetics for high and low sugar yield derived by S_1 evaluation were separated by about 21% difference in sugar yield performance whereas those derived by TX evaluation were separated by about 10% difference in sugar yield. Thus, S_1 evaluation appeared to be more effective than TX evaluation at discriminating S_o genotypes that contribute to population sugar yield.

The results for the second cycle of S_1 family evaluation and selection were similar. The relative sugar yield differences of the synthetics for C1 (low sugar yield), C0, C1 (high sugar yield), and C2 (high sugar yield) were -6.7, 0.0, 9.2, and 15.0%, respectively, in tests in 1982.

In summary, S_1 family performance identified both higher and lower performing genotypes for the traits in question. The changes produced in the performance of the synthetics were greater for S_1 evaluation than for TX evaluation. After two cycles of S_1 progeny recurrent selection, S_1 family performance proved effective at discriminating differences in the performance of S_o plants and for improving the breeding value of this monogerm, self-fertile population.

BREEDING COTTON FOR CROP EFFICIENCIES I: HISTORICAL RESPONSES

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Evidence indicates that cotton was first grown in California in small plots on Spanish mission lands. Later cotton culture was tried, generally unsuccessfully, in the central valleys by immigrants who had turned to farming after failures at gold prospecting. With the development of irrigation in the Imperial Valley in the early 1900's cotton culture first became commercially successful in California in that area. At first Yuma and Pima which are American-Egyptian varieties were grown. Later Upland varieties were grown, notably Durango. Peak production came in 1920. Pests and economics reduced production in the southern valleys until cotton culture was abandoned by 1930. In 1951 the lower valleys returned to cotton production with the growing of Acala 4-42. By 1957 growers in this area had switched to Deltapine varieties.

After abandoning cotton culture in the central valleys in the 1880's cotton returned to the San Joaquin Valley in 1909. Although *Gossypium hirsutum* Upland varieties were tried most of the interest was in *G. barbadense* American-Egyptian varieties. This interest was particularly intensified during World War I due to the increased demand for these high strength varieties. After the war, demand for the American-Egyptian cottons dropped and growers attention turned to the higher yielding Upland varieties. It was at this time that Acala cotton came on the scene in California.

At the reawakening of interest in cotton in the San Joaquin Valley interest was rekindled in the Sacramento Valley. Experimental plantings were made at Chico in 1919. After that commercial plantings were made but cotton production never became successful and by 1927 cotton had left that area.

In 1906 two USDA plant explorers searching for boll weevil resistant cottons found a small patch of cotton near the town of Acala in southern Mexico. Because they thought this cotton might exhibit resistance to the boll weevil, they collected seed from the patch, labeled the seed Acala and brought the seed to the United States for evaluation. Although boll weevil resistance was not found when the cotton was grown in the States, it did manifest other desirable agronomic traits and eventually became important in cotton production in western United States.

Acala cotton was first planted in the United States in Texas in 1907. After several years of growing and selection some material was sent to Oklahoma in 1914 where further selections were made. There a row 8 was selected and seed was sent back to Texas where it was mixed with Texas Acala stocks. This mixed cotton was labeled Acala 8 and sent to California where it was grown at Arvin in 1919 and in Arvin and Indio in 1920. It was seed from these plantings that served as a nucleus for all commercial plantings of Acala cotton in California for the next decade. Actually records show that Acala cotton was introduced into California as early as 1910 but these stocks never became important commercially.

Acala cotton was found to be well adapted to San Joaquin Valley conditions and became well accepted by the growers. For years USDA personnel at Washington D.C. had been advocating the formation of cotton one-variety communities to prevent varietal deterioration that frequently occurred by varietal mixing at the gin and to take the economic advantage of marketing one fiber type to the mills. California growers became convinced of the desirability of such a practice and decided to do this in a grand western style. In 1925 a grower backed bill was passed by the state legislature establishing a one variety district comprising all the counties in the San Joaquin Valley and Riverside County. In 1941 Riverside left the district. The law stipulated that only the Acala variety could be grown in the district. With a few modifications this law is still in effect.

During 1918 and 1919 the Acala 8 material was yield tested at several locations in Kern County and was found to be the top yielder of the several varieties tested. As stated previously the Acala 8 material was the nucleus of the Acala variety grown in the San Joaquin Valley in the 1920's. From 1932-39 varietal releases came from P12 stocks at Shafter. These P12 stocks were different from the Acala 8 stocks and came to Shafter from Indio where some different Acala stocks were being maintained. Evidently during the 1920-39 period different Acala stocks were released and grown in the San Joaquin Valley but name identification of these stocks has not been preserved. Although Shafter Acala and Acala S5 are mentioned in the literature it is not certain whether these were grown commercially or were just experimental lines. Not only is name identification lacking during this period but yield and fiber data are also lacking on these varieties.

In 1939 a new Acala variety P18C was released to the growers. This also was derived from the P12 stocks and was grown until 1949. By this time California cotton had lost the good reputation it had gained earlier and was experiencing marketing problems. Acala cotton had found its way into New Mexico and from a Texas stock called Young's Improved Acala, breeders had selected a strain designated as 1064. From this was derived Acala 1517 which was found to possess superior fiber length and strength and Verticillium wilt tolerance to that found in other Acala types. Some have speculated that genes from non-Acala cottons grown in the New Mexico nurseries may have been introgressed into their Acala stocks through outcrossing. Pima outcrossing is a possibility. Acala 1517 was brought to California and at Shafter Acala 4-42 was selected out of it. Acala 4-42 plant type is distinctly different from that of 1517 so again outcrossing may have been a factor in the 4-42 development.

Acala 4-42 was released to the growers in 1949 and continued in production until 1966. Only limited data comparing the performance of P18C to the original release of 4-42 is available from past records, but these records indicate a slight improvement in yield and a dramatic improvement in fiber length, uniformity and yarn strength. These fiber improvements established an excellent reputation for California Acala in the cotton mills of the world that still exists today. Because of these excellent qualities California Acala demands a premium in most years. Also 4-42 was the first California Acala to show appreciable Verticillium wilt tolerance.

During the time when 4-42 was grown each year breeders at Shafter released a new "Model" of the variety. Gradual improvements were made in yield, fiber strength, and Verticillium wilt resistance. The data indicates about a 12 percent gain in yield and a 7 percent gain in fiber strength over the years.

In 1967 Acala 4-42 was replaced by Acala SJ-1. Breeders prior to this were concerned about maintaining the purity of Acala so they shied away from purposely introducing foreign genes into Acala varieties. With the advent of SJ-1 and subsequent Acala varieties we see that the germplasm base was greatly broadened by the introduction of non-Acala germplasm into the Acala stocks. Acala SJ-1 was derived from a cross of a Shafter line AXTE 1 and New Mexico Acala 1517D. AXTE 1 had in its background Triple Hybrid material, a Georgia variety called Early Fluff, New Mexico Acala 29 and Misdel Acala (a cross between Mississippi Misdel and Acala). Triple Hybrid came from crosses of *G. arboreum*, an Asiatic diploid cotton, *G. thurberi*, a wild Arizona diploid cotton, and *G. hirsutum.* New Mexico breeders have thought their 1517D carries Pima genes through outcrossing.

Although Acala SJ-1's gin turnout was two percent less than Acala 4-42 its prolific fruit set gave it an eight percent yield advantage over 4-42 with slightly earlier maturity. Fiber of SJ-1 was 1/32 of an inch longer than that of 4-42. Although Verticillium wilt symptoms on SJ-1 were a little greater than on 4-42 the yield advantage of SJ-1 was maintained under wilt conditions.

In 1974 Acala SJ-2 replaced Acala SJ-1. This variety was a selection out of the same breeding material from which SJ-1 was derived. Phenotypically SJ-2 and SJ-1 are alike except that SJ-2 has an eight percent yield advantage. Presently SJ-2 occupies about 85 percent of the cotton acreage in the San Joaquin Valley where over 90 percent of California's cotton is produced.

The fungal disease Verticillium wilt has been a major cotton production problem in the San Joaquin Valley since cotton has been cultivated there and breeders have constantly been challenged to help control the disease by incorporating wilt resistance in the variety. In the mid 1960's special efforts were started by the breeders to incorporate even higher levels of wilt resistance into the varieties. This resulted in the release of Acala SJ-3, SJ-4 and SJ-5 in 1975, 1976, and 1979, respectively. The wilt resistance of SJ-3 was not as great as desired nor was fiber length long enough therefore it was replaced after only one year of production. SJ-4 and SJ-5 are major break throughs in wilt resistance carrying some of the highest levels of any known Upland variety.

SJ-4 and SJ-5 were derived from a cross of the Shafter breeding line C6TE and New Mexico Acala B3080. In its background C6TE had Triple Hybrid, Early Fluff and Hopi Acala. The parentage of Hopi Acala includes Hopi Moencopi, a Hopi Indian *G. hirsutum* cotton, and an early Acala line. B3080's parentage includes New Mexico Acala, Tanquis and Pima, *G. barbadense* cottons, and Hartsville, an old southeastern U.S. variety.

The yield of SJ-4 was 10 to 20 percent greater than that of SJ-2 when grown on moderate to heavily infested wilt land respectively. Yarn strength of SJ-4 was 10 percent greater than that of SJ-2. The release of SJ-5 was made because of its 4 percent yield advantage over SJ-4. In all other characteristics they are nearly identical. SJ-5 is grown mainly on moderate to severely infested wilt soils and occupies about 15 percent of the San Joaquin Valley cotton land.

Prior to 1979 all varietal development work in the one-variety district was done only by USDA personnel as authorized by the one-variety law. Due to policy change, the USDA decided to stop all applied cotton varietal development in California after 1978, therefore, the law was revised to permit varietal development by private firms. To obtain better information as to the genetic advances made in the California Acala breeding program from the time of its inception until 1979 the authors have collected 16 Acala seed stocks which are representative of the Acala material that have been grown in California during these years or was parental material of that grown. These have been yield tested for two years in four different tests. Data from these experiments will be presented.

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BREEDING COTTON for CROP EFFICIENCIES II: NEW DEVELOPMENTS

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Summary

The objective of the cotton breeding program of the California Planting Cotton Seed Distributors (CPCSD) is to develop higher yielding Acala cottons with improved fiber and seed quality traits for production in the San Joaquin Valley so that growers can economically retain the market preference for their products that they now enjoy. The development of an economically superior cotton requires combining many individual traits into a balanced variety. The major traits considered are to improve tolerance to Verticillium wilt, earliness, to maintain fiber length, (1-3/32"), to improve fiber uniformity and strength, to reduce neps and waste. Major seed quality traits are to increase oil and protein, and to decrease linters and gossypol.

Acala SJC-1, developed by CPCSD, was approved for release by the Acala Cotton Board (ACB) in 1982. Acala SJC-1 was compared to Acalas SJ-2 and SJ-5 at 19 locations by CPCSD and at 16 locations by ACB. Acala SJC-1 exceeded the yields of SJ-2 and SJ-5 by 25% and 5%, respectively, in the CPCSD tests at wilt locations. Acala SJC-1 exceeded the yields of SJ-2 and SJ-5 by 10% and 4%, respectively, in the ACB wilt tests. There were no significant differences between the cottons at non-wilt locations; however, Acala SJC-1 had the

highest yield. Verticillium wilt tolerance has been associated in the past with late maturity and non-productivity on wilt free or near wilt free soil. It appears that we are making progress in breaking this relationship.

Acala SJC-1 has improved fiber uniformity, strength and less waste. Yarn strength of Acala SJC-1 is significantly stronger and the fiber produces a smoother yarn than fiber of Acalas SJ-2 and 5.

Acala SJC-1 has significantly better seed properties, with higher oil and ammonia, and lower linters and gossypol. The higher oil and ammonia (protein) contents provide a greater net return. Lower linter content of the seed reduces energy used in delintering. This is where approximately 50% of energy expended in processing seed is used. Lower gossypol reduces refining costs of the oil and produces a meal containing lower free gossypol and higher lysine.

The 1983 test results indicate Acala SJC-1 is performing as expected.

Cotton breeding and testing are conducted in an area on the east side of the valley where air pollution is known to limit yield. This allows us to select for improved tolerance.

We have two experimental advanced glandless Acala cottons which show improved tolerance to Verticillium wilt and improved fiber properties. Fiber properties appear to be equal to Acala SJ-2. The glandless cotton seed are gossypol free. The kernels and meal can be used for a human food source and can be used in greater proportions in poultry, swine, and fish rations. The yields of these two strains are below that of Acalas SJ-2 and SJC-1; however, we have strains in earlier stages of testing which have shown higher yields. The glandless cotton seed will produce a greater yield of oil which will be considerably more economical to refine and a meal with a higher lysine content than that produced from glanded seed.

Breeding efforts are directed toward developing nectariless cottons which display tolerance to insects and cottons with high levels of tolerance to nematodes and Fusarium wilt. Breeding for tolerance to the root-knot nematode-Fusarium complex in cotton will have to be intensified since we are losing soil fumigants for nematode control. Acala SJC-1 is tolerant to Fusarium wilt but susceptible to nematodes.

The renewed interest in producing cotton in thirty inch rows may necessitate some change in plant type. Acalas SJ-2 and SJC-1 are performing very well in 30" culture. It is too early to assess the acceptance of this system of production and whether or not we have to alter the plant type.

The workers at Phytogen, a genetic engineering laboratory, have initiated investigations with cotton. They successfully produced plants from single cells. This work is in its infancy. It will be some time before the real value of such work in plant breeding can be assessed. If genetic engineering laboratories are successful in transferring traits as postulated, it should expedite variety improvements.

Plant breeding efforts involving the traits mentioned above will lead to more efficient cotton varieties for the future.

ROOT EFFECTS ON RHIZOSPHERE* CHEMISTRY

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Roots tend to grow into soil pores and channels of approximately their own diameter thus the association between the root and soil particles is generally intimate. With time the root surface is colonized by microorganisms, expands laterally, and removes water and solutes from the soil of its immediate vicinity. Thus root activities influence the biological, physical, and chemical characteristics of the rhizoshpere soil. The individual effects are difficult to quantify. If the duration of the study is limited to the period of active nutrient accumulation by a root section, soil physical changes would be minimal and not exceed those from normal aggregation. Changes in the microbial populations of rhizosphere soils are known to occur and to significantly influence both the root and the adjacent soil. The magnitudes of these effects differ depending on other parameters (e.g., the interaction of mycorrhizal influence and soil phosphate level) and have generally only been qualitatively estimated. Their lack of dominance is evidenced by satisfactory growth of crops in sterile soils and the presence of uncolonized areas on two-week old roots.

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* The term rhizosphere was coined by Hiltner in 1904 and is generally considered as the transition zone between the soil and the root extending not more than a few millimeters from the root surface.

The chemical effects of roots on the rhizosphere soil arise from several sources including: selective uptake of cations and anions, release of hydrogen and bicarbonate ions, excretion of organic substances and CO_2, changes in O_2 pressures and redox potentials, and changes in the concentration of the soil solution that influence the ionic form and solubility of other ions. Either hydrogen ions or bycarbonate ions are released to maintain electrical neutrality when the absorption of nutrient cations and anions is unequal. (Anion intake exceeds cation intake with nitrate as the source of N. The reverse occurs with ammonium.) In addition, as the highly mobile nitrate is transported to the root it is accompanied by cations, principally Ca, which accumulates in and influences rhizosphere characteristics. Nutritional stresses, notably Fe and P deficiencies cause some species to excrete protons and with sufficient acidification increase the solubility of both elements in the rhizosphere soil.

Considerable amounts of C compounds (to 25% of the total dry matter production) are exuded from healthy, undamaged plant roots. A very long list of compounds has been identified. Their postulated roles have included serving as microbial substrates, maintaining root-soil contact, metal chelate formation, redox reactants and many others.

Research into the reactions in the rhizosphere is difficult and progress has been slow. The elucidation of the processes involved and their mechanisms can be expected to greatly enhance our understanding of soil-plant relationships.