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CALIFORNIA PLANT
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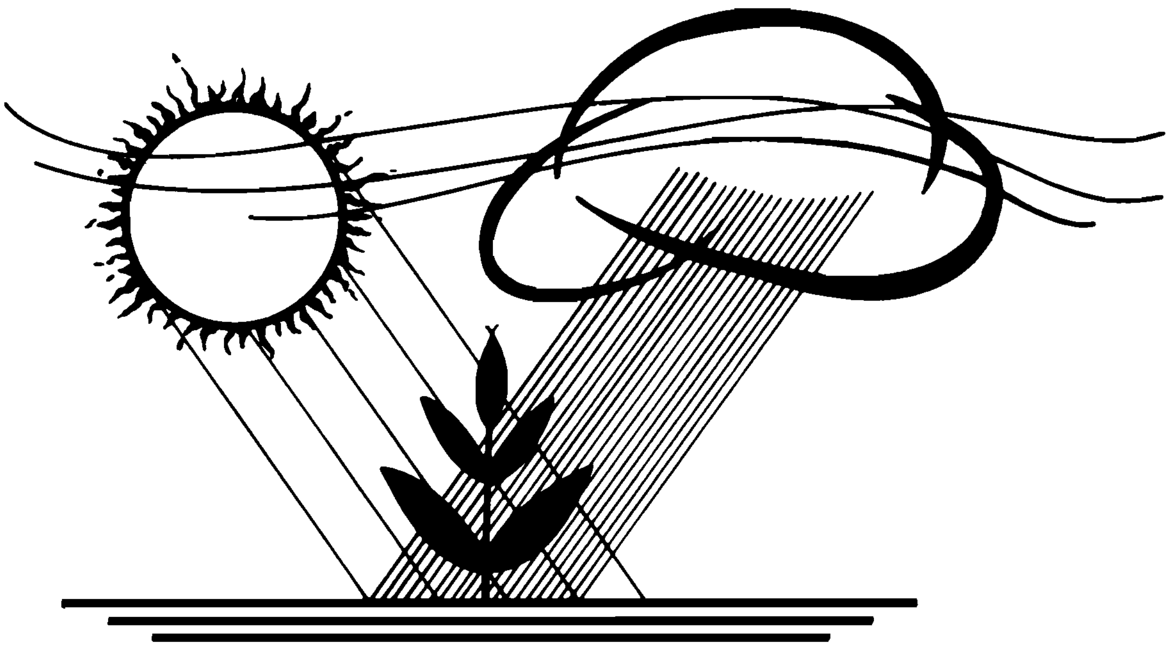

January 28-30, 1981

Sacramento Inn

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San Mateo

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A Farmer's Perspective
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N_2-FIXATION AND ITS EFFECT ON NITROGEN FERTILIZATION

F.E. Broadbent

Recent years have witnessed a tremendous resurgence of interest in biological nitrogen fixation as a consequence of the rapidly escalating costs and possible shortages of fossil fuels from which synthetic nitrogen fertilizers are produced. Aside from these considerations, three scientific developments have heightened interest in N_2-fixation. The first is the acetylene-reduction method for estimating N_2-fixation activity. The method is so sensitive that N_2-fixation can be measured at very low rates and over relatively short time periods. Microorganisms and plant-microbial associations not previously known to fix N_2 have been shown to have this capability by means of the sensitive acetylene-reduction technique. The second development is the discovery that an associative kind of symbiosis involving free-living bacteria in the root zone of certain non-legumes results in an appreciable amount of N_2 fixed. The third is the development of genetic engineering techniques which suggest the possibility of conferring the ability to fix N_2 on organisms which presently do not have it.

Measurement of N_2-fixation

It needs to be said at the outset that at the present time we do not have available a good method for measuring N_2-fixation in a field situation. For all the thousands of acetylene-reduction measurements which have been made, it must be kept in mind that a measurement made on a small sample, usually representing only only a fraction of the total plant root system, over a period of a few minutes, or a few hours at most, under highly artificial conditions, cannot be extrapolated to the field scale over an entire growing season with any degree of confidence. The difficulty is compounded by use of the theoretical ratio of 3:1 for acetylene reduced: N_2-fixed, which may often be in serious error. Accordingly, the sometimes extravagant claims made for N_2 fixed by non-leguminous plant-bacterial associations can be viewed with some degree of skepticism.

The best method available for evaluating N_2-fixation by legumes is still the old one of comparing total N uptake by a legume and a non-legume grown under identical conditions and attributing the difference to N_2-fixation. One of the serious drawbacks of this method is that if the non-legume is unfertilized, its growth may be poor and its value for purposes of comparison highly questionable. On the other hand, if the reference crop is fertilized, the quantity of N derived from soil cannot be determined by conventional means. By using isotopically labeled N fertilizer, the contribution of soil N to a fertilized reference crop can be measured, but even when that is done some differences between reference and N_2-fixing crop may remain, for example, in rooting pattern, duration of growth, responses to climatic variables, etc. The closest to an ideal comparison is between nodulating and non-nodulating isolines of the same legume, but at present these are available only for soybean.

Energy as a Limiting Factor

In the biological world as in the industrial world, the fixation of N_2 exacts a cost in energy. In the symbiotic association between legume bacteria and the host plant, this energy in the form of photosynthate produced in the leaves is made available to bacteroids in the root nodules by translocation through the conductive tissues of the plant. Reliable estimates of this energy cost under field conditions are scarce, but as an indication of the order of magnitude, Atkins et al (1978) report 17 grams carbohydrate consumed per gram of protein synthesized in vegetative parts of the cowpea, and 33 grams of carbohydrate required for synthesis of a gram of seed protein. Corresponding values for white lupin are 25 grams carbohydrate per gram of vegetative protein and 31 grams carbohydrate per gram of seed protein.

The legume nodule bacteria live in an environment protected from competition from other species of microorganisms and with a pipeline to solar energy, that is to say photosynthate. Under these very favorable conditions considerable amounts of N_2 are fixed, often exceeding 100 lbs N/acre/year.

Among the N_2-fixing organisms, the blue-green algae also have access to the energy of sunlight, and under favorable conditions may contribute to the N economy of soils where lowland rice is grown. Two obstacles to increasing the contributions of N through algal N_2-fixation are the shading of the rice paddy by the rice plants early in the growing period, thereby reducing photosynthesis by the algae, and the relatively high phosphate requirements for good algal production. In the U.S., algal contributions to the N budget of croplands are minor.

This brings us to the associations between non-symbiotic N_2-fixers and non-leguminous plants. Here the N_2-fixing bacteria are dependent for energy upon plant root exudates, sloughed-off root tissue and soil humus. Unlike the root nodule bacteria, they live in a highly competitive environment where other, non-N_2-fixing microorganisms are competing aggressively for a limited amount of substrate to be used as an energy source. The quantities of N_2 fixed under these conditions of restricted available energy have been estimated variously from less than 5 lbs/acre/year to more than 100. Most of these estimates are based on the quantitatively unreliable acetylene-reduction procedure. Estimates of non-symbiotic N_2-fixation by other techniques indicate fairly low values unless substantial inputs of readily available energy sources are made. Conservative estimates of N contributions by such associations would seem realistic.

It is possible by genetic selection to find cultivars of non-legumes which produce more than the usual amounts of root exudates, but that is not likely to change the basic problem of inefficient transfer of substrate to N_2-fixing bacteria in the rhizosphere, because the competition is not eliminated. It may eventually be possible by genetic manipulation to develop cereals which are nodulated by N_2-fixing bacteria, but that prospect is not a near-term one. On a global scale, non-symbiotic N_2-fixation contributes significantly to the world N budget, but in my opinion, developments in this area will not have an important effect on fertilizer N requirements in intensive agricultural systems.

N_2-fixation in Relation to Fertilizer Demand

The conclusion to be drawn from the foregoing considerations is that for the forseeable future, legumes will remain the principal alternative to synthetic fertilizers as a source of N. Changes in acreage devoted to legumes and the ways these are managed have the potential for bringing about some reduction in the requirements for synthetic N, but a large reduction would require major shifts in land utilization. In California, such shifts are unlikely in areas devoted to fruits, nuts and vegetable crops. Where livestock operations are combined with field crops some increase in legume acreage could be more readily accomplished.

The present prospect is that N fertilizer demand in the next few years will be shaped more by economic and political developments than by scientific discoveries.

REFERENCE

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RECENT DEVELOPMENTS IN RANGE FERTILIZATION

Milton B. Jones

Experimental work in California has shown that nitrogen, phosphorus, and sulfur are important limiting elements for forage production on annual range soils. Nitrogen is nearly always limiting and phosphorus and sulfur are often deficient. Potassium and molybdenum deficiencies have been found in some areas, and calcium is deficient on some serpentine soils.

Much research has been done on the use of commercial nitrogen, and its most efficient use is in the 15 to 25 inch rainfall zone. However, with the increased cost of energy to produce it, recent research efforts have emphasized nitrogen fixation by subclover, rose clover, and other legumes.

Many new varieties of clover adapted to a wide range of climatic and soil conditions are now available. New strains of rhizobia have also been selected from the few healthy clover plants found in fields where stand establishment has been a failure. After screening and testing in the laboratory and field, rhizobial strains have been isolated that are very competitive with native ineffective rhizobia, and which are able to survive the hot, dry California summers much better than rhizobial strains formerly used in commercial inoculum. Methods have also been improved for sticking large numbers of the bacteria to the seed in coatings which assists in their survival until germination. These advances have resulted in a much higher success rate in clover stand establishment. These stands are usually productive by the first or second year, whereas without these new rhizobial strains it often took several years for good clover stands to develop into productive pastures, if they ever did.

Productive stands of subclover produce forage equivalent to grasslands fertilized with from 40 to 200 pounds nitrogen per acre. The higher levels of productivity have been observed in wet years or wetter areas of the state where clovers are more productive and fertilizer nitrogen is more subject to leaching.

If commercial nitrogen is to be utilized efficiently or if clovers are to be productive, other essential nutrients must be available in adequate amounts. A recent study was conducted on 22 rangeland sites in Mendocino County to determine: 1) how much P was required to maximize subclover yields; 2) if sulfur would increase production with and without P; and 3) what physical and chemical site-soil characteristics were related to yields with and without fertilization. Rates of phosphorus were applied with and without sulfur to seeded subclover. Of the 18 site characteristics measured, soil pH, Bray 1 available P, and exchangeable Ca were the three measurements that accounted for the highest proportion of yield variation where no fertilizer was applied. The R^2 equalled .55 in a multiple ridge regression analysis of the data. Where S was applied Bray P accounted for about 67% of yield variation with the over-all R^2 equal to .77. Where P was applied exchangeable K accounted for about 50% of yield variation, and where both P and S were applied, Bray 1 P and exchangeable K were most closely related to forage production.

The amount of applied P required to obtain yields 90% of maximum varied from 3 to 90 pounds per acre. This P requirement was more closely associated with NaH_2CO_3 extractable P (r = -.88), or Bray 1 P (r = -.84) than P sorption or P buffering capacities.

Studies on the residual value of P indicate that 200 pounds P/A applied in 1960 gave yields of 4,300 lbs/A in 1980 compared to 2,000 pounds from the zero P treatment. Applications of 25 lbs P/A in 1979 gave yields of 6,500 lbs/A. Yields dropped to a plateau three to six years after application for 25 and 200 lbs P/A, respectively.

Sulfur is deficient on at least 75% of the range grassland pastures of the north-coast range as indicated by field plots, pot tests, and tissue analysis. Soils tests have been of little value in assaying the pasture S status, even though many different extractants have been tried. In contrast, plant tissue analysis appears to be quite useful. The SO_4-S level in sub-clover is preferred over total S as a measure of S status, because it is easier to determine, is less sensitive to plant part sampled, stage of growth, and to previous defoliation by grazing. The ratios SO_4-S/S and N/S may be useful but they require two determinations and thus have the variability of both. About 40 lbs S/A is usually adequate for maximum yields but clover percentages and quality of summer feed can increase with higher rates.

The residual values of sulfate forms of sulfur are dependent on amounts of rain and soil type. Generally, gypsum gives slightly higher first year yields than elemental S in the 15 to 25 inch rainfall zone, and responses to both are equal in wetter areas. The residual value of elemental S is dependent on how fine it is ground, but even the finest (dusting S) is as effective the second year as the first on the north coast. Courser materials give less response the first year but last longer.

Forage quality on S deficient pastures can be enhanced by S fertilization. As S levels increase, rate of gain by lambs and feed efficiency increase. The SO_4-S level in blood of sheep is directly related to the S level in the forage. This fact may make it possible to assay the S status of a pasture by determining the SO_4-S level in the blood serum.

If maximum forage production from California's annual rangeland is to be achieved, fertilization must play an important part. For such a goal provision must be made to provide the required levels of N, P, and S and the manager should be aware that K, Mo, and Ca deficiencies have been found. Soil tests and plant analysis can be valuable aids in assaying soil fertility status of rangeland pastures. The grazing animals must be managed to utilize the increased forage produced by proper fertilization.

NEW TECHNIQUES IN FOLIAR FEEDING

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Foliar feeding is generally used when a nutrient in question cannot be supplied adequately to the plant by soil applications of the nutrient in question. In most instances, a soil application of a nutrient is preferred if it can be adequately supplied to the plant by this method of application. However, in many cases a soil application of nutrient is not effective, so one must rely on foliar applications to supply the nutrient.

Several nutrients can be applied effectively to the soil or foliage. Foliar applied nutrients are usually more rapidly available to the plant than soil applied nutrients. Application costs of a nutrient may be reduced if the nutrient can be combined with a pesticide, growth regulator, or other spray. During certain periods, fields may be too wet for ground equipment to get into fields. Both soil and foliar applied nutrients can be applied by fixed-wing aircraft or helicopter.

Since this writer's field of expertise is with citrus, this crop will be used as a model to show techniques. Some history will be given to illustrate development of present techniques.

Zinc and Manganese

At one time Zn deficiency was the major limiting factor in citriculture in California. It was known as "little leaf," "mottle leaf," or "rosette." The committee that selected the site of the Citrus Experiment Station at Riverside stipulated that the malady in question must exist on the site selected so proper research could be conducted. The cause of this malady was identified in the 1930's.

Initial research to supply Zn to the trees showed that soil applications of Zn materials were usually not effective and sometimes resulted in injury to trees. Foliar applications were effective, but sometimes resulted in injury to foliage unless most of the soluble Zn in the spray solution was precipitated with hydrated lime or soda ash. Similar observations were made in studies to supply Mn to trees. For about two decades the recommendation was to combine the sulfates of Zn and Mn in the precipitated form. A common mixture was:

3 pounds zinc sulfate (36.4% metallic zinc)

3 pounds manganese sulfate (28% metallic manganese)

4 pounds of hydrated lime or soda ash

100 gallons water

Using the above resulted in applying a suspension of precipitated Zn which left a deposit on the leaves. Entomologists observed that such deposits on leaves repelled predators of some of the insect pests. In the 1950's effectiveness of soil applications of Zn and Mn was reevaluated with the use of leaf analysis as a guide to effectiveness. It was shown that soil applications of Zn and Mn were effective on acid but not alkaline soils. Further research resulted in the development of low residue Zn and Mn sprays which were effective and were compatible with most other nutrient, pesticide and growth regulator sprays. Essentially, these new sprays were made by dissolving sufficient sulfates of Zn and Mn in water to give the same concentrations of Zn and Mn in solution as was in solutions of the precipitated materials mentioned previously. Such sprays are effective and present no residue problems.

Nitrogen

After it was demonstrated that foliar sprays of urea effectively supplied N to apple trees, research on such sprays on citrus was initiated in the late 1940's. Urea foliar sprays did supply N to the trees, but considerable chlorosis developed on the leaves. Subsequently, this chlorosis was shown to be due to biuret, an impurity that developed in the manufacturing of urea. Industry responded by producing low-biuret urea. Urea sprays are compatible with most micronutrient, pesticide and growth regulator sprays. Supplying part of the N needs of the trees by foliar sprays became common practice. With the onset of the energy crisis, low-biuret urea became hard to obtain, but some companies continued to produce it and such sprays are still being used effectively.

Some 60 odd "experiment years" of citrus data showed that, in terms of producing fruit, the efficiency of N in foliar-applied urea was about equal to that of N from soil applications for oranges, grapefruit and the less vigorous strains of lemon.

In studies on the effects of fertilizers on the nitrate-pollution potential for groundwaters, it was shown that the nitrogen needs of vigorous citrus trees could be supplied completely by foliar sprays of urea. At least 3 sprays a year were required. Such sprays resulted in a substantial reduction in the nitrate-pollution potential when compared with soil applications of N. In the case of vigorous lemons, such sprays resulted in yields equal to the highest rate of soil-applied N while using less than 1/3 as much N. Three foliar sprays of urea per year were used at 12 pounds of urea per 100 gallons of spray. The following table illustrates these points:

Table:

Effect of rate and method of application of N upon N leached and fruit yield of vigorous Lisbon lemons, 1973-1979

N rate, lb. acre^{-1} year^{-1} and method of application		N leached, lb. acre^{-1} year^{-1}	Fruit yield, tons acre^{-1} year^{-1}
53	Soil	33 z	24.4 z
148	Soil	95 y	26.1 y
434	Soil	261 x	28.2 x
121	Foliar	33 z	28.2 x

The citrus data suggest that a low N rate applied to the soil and supplemented with foliar-applied N would produce a lower nitrate-pollution potential than applying all the N to the soil. The combination program would not affect adversely yield or fruit quality. Such a program likely would be accepted by regulatory officials and citrus growers.

Magnesium

Soil applications of Mg materials are effective only on acid soils. In the 1950's effective Mg foliar sprays were developed. This consisted of 10 pounds of magnesium nitrate per 100 gallons of water. A less expensive, but equally effective, spray may be formulated by mixing 10 pounds of magnesium sulfate (Epsom salts) and 10 pounds of calcium-nitrate per 100 gallons of water. The combination of these two materials results in magnesium nitrate being dissolved in the water. The other product of the combination, calcium sulfate, may form a milky suspension which will leave a light deposit on the foliage. To mix, add the magnesium sulfate to the filled spray tank under full agitation. Dissolve the calcium nitrate in a container and pour slowly into the tank while continuing full agitation. One spray a year keeps trees free of Mg deficiency symptoms. Timing is very important. Apply when the spring flush is 3/4 to fully expanded.

Potassium

On some citrus soils in California soil applications of K materials are not effective. In the 1960's effective K foliar sprays were developed. Over the years we have sprayed with 40 pounds of potassium nitrate per 100 gallons of spray. This has not caused injury. Sprays are effective most any time of the year, but they are slightly more effective if applied when the spring flush of growth is 3/4 to fully expanded.

CHANGES IN FERTILIZER MARKETS

Charles F. Merrill
V. P. Chemical Marketing
Union Chemicals Division
President, C. F. A.

Union Chemicals produces 3000 tons of Ammonia and 2400 tons of Urea per day in Alaska. To move this material south we have a 23,000 ton Anhydrous Ammonia ship and two 13,000 ton Urea barges. To receive product on the west coast we have two ocean access terminals. Portland, Oregon has storage for 25,000 tons of Anhydrous Ammonia (with an additional 25,000 tons being added) and 70,000 tons of Urea storage. An up river storage facility at Hedges, Washington can receive 50,000 tons of Anhydrous Ammonia. At Sacramento, we have 40,000 tons of Ammonia storage and 40,000 tons of Urea storage. We are currently constructing a 200,000 ton per year plant for Urea Ammonium Nitrate solution. The relation of this production to total Western market will be discussed. The Nitrogen market today has many facets which affect change. Currently, a large scale demand for Urea in World Markets, which is firm and rising is creating a 30-40 dollar premium over Domestic market prices. This demand is being fueled by increased use of Nitrogen Fertilizers world wide, production curtailments due to the Iran-Iraq conflict, and delays in on stream production by World scale plants in Russia and Mexico. As some of these factors ease, well price differential will narrow, but World markets will probably be more attractive through 1981.

The Ammonia market is quite different. There is more supply available and the markets, while strong, are affected differently by the world markets. Some considerations include:

The Iran-Iraq war has curtailed production from the mideast which has crimped that supply.

However, Russia and Mexico have come on stream with world scale plants and are active in the foreign market. Particularly active, since as mentioned before, the Urea Plants that these Ammonia Plants will feed have not been completed.

In addition, Ammonia is not as popular in the world as Urea is as a fertilizer since it requires special equipment to off load, store and apply. And, many other nations do not have this capability.

Since Ammonia and Urea have the greatest impact on Nitrogen fertilizers, that about summarizes the overall situation. I guess we could generally say that supply-demand is about in balance with some precarious possibilities if the mideast situation becomes worse.

In California we are experiencing a tremendous growth in use of Urea and Urea Ammonium Nitrate solution (UAN 32%). At the same time Ammonia has remained relatively flat. As we see the Nitrogen market in California at this time, it will be in tight balance through 1981 but all demands will be met provided there are no unforeseen delays in shipments of offshore material - and I include Alaska in that, and provided we are not curtailed in our California production by gas shortages.

The total food system in the U.S. is a major energy consumer. In fact, this food system consumes one-sixth of all energy used in the U.S. . . . . Although this is a large amount of energy, it is certainly, I feel, one of the best and most valuable uses of energy.

Farm production or agriculture is one element of this total food system. The energy used in the farm production protion is only 20 percent of the energy used in the total food system or about 3.2 percent of the energy used in the U.S. (20 percent of one-sixth). Farm production, by the way, includes all energy consumed on the farm and in the materials consumed by farmers.

One quad is a thousand million, million BTU. The total energy consumed in agricultural production is slightly over two quads per year. The energy consumed to manufacture and deliver fertilizer is 32 percent of all energy consumed in agriculture . . . reflect a minute on this percentage. 32 percent of energy consumed in agriculture is used to manufacture and deliver fertilizer. Agriculture or farm production energy consumes 3.2 percent of the energy consumed in the total U.S. Therefore, fertilizer consumes 32 percent of

3.2 percent or just a little over one percent. A little over one percent of all of the energy consumed in the U.S. ... This 32 percent proportion is increasing, because as our farm management and technology becomes more efficient and economical, we use more fertilizer for agricultural production. But it still seems small in relation to the importance of agriculture.

One farmer today produces enough food and fiber to provide the needs for about 60 people, tomorrow this number must and will increase. I am told by some of our leading research statisticians that the world population in 1975 was 4 billion people. And that by the year 2000 (2000-2010) that number is expected to double. This, of course, means our food production must double - or between now and the year 2000 we must produce again as much food as we have been able to produce up to now. Staggering statistics and even if our crystal ball is off 20 to 30 percent it still is a monumental task.

Manufacturing consumes 94 percent of the energy used in fertilizer while application and transportation consume 6 percent. Energy required per ton of plant nutrient is much greater in nitrogen... than either phosphate or potash. 56 million BTU are required for each ton of nitrogen, or 86 percent of the energy consumed in the three major nutrients. You can see why natural gas is so important to us and a reliable supply is essential.

The future agricultural energy problems that we face fall into two areas: Supply and price. As far as the supply problem is concerned, agriculture and fertilizer are in an enviable position. Congress has recognized the essential nature of agricultural production. Because of its favorable effect on balance of trade.

Domestic gas prices were controlled long before petroleum prices were controlled. That is why we had severe shortages of natural gas in 1974 and 1975. Domestic gas price has increased but its obviously far, far below its true market value. So we must expect gas prices will increase even more rapidly than domestic oil prices. Fertilizers are especially sensitive to gas prices...because most of the energy consumed in fertilizer manufacturing is in the form of natural gas.

At a recent California Fertilizer Association meeting, one energy analyst forecast the following. Starting with an average well head gas price in the U.S. today of $1.35 - $1.50 per million BTU, this will increase to $5.73 by 1985 and continue at this growth to reach $16.00 by the year 2000. In then current dollars i.e. including inflation ... that is a compounded growth of 13 percent in 20 years. This will obviously have a big impact on agriculture.

Nitrogen prices have not kept pace with the increase in prices of other goods and services purchased by farmers. Although the pressure of increasing costs ... has been greater with nitrogen than other fertilizers, nitrogen price has lagged behind other fertilizers.

What's going on here? Natural gas makes up two-thirds of Ammonia or Nitrogen manufacturing cost. Gas prices have been increasing rapidly but nitrogen prices have not kept pace. Nitrogen fertilizer prices are fundamentally out of line with energy values. An economic disequilibrium of this magnitude ... must create problems.

At the present time, the move to match consumption and production is being affected by external factors.

Surplus capacity and competition in the world market held prices down creating an economic hardship on U.S. plants. In 1978 new ammonia plants came on stream in other countries. Notably Russia and Mexico.

Almost all of this new nitrogen capacity outside the United States is owned by agencies of foreign governments not by private companies. Once they have built these plants, those government owned entities tend to run them at maximum capacity irrespective of the price they receive for their product. They can do this because it helps their national balance of trade, helps their employment, helps their gross national product, and provides their politicians with material for speeches.

In 1978, Russia and Mexico decided they were going to force new major quantities of Nitrogen into the world market and specfically into the U.S. Gulf Coast. The price was lowered to the point required to shut down enough U.S. producers to allow this foreign material to enter.

In 1977 there were 101 nitrogen plants in the United States. Today 27 of these plants are shut down. By the way, in California there used to be eight plants operating, today there are two.

Lets see now how this shut down of 27 plants affected our curves for capacity and consumption.

The shut down of these 27 plants in the United States has reduced

capacity below our total requirements for Nitrogen fertilizers.
Note the major shift in 1980. U.S. manufacturers are not competitors in a free market against other companies. U.S. manfacturers are competing against the government of Russia and the government of Mexico. If the U.S. government takes no action...we must anticipate that in the future, more U.S. nitrogen plants will be shut down by foreign sources. We could then become so dependent on foreign supplies, that we have created a new OPEC. A very small group of foreign governments... could then control our supply of nitrogen fertilizers. We know Nitrogen fertilizer prices will increase. But if they are controlled by a foreign cartel, we will have future increases and future shortages which could seriously damage our agricultural industry...and no control over them.

Since the growth of crops in our nation is dependent upon reliable sources of nutrients and since nutrients are so dependent on energy, I'm sure you can see the impact of a discontinuity in supply. Therefore the importance of energy to our industry and agriculture. It would certainly have a dramatic effect on all of us and definitely change the statistics of farm production.

I hope today I have covered some subjects of interest and not created too much of a puzzle. Perhaps if there are some missing pieces in this jigsaw they can be filled in by questions from the audience.

Thanks again for the invitation.

SENESCENCE, PHOTOSYNTHESIS, PROTEIN DEGRADATION, AND CROP PRODUCTIVITY

James W. Friedrich

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Senescence is a developmental phenomenon that precedes the death of a plant or a specific plant tissue such as the leaf. Visually, leaf senescence is associated with a loss of green color (i.e. chlorophyll). However, a decline in the functionality of the leaf often occurs prior to any visible change. This decline in functionality is marked by a loss of soluble protein and photosynthetic ability. Thus, senescence can have a great influence on crop productivity.

The loss of soluble protein during the senescence of barley leaves is attributable to a loss of ribulose-1,5-bisphosphate carboxylase (RuBPCase). RuBPCase functions as a storage protein, constituting up to 70% of the total soluble leaf protein. It also catalyzes the initial and probably most limiting reaction in C_3 photosynthesis. The relationship between RuBPCase concentration and photosynthesis during leaf senescence is the subject of this paper.

The decline in RuBPCase concentration during the senescence of barley leaves is highly correlated with the decrease in total photosynthesis ($r = 0.96$) and the decline in *in vitro* RuBPCase activity ($r = 0.95$). Approximately 85% of the loss in soluble protein is due to RuBPCase degradation. This loss is probably not due to a selective degradation of RuBPCase but is the result of decreased RuBPCase synthesis. The decline in photosynthesis occurs simultaneously with a decrease in transpiration. Thus, changes in stomatal aperture are associated with decreasing photosynthesis during senescence. Mesophyll (residual) resistance increases three-fold as opposed to a nine-fold increase in stomatal resistance. The ratio of photosynthesis to transpiration (leaf water use efficiency) increases during senescence. Also, the ratio of photosynthesis to RuBPCase concentration increases. Apparently, the RuBPCase protein catalyzes the CO_2 fixation reaction more efficiently when RuBPCase concentration is low. At high concentrations of RuBPCase, other factors such as light harvesting or the *in vitro* regulation of RuBPCase may limit photosynthetic productivity. In any event, the increase in the photosynthesis/RuBPCase ratio is not sufficient to completely compensate for the loss of RuBPCase protein during senescence.

The amount of N supplied to barley seedlings does not slow the senescence process. The percent reduction in RuBPCase concentration and photosynthesis is the same for both low and high N treatments. However, N supply does have a marked effect on the actual RuBPCase concentration and photosynthetic rate. The ratio of photosynthesis to RuBPCase is highest in senescing leaves of low-N treatment plants. Increased N supply results in a higher photosynthetic rate due to a decrease in stomatal resistance, not mesophyll resistance. The effect of other environmental factors (e.g., water, temperature, light) and plant factors (e.g., species, variety) on the relationship between photosynthesis and RuBPCase concentration during senescence is not well understood.

GENETIC ENGINEERING IN AGRICULTURE: INCREASING THE EFFICIENCY OF SYMBIOTIC NITROGEN FIXATION

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In the past ten years, a technology has been developed that allows the manipulation of genetic material. Using enzymes that modify DNA, researchers have been able to isolate, dissect, and characterize genes from a variety of organisms. Manipulation of genetic information has progressed to the point that genes have been chemically synthesized and bacteria have been constructed that produce mammalian proteins, such as interferon and insulin. This technology, which is often referred to as recombinant DNA, is being applied to a variety of topics in agricultural research, such as the analysis of gene expression in plants and the genetic manipulation of crops to increase productivity. In the lab of Dr. R. C. Valentine, we are using this methodology in an attempt to increase the relative efficiency of nitrogen fixation in *Rhizobium japonicum*, the bacteria that are symbiotically associated with the soybean plant.

R. japonicum is able to form nodules on the roots of the soybean plant. Within these nodules the bacteria differentiate into a structure known as a bacteroid in which the bacterial metabolism has been modified. The primary function of the bacteroid is the conversion of nitrogen gas to a fixed form of nitrogen, such as ammonia, which can then be utilized by the host soybean plant. In exchange for this fixed nitrogen, the plant provides the bacteroid with the energy necessary for survival of the bacteria. Biological nitrogen fixation requires large amounts of energy--as much as 40-45 moles of ATP per mole of nitrogen fixed--and it has been shown that the enzyme nitrogenase can participate both in nitrogen fixation and in ATP-dependent hydrogen evolution. It has been suggested that as much as 40-60% of the energy consumed by nitrogenase during nitrogen fixation is actually utilized in hydrogen evolution and that strains of *R. japonicum* that can recover this hydrogen will be more efficient during symbiotic nitrogen fixation and more effective as agricultural innoculum. Our goal is the introduction of hydrogen uptake genes into agronomically important strains of *R. japonicum*.

Our approach to this problem involves the isolation of hydrogen uptake genes from *R. japonicum* and the autotrophic hydrogen bacterium *Alcaligenes eutrophus*. Mutants deficient in hydrogen uptake genes have been constructed in *A. eutrophus*. Using recombinant DNA methodology, we are constructing small extrachromosomally replicating plasmids that contain hydrogen uptake genes. Following the characterization of these genes, we hope to maximize the expression of hydrogen uptake activity in strains of *R. japonicum* and develop a method for the introduction of these desirable hydrogen uptake genes into the root nodules of soybeans.

PROBING NO_3^- METABOLISM IN BACTERIA FOR USE AS A TOOL IN CONSERVING NITROGEN IN AGRONOMIC SOILS

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ABSTRACT

As part of a soil nitrogen conservation study, we analyzed mutants of the bacterium *Klebsiella pneumoniae* which convert NO_3^- to NH_4^+ but do not assimilate it. The mutants excreted all of the NO_3^- reduced as NH_4^+ under aerobic conditions and as NO_2^- and NH_4^+ under anaerobic conditions. This conversion, if performed in agronomic soils might reduce loss of applied NO_3^--N by leaching and by denitrification.

The physiology of this process was examined in a dialysis culture system which holds the bacteria in a non-growing but metabolically active condition. Under these circumstances, the maximal rate of NH_4^+ production occurs anaerobically at 20-25 C and pH 7.

The molar ratio of NH_4^+ produced per glucose utilized was used as a measure of the efficiency of the process. The optimal efficiency also occurred at pH 7 and 20 C, anaerobically. By comparing

the rate of NH_4^+ production of the culture under aerobic and anaerobic conditions we inferred that the rate limiting step aerobically is NO_3^- transport or reduction. Anaerobically NO_2^- transport or reduction appears to be rate limiting.

We then produced and purified radioactive NO_3^- using the cyclotron housed in the Crocker Nuclear Laboratory at UC Davis. This radionuclide of N is produced by bombarding water with a proton beam. The protons are captured by the oxygen of the water molecule, and an α particle is emitted [^{16}O (p, α)^{13}N reaction] resulting in an ^{13}N nucleus. This radionuclide decays with a 10 minute half-life to ^{13}C, which is not radioactive, by emission of a positron. When the positron encounters an electron, both annihilate releasing two γ rays which we count using a NaI (T_l) crystal equipped scintillation detector. The radiochemical form of ^{13}N produced has been determined by rapid high-pressure liquid chromatography (HPLC). The products of the target system at Crocker Nuclear Laboratory are 95% $^{13}NO_3^-$, 3-4% $^{13}NO_2^-$, 0.3-1% $^{13}NH_4^+$. Using the HPLC system we purified the $^{13}NO_3^-$ to 99.5% radiochemical purity for use in the transport assays. Radioactively labeled NO_3^- was used to measure NO_3^- transport in aerobically grown *Klebsiella pneumoniae* in order to determine if transport or reduction was rate limiting.

We determined that NO_3^- is taken up into *K. pneumoniae* by two different transport system which were saturated at very different NO_3^- concentrations. Both of these were inhibited and repressed by NH_4^+ and induced by NO_2^- as well as NO_3^-.

The intracellular concentrations of NO_3^-, NO_2^- and reduced forms of nitrogen were determined after 15 to 45 seconds of NO_3^-

transport by analyzing labeled then extracted bacteria by rapid anion exchange HPLC.

These experiments showed that aerobic NO_3^- transport into *K. pneumoniae* was not rate limiting and confirmed our previous inference that NO_3^- reduction was.

MUTANT SELECTION IN PLANT CELL CULTURES

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Cultured plant cells can be manipulated in a variety of ways under carefully controlled conditions and as such are routinely used for biochemical, physiological, developmental and genetic studies. Their usefulness is in large part due to the existence of mutant cell lines which differ from the norm in some trait. Such variants can be the basis for a study whereby some process (be it developmental, physiological, or biochemical) is elucidated by comparing normal cells with mutant cells exhibiting some defect or difference in the particular process in question. In such a case the mutant plant cell line becomes a laboratory organism, much like mutant strains of bacteria or mice which are maintained strictly for research purposes.

Mutant cell lines also have an agricultural application. Mutations which confer useful improvements to a crop may be selected in cultured cells. Such cell lines can then be induced to regenerate plants which may then constitute a new variety or may be incorporated into a breeding program to contribute to a new variety.

Many mutants have, of course, been identified by conventional plant genetic methods. Cell culture, however, offers two significant advantages. The first is quantitative. Plant cells in culture may be considered individual organisms and so a cell suspension may contain around 10^6 individuals per milliliter. As mutation is a spontaneous, albeit rare, event, mutants are much more likely to be detected in cultured plant cells because so many individuals can be grown in such a small space. Prohibitively large amounts of land would be required to detect the same rare event in a population of whole plants.

The second advantage is qualitative. Cultured plant cells are grown in a completely controlled environment. Variability is minimized because of the constant and uniform environment to which the cells are exposed. In such a uniform background, mutants are more likely to be detectable. More importantly, manipulation of the environment, permits the identification of types of mutants which might be undetectable as whole plants.

To isolate mutant cell lines, one must devise some means of enriching the cell population for the type of mutant desired. Although any large population of cells will contain spontaneous mutants, mutagens may be used to increase their frequency (Sung 1976). Some means must then be devised to permit the identification of the variants. Some sort of selection pressure is generally employed which permits the preferential survival of the desired cell type. Occasionally some non-selective method may be used (e.g. when the variant cell type can be identified morphologically).

Once the mutant is isolated, it can be grown up and its characteristics confirmed. Plants may then be regenerated from the cell line and further genetic tests with the plants can determine the nature of the mutation.

It cannot be too greatly emphasized that many of the variants selected in plant cell cultures are not mutants. They result from epigenetic rather than genetic changes. Epigenetic variants may be quite stable and thus may still be very useful as experimental cell lines. However, for most crop improvement purposes, the variant must have a genetic basis.

The most convincing proof that a variant is a true mutant comes from inheritance tests. In crosses with plants regenerated from the selected cell line, sexual transmission of the trait indicates that the trait is genetic. Inheritance patterns determine whether the mutation is dominant or recessive, nuclear or cytoplasmic. Alternatively, if inheritance tests cannot be performed (e.g. if the plants are not fertile) the demonstration of an altered gene product has also been considered evidence for mutation.

Over a dozen mutants have now been selected with plant cell culture methods. That these are true mutants has been shown by inheritance tests. Several other selected variants have demonstrated sexual transmission, but the data is not yet conclusive. Many other variants have been reported, and, while some may actually be mutants, sexual transmission has not been demonstrated (see Maliga 1980 for a comprehensive review).

Most of the mutants so far reported are resistant to drugs or inhibitors, for example streptomycin and isonicotinic acid hydrazide (Maliga et al. 1973, Berlyn 1980). The prevalence of these phenotypes is based on the ease with which they can be selected. Resistant variants are easily isolated as growing colonies when cells are subjected to inhibitory concentrations of these substances. While these particular types of mutants may have no immediate agricultural use, they are invaluable in metabolic studies.

Herbicide resistance is also a relatively common class (Chaleff and Parsons 1978, Radin and Carlson 1978). Again, this kind of mutant is easily isolated by subjecting cells to an inhibitory dose of the herbicide. Herbicide resistant mutants may have some utility in field situations where there are no effective herbicides which do not produce phytotoxic symptoms in the crop plant (see Meredith and Carlson 1981 for comprehensive review).

Disease resistance promises to be an area where in vitro selected mutants may be useful. Resistance to the Southern corn leaf blight organism, Helminthosporium maydis has been selected in corn callus cultures (Gengenbach and Green 1975). Other pathogens which produce host-specific toxins are good candidates for this approach.

The most crucial aspect of mutant selection in plant cell cultures is in the devising of a selection method by which to identify variants. Drug, analog, herbicide, and toxin resistance are among the first cell culture-selected mutations to appear because the appropriate selection method was readily apparent. The selection of other kinds of mutants will pose new problems. While we may know what kind of mutant we desire (e.g. increased photosynthetic efficiency or delayed senscence) we may not know how to identify mutant cells in which the appropriate genetic change has occurred. As the biochemical and cellular basis for agronomic characteristics is slowly revealed, mutant selection in cell cultures will progress. In the near future, with cooperation among geneticists, physiologists, biochemists, plant pathologists and other plant scientists designing a better crop plant from the cell up may be a reality.

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POLITICS AND AGRICULTURE-FEDERAL AGENCIES
ROBERT W. LONG PRESIDENT COUNCIL OF CALIFORNIA GROWERS

Before I talk about people and events, you should know where I'm coming from on the subject of the United States Department of Agriculture and certain other departments in the Federal Government. You can't spend four years of your life in one area without learning a great deal about the place and, more importantly, drawing some judgments from the experience.

The Department of Agriculture, as part of the executive branch, has been declining in terms of influence and prestige for several decades. As background for this statement, the USDA is what is known in Washington as an old-line agency. Created by Congress during Lincoln's term in office, it had a long and distinguished record of achievement on behalf of farmers and consumers alike. The nation is truly stronger today as a consequence of this remarkable history of dedicated service.

In the early days, the agricultural industry had a strong political base and used it effectively up to the advent of WW II. The Henry Wallace era, however, was not a part of this distinguished record I refer to - it was really the beginning of the end. When Government stepped in as a substitute for market-oriented agriculture in the basic crops, agriculture became a pawn, not a queen, in the chess game of politics. As improved technology and production skills of the farmer reduced their numerical strength, and thereby, their political power, you can easily visualize the rest without my detailing the process.

The good old days are gone forever. The Department of Agriculture has become a shadow of its former greatness. What remains, by and large, is a collection of bureaucratic fiefdoms squabbling among themselves.

Today most Federal employees are primarily concerned with their own welfare rather than that of a diminishing political base. Survival and justification of existence has become the paramount issue within this lethargic group.

For a brief time during the reign of Earl Butz, there was a mild renaissance because of his personal vitality and political acumen. He knew how to cope with the in-fighting required among Federal departments, the White House and Congress. The general public once again heard from this aging goliath. With the advent of Bob Bergland, the process of decline has resumed its downward course. Bergland is a nice guy, but inneffectual. I can't think of anything more disparaging than such faint praise, but the judgment will check out with any knowledgeable Congressman or commodity advocate in Washington.

What to do? Is it worth saving for the few good elements still associated with this public burden? I do not think so. Well then, if the problem is so transparent, why haven't others drawn the same conclusion? Many have.

Every government reorganization task force since the Hoover Commission of the twenties and thirties, has recommended the elimination of the Department of Agriculture. The most recent, and the one which came the closest, was the Ash Commission in 1969, but it failed, as have all others, and for two simple reasons - both of them political. 1) Some farm organizations have the mistaken concept that they need a departmental voice, no matter how weak, in the Capital. 2) The Congressional committees for Agriculture don't want to lose their control over an executive department. Those few states who have agriculture as a major economic force, usually stack the agricultural committees and these Congressmen are fiercely defensive. The issue is hardly more complicated than this simple statement.

The Carter Administration tried to extract the Forest Service and part of the Soil Conservation Service last year, but gave up when everyone objected to putting two of the few good agricultural agencies into the Department of Interior. If there is one old-line department in the executive branch that is more useless than Agriculture, it has to be Interior. Everything I have said about USDA applies fully to USDI only more so because they have been wasting public resources since the turn of the century.

Critics of our Federal Government have been talking for years about reorganizing the executive branch to improve its efficiency and thereby lower the cost to taxpayers. A noble objective, but so far just talk. It's time to look at some practical solutions. First, I remind all of you of an old axiom - it is not enough to just complain about a difficult problem unless you are prepared to offer reasonable alternatives; otherwise you become part of the problem.

Let's review the rules. A true reformer must observe certain basic tenets of our political system if there is to be even the smallest chance of success. No past administration has done so.

Here are the basics which must be adhered to:

1. Have a detailed reorganization plan prepared with reasonable options <u>before</u> the new administration takes office. If a newly elected President has a good margin over his opponent in the General Election, it will be easier, but even if not, there is a period of grace which occurs only once for every new Chief Executive and the ground work must be done in advance. Four years is too short a time to get the job done unless the preliminary work is complete; the second two years of any term becomes increasingly political and thereby, less productive.

2. Reach agreement early on the plan with the related Congressional committees as any change will always affect their jurisdictions. Congress must realign its committees at the same time or the plan won't work.

3. Get the special interest groups most impacted by the reorganization plan to be involved with its solution and implementation. Nearly all of the advocates are headquarted in Washington and they are there to carefully watch for any political action which might concern their constituencies. Many are either former Congressmen or executive branch personnel and all are experienced. They can make or break any reorganization effort no matter how sound the concept.

4. Finally, be prepared, as a Chief Executive must, to put your prestige and power on the line with the general public. Any President has enormous strength when the executive branch is directly involved and most people will follow his lead if he knows how to use that strenghth. This is the litany on this element:

   Kennedy wasn't really interested in reorganization soon enough - he had no chance to finish. Johnson was not prepared in time and busied himself with social legislation first and then Viet Nam got out of hand. Nixon was concerned early (Ash Commission) but he and his White House staff didn't work well with Congress or the advocates. Carter was concerned early, but went about the process all wrong because of his inexperience and then a growing lack of confidence in him among the principals who would be affected. What he did do was create two departments, which is must easier to do. He added a heavier burden on the taxpayer without any significant improvement in public service. A step backward! The one President who should have been successful was Eisenhower, but, he was a military person who preferred the status quo and wanted stability more than public section efficiency. He wouldn't rock the boat even though he had eight years to accomplish the task!

I could go further back in terms of even earlier administrations, but it is sufficient to note that the old-line departments have nicely survived past executive efforts to reorganize them and have continued to balloon in size and bureaucratic power.

Can anything be done? My answer is a resounding "yes!" Yes, it can be accomplished but the new administration 1) must follow the strategy outlined above and then 2) have an effective program to overcome the strong resistance from entrenched bureaucrats.

Career people (they prefer this term) can be formidable when their jobs are at stake and any reform plan must stand the test of weathering a rough fight from people who have learned how to survive in the pits. The senior career employees have usually been around twenty to twenty-five years and are more seasoned in the political game than any reform group in a new administration.

Much more could be added to support these brief comments on the politics of Washington, but this summary should give you at least a general idea of the combat arena when change is in the wind.

This is my outline of a plan to reduce the size of some Federal agencies without giving up any of the truly needed services which government should provide to its citizens.

1. Abolish outright the Departments of Commerce, Agriculture and Interior. I would include more (such as Labor and HUD), but the mountain to climb is fairly high with the three named. As for Commerce, most of the agencies under this umbrella could be completely eliminated in favor of a small trade and business support group attached to the White House. The Weather Service and NOAA, for example, could be assigned (with others in research) to a science and technology public corporation to work cooperatively in support of private enterprise.

2. Create a Department of Food and Natural Resources. You would recharter only the best and most effective agencies in Agriculture and Interior. Needed services for farmers, consumers, miners and foresters could be grouped easily in smaller agencies with one research complex to serve all.

The balance of the so-called "essential services", long provided by Agriculture and Interior, would be eliminated unless they couly prove their worth to an independent review board composed of people appointed by the President from the private sector. It would be my judgment that there would be a wholesale slaughter and it couldn't happen too soon if the reorganization is to be meaningful in our time.

That's it! A seemingly simplistic approach to a complex issue, but we have to start somewhere.

Now, what are the practical considerations for success beyond what I've already mentioned? The key to meaningful action resides in convincing farm organizations they would be better off under this modernized plan for efficient government.

Agriculture alone, among the three departments, has a sizeable constituency who could still frustrate any revitalization plan unless they were convinced it was not a move to further reduce their place in the sun. By attacking several areas of useless government expenditure at the same time, the onus of being singled out as the only culprit is generally reduced. The rest is just 1) hard work and a series of 2) intelligent decisions which can be supported by the Congress and an informed public.

Nothing is easy in our complex society. It will take considerable time and patience to make something worthwhile happen. But then, it took two centuries to reach the apex of the problem I am addressing. A few years of patience and perseverance is not too high a price to pay.

Let me hear from you if what I have tried to convey makes some sense to you. Otherwise, be prepared to pay more taxes for more regulation and no gain in the quality of life. The average career civil servant thinks you are a bit stupid anyway, so you have only money and (thru more control), your freedom, to lose. For me, I want to drive an axe through that block of dead wood - and I believe there are many who know how to use it!

A FARMER'S PERSPECTIVE

As I look back over the past decade, California agriculture has had to contend not only with our normal production variables of land, labor, water and weather, but now more than ever we have had to contend with politicians and an ever increasing multitude of laws and regulations that affect us. Government at all levels has become a partner in the decision making process of our farming operations. Laws and regulations affect our use of land, water, labor, machinery and chemicals. Some controls and restrictions are necessary to protect all concerned parties. My concern is that the majority of the people promulgating these laws and regulations have little or no firsthand knowledge of farming or it's allied industries.

Our challenge in agriculture is to educate the politicians and the people that elect them of our needs and why it is in their best interest to support us. We cannot expect to win every time, but we can expect to win our fair share if we support legislation and regulations that have a benefit to agriculture as well as our society as a whole. This educational process is a full time job. It is too important and time consuming to be done by production agriculturalists on a part time basis. We have been forced to hire legislative advocates to represent our positions and we are also forced to raise large sums of money in an attempt to elect officials that possess an understanding of agricultures needs. I use the word forced because most farmers are independent people that would prefer to leave people alone and be left alone. However, we cannot be so naive as to believe that politicians are going to look out for our best interests without constant communication of our positions and desires. Without constant communications, agriculture could find itself at the top of the list of endangered species.

There have been many political events that have taught agriculture valuable lessons. Proposition 14 and the ALRB are two events I would like to discuss today. The defeat of Proposition 14 by the voters of California in 1976 proved that the many groups that make up California agriculture could unite and take our story to the people and win. We walked precincts, we told our story on radio and television and in newspapers, and we defeated the U.F.W. and Governor Brown. We learned that all of agriculture could unite behind a common cause and work toward a common goal. In 1975 the Agricultural Labor Relations Act was written to promote peace in the fields and to help farmworkers. Governor Brown promised the agricultural community that the members of the ALRB would be neutral and unbiased. However, the Governor ignored his promise and has continually packed the Board with a majority of pro-U.F.W. appointments. Because of the close relationship between Cesar Chavez and the Governor, it has been impossible for the ALRB to act fairly and evenhandedly. Agriculture learned that Governor Brown was not a man of his word and could not be trusted.

I look ahead to the future of agriculture encouraged by the events of 1980. The election of Ronald Reagan as President puts a man in the White House with a far greater understanding of California agriculture than President Carter had demonstrated.

The rejection of Governor Brown's reappointment of Gerald Brown and the nomination of Ralph Faust to the Agricultural Labor Relations Board was a tremendous victory for agriculture. Great pressure, by Governor Brown's staff, was placed on Senators to persuade them to approve the two appointments. Notwithstanding such pressure, the Senate rejected Governor Brown's reappointment of Gerald Brown and the nomination of Ralph Faust to the ALRB. These two pro-U.F.W. supporters were defeated by the combined efforts of agricultural groups and the political integrity of the Senators that case no votes. I am very encouraged by Governor Brown's statement that he does not plan to seek reelection. I personally do not believe that agriculture could do worse.

Agriculture is learning how to play the political game. We have learned that we must play as a team if we hope to win. We can no longer solely be cattlemen, citrus growers or grain farmers. We must join together to present a united front for agriculture.

The great majority of people in our society no longer have relatives or friends who own or work on a farm. They have lost all firsthand contact with agriculture. It is agriculture's challenge to communicate our story to them. I feel it is an exciting story of a dynamic industry. Agriculture is not just the growing of crops, it is also the research and development of new products, varieties and techniques. It is the loan officer at the bank and the farm advisor and cooperative extensionist, it is the processing, packing, marketing and transportation industries. We raise and distribute, in one form or another, a wider variety of agricultural products than anyone else in the world. Everyone involved in this amazing industry should be proud and we should not hesitate to tell people our story. The entire population of California should be proud of what our state has accomplished.

"The Last Word"

Dick Beeler, Editor

AGRICHEMICAL AGE

CALIFORNIA FARMER

San Francisco, CA

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Thank you George, Ladies and Gentlemen, it is an honor and a pleasure for me to participate in your program and to visit with your members of this distinguished society.

As an agricultural editor, I know you folks as experts and sources of facts and stories. Today, with our normal roles of talker and listener reversed, I'm a little uncomfortable. I am accustomed to sitting out there with a notebook while one of you occupies this position up here. It was important, therefore, that George be explicit about our respective assignments. Mine, he said, is to talk, and yours is to listen. And, he said that if any of you finishes his job before I do mine, you are to hold up your hand.

George's introduction was a nice one. Thank you George. But you did leave one thing out. That is, I was president of my sixth grade class for two years in a row.

Now seriously, I want to compliment you, George, for the way you put this program together and for selecting some real experts to appear before this audience. It seems to me that most convention programs at least for the past ten years featured experts discussing subjects outside their fields of expertise. Linus Pauling won a nobel prize in physics, but quickly became an expert on Vitamin C and runny noses. Eddie Albert, an expert actor, lectures to us on the environment, Ralph Nador has become the nation's leading automotive engineer, Joan Baez advises us on International relations, Jane Fonda on patriotism, Eldridge Cleaver on good citizenship, Carol Foreman on food technology, and Teddy Kennedy on morals and ethics.

One thing you can say about me is I'm a non-expert, and no one can accuse me of getting out of my field of expertise. The theme for this morning's session has been "Politics and Agriculture." Certainly politics has had a tremendous effect on agriculture during the past decade, and in spite of what now may be a more favroable political climate, politics may have even more effect on agriculture in the years just ahead.

Politically, agriculture has just had ten black years. We've been saddled with regulations we never dreamed of. We've lost our voting effectiveness. We've lost most of our public funded research. The U. S. Department of Agriculture has been converted to a consumer protection and welfare agency. In Sacramento the flag has all but been replaced by the red banner of Chavez.

During the past ten years agriculture's problems have been aggravated by three important factors:

1) The so-called farm bloc disappeared once and for all. Nationally, the farmer is out-numbered something like 73 to one. In California he's behind about 320 to one! We simply lost all our political clout.

2) Those of us who were left in and near agriculture have had a tendency to be too busy and perhaps too fatalistic to try to influence the politicians of this country. We have been a house divided.

3) Even when we did lay out the facts before the politicians and bureaucrats, we got nowhere because we met not friends with sympathetic ears, but adversaries who saw political gains in punishing the agriculture community as the source of high food prices and polluters of the air, water and soils.

Agriculture, particularly in California, should be a source of continual good news to the readers and viewers of this country--last year, California farmers and ranchers set an all time record in gross income of nearly 15 billion dollars, leading the nation for the 30th year, and contributing more to the state's income and prosperity than any other industry. California produces a quarter of the nation's table food, including 33 percent of all U. S. vegetables and 40 percent of the fruit. It is estimated that one in every four jobs in California is related to agriculture. That's all good news, or at least it should be. At a time when we are learching from one economic crises to the next, agriculture is the sole large stabilizing force in the country. Yet all we have heard for ten years has been bad news.

Speaking of bad news, I have a list here of nine of the worst things in the world that can happen to you. The list is getting a little tired, but I'll risk the possibility that you may have heard some or all of it. It goes like this:

1. You wake up face down on the pavement.
2. You put your shorts on backwards and they fit better.
3. You call suicide prevention and they put you on hold.
4. Your only son tells you he wishes Anita Bryant would mind her own business.
5. You turn on the television and they're showing the emergency routes out of your city.
6. The woman you have been seeing begins to look like your wife.
7. You wake up and discover that your water bed broke and then you remember you don't have a water bed.

8. Your horn goes off accidentally, and remains stuck as you follow a group of hells angel down the freeway.
9. You come to work in the morning and there's a 60 minutes news team waiting in your office.

Now, that last item deserves some attention. Not too long ago, we would have welcomed the chance to be featured on a nation-wide news program, for fortune almost always followed fame. That's not necessarily so today, as publicity often leads not to fortune, but to trouble. Much of the trouble besetting agriculture can be traced directly back to bad press, which results in a poor public image, and ultimately unfavorable legislation and unfriendly government at all levels; state, national and local.

And if you don't think this situation continues, all you have to do is look at the problems we have had with the Medfly right here in this state. We have a state administration that is playing hearts and flowers to the environmentalists and the farm labor unions, and failed miserably to employ the tools modern science created to eradicate this terrible threat to our agriculture. And, thanks to bad press we have a mis-informed, ignorant, and badly scared general public that is petrified of a completely harmless spray program. Local governments tried to prevent spraying and USDA officials sat on their hands.

Those of us who have neglected agriculture's public relations have at last begun to see how serious bad publicity can be. It is not simply a matter of hurting our pride or our "image." Bad press has given people reasons for avoiding us and our products, and that's hurt our income, but more than that, it has caused people to think they need to be protected from us, our associates, and our products.

They are afraid they will be poiaoned, that their children will be born with defects, that you will give them dizzy spells, skin eruptions, nausea and cancer.

Mothers want to protect their infants from you. Audobonists want to protect their birds from you. Greenpeace members want to protect whales and dolphins from you. Sierra clubbers want to protect mountains and white water from you. Ralph Nader wants to protect consumers from you, and most politicians are eager to accept the task of protecting everybody from you.

So you get restrictive laws and new agencies to take charge of your life. You get regulated, inspected, you get your products recalled, you get investigated and you get sued.

That's where we are today.

And that's how we got there. Show me a case of over-regulation, and I'll show you a history of bad press that made it possible.

There are lots of obvious examples, but let me give you one that's not quite so obvious. It is the case of organic farming.

Organic farming is a fraud. So is organic gardening. So is the health food industry. So are the notions that preservatives, pesticides and ferilizers are bad.

You people in this room know that to be true. You know that the claims of the food faddists are so unscientific as to be downright silly.

But it is far from a joke. Consider that our United States Department of agriculture has taken a position very close to endorsement of the organic and health food frauds.

Make no mistake about it. The "organic" movement is anti-agriculture and it is anti-science. Of all people, the last secretary of agriculture of the United States gave official endorsement and blessing of the "organic" farming movement. This is the same man who vowed to stop public support of research in labor saving agricultural equipment. Our new secretary has his work cut out for him and needs your support.

Whether we promote the "organic" fraud, or just permit it; whether we are mistaken, or just don't care; the results are the same. Our food supplies, our national health, our economy, our freedom, our agriculture and our people all suffer.

The greedy, die-hard promoters of the "organic" and health food movements, and those who oppose modern science and industry, are working in concert, and they are in it for everything they have. Theirs is a crime that has severely damaged agriculture and has been a tremendous disservice to their fellow American consumers.

The incredible success of the health food fraud is only one example. A more dramatic one is the success of the marijuana industry which has been responsible for a series of government bans--at local, state and national levels--on the use of phenoxy herbicides. And, in the face of absolutely overwhelming proof that these chemicals are harmless to humans. If you think I over-dramatize, consider that the annual marijuana crop in just four California counties is officially estimated to sell for more than one billion dollars.

All across the board there has been a slow down, and in a few cases, actual reversals for scientific farming and food production. One chemical product after another has been taken off the market and the introduction of new products has been slowed by purely political, and even hysterical action, to the point where only one or two major agricultural chemicals a year come into use, and even then at an average cost per compound of around twenty million dollars in research and fighting government red tape.

Of course agriculture is not the only industry affected by bad press and regulatory activities in our government. Every major industry has been hurt badly.

Up until the mid-nineteen fifties, federal regulation in this country was limited to five major business activities.

Then suddenly there was an explosion. Today we have more than 85 regulatory agencies in Washington, dealing not just with companies and concepts, but with the nuts and bolts of how products are made, how records are kept, and how people live and work.

The cost of this massive regulation of all American life is said to be well past the $65 billion annual mark just in increased taxes. A small example is the annual cost to California taxpayers of our newest set of pesticide regulations which is estimated to be more than $18 million. A large example is the budget of the U.S. Department of Energy which is greater than the annual cost of production of all oils and gas in the United States.

The regulators have invaded factories and warehouses and now impose their view of life on all of us. Today they form a huge class of career professionals who excerise some control over virtually everything we do. In many cases, they are the dissatisfied youth who have moved in one or two jumps from the steps of Sproul Hall in Berkeley to the Carter Administration in Washington. At last count, more than 60 of the more radical activists from those days now hold key positions near the top of those regulatory agenices. This is no accident.

In August of 1976, Mr. Jimmy Carter, then the democratic nominee for President made the following public promise -- and I quote -- "One of the goals that I have for my own appointees is that they would be acceptable to Ralph Nader."

None of this damage to American business and personal freedom would have been possible without the softening up via bad press. The regulatory explosion of the fifties, to which I referred a moment ago closely paralleled the rapid growth of the television industry and emergence of the TV commentator as America's official thinker and philosopher. It is his thinking and philosophy that ends up in the public opinion polls -- and those polls are what congressmen read before they go to work in the morning.

Unfortunately for all of us, sometime in the past ten to twenty years, politics in the United States became a matter of simply reading public opinion polls back to the public. No longer a matter of leadership, as it once was, politics has been simply a matter of following what is thought to be the mood and whim of the public. Find out where the parade is and then run in front of it.

As a result, we have had a leaderless country. No one has had the courage to stand up before the nation and deliver a lecture on simple economic or scientific truths.

Everyone has been sold on the idea that political success comes only to him who takes the strongest stand against those things which Walter Cronkite and George Gallup say we do not like. And, taking a strong stand against something invariably means smothering it in public money and bureaucracy. During the past ten years we have done so much of this that we have run out of real money, and the paper stuff we print to substitute for it has been the real cause for our terrible inflation -- inflation that ironically is blamed by the press and the politicians on business and agriculture.

It is also ironic that most if these terribly costly regulatory programs are gross failures. In spite of astronomical costs, there is more smog in our cities than ever before.

We have fantastic sewage programs and budgets, not just for big cities, but for isolated farms that are miles from a neighbor.

You and I pay seven hundred to a thousand dollars extra for Rube Goldberg gimmicks on our automobiles without the slightest indication they are safer, cleaner, or any more efficient. The only real result is the ruination of the auto industry.

Incredible amounts of our money is being poured into public transportation systems that never seem to work, and it takes us all longer to get to our job than ever before.

We are spending billions of public money on wild schemes to produce alcohol from food and feed products, even though no one predicts we could ever get the cost down to compete with gasoline.

Disposal of waste such as beer and pop bottles is now the first order of business for the world's greatest government which can't even protect it's own diplomatic personnel from kidnapping and imprisonment.

All of this time we are being told that we are living too high on the hog; that we are guilty of being too affluent; that we had better start living more like the people in the under developed countries.

Ironically, that is exactly what we are doing. As our government grows our economic and political freedom shrinks and our productivity grinds to a halt.

We no longer believe in moving ahead, in scientific progress. Agricultural research receives only two percent of the total USDA Budget, contrasting to ten percent just twenty five years ago. In 1980, total USDA outlays were $23.6 billion, but more than $13 billion of that - way over half - went into food stamps and school lunches.

Incentive to work and to invest in America has reached a 200 year LOW. Last year for the first time our national rate of productivity actually was reversed.

Now one of the big questions about all this is why do so many industries businesses and professions get so much bad press? The man on the street always had this expanation: "Those people are after headlines. Headlines sell newspapers, bad news makes headlines. Good news is dull."

There's not much truth in that theory. Here's why. The top management of a publishing or broadcasting company is about the only level at which there is a true concern for profit. The working reporters and editors, are often as antagonistic toward the business aspects and the management of their own company as they are of business in general. They couldn't care less whether it sells papers and makes money. The same is true about the news staff of a TV station. There is frequently open antagonism between them and the sales or business end of the station.

So then you wonder why top management of these organizations puts up with writing and preaching against American business, industry and professional people? There are two reasons why they put up with it. One is that news people are strongly unionized and it is nearly impossible to fire one of them for what can be called his political philosophy, and the other reason is that no matter what the top management policy of a newspaper or electronic medium is, it cannot control the slant, innuendo, or even the choice of words used in headline writing and copy composition. Time and nature of the work just does not allow it. Not any more than a school board can dictate the choice of words, the use of emotion or the subtle conduct of a teacher.

Besides that, there is a strong traditional distrust of business among journalists based on the fear that advertisers or other commercial interests might try to dictate to the writer and editor. That distrust extends to their own companies and managements. In many newspapers the purity and sanctity of the editorial department is guarded to the point that reporters and editors do not speak to the management or advertising personnel.

Okay, so the next questions is why do so many of these writers, news announcers and analyts want to bad mouth American business, industry and professions?

These people are called journalists. In these days of professional specialization and expertise, journalists stand out as a different breed. They are not trained in any of the sciences, the arts or commerce.

Increasingly they are called "communications experts" but it is difficult to accept the word "expert" in the description of a man whose work takes him from the police beat to space science, to the maternity ward and a Central American revolution all within thirty minutes.

A more classic definition of a journalist would be one who keeps a journal. That is, he keeps an account of things that he sees, hears, tastes, smells or feels. He is not supposed to write about things he imagines and because of that, most of the people you find working for newspapers, radio and television these days are not really journalists at all. At best, they are entertainers, and at worst, salesmen of a wide variety of ideas and philosohies.

Unfortunately, most people still have the classic definition in their minds. They think of him and his paper or station as dealers in absolute facts, they don't filter out imaginary stuff, the entertainment or the sales job.

There is one other source of information, one other profession besides journalism that most people readily believe. That is the classroom teacher, the instructor, the professor.

Now, there is nothing wrong with that. We should be able to trust our news and educational sources. I don't want to shake that faith. What I would like to do is to see it justified.

We all know there are problems, not just with carelessness and inaccuracies, but with deliberate distortion, deliberate propaganda and downright falsehood. Why is that? Why would any journalist, or any teacher want to avoid the truth and clarity? Is not that the very essence of their chosen careers?

Well, let's suppose you are a young person standing at the threshold of your career and you happen to be severely disenchanted with what you call the "establishment." You don't like hanging up your clothes, or saluting the flag, or the way the white man treated the Indians. You don't like shoes, deodorants, barbershops, plastics, the Vietnam war, chemicals, corporations, made in U.S.A., Anita Bryant, nuclear energy, pesticides, dams, or livestock produced with modern feeds.

You are not sure what you do like, but you have a feeling that the greed of your fellow men is responsible for all the world's ills, and that if you could just help get rid of all those things you have on your list then eternal youth, whitewater, total equality, wood stoves, herbs, mother earth, whales and clean air would all come back to us.

So, you feel it's up to you to go out and open some eyes, to spread the Gospel, and to get this country back to basics -- pick up where the Indians were interrupted -- make it more like Sweden, and borrow some of those good ideas from Chairman Mao.

If you want to make basic changes in the American system, how do you go about it? You get into either of those two most believable professions, teaching or journalism.

So it's either journalism school or teachers' college for you. Or better yet, do them both -- be a journalism teacher!

If you're a young idealist who wants to upset the establishment, don't think you won't be welcome in any journalism school on any campus. The reason is simple: The faculty will be largely made up of people who arrived there by the same route -- and they became journalism teachers.

So the next question is what can we do about all this? If you sincerely believe, as I do, that many of the fundamental guiding principles of American life have been abandoned, you are outraged and you would like to do something about it. Too many of us who are worried, simply do nothing; we procrastinate.

It reminds me of the story of the moose and the honeybee: The moose and the honeybee were eating wild flowers when the moose consumed the bee. Inside the dark cavernous innards of the moose, the outraged bee decided to teach the moose a lesson by giving him a sting like he'd never felt before. But that requires considerable energy, so first, the bee elected to rest up with a nap.

When the bee woke up the moose was gone. The moral is simple. Those who procrastinate, who delay making their presence and their feeling known, frequently get left behind in the shuffle of events.

How can we best defend ourselves, our professions, our industry, and in fact, our American way of life, against this onslaught of bad public relations and the political repercussions it engenders?

For at least ten years now, most of us in agriculture have been procrastinating, ignoring the attacks, waiting for someone else to defend our jobs and way of life, or just hoping the problem will go away.

For the last two months we have been rejoicing that maybe at long last the pendulum has begun to swing back. November 4 was that start of a new life.

November 4 was indeed significant. It demonstrated clearly that while the politicians (at least those in power) and the media, that is to say our unfriendly bad press -- continued to follow the commentators and the polls, the American people started their own parade.

As of today, with the new Reagan appointments we have seen, we are encouraged. At last we have some people in Washington who appear to have sympathy for business, science, and agriculture. In California, unfortunately, we still have, as of today, 610 days before we can expect relief.

But this does not mean they are going to carry the ball for us. We have had ten years of bad experiences with government and we had better profit from that experience.

We must step up our activities on three fronts. The first is to make sure we maintain constant contact with our representatives in government. Letters and telephone calls to your congressmen and senators were never more needed than in the next few months. And you must make sure the new USDA, EPA, FDA and other agency officials hear from you regularly on behalf of agriculture.

Second, we need grassroots public relations. Next time somebody asks you a question at a cocktail party or any kind of get together let him have it with both barrels. Our job of feeding this country and a good part of the world overseas is one which we ought to talk about and explain at every chance.

Finally, there is one very important task for you and me in these next few years. That is to strike back at the detractors of the American way who infest our communications industry and our school system. Remember not one of them changed his stripes November 4 or since. They are already hard at work re-selling their philosophies. Remember that they are professional propagandists who were enormously successful before and they intend to swing <u>their</u> pendelum back just quickly as they possibly can.

Ironically, business in this country accounts for a huge share of the financial support these people get. Business must quit subsidizing colleges and universities whose departments of journalism, economics, government and social science are hostile to free enterprise and to the furtherance of science and technology.

The most effective way to correct the situation is to cut off the grants and the subsidies, and to reestablish them in other, more progressive institutions or departments where human freedom receives real respect.

I urge you whose companies made a practice of supporting colleges and universities to take a close look at what you are giving to whom, and whether that money is being used to propagandize the very system that supports your company, your job, and even produces the money the institution receives.

I am not talking about censorship. Academic freedom is not at stake. What I am suggesting is that you stop offering your right hand to the animal that just bit your left.

I also urge you to look closely at the non-profit foundations and organizations which you and your company support. Altogether too many of these groups with the attractive names and beautiful sounding objectives are active and highly successful enemies of agriculture, free enterprise and modern science.

You should also do your best to prevent your company's advertising in the publications or networks that preach against the things essential to your freedom and your legitimate business and career goals. Advertising is the nourishment without which media will die. The radio, television and newspaper personnel of this country owe a debt of gratitude to the American free enterprise system and an obligation to the truth. You can remind them of these debts and obligations.

Of course it would be wrong for an advertiser to try to dictate to the newsman or an editor, and I am not talking about that. I am talking about the clearly established limits of truth, ethics, propriety, decency and patriotism beyond which the editor or newsman should not venture.

Each of us has limits as to his freedom the freedom of others, and it is the duty of all of us to see that those limits are respected.

November 4 was a wonderful day, and it meant many things to many people, but one thing it did not mean to us is that anybody is going to do this job for us. Scientific agriculture has learned a bitter lesson. November 4 has given us a chance to apply what we have learned, and we had better get on with it.

Thank you.

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MANAGING GROUNDWATER SUPPLIES -- PROSPECTS AND PROPOSALS FOR CALIFORNIA

BY

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(Senior Partner, Best, Best & Krieger;
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Review California Water Rights Law)

1. Groundwater: The Present Problem

Approximately 40% of California's annual water needs, or about 15,000,000 acre feet per year, are met from groundwater pumping. A state-wide overdraft in the order of 2,000,000 acre feet per year exists, approaching 20% of the total groundwater supply in some areas. Most of the overdraft occurs in the San Joaquin Valley as the result of agricultural demands. Overdrafting results in permanently increased pump lifts and energy demands. It raises the prospect of severe economic and agricultural dislocations as supplies diminish. In some areas, it causes sea water intrusion and land subsidence. Approximately 490,000 acres of still undeveloped land overlie groundwater in the Southern San Joaquin Valley. One study indicates that approximately 220,000 acres of this land might reasonably be expected to develop by the year 2000. There is no way to assure that new water supplies will be used to reduce the existing overdraft rather than to be applied to new lands brought into production. Nor is there any assurance about the availability of new supplies of water.

2. Existing Groundwater Law

With no major review of water law in California since 1913, groundwater pumping is essentially uncontrolled by statute. Groundwater law has consequently been left to the courts and the use of groundwater has developed largely under the control of the judiciary.

California law permits any overlying landowner and any distributor of water to drill a well without prior approval, and to take whatever amounts of water may be needed without regard to whether the supply is in a condition of overdraft. An injured pumper, or any party concerned about the long-term supply of the basin, is required to sue in court for an adjudication of the affected water rights. Adjudication procedure in the courts can be long, complex and expensive. The last contested suit, Los Angeles v. San Fernando (1975) 14 C.3d 199, was in the courts for 20 years.

3. Governor's Commission to Review California Water Rights Law

Faced with these problems, and following a two-year drought, Governor Edmund G. Brown, Jr. created the Governor's Commission to Review California Water Rights Law in 1977. Chaired by retired Chief Justice of the California Supreme Court, Donald R. Wright, the Commission was composed of 12 members well-known and experienced in water matters. From the outset, groundwater was the major issue before the Commission. The Commission made recommendations in three general areas of groundwater law.

4. Commission Proposals

A. Use of Groundwater Basins for the Underground Storage of Water

The Commission recommended codification of the *Los Angeles v. San Fernando* holding that underground storage capacity is a public resource that may be used without permission of the overlying landowner and without payment of compensation, and that title may be retained to commingled water stored underground. Further, it recommended that authority to allocate the use of underground storage capacity be vested in a local management authority. Priorities for use should be: first, for normal operation of the basin to ensure that the natural supply during wet years could be fully accommodated; second, available storage capacity be used for the benefit of users within the basin; and third, any remaining storage capacity be available for other areas of the state. Any entity storing water would be required to enter into an agreement with the local management authority, controlling such matters as losses, duration of the storage rights, use of spreading grounds, places of withdrawal, rates of withdrawal, etc. The Commission's recommendations in this area appear to have been generally accepted.

B. Adjudication Procedures in Groundwater Suits

The Commission recommended certain procedural changes to facilitate settlement, eliminate delay, and make the court process more effective and available. Accordingly, the Commission recommended there should be one judge appointed from outside the area for all proceedings; no peremptory challenges of the judge; utility records be made available to identify basin pumpers; basin boundaries for actions be established; a lis pendens procedure to bind successors in interest; exemption of small users; no mandatory dismissal of an action after five years; and no withdrawal from a settlement agreement without court approval.

Substantive changes recommended by the Commission were that preliminary injunctions be specifically authorized by statute;

and where conditions of long term overdraft have existed, that rights be allocated primarily on the basis of recent use. This would temper the Los Angeles v. San Fernando rule that Civil Code Section 1007 allows public agency pumpers to gain prescriptive rights against private pumpers, but not the reverse. It would also modify first in time, first in right concepts.

C. Groundwater Management Proposals

The Commission recommended the need for groundwater management, in addition to that presently in existence through court decrees or special statutes. Primary responsibility for groundwater management should be at the local level, but within a framework that would protect state interests. Management should be imposed only in areas of need and only to the extent needed. Adjudicated basins under the continuing jurisdiction of the courts, and certain other areas already managed on a safe-yield basis would be exempt. Establishment of groundwater management areas would take into account political boundaries as well as hydrology.

A local groundwater management authority should have broad powers including data collection, metering, storing water underground and regulating underground storage, exporting and regulating exports, licensing new wells, limiting pumping where necessary, and imposing extraction charges. State Water Resources Control Board oversight of the program would be established, and if the Board determined after a hearing that the local program did not conform to state policy, the Board could request the Attorney General to seek judicial relief.

5. Subsequent History of Commission Proposals

The Commission submitted its proposals to Governor Brown on December 22, 1978. While the recommendations of the Governor's Commission for underground storage and for a simplified adjudication process were generally accepted, great controversy arose over the management proposals. Opponents of the recommendations perceived them merely as rationing proposals, and easy excuses for not developing new supplies.

During the 1978 and 1979 sessions of the California Legislature, bills were introduced to codify the proposals of the Governor's Commission, but to date, the only legislation enacted with respect to groundwater has been SB 1505 (Nejedly, 1978, Ch. 601, Statutes of 1978, adding Section 12924 to the Water Code). Originally incorporating all of the recommendations for groundwater management proposed by the Commission, subsequent amendments completely changed the bill. Water Code Section 12924, as enacted, merely directs the Department of Water Resources to identify the groundwater basins of the state, including those subject to critical conditions of overdraft. Basins are to be identified on the basis of geological and hydrological conditions and consideration of political boundary lines whenever practical. Groundwater Basins in California (Bulletin No. 118-50, January, 1980), was issued in response, identifying groundwater basins, including 11 basins subject to critical conditions of overdraft.

Other legislative proposals included AB 442 (Kapiloff), which incorporated the recommendations of the Governor's Commission, including a proposed Groundwater Management District Act. After numerous amendments, AB 442 died in committee. A companion bill, SB 47 (Nejedly), introduced December 5, 1978, also failed in committee. A final effort to codify some of the groundwater recommendations of the Governor's Commission, SB 1361, introduced by Senator Nejedly in January, 1980, required local districts to develop their own groundwater management plans and method of conservation. It also was left in committee in late summer, 1980.

6. Future Prospects

At one time, development of surface water was expected to provide all of the additional water which a growing state might foreseeably need. Now, new water development faces not only north-south problems, but environmental and growth control problems as well. Groundwater management, or opposition to it, have become bitter parts in those struggles. Agricultural interests argue that all that is needed is more water, and they believe the undeveloped supplies in the state are ample to meet all of our needs. They see groundwater management programs as a deliberate way to divert the state from development programs. On the other hand, environmentalists and Northern Californians generally argue that supplies are more limited, that in-stream values must be protected, and that new river supplies should not be developed until we first conserve and manage our existing supplies as carefully as possible. We have been at this impasse for several years. The referendum on SB 200 will decide whether the stalemate continues. It would seem however that these fears, distrust and provincialism must be overcome. Both water resources development and more effective groundwater management are required to meet our future water needs.

ACHIEVING EFFICIENT WATER USE*

Charles E. Phelps**

Is water being used efficiently in California? A recent Rand Corporation study concludes that water use throughout the state is *not* efficient. This lack of efficiency is not due to mismanagement or waste by water users (agriculture, business, and households) but rather to a myriad of legal and institutional restrictions on water pricing, transfer, sale and use. In general, water users individually appear to use water efficiently, *given the circumstances they face*, but those circumstances (the body of water law, water supply institutions, and legal rulings) essentially dictate that water use be inefficient from a statewide perspective. More important, improvement in the efficient use of state water supplies could forestall or even eliminate the need for constructing expensive new water development facilities now being considered by the Legislature. The current system generates annual losses to California conservatively estimated to be $60 to $370 million, which is equivalent to a once-and-for-all wealth loss of $1 to $5 billion. It is this loss that should be contrasted against legal, political, and economic costs associated with a move to efficient water use.

HOW EFFICIENCY COULD BE ACHIEVED

I define water use as efficient when the added costs of supplying water just equal the added benefits to water users. This concept of benefit measurement accepts as pertinent the users' valuation of the water. Since 85 percent of the water used within California is in agriculture, this primarily implies accepting farm profitability as the measure of water value. The best measure of cost is often the value of the resource to the user valuing it most highly, independent of actual production costs. The concept of cost is meant to include all costs

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*This paper summarizes research performed by Charles E. Phelps, Nancy Y. Moore, and Morlie Graubard, reported in *Efficient Water Use in California: Water Rights, Water Districts, and Water Transfers*, The Rand Corporation, R-2386-CSA/RF, November 1978. The views expressed herein are those of the author and should not be attributed to The Rand Corporation or any of its research sponsors.

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generated by supplying the water, both private costs and "public" costs (i.e., those not borne directly by the water users). Private and public costs can diverge markedly, as, for example, in use of groundwater basins.

Efficiency of water use can *in concept* be enhanced under three different systems: (1) central planning of water use and supply; (2) pricing of water to reflect the incremental (marginal) costs of the supplier; and (3) enabling water users to buy and sell water, independent of the initial price paid for the water.

Central planning can lead to efficient use if the planners can assess the value of water in each use and the costs of delivery of water to each user, and can establish a distribution system to send the water to each user in such amounts and with such timing that added value to each user from receiving more water just equals the added costs of supplying that water. The informational difficulties in such an activity appear to us to be overwhelming, and we reject central planning as a feasible method of achieving efficient use of water. Instead we concentrate on other ways of achieving efficient water use.

Efficient use can also be achieved when the price to each user reflects the incremental costs to society of supplying the water. This concept is known as marginal cost pricing. Users can be expected to increase their use of any resource only to the point where the added benefit from the incremental amount used just equals the price charged. For example, in farming, the farmer would add water to his crops only to the point where the added water increases farm profits by just the amount that the water costs. Any further use of water would mean spending more on water than it was worth; less use would imply that some profits had been forgone. In general, we anticipate that water use would increase until marginal benefit to the user equaled the price paid. When that price is also set equal to the marginal cost to society, then efficiency has been achieved, because the added benefit from supplying the additional water will have just equaled the added cost.

Finally, even if water is not priced to the initial buyer at marginal cost, efficiency can be achieved by allowing unhampered buying and selling of water among water users. Efficiency occurs because those who value water highest may purchase water from those who value it less, and both parties are made better off. Thus, in general circumstances, a free-trading market leads to the same pattern of use as a market with marginal cost pricing.

This analysis concentrates on improving understanding of water trading and water pricing as mechanisms for enhancing water use efficiency. I discuss, in order, the possibilities for water sales and trades by water district, water district pricing practices, and finally a modification in the general pattern of water rights assignment which would enhance water sales at the final user level. Associated legal complexities arising from each of these concepts are next discussed.

Suppose a water district were to offer water for sale to some other water user. Water districts have available to them basically three mechanisms to distribute or use revenues from such water sales: They can add new physical facilities for the district, they can reduce the price of water actually sold within the district, and they can reduce property taxes collected within the district. Each of these mechanisms presents operational difficulties to the water district, as well as potential problems regarding efficiency of water use within the district.

Consider first the notion of adding new facilities. If a water district chose to sell part of its water resources systematically through time, the revenues would accumulate so much that it could not justify further capital expansion or improvement. The ultimate result of such a strategy for using water sales revenues would be "gold-plating" of district facilities. In addition, there would probably be tax reductions or water toll reductions within the district that would otherwise have been used for some of the capital improvement, each of which presents its own potential problems.

The problem with using water toll reductions to distribute district revenues from outside water sales is its effect on water use: A reduced water price leads to increased amounts demanded by members within the water district, thus leading to inefficient use. There may also be a disparity between amounts supplied and demanded under such a situation.

Supply within the district is decreased (by the sale of water elsewhere) and demand is increased (because of the lower price). Thus a rationing system may be required, which could also potentially lead to inefficient use within the district. (If retrading of water within the district is permitted, this problem can be resolved, but some water districts we contacted seemed strongly opposed to such reselling of water, even within the district. Such intra-district sales are nevertheless fairly common.)

Property tax reductions are the third potential mechanism to distribute the profits from district water sales. Such reductions are not uniformly available to water agencies, because some agencies rely only very little upon taxation, whereas others rely almost completely on taxation to meet district costs. Those with only little taxation revenue find tax reduction only a limited vehicle for water sales profit redistribution at best. Even if the mechanism is available, the directors of the district may have little interest in using it. There is the potential for significant income redistribution among residents within water districts through the taxation mechanism: In general, relatively heavy water users within a water district have incentives to rely more upon taxation than upon water tolls, particularly if the taxes are levied on some basis relatively independent of water use. (In one district, we observed that 80 percent of the taxes were paid by users receiving 20 percent of the water. This was, however, the extreme we observed in our contacts with over 50 water agencies.) If a majority of voters within a district has achieved such a favorable redistribution process, they may be loath to use tax reductions or rebates as a way of distributing any profits arising from water sales by the district.

The circumstances wherein such redistribution can potentially arise are too numerous to catalog. Voting rights within water districts may be based upon acreage owned or assessed valuation, or on a per capita basis. Thus various combinations of land ownership and tenant farming can be expected to produce a variety of potential redistributive systems. Without detailed knowledge of land ownership patterns within any given district, or about tax payments and water use, it is impossible to assess the extent to which such redistributions are actually employed.

A separate concern of financing water district operations through taxation is the potential for inefficiency introduced. Whenever property taxes are employed to reduce water tolls, there are incentives for overuse of water within the district. This arises because the tax payment is independent of actual water consumption, and thus does not affect water users' decisions about the amounts of water to consume. In general, taxation is desirable as a part of the pricing strategy for an organization only when average costs systematically decline as the scale of the organization increases. (A common example is the telephone system, where multiple systems of telephone lines, each connecting different subsets of the households and businesses within a community, would be more costly than having a single system serving every phone user.) But such is normally not the case within the operations of a water district. Many water districts have multiple sources of water supply, for example, one being more costly than the other. Consequently, correct pricing decisions by the water district--i.e., pricing at the full cost of the most costly water source--would lead to a profit by the district. In such situations, taxation should not be at issue, but rather how to dispose of the profits within the confines of the water district environment.

THE ROLE OF PRICING

A large number of studies indicate that amounts of water used in virtually every water-using activity are dependent upon the price of water. The sensitivity of water use to price depends upon the nature of the use--outdoor home use appears more sensitive than indoor home use; agricultural use appears more sensitive than homeowner use, and also becomes more sensitive as the price of water increases. (See Phelps, Moore, and Graubard, 1978 for a summary of this literature.) Thus the pricing decisions of water agencies throughout the state could play an important part in determining overall water use.

As previously stated, efficiency in water use is achieved when the price of water is set equal to the cost of supplying additional water in the system. For a local water district, this means determining the cost of adding new water supplies to their system. For the State Water Project (SWP), this means adding new supply facilities.

For the individual farmer, it may mean either obtaining more water from the water district serving him, or pumping additional water from the ground. In general, when a water system employs a variety of sources for its supply, some will be more costly than others. The marginal cost of the system is the cost of the most expensive source used. The average cost of the water, by contrast, will generally be less than the marginal cost, because it includes some water available from lower-cost sources.

Water agencies throughout the state tend to price water at its average cost, rather than its marginal cost, and since the average cost is lower, there is a general tendency to over-use water from such sources and inefficiencies arise. Water districts (and the SWP) chose average cost pricing rather than marginal cost pricing for a variety of reasons, but the predominant reason appears to be that marginal cost pricing would lead to a profit, and the water district (and the SWP) cannot legally make a profit systematically. Thus the legal constraints on the operation of a water district (and the SWP) generally force them to engage in a pricing policy that leads to inefficient water use. The problem is pervasive not only within local water districts, but also within state and federal water supply agencies. Within the SWP, the problem is so severe that current proposals for expansion of the SWP could lead to construction of water reservoirs which have a marginal cost of over $250 per acre-foot, *just for the capital costs*, yet the water would be sold for less than one-fifth that amount. The reason is similar--if the SWP were to price water at the marginal cost, a substantial profit (possibly over $100 million per year) would be made, and the SWP has no effective mechanism to deal with such a profit. (See Phelps, Moore, and Graubard, 1978) for calculations supporting these numbers.)

The problem of average cost pricing is exacerbated by the use of taxation to support part of the costs of water districts. Whenever taxation is available to help finance water supply systems, it eventually leads to too much water used. The reasons are that the water toll becomes lower than it would be without the tax, and that reduced prices systematically increase amounts of water use.

A similar average cost pricing problem arises in the federal Central Valley Project (CVP). In addition, the CVP engages in several direct subsidies to water use, through pricing reflecting estimated ability to pay, through the use of very low interest rates for project construction costs, and through deferral of repayment of capital costs for a considerable period.

ALTERNATIVE WATER SUPPLY ARRANGEMENTS FOR EFFICIENT WATER USE

Several mechanisms are available to enhance the efficiency of water use within the state. One prominently mentioned concept is that water districts should adopt marginal cost pricing. As discussed above, such pricing practices would violate the zero-profit constraint of most water districts, unless changes in the district organization are made. One method is the one of increasing block pricing, by which some water is made available at low cost (or free) to each water user, with any added amounts of water supplied only at the correct marginal cost. The profit of the system can thus be distributed through the use of fixed amounts of water to each user. Such a pricing system can lead toward efficient use of water if most or all water users actually consume more water than their initial low-cost allocation, so that they face the marginal cost of the system as the relevant decisionmaking price. There may be political difficulties in establishing the appropriate amounts of low-cost water to be received by each water user, but such problems do not appear tc be insurmountable. However, even use of such pricing mechanisms within water districts cannot solve all problems of inefficient water use, because disparities in value of water can still arise across water district boundaries.

An alternative mechanism to induce efficient water use is to modify the way in which the rights to use water within a water district are held. In usual water district practice, water rights are typically held by the district itself, and the water district then apportions water use among landowners within the water district. The rights to receive water from the district are typically based upon acreage owned or tax payments, but the rights are not fully transferable to other persons or parties.

Thus the ultimate user of 85 percent of the state's water--the farmer--is faced with the choice of receiving his allocation of water (at a price typically below marginal cost) and using it in his farming, or giving up that water use and gaining only the water toll that would have been charged by the water district. That water toll may be quite low--$3 to $6 per acre-foot of water--whereas users elsewhere in the district, or particularly persons outside the water district in less water-rich areas, evidence willingness to pay up to $150 per acre-foot of water. The ability of the farmer to sell title to use of his allocation of water can improve the efficiency of water use within the state by providing incentives for voluntary sales or exchanges of water.

To achieve such a system of water sales, it is necessary for water districts to provide a clear title to the use of water from the water district to the ultimate water user. It is also necessary to eliminate prohibitions against transfer of that water, but the problem of providing appropriate incentives to the water user seems prominent in achieving efficient water use. In addition, the cooperation of local, state, and federal agencies is critical in supplying major cross-state transportation for the water through existing canals, while charging users appropriately. The important notion involved in establishing a water market is that the relevant price facing any water user would be the highest amount he could obtain while selling that water, rather than the price actually paid to the water district for delivering that water. Thus, even if water district pricing could not be rationalized to lead to efficient water use, mechanisms for water sales would reach the same goal through different channels.

OTHER LEGAL CHANGES TO ENHANCE EFFICIENCY

Certain modifications in basic water rights law also appear desirable in terms of increasing efficiency of use. One issue involves return flows from imported appropriated water. Under some circumstances today, this water is considered available for later appropriation by downstream users, so that changing the point of use of the original appropriation can lead to claims of third-party damage. I recommend that any new appropriations explicitly state that return flows are a part of the original appropriation so that *no* downstream users can claim damage unless they have contracted for use of that return flow explicitly. Further, I recommend that quantification of existing return flow dependencies should be made, so that every water appropriator can be certain of the potential damage claims, should he wish to sell his existing appropriation. Mechanisms to compensate for any damages must be arranged, but we believe that clearer indication of where title to such return flows lies will enhance the ability of water users to voluntarily transfer their water to more highly valued uses.

An expanded surface water market will almost certainly lead to increased groundwater extraction in some areas of the state. Groundwater users impose costs on others within the same basin through increased extraction, but they do not personally bear the brunt of these costs. Because total costs to society diverge from the sum of private costs, a basinwide management scheme is desirable. The issues surrounding groundwater management are analyzed in:

Efficient Water Use in California: Groundwater Use and Management, by David L. Jaquette and Nancy Y. Moore, with Albert J. Lipson, R-2387/1-CSA/RF, November 1978;

Efficient Water Use in California: The Evolution of Groundwater Management in Southern California, by Albert J. Lipson, R-2387/2-CSA/RF, November 1978;

Efficient Water Use in California: Economic Modeling of Groundwater Development with Applications to Groundwater Management, by Bruce Wetzel, R-2388-CSA/RF, November 1978;

and *Efficient Water Use in California: Conjunctive Management of Ground and Surface Reservoirs*, by David L. Jaquette, R-2389-CSA/RF, November 1978.

The gains from these modifications to California water law and institutions are most productive if taken as an entire package rather than piecemeal. For example, improved management of groundwater basins allows more aggressive conjunctive use of surface and groundwater storage, thus enhancing the output of existing surface developments. The effects of surface water sales will almost certainly include increased groundwater pumping in some regions; hence, management of groundwater extraction in all basins will guarantee that no adverse social effects arise from the surface water sales. While each of the components is likely to be useful in its own right, the entire system of modifications is synergistic in benefits.

DRAINAGE OF GOLF GREENS

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The majority of golf putting greens constructed in the past 5-10 years use a pure sand or a hgihly permeable sand mix as the growing medium. The depth of the growing medium usually does not exceed 12-15 inches due to the cost of the imported medium, the need to have only 8 inches to accommodate the cup, and the shallow rooting characteristics of bentgrass when highly maintained to produce a reasonably firm putting surface. A 4-inch gravel blanket underlying the growing medium is sometimes used as recommended by USGA, or the medium may be in direct contact with the parent soil of the site. But in most cases, a tile drainage system is recommended. The purpose of the tile system is to remove the perched water that can accumulate at the interface of a highly permeable growing medium and the lower permeable on-site soil. Contrary to the belief of some golf course architects and superintendents, the tile system does not improve the drainage characteristics of the growing medium. It only functions to remove excess free water which can accumulate at the sand-soil interface. If the tile system does not function properly the perched water can rise to a depth which could cause restricted root growth, increased disease problems and reduced playability of the green.

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In reviewing the literature we find a number of references indicating tile lines should be placed 5 to 20 feet and that some type of herringbone or flag configuration is used. Some architects prefer one to three lines running up through the green in the lowest area of the subbase. These patterns of tile placement have been commonly accepted although there appears to be no specific research pertaining to golf green drainage on which to base these drainage designs. We did find however, that extensive research has been done on the subject of agricultural field drainage. When looking at numerous green drainage designs one sees the application of several properties of agricultural drainage. Although putting greens and agricultural fields are comparable in some respects their construction, management and use do not correlate and these disciplines should have the greatest influence on drainage design.

In the fall of 1970 we constructed an experimental green with a two percent slope from back to front. The drainage cells were 25 feet in length with three tile lines intercepting the slope. One line was placed at the toe (or front) of the green and the other two were equally spaced up slope approximately 10 feet apart. Under normal irrigation only the tile line at the toe of the green would flow. During periods of excess irrigation or heavy rain the upper tiles would flow for a short period of time. Due to the variation of mixes in the individual drainage cells and the fact that the upper two drains were connected, we could not determine which of the upper drains were flowing.

When rebuilding old greens we observed that the upper line seldom appeared to have functioned. In some greens the type of shallow mix had such a low hydraulic conductivity there was some question as to whether or not a perched water table would have developed. Drainage of excess water had to depend on surface run off. Golf greens are not typically flat, they have slopes of two to four percent, some even as high as six percent.

In order to study tile placement in some detail before building our new experimental green, a laboratory model was constructed. This model was a water tight box 10 feet long, 10 inches wide and 14 inches deep with seven tile lines equally spaced widthwise on the bottom. The box was secured to a pivit so that the back end could be elevated to assimilate varying slopes of typical golf course greens. The #1 drain in our model corresponded to the toe of a green, and the #7 drain corresponded to the back of a green. Twelve inches of a medium fine beach type sand was placed in the box. The sand filled box was saturated by closing the tile outlets, then allowed to drain. Once drainage stopped, water was applied uniformily to the surface with special watering wands at application rates of 1/2, 1 and 2 inches per hour. Graduated cylinders were placed under each tile outlet to collect the drainage from each tile. As the sand in the box was holding all the water it could retain at the time of application, 95 to 100 percent of the water applied was collected in the cylinders. The water drained from each tile was measured and the data converted to percentage of the total water collected for each tile.

We also measured the time it took to complete drainage and the percentage of the total water drained in 10, 30, 60, 90 and 120 minutes. Tables I, II and III clearly illustrate that when a slope is introduced to the green the upper tile comes under tension and only the lower tiles will drain excess water. The greater the slope the less effective upper tiles become. As you increase the application rate the upper tile line will drain, but the percentage of water drained is relatively low when compared to the drains at the toe of the green.

Time needed to complete drainage in this study never exceeded 120 minutes. Table IV illustrates the need to allow for drainage designs to be set so that the longest drainage time is taken into consideration. As the slope is increased fewer tiles drain and, therefore, it takes longer to drain the system.

A practical application of this study and our field observations would indicate that properly installed tiles at the toe of the slope will adequately remove perched water tables which may develop at the interface of the sand growing medium and subbase soil of golf greens. If the green is located in an area where it is subject to heavy rain fall additional tile further up the slope may be advantageous. All too often, tile drainage systems have been based on arbitrary decisions. More tile lines are used than are needed and their installation is poorly done. We are advocating fewer tiles, in the right place, with close supervision as to their installation. With more field testing we hope to produce guides to the number of tiles needed as slope and application rates vary.

Table I Percentage of water drained from each tile at varing slopes when water is applied at 0.5 inch per hour.

Tile Drain	1	2	3	4	5	6	7
Degree of Slope			Percent Water Drained				
0%	11	23	14	13	13	14	12
2%	78	21	1	0	0	0	0
4%	100	0	0	0	0	0	0
6%	100	0	0	0	0	0	0

Table II Percentage of water drained from each tile at varing slopes when water is applied at 1 inch per hour.

Tile Drain	1	2	3	4	5	6	7
Degree of Slope			Percent Water Drained				
0%	11	20	14	14	14	15	12
2%	62	25	10	3	0	0	0
4%	92	8	0	0	0	0	0
6%	100	0	0	0	0	0	0

Table III Percentage of water drained from each tile at varing slopes when water is applied at 2.0 inches per hour.

Tile Drain	1	2	3	4	5	6	7
Degree of Slope			Percent Water Drained				
0%	11	17	15	14	14	16	12
2%	36	22	16	4	7	7	3
4%	75	7	7	1	0	0	0
6%	90	10	0	0	0	0	0

Table IV Percentage of water drained in minutes with a water application rate of 2 inches per hour and varying slopes.

Minutes	10	30	60	90	120
Degree of Slope	Percent Water Drained				
0%	92	8	0	0	0
2%	70	20	6	4	0
4%	39	27	14	14	6
6%	33	22	15	17	13

TURFGRASSES FOR WATER CONSERVATION

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Predictions of an impending water crises in California, particularly in the southern part, abound. Whether or not these predictions materialize, we can be certain that water for irrigation will be lower in supply and higher in cost in the years to come. As this develops there will be mounting pressures from many directions to curtail water use on landscaped areas and recreational facilities. At the same time, high energy costs will force people to seek outdoor recreation nearer home thus increasing the use of many local turfed areas. The selection of heat resistant, water efficient grasses and the adoption of water efficient management practices will become a necessity.

The grasses to be used in this situation must be able to thoroughly tap the available soil water supply and use it efficiently in the metabolic processes. They must also be able to survive long periods of drought when the need arises. The first characteristic of grasses that will meet these requirements is a deep and extensive root system. Effective rooting depths may range from a few inches for some bentgrasses to several feet for bermudagrasses and zoysia.

Grasses with the C_4 photosynthetic pathway have been found to be more efficient in the utilization of moisture than those with the C_3 pathway. This ability is due at least in part to the fact that they are more efficient converters of energy. Even though they close their stomata under water stress as do the C_3 grasses, they are able to synthesize more carbohydrate during the brief time the stomates are open. As a result, more carbohydrate (energy) is available for root growth and activity which in turn results in better water extraction from the soil.

Some grasses, such as red fescue, have inrolled leaves making them needlelike. Stomata are on the inner surface of these acicular leaves set in deep pits. This arrangement places them in a more humid environment where transpirational water loss is reduced. The normally flat leaves of tall fescue roll together under water stress to create a similar condition.

Of the grasses presently in common use, the most water efficient in a generally declining order are as follows:

Zoysiagrass - *Zoysia* spp.
Hybrid bermudagrasses - *Cynodon* spp.
Common bermudagrass - *Cynodon dactylon*
St. Augustinegrass - *Stenotaphrum secundatum*
Tall fescue - *Festuca arundinaceae*
Sheep fescue - *Festuca ovina*
Red fescue - *Festuca rubra*

The first four are C_4 plants while the lower three are C_3 plants with the special leaf characteristics described above.

Kikuyugrass, Pennisetum clandestinum, although still looked upon as a weed in most places, is a highly water efficient C_4 grass. It may be more widely used in the future as this characteristic receives greater appreciation. The water use characteristics of Paspalum vaginatum, another C_4 grass have not been determined. However, it has exceptionally high salinity tolerance.

Current turfgrass breeding programs at the University of California are directed primarily at improving the turf quality of several of the species known to be water efficient. This approach generally has more promise than that of attempting to improve water use efficiency of such high quality grasses as Kentucky bluegrass.

A number of zoysia cultivars are under final test at this time. Two or three of these may be released within the near future. A tall fescue of superior turf quality is also being considered for release after some additional testing.

A new study has been initiated at the University of California South Coast Field Station with partial support from the Metropolitan Water District. This study is designed to determine the ability of three warm-season and three cool-season grasses to grow or survive under irrigation regimes replacing less than evapotranspiration water loss.

Good management is the key to achieving success with even the most water efficient grass species. It is necessary to prepare the turf in advance of anticipated water stress periods. This includes maintaining the grass at the highest cutting height permitted by turf use to develop the best possible root system. Gradually increasing water stress will increase the root to shoot ratio. Reducing nitrogen fertilization as the summer season approaches will also increase the root to shoot ratio.

Growth Regulation of Turf and Landscape Plants

Henry Hield

Plant growth regulators have been extensively tested for influences such as promotion of flowering, elimination of flowers, fruit set reduction, holding of mature fruit, increasing vegetative growth, decreasing vegetative shoot growth, reducing sucker growth, and as an aid in propagation. This report will deal with growth regulator use for the reduction of vegetative shoot growth and one instance of use for decreasing fruit set. Selected examples of success will be shown as well as limitations which have restricted a more widespread use.

The chemicals to be covered are primarily ones classified as inhibitors, also called apical inhibitors. These chemicals characteristically kill terminal buds and inhibit meristematic activity. Another grouping, also on type of response, includes chemicals referred to as retardants or subapical inhibitors. These chemicals are active through a reduction in internode length without a disruption of the apical meristem functions.

Turf. Since the advent of maleic hydrazide (MH) there has been interest in a chemical means of reducing turf growth. The undesirable effects on color and density occurring from MH treatments has resulted in few uses on fine turf and a limited application on roadside grasses.

Melfluide (Embark) offers the most effective turf growth control with the least leaf color change of available chemicals. The use of Embark on warm season grasses is appropriate on high maintenance, low use turf such as around trees, fences, on banks or around sandtraps (Table 1). An experimental chemical, MBR18337, is more active than Embark and may give a similar turf response.

The experimental retardant, EL500, has shown growth control for as long as 6 weeks with acceptable appearance. The number of seedheads are not reduced by the retardant type chemicals.

Groundcovers. The inhibitor, chlorflurenol (CF125), is used for border growth control with ivy and iceplant (Table 2). MH is also effective for ivy. Embark, which gives control on ivy, is not effective on iceplant. Dikegulac (Atrinal) is very effective for ivy. Other groundcovers may respond to one of this group of chemicals or to EL500.

Shrubs. Oleander is widely planted in southern California and generally requires pruning. Atrinal is the most effective product for this species, with the experimental EL500 showing good promise on effective growth control (Table 3). CF125 reduces oleander growth, but the appearance is not acceptable for other than a distant landscape. EL500, which is in early testing, and Atrinal are also the most effective chemicals on Xylosoma. Varying effectiveness with many instances of growth control are found on other shrubs from the available products.

Trees. Fruiting of ornamental trees is often undesirable both because of allergy from the pollen and because of the litter caused by dropping fruit. The olive is shown as an example of fruit elimination by 3 chemicals (Table 4).

Pruning of shoot growth from trees beneath utility distribution lines has been estimated to cost the country $500 million annually. Foliar sprays of MH or CF125 are used to reduce growth on responsive tree species where spray drift is not a problem (Table 5). Injection of Atrinal and MH have been tested to reduce growth without spray drift injury and this type application could reach commercial use. In California, CF125 applied to the trunk base in an oil carrier by a 3 gallon sprayer is effective for shoot growth reduction on a number of tree species. This procedure is practiced by some utility companies and also by a few cities on certain trees.

MH and Atrinal are effective as foliar sprays on Sycamore. CF125 is effective both as a foliar or a trunk banding application on ash, elm, pine, and certain ficus. Atrinal, while very effective, is not registered for tree use and is probably not practical because of the chemical's cost.

Summary. Growth regulators have been slow in reaching applied uses. This may be the result of too high expectations as well as many instances of illadvised application. While stopping new growth these chemicals can also increase the rate of ageing of mature leaves. Thus the duration of growth control is limited by the need for foliage replacement, both for appearance and for metabolic function. The effective period of growth control is regulated by the concentration of chemical applied and by the frequency of treatment. Appearance may be influenced by a color change directly induced by certain chemicals, MH for example, as well as by the increased rate of senescence. In the case of turf, matured leaves, which would otherwise have been removed by clipping, may cause a slight color deterioration with time.

Differences in the required chemical concentration vary with species and monocultures are best adapted for ease of treatment. Commercial treatments are practiced on groundcovers, shrubs, and trees. Turf growth control is possible and use should increase.

Spray drift from foliar applications has been a deterrent for widespread use. Application adaptions of trunk banding or injection are effective and give an exact placement of the chemical on trees. Newer chemicals which are active through soil uptake may help to localize plant response and increase the use of growth regulators.

Table 1. Responses of Common Bermudagrass (*Cynodon dactylon*) to Various Growth Regulators

Chemical	Rate lb/A	Time effective, weeks	Height reduction leaf blade	Height reduction seed-head	Color response	Seedhead number reduction
MH[1]	1					
CF125	1		poor	good	poor	good
Embark[2]	1	4	good	good	acceptable	good
EL500[3]	1	6	good	good	good	poor
MBR18337[3]	1	6	good	good	?	good

[1] Used to suppress bermudagrass when over seeding with ryegrass.

[2] When applied twice annually.

[3] Experimental chemicals.

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Table 2. Response of Ivy (*Hedra helix*) and Iceplant (*Carpobrotus edule*) to Various Growth Regulators.

Chemical	Conc., %	Control time, months	Response evaluation
	IVY		
MH	0.5	3	good
CF125	0.04	3+	good
Atrinal	1.6	3+	good
Embark	2.0	3+	fair
	ICEPLANT		
CF125[1]	0.03	3+	good
Embark	0.3	0	none

[1] Plus 0.1% surfactant

Table 3. Responses of Oleander (*Nerium oleander*) and Xylosoma (*Xylosoma congestum*) Hedges to Growth Regulator Sprays.

Chemical	Conc., %	Control time, months	Response evaluation
		OLEANDER	
MH	0.3	4	poor, chlorosis
CF125	0.03	3	fair to poor, leggy
Atrinal	0.3	4	excellent, flowers
		XYLOSOMA	
MH	0.3	1	poor appearance
CF125	0.06	2	excessive curl and leaf drop
Atrinal	0.3	3+	acceptable

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Table 4. Responses of Growth Regulators for Defruiting of Ornamental Olive Trees (*Olea europaea*).

Chemical	Conc. %	Leaf drop	Response
NAA	0.015 (2 treatments)	some curl, acceptable leaf holding	varies with duration of bloom
Ethephon	0.05	satisfactory	good
Atrinal	0.8	acceptable	good

Table 5. Shoot Growth Control of Ornamental Trees with Growth Regulators.

Chemical	Conc. %	Tree Species	Control time, months	Leaf curl	Leaf color	Response
MH	0.25(S)[1]	Ulmus parvifolia	12	slight	yes	accept. distant lndscpe.
	0.3 (S)	Platanus racemosa	12	yes	accept.	accept. distant lndscpe.
	0.3 (S)	Ficus nitida	4+	no	accept.	good
CF125	0.015(S)	Ulmus parvifolia	12	yes	accept.	good
	1.0 (B)	Ulmus parvifolia	7	"	"	"
	0.015(S)	Ficus nitida	6	no	"	"
	1.0 (B)	" "	6	"	"	"
	1.0 (B)	Fraxinus uhdei	5	yes	"	"
	1.0 (B)	Pinus radiata	12	slight	"	"
Atrinal	0.3 (S)	Fraxinus uhdei	12	no	good	excellent
	0.3 (S)	Morus alba	12	no	slight	"
	0.3 (S)	Ulmus pumila	12	no	slight	"
	0.3 (S)	Ficus nitida	12	no	good	"

[1] S = foliar spray application, and B = trunk banding application.

12/8/80

THE CALIFORNIA TURFGRASS SOD INDUSTRY

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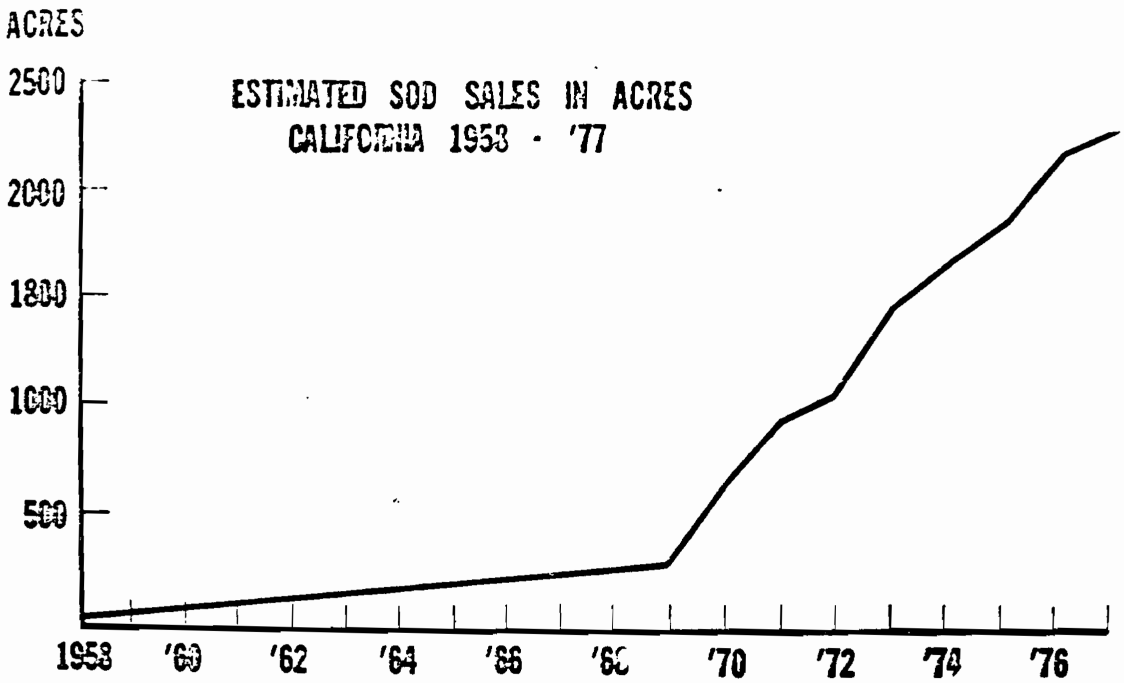
The California turfgrass sod industry is generally considered to have begun in the late 1950's. Not having native pasture sods to draw from, the whole thing started with large capital requirements and the raising of cultivated sods. Today the capital requirements have intensified, the grasses have improved, and the industry has come a long way.

There are between forty and fifty sod growers in California. Ten of these growers account for approximately 5000 acres of the estimated 6000 acres in production. Average time for production would be around nine months from planting to harvest. Field losses for the industry would be nearly 25% with 30--40% ready for harvest at any one time.

The business is seasonal with 60% plus being sold in the months April through August, however, sales do continue for the entire year. Sod sales have been relatively immune to economic recession until the disaster of 1980. Sales dropped off 15% to 40% from those of the previous year. The magnificent growth of the industry was finally stopped.

The following graph (from The Evolution of California's Sod Industry, Cockerham, S. T., and R. J. C. Evans, California Turfgrass Culture, 28:19-21, 1978.) indicates the historical development of the sod industry. This shows the growth in sales from the beginning through 1977.



In 1979, it was estimated that nearly 3400 acres of sod was sold in California which would have generated somewhat over $28 million.

The market is primarily to landscape contractors with retail nurseries a distant second. Most of the sod goes into new single family dwellings. Apartments and condominium complexes are perhaps second, industrial parks and other commercial operations third. Contrary to popular belief, golf courses and parks use little commercial sod.

The turfgrass sod industry in California is still quite young. It is going through the throes of development. In general, the industry is felt to have a very good future. However, many variables stand as hurdles to forecasting including water, energy, and inflation. But then, all of California is faced with those same hurdles.

FROM: Mel Androus, Manager, California Rice Research Board

TO: The American Society of Agronomy

TITLE: Recent Developments in Handling Rice Straw

In 1969 when the California rice industry instituted their accelerated rice research program the growers knew they had a potential problem with their urban neighbors from the effects of burning their rice straw. Some research was initiated such as investigation of straw handling systems; burning techniques; the long-term affects of incorporation; the control of diseases by burning; development of short statute varieties. By developing new burning techniques and reducing the amount of dry matter to burn through short statute varieties the industry did reduce the amount of emissions by some 40% to 50%. This has not been sufficient to stop the irritation of the urban areas.

The full impact of what the industry was facing hit them about three years ago when we were made privy to a report prepared by the environmental section of the Attorney General's office which called the rice industry an unfortunate crop for the State of California and proposed legislation that would eventually ban all agricultural burning. It was interesting, of course, to note that in listing why rice was an unfortunate crop, in addition to polluting the air with burning it also used a great deal of water and if rice was not grown this water would then be available to the expanding urban areas without further water facilities. Like our rice straw burning our use of water is very visable even though the consumptive use is actually less than a number of other crops.

This then was followed by the introduction of Assembly Bill 681 by Assemblyman Leroy Greene which called for the charging of a burning fee of $3.00 per acre for each acre the grower desired to burn. These funds would be used for research as directed by the California Air Resources Board to find alternative uses of agricultural waste. The legislation also called for the eventual banning of all agricultural burning when these economically feasible alternatives had been found as determined by the Air Resources Board. The bill also included some other very disturbing features that I do not need to get into at this time.

This Legislation did not get out of committee primarily on the basis that the rice industry would increase it's efforts to fine alternative uses for it's straw. In keeping with it's committment, the industry then voted to double the assessment upon every rice grower with a substantial amount of this increase to be used on that type of research.

The frustrating part of this was that growers knew there were a number of uses for their straw, however none of them were economically feasible. In other words, the ultimate user could not pay a price sufficiently high to cover the costs of removing the straw from the field and getting it to his plant.

This picture appears to be changing rapidly with the escalating cost of fossil fuels and competitive products such as wood chips. The accelerated program has only been in effect five months and the funds are now coming in. We are funding projects such as literature review to find out what is going on around the world as far as use; we are studying the economics of removal of the straw for various uses; and the pulping of rice straw for making paper and cloth. More projects are on the drawing boards, however it is the feeling of many that the eventual answer will come from private industry. In furtherance of this, we have baled up a considerable amount of straw to be made available to researchers. When this fact was publicized, the reaction was considerable from both private industry and government agencies. The use for energy seems to the most studied, however other uses also look promising.

The uses being studied include conversion to alcohol, to oil, gasification, direct use as fuel to generate power, and the manufacture of building materials such as press board.

With the amount of straw, 1,500,000 tons per year, at this time we believe there will not be one use but several. We do maintain however, that burning must always be retained as an alternative. If substantial rains come, in many areas it will be impossible to remove any straw from the fields because of ground conditions, and that straw must be then eventually burned. In addition, there was always the factors of ditch banks, levies, and the straw that cannot be picked up because it is knocked down by the tracks of the combines and the bank out wagons.

We are going through an interesting period and only time will tell us whether we can obtain the answers and time is what we are asking from our urban neighbors.

Presentation of William Hazeltine

January 30, 1980

Activists, Regulation and Agricultural Production

The areas of general agreement between all the disciplines of agricultural technology include these items:

- .. Pesticides are necessary for efficient agricultural production and for health protection.
- .. IPM has long been used, and is simply good practice.
- .. Reasonable risks are acceptable and necessary in order to have reasonable benefits.
- .. Starvation is an important environmental hazard as are epidemics of disease.

With this agreement, we can briefly review the various factors which serve to restrict or inhibit our achieving of efficient agricultural production and health protection.

Agriculture and health protection are hurting because of the Federal pesticide regulations by EPA. While acting in the name of environmental protection, the apparent over-emphasis on risks by EPA does not seem to be meeting the requirement for balance; the actions seem to be more properly called tilts. The Rebuttable Presumption Against Registration (RPAR) is risk oriented, as are the numerous new regulatory requirements for product registration. The Federal Statutory Standard for Product Registration, within 30 days after submission, is simply ignored.

These Federal restrictions which cost an average of about 119 million dollars for each product, and over emphasis on risks, has essentially stopped the flow of new pesticides. This total net figure is more realistic than the much smaller cost to register only those products that make it to the market.

The basic problem is over-emphasis on risks, with the users' representatives (USDA & HEW) not pushing the understanding of benefits with the same vigor used to advertise the risk potential. One of EPA's own scientific advisors has clearly pointed out the need for EPA to help people better understand the risk side of the equation.

California is in even worse shape, largely from political in-breeding and the influence of environmentalists upon the present governor and his appointees. Regulations have been adopted as emergency measures, amended to meet pressures and to correct previous errors, again by emergency action and to avoid court ordered compliance with law. As a result, California is in a state of regulatory confusion, which will take a long time to unravel. In the meantime, users of pesticides are at the mercy of the regulators.

A good specific example of how the present attitude on pesticides is damaging the environment is the way the Mediterranean Fruit Fly episode was handled. Effective and decisive pesticide use was delayed in favor of biological and genetic control programs.

Another example deals with adding another level of expertise (IPM coordinators) while failing to fund and hire crop production specialists. It is time to claim back the term IPM from those who think they discovered balanced pest management, before all public credibility is lost.

On a wider scale, the campaign to ban pesticides may be nearing a stand still. The latest action focuses on 2,4,5,T, while a less public campaign is working on EDB and the so called toxic organo-phosphates. The environmentalists seem to be orchestrating the frontal attack, by building public hysteria about chemicals by working with the media which feeds on fears, both real and imagined. One damaging proposal concerns a request to EPA & FAA for a requirement for written permission before any aerial application of a pesticide within 1,000 feet of anyone's property.

There are signs of hope, however. Proposed amendments to Federal law would allow Congress to veto EPA pesticide regulations, but by a 2/3 vote. The present political mood seems to be to reduce regulation, but the environmentalists' strategy, developed in part with public money, is to try to take advantage of the trend to States Rights, to control pesticides at the State level.

World famine in 1974 was triggered by only a 4% drop in world cereal grain production. Environmentalists propose that pesticides only increase yield by 7 to 9%, and try to get people to think pesticides are not important. Yet that percentage of increase is double what it apparently takes to trigger mass starvation.

Successful survival of efficient production agriculture and health protection seems to demand a clear and unmistakable agreement by all those producers and advisors who are responsible for feeding a hungry world and those who protect it from diseases to resist the nonsense, and fight to keep science ahead of politics, in pesticide regulations. The alternative to efficiency is less than enough food or disease, which in themselves are very real environmental hazards.

SALINITY AND CROP PRODUCTIVITY

E. V. Maas

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INTRODUCTION

Salinity is probably the most pervasive problem affecting crop production on irrigated lands in the world today. The term salinity is used here to refer to the excessive concentrations of soluble salts in the soil that limit plant growth. Chloride, sulfate, and bicarbonate salts of sodium, calcium, and magnesium contribute in varying proportions to soil salinty. Saline soils should not be confused with sodic soils, which may or may not be saline. Sodic soils are calcium deficient for most crops whereas saline soils are not. Although problems of sodicity are also common throughout the world, this presentation will be concerned only with salinity.

The extent of crop losses due to salinity in California, let alone the world, are probably impossible to ascertain. Neither the extent nor the degree of salinity on cultivated lands is known with any certainty. This is due in part because no comprehensive salinity surveys have ever been conducted and also because the salinity status of agricultural lands is continually changing. Wadleigh (1968) estimated that salinity limited crop production on about one-fourth of the irrigated land in the Western United States and that it was a potential threat to another one-fourth of the area. Worldwide the problem may be even worse with perhaps one-third or more of the irrigated crop land already affected by salinity (Eckholm, 1975). Of course, the actual extent of crop losses on these soils depends upon the salt concentration as well as the particular crops being grown. For example, salinity levels that are intolerable for lettuce would be perfectly acceptable for cotton. It is imperative, therefore, that we determine salt tolerance limits of all crop species so that we can select and manage crops to maximize production on salt-affected soils. This paper presents the salt tolerance data currently available, discusses the criteria and measurements necessary to obtain these data and briefly points out their limitations.

CRITERIA FOR RATING CROP SALT TOLERANCE

The ability of crops to tolerate salinity has usually been determined by measuring one of the following three criteria: 1) plant survival, 2) absolute plant growth or yield, or 3) relative growth or yield. Plant survival on saline soils has been widely used by ecologists to judge the tolerance of native species growing on uncultivated lands. To the farmer, however, survival without an economic yield obviously has little value. Indirectly, this criterion is potentially useful because plant breeders can use it as the basis for selecting salt-tolerant lines and cultivars.

Absolute yields are certainly of greatest interest to the farmer.

However, while they permit one to calculate economic returns under given salinity conditions, they also reflect crop responses to many other environmental factors. Even when all other conditions are optimal, e.g. fertility, water, climate, pest and disease control, etc., these data do not permit comparisons between crops because yields for different crops are not expressed in comparable terms.

Relative yield is the yield of a crop grown on a saline soil expressed as a fraction of what would be obtained under nonsaline conditions with other factors remaining the same. This criterion permits one to compare crops whose yields may be expressed in quite different units. The reliability of relative yield data depends upon whether yield reductions are unaffected by the level of other essential factors. If relative yield losses due to salinity are independent of differences in absolute yield caused by irrigation, climate, fertility, and other variables, the relative yield vs salinity relationship permits a useful expression of salt tolerance data.

TESTING CROP TOLERANCE TO SALINITY

Salt tolerance is a difficult parameter to measure because it depends upon many plant, soil, water, and environmental factors. Plants may tolerate a given level of salinity under one set of conditions and yet show considerable signs of salt stress under others. Nevertheless, we all recognize that some crops are more tolerant than others. Because such differences are evident despite the influence of other environmental factors, it has been possible to measure the relative tolerances of crops. Salt tolerance testing of crops at the U.S. Salinity Laboratory has usually been conducted under conditions that simulate cultural and management practices recommended for commercial production in the southwestern United States.

Although reliable salt tolerance data ultimately must be verified in the field, experimental data obtained under field conditions are difficult to interpret because of the lack of control and the variability in soil salinity frequently encountered. Therefore, salt tolerance data are best obtained in artificially-salinized field plots. Crops should be grown in fertile, permeable and well-drained soils. Irrigation waters with four or more graded salinity levels should be applied frequently enough to avoid any water stress and in sufficient quanities to leach the salts through and below the root zone. Normally a leaching percentage of 50% produces an acceptable soil salinity profile.

To determine crop tolerances to soil salinity it is essential to measure the salt concentration in the soil to which the crop is responding. Generally this is assumed to be the salt concentration in the soil water surrounding the roots. Since electrical conductivity is directly related to the salt concentration in the soil solution, it has proven to be a useful measure of soil salinity. Traditionally, though, soil salinity has been determined by measuring the electrical conductivity of soil saturation extracts (EC_e) rather than of soil water (USSL, 1954). EC_e has been widely accepted because saturation extracts are easily and reproducibly obtained in the laboratory and one can correlate the measurement with the soluble salt concentration of the soil solution at field capacity. Despite these arguments, soil salinity measurements are more reliable if made on the soil solutions bathing the roots. Two instruments that permit rapid, reliable, and non-destructive salinity measurements are salinity sensors (Oster and Ingvalson, 1967) and four-electrode conductivity probes (Rhoades, 1979). Both instruments measure in situ electrical conductivities of soil water within the range of plant water availability and they respond adequately to salinity changes typically found in the field.

The only agronomically important plant response measurement for establishing salt tolerance of a crop is the commercial yield. For crops that may produce either vegetative or seed yields, e.g. alfalfa, corn, etc., it is advisable to measure both responses to salinity. Too often vegetative responses are unreliable for predicting salt effects on fruit or seed production (Maas and Hoffman, 1977). Salinity may decrease grain yields of corn and rice, for instance, without appreciably affecting stover or straw yields. On the other hand, vegetative growth of several other crops, e.g. barley, wheat, cotton, and several tolerant grasses, is decreased much more than seed or fiber production. The salt tolerance of root crops is often lower than would be predicted from decreases in shoot growth.

RELATIVE SALT TOLERANCE RATINGS

Salt tolerance ratings of 149 agricultural crops are given in Table 1. Crops are listed alphabetically within four groups: field, forage, vegetable, and fruit crops. Salt tolerance data, where available, are given in terms of two key parameters: (1) the threshold salinity, i.e. the maximum soil salinity that does not reduce yield below that produced under nonsaline conditions; and (2) the yield reduction per unit salinity greater than the threshold. The salinity values are expressed in traditional terms; i.e., the electrical conductivity of soil saturation extracts. To accurately convert these values to electrical conductivity of the soil water, it is necessary to know the water content of the soil. A useful rule of thumb that holds for most soils, however, is that the soluble salt concentration of the soil water at field capacity is about twice that at saturation. Therefore, if the values in Table 1 are doubled, they will give reasonably accurate salt tolerance values for soil water. The unit dS/m (deciSiemen per meter) is the newly adopted international unit for electrical conductivity and is equal to the more familiar unit mmhos/cm. Two significant digits are given for the convienence of separating crops and not to imply that level of accuracy.

With these two parameters, the relative yield (Y_r) at any given soil salinity (EC_e) exceeding the threshold can be calculated with the following equation:

$$Y_r = 100 - B(EC_e - A)$$

where A = the salinity threshold; and B = the percent yield reduction per unit salinity increase. For example, grain yields of barley decrease about 5% per dS/m when EC_e exceeds 8 dS/m; therefore at a soil salinity of 13 dS/m, the relative yield, $Y_r = 100 - 5\ (13 - 8) = 75\%$.

The four qualitative salt tolerance ratings are defined by the division boundaries shown in Fig. 1. Many crops are listed with only a qualitative rating because there are no known quantitative data available.

Since salt tolerance data are commonly obtained where salinity treatments were applied after the seedlings became established in nonsaline plots, the data represent salt tolerance data after the late seedling stage. However, only a few crops appear more sensitive during germination and early seedling stages than at later stages. The tolerance levels for known sensitive stages are footnoted for those crops.

Varietal differences in salt tolerance are not common but they may occur more frequently than once thought. Significant differences among varieties have been observed for bermudagrass, bromegrass, berseem clover, birdsfoot trefoil, creeping bentgrass, barley, rice, soybean, and wheat. It is not always clear, however, whether varietal differences reflect differences in salt tolerance or differences in adaptation to climate or nutritional conditions under which the plants were tested. Consequently, the data in Table 1 represent the average tolerance of the varieties studied. Some known varietal differences in salt tolerance are indicated in the footnotes.

The salt tolerance of fruit crops is further complicated because specific salt constituents, as well as salinity, must be considered. Woody plants are especially susceptible to leaf injury caused by the accumulation of toxic levels of Cl^- or Na^+ in the tissue. Because different varieties and rootstocks absorb Cl^- and Na^+ at different rates, each one must be evaluated individually. With varieties or rootstocks that restrict Cl^- and Na^+ uptake, osmotic effects predominate and salt tolerance can be expressed as a function of total salinity. The salt tolerance ratings in Table 1 are believed to be reasonably accurate in the absence of specific ion toxicities.

LIMITATIONS OF SALT TOLERANCE DATA

Salt tolerance ratings have been invaluable to farmers who needed to know how one crop might fare relative to other crops he has grown on saline soils, but they cannot provide an accurate prediction of the expected yield. As stated above, absolute yields of crops depend not only upon salinity levels but upon many other cultural and environmental factors. Even if optimal growing conditions were known and attainable for various crops, absolute tolerances could not be predicted. The interactions between salinity and various soil, water, and climatic factors change the plant's ability to tolerate salt.

Climatic conditions probably influence plant response to salinity as much if not more than any other factor. Most crops tolerate salinity much better if the weather is cool and humid than if it is hot and dry. Air pollution also greatly affects the apparent salt tolerance of crops. For example, alfalfa grown at ozone concentrations found in many agricultural areas of California produced its highest yields at moderate salinity levels that reduce growth in the absence of ozone (Hoffman et al., 1975).

Soil conditions also influence the apparent salt tolerance of many crops. For example, plants grown on infertile soils may seem more salt tolerant than those grown with adequate fertility. This is simply because fertility, not salinity, is the primary factor limiting growth. Proper fertilization would increase yields whether the soil was saline or not, but proportionately more if it were nonsaline. Other limiting soil conditions could be expected to have similar effects.

Crop salt tolerance data must also be considered in light of irrigation management. Plants can tolerate a moderately saline water better when irrigations are frequent than infrequent. As they extract water from the soil, the remaining water becomes more concentrated; consequently, plants must consume increasingly saltier water as the time between irrigations increases. Crops subject to foliar injury caused by foliar salt absorption from sprinkling waters are less tolerant under sprinkler irrigation than with various soil irrigation methods.

It should be clear that salt tolerance ratings serve only as quidelines to the relative tolerances among crops. They can not nor are they intended to be used for estimating economic crop losses. In many cases the data were compiled from less than satisfactory sources, but they represent the best information currently available. For many crops data are lacking or inadequate and we must continue to test tolerances of those species and cultivars. Perhaps as we learn the tolerances of crops under various cultural conditions and more accurately assess the salinity status of agricultural lands, we will at least be able to make an educated guess as to the true extent of crop production losses caused by salinity throughout the world.

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Table 1. Salt tolerance of agronomic and horticultural crops[a].

Common Name	Botanical Name	Salinity threshold[b]	Yield Reduction[b]	Tolerance Rating[c]
FIELD CROPS		dS m^{-1}	% per dS m^{-1}	
Barley[d]	Hordeum vulgare	8.0	5.0	T
Beans	Phaseolus vulgaris	1.0	19.	S
Broadbean	Vicia Faba	1.6	9.6	MS
Castorbean	Ricinus communis	-	-	MS*
Corn	Zea mays	1.7	12.	MS
Cotton	Gossypium hirsutum	7.7	5.2	T
Cowpea	Vigna unguiculata	1.3	14.	MS
Flax	Linum usitatissimum	1.7	12.	MS
Guayule	Parthenium argentatum	-	-	S*
Jojoba	Simmondsia chinensis	-	-	T
Millet, foxtail	Setaria italica	-	-	MS
Oats	Avena sativa	-	-	MT
Peanut	Arachis hypogaea	3.2	29.	MS
Rape	Brassica napus	-	-	MT*
Rice, paddy[d]	Oryza sativa	3.0	12.	MS
Rye	Secale cereale	-	-	MT*
Safflower	Carthamus tinctorious	-	-	MT
Sesame	Sesamum indicum	-	-	S
Sesbania[d]	Sesbania exaltata	2.3	7.0	MS
Sorghum	Sorghum bicolor	-	-	MT
Soybean	Glycine Max	5.0	20.	MT
Sugarbeet[e]	Beta vulgaris	7.0	5.9	T
Sugarcane	Saccharum officinarum	1.7	5.9	MS
Sunflower	Helianthus annuus	-	-	MS*
Triticale	X Triticosecale	-	-	MT*
Wheat[d,f]	Triticum aestivum	6.0	7.1	MT
FORAGE CROPS				
Alfalfa	Medicago sativa	2.0	7.3	MS
Alkaligrass, Nuttall	Puccinellia airoides	-	-	T*
Alkali sacaton	Sporobolus airoides	-	-	T*
Barley (forage)[d]	Hordeum vulgare	6.0	7.1	MT
Bentgrass	Agrostis stolonifera palustris	-	-	MS
Bermudagrass[g]	Cynodon dactylon	6.9	6.4	T
Bluestem, angleton	Dichanthium aristatum	-	-	MS*
Brome, Mountain	Bromus marginatus	-	-	MT*
Brome, Smooth	B. inermis	-	-	MS
Buffel Grass	Cenchrus ciliaris	-	-	MS*
Burnet	Poterium sanguisorbia	-	-	MS*
Canarygrass, reed	Phalaris arundinacea	-	-	MT
Clover, alsike	Trifolium hybridum	1.5	12.	MS
Clover, Berseem	T. alexandrinum	1.5	5.7	MS

Table 1. (cont'd)

Common Name	Botanical Name	Salinity threshold[b]	Yield Reduction[b]	Tolerance Rating[c]
		dS m^{-1}	% per dS m^{-1}	
Clover, Hubam	Melotus alba	-	-	MT*
Clover, Ladino	Trifolium repens	1.5	12.	MS
Clover, Red	T. pratense	1.5	12.	MS
Clover, Strawberry	T. fragiferum	1.5	12.	MS
Clover, Sweet	Melilotus	-	-	MT*
Clover, White Dutch	Trifolium repens	-	-	MS*
Corn (forage)	Zea mays	1.8	7.4	MS
Dallisgrass	Paspalum dilatatum	-	-	MS*
Fescue, tall	Festuca elatior	3.9	6.4	MT
Fescue, Meadow	F. pratensis	-	-	MT*
Grama, blue	Bouteloua eriopoda	-	-	MS*
Hardinggrass	Phalaris tuberosa	4.6	7.6	MT
Kallar grass	Diplachne fusca	-	-	T
Lovegrass[h]	Eragrostis sp.	2.0	8.4	MS
Meadow foxtail	Alopecurus pratensis	1.5	9.6	MS
Milkvetch, Cicer	Astragalus cicer	-	-	MS*
Oatgrass, tall	Arrhenatherum, Danthonia	-	-	MS*
Oats (forage)	Avena sativa	-	-	MS*
Orchardgrass	Dactylis glomerata	1.5	6.2	MS
Panicum, blue	Panicum antidotale	-	-	MT*
Rescuegrass	Bromus unioloides	-	-	MT*
Rhodesgrass	Chloris Gayana	-	-	MT
Rye (forage)	Secale cereale	-	-	MS*
Ryegrass, Italian	Lolium italicum multiflorum	-	-	MT*
Ryegrass, perennial	L. perenne	5.6	7.6	MT
Saltgrass, desert	Distichlis stricta	-	-	T*
Sudangrass	Sorghum Sudanense	2.8	4.3	MT
Timothy	Phleum pratense	-	-	MS*
Trefoil, big	Lotus uliginosus	2.3	19.	MS
Trefoil, narrow-leaf birdsfoot	L. corniculatus tenuifolium	5.0	10.	MT
Trefoil, broadleaf[i]	L. corniculatus arvenis	-	-	MT
Vetch, common	Vicia angustifolia	3.0	11.	MS
Wheat (forage)[d]	Triticum aestivum	-	-	MS
Wheatgrass, standard crested	Agropyron sibiricum	3.5	4.0	MT
Wheatgrass, fairway crested	A. cristatum	7.5	6.9	T
Wheatgrass, intermediate	A. intermedium	-	-	MT*
Wheatgrass, slender	A. trachycaulum	-	-	MT
Wheatgrass, tall	A. elongatum	7.5	4.2	T

Table 1. (cont'd)

Common Name	Botanical Name	Salinity threshold[b/]	Yield Reduction[b/]	Tolerance Rating[c/]
		dS m^{-1}	% per dS m^{-1}	
Wheatgrass, western	A. Smithii	-	-	MT*
Wildrye, Altai	Elymus angustus	-	-	T
Wildrye, Beardless	E. triticoides	2.7	6.0	MT
Wildrye, Canadian	E. canadensis	-	-	MT*
Wildrye, Russian	E. junceus	-	-	T
VEGETABLE CROPS				
Artichoke	Helianthus tuberosus	-	-	MT*
Asparagus	Asparagus officinalis	-	-	T*
Bean	Phaseolus vulgaris	1.0	19.	S
Beet, red[e/]	Beta vulgaris	4.0	9.0	MT
Broccoli	Brassica oleracea botrytis	2.8	9.2	MS
Brussels sprouts	B. oleracea gemmifera	-	-	MS*
Cabbage	B. oleracea capitata	1.8	9.7	MS
Carrot	Daucus carota	1.0	14.	S
Cauliflower	Brassica oleracea botrytis	-	-	MS
Celery	Apium graveolens	-	-	MS
Corn, sweet	Zea mays	1.7	12.	MS
Cucumber	Cucumis sativus	2.5	13.	MS
Eggplant	Solanum Melongena esculentum	-	-	MS*
Kale	Brassica oleracea acephala	-	-	MS*
Kohlrabi	B. oleracea gongylode	-	-	MS*
Lettuce	Lactuca sativa	1.3	13.	MS
Okra	Abelmoschus esculentus	-	-	S
Onion	Allium cepa	1.2	16.	S
Parsnip	Pastinaca sativa	-	-	S*
Peas	Pisum sativum	-	-	S*
Pepper	Capsicum annuum	1.5	14.	MS
Potato	Solanum tuberosum	1.7	12.	MS
Pumpkin	Cucurbita pepo	-	-	MS*
Radish	Raphanus sativus	1.2	13.	MS
Spinach	Spinacia oleracea	2.0	7.6	MS
Squash	Cucurbita pepo	-	-	MS*
Sweet potato	Ipomoea Batatas	1.5	11.	MS
Tomato	Lycopersicon Lycopersicum	2.5	9.9	MS
FRUIT & NUT CROPS [j/]				
Almond[k/]	Prunus duclis	1.5	19	S
Apple	Malus sylvestris	-	-	S
Apple, rose	Syzygium jamcobos	-	-	S*

Table 1. (cont'd)

Common Name	Botanical Name	Salinity threshold[b]	Yield Reduction[b]	Tolerance Rating[c]
		dS m^{-1}	% per dS m^{-1}	
Apricot[k]	Prunus armeniaca	1.6	24	S
Avocado	Persea americana	-	-	S
Blackberry	Rubus sp.	1.5	22	S
Boysenberry	Rubus ursinus	1.5	22	S
Cherimoya	Annona cherimola	-	-	S*
Cherry, sweet	Prunus avium	-	-	S*
Cherry, sand	P. besseyi	-	-	S*
Currant	Ribes sp.	-	-	S*
Date palm	Phoenix dactylifera	4.0	3.6	T
Fig	Ficus carica	-	-	MT*
Gooseberry	Ribes sp.	-	-	S*
Grape[k]	Vitis sp.	1.5	9.6	MS
Grapefruit[k]	Citrus paradisi	1.8	16	S
Jujube	Ziziphus jujuba	-	-	MT*
Lemon	Citrus limon	-	-	S
Lime	C. aruantiifolia	-	-	S*
Loquat	Eriobotrya japonica	-	-	S*
Mango	Mangifera indica	-	-	S*
Muskmelon	Cucumis melo	-	-	MS*
Olive	Olea europaea	-	-	MT
Orange	Citrus sinensis	1.7	16	S
Papaya	Carica papaya	-	-	S*
Passion fruit	Passiflora edulis	-	-	S*
Peach	Prunus persica	1.7	21	S
Pear	Pyrus communis	-	-	S*
Persimmon	Diospyros virginiana	-	-	S*
Pineapple	Ananas comosus	-	-	MT*
Plum; Prune[k]	Prunus domestica	1.5	18	S
Pomegranate	Prunica granatum	-	-	MT*
Pummelo	Citrus maxima	-	-	S*
Raspberry	Rubus idaeus	-	-	S
Sapote, white	Casimiroa edulis	-	-	S*
Strawberry	Fragaria sp.	1.0	33	S
Tangerine	Citrus reticulate	-	-	S*
Watermelon	Citrullus lanatus	-	-	MS

a/ Adapted from Maas and Hoffman (1977). These data serve only as a guideline to relative tolerances among crops. Absolute tolerances vary depending upon climate, soil conditions, and cultural practices.

b/ Tolerance expressed in terms of EC_e.

c/ Ratings are defined by the boundaries in Fig. 1. Ratings with an * are estimates (for references consult the indexed bibliography by Francois and Maas, 1978).

d/ Sensitive during emergence and seedling stage. EC_e at this stage should not exceed 4 or 5 dS m^{-1} for barley and wheat or 3 for rice and sesbania.

e/ Sensitive during germination. EC_e should not exceed 3 dS m^{-1}.

f/ Semidrawf cultivars may be less tolerant.

g/ Average of several varieties. Suwannee and Coastal are about 20% more tolerant and common and Greenfield are about 20% less tolerant than the average.

h/ Average for Boer, Wilman, Sand, and Weeping cultivars. Lehmann seems about 50% more tolerant.

i/ Broadleaf birdsfoot trefoil seems less tolerant than narrowleaf.

j/ These data only apply to rootstocks that do not accumulate Na or Cl rapidly or when these ions do not predominate in the soil.

k/ Tolerance is based on growth rather than yield.

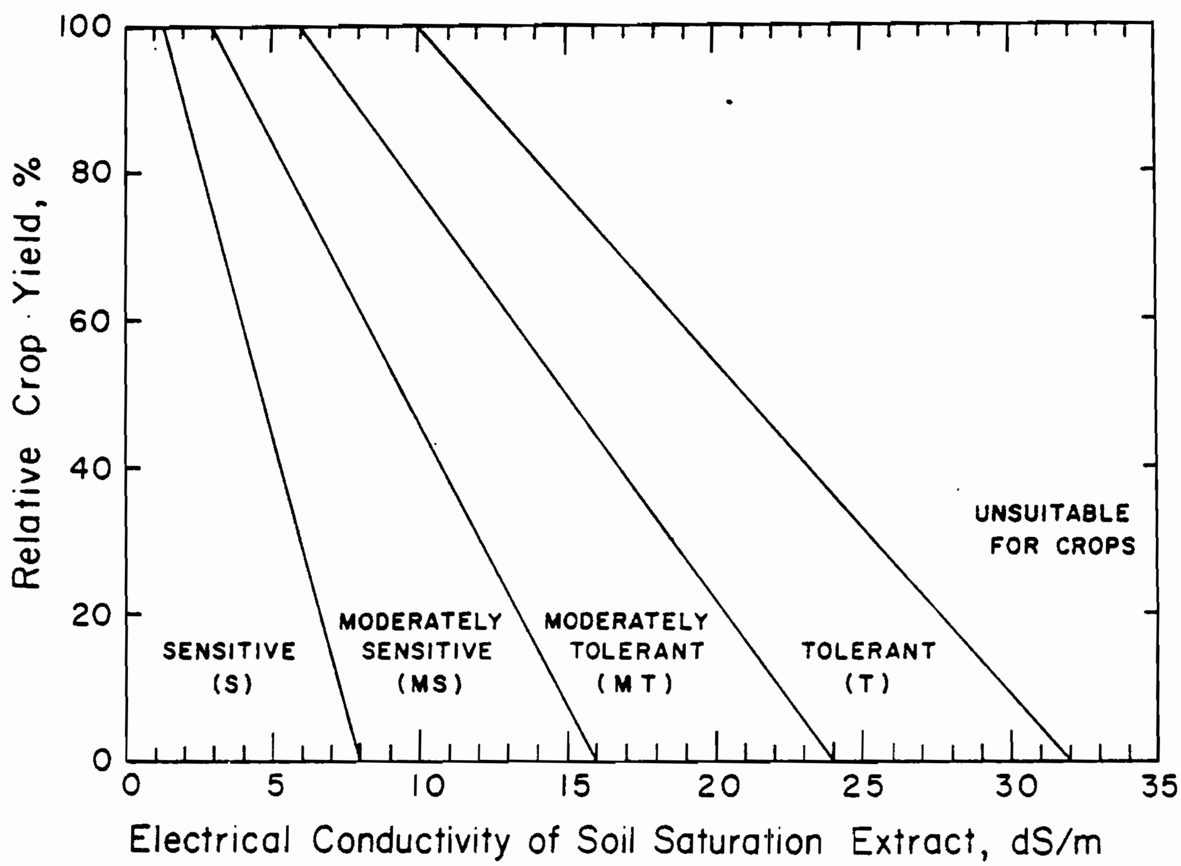

Figure 1. Divisions for Salt Tolerance Ratings of Crops.

Effects of Air Pollutants on Tall Fescue Forage

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Many air pollutants are present in California, but only a few have been demonstrated to exist at sufficient concentrations for sufficient periods of time to be of concern to the agricultural community at present. Two of these pollutants, ozone and sulfur dioxide, are known to cause damage to a great number of crops grown in California, and as such pose a threat to crop producing regions of the state. Long distance transport of pollutants with air masses has been demonstrated, thus significant levels of pollution can be carried from urban areas where they predominate, to suburban and agricultural communities. Because little data exists on the effects of ozone and sulfur dioxide on yield and quality of forage grasses, a series of experiments were initiated to determine effects of the two pollutants on these parameters.

In two experiments, the tall fescue (*Festuca arundinacea* Schreb.) cultivars 'Alta', 'Fawn' and 'Ky 31' were exposed to either ozone (ranging from 0 to 0.40 ppm) or sulfur dioxide (ranging from 0 to 0.50 ppm) to determine if differential susceptibility existed for growth and yield parameters. All three cultivars responded by linear decreases in yield to the ozone treatments. Comparison of slopes from regression analysis was chosen as a means of determining susceptibility to the pollutant. 'Ky 31' had a significantly steeper slope than either 'Alta' or 'Fawn'. Sulfur dioxide had no significant effect on either growth or yield of any of the cultivars.

In a third experiment, plants of the cultivar 'Alta' were exposed to a range of ozone concentrations (0 to 0.30 ppm) in the presence or absence of 0.10 ppm sulfur dioxide to determine the effects of the pollutants on growth, yield, and quality constituents. Dry matter production was reduced by 52.5% due to ozone and 7.3% due to sulfur dioxide. Partitioning plant dry weight into root and shoot components revealed shoot weight (yield) reductions of up to 46% and root weight reductions of up to 63.6% due to ozone. Sulfur dioxide reduced root dry weight 11%. Number of tillers was unaffected by either pollutant singly, but an 18.6% reduction occurred when sulfur dioxide was present in the 0.30 ppm ozone treatment.

Ozone affected nearly all quality parameters examined. Percent crude protein increased linearly with increasing ozone concentration. Percent crude fat (ether extract) responded curvilinearly to ozone, with a decrease evident at the highest treatment level. Percent crude fiber decreased linearly as ozone concentration increased and was decreased still further by an interaction with sulfur dioxide. Percent total nonstructural carbohydrates (TNC) also decreased linearly as ozone concentration increased. Percent ash increased linearly with increasing ozone concentration and increased still further due to an interaction with sulfur dioxide.

Many of the changes in the quality parameters are closely correlated with changes in dry matter production. The reductions in percent TNC and percent crude fiber (essentially structural carbohydrates) indicate that ozone is affecting the photosynthetic process. This in turn leads to reduced growth and hence lower yields. The reduction in percent crude fat may be explained by direct effects of ozone on lipid metabolism or chlorophyll, two groups of compounds that fall within the crude fat fraction. Increases in percent protein and percent ash were probably the result of dry matter being reduced at a more rapid rate than either proteins or minerals.

Many of the results of this study are similar to those reported for air pollutant effects on alfalfa (1, 2) and clovers (3, 4, 5). Yield reductions in tall fescue due to ozone have been reported (4, 6) but these experiments involved relatively short term exposures and did not include pollutant mixtures. Most of the information available suggests that air pollutants (especially ozone) can cause significant reductions in crop yields and can also alter quality constituents of forages. As such, air pollutants should be considered by forage managers as factors which can lower production. This study indicated that genetic variability exists within the species for ozone resistance. Resistant cultivars have been used extensively to avoid disease problems. Similarly, air pollution resistant cultivars should be considered by forage managers for use in areas troubled by air pollution.

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POTENTIAL AGRONOMIC IMPACTS

OF FLY ASH FROM WESTERN USA COALS

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SUMMARY

Fly ash is a major combustion residue generated in modern coal-fired power plants. It represents more than 70% of the total amount of coal ash collected in power generation plants equipped with electrostatic precipitators or bag filters. Various estimates indicate that approximately 60 million tons of fly ash are produed annually in the USA. Less than 15% of the total poroduction of fly ash is recycled, while the remaining tonnage poses disposal problems and subsequent environemtnal concerns.

The key to the successful management of industrial wastes, including fly ash, is to find a means by which they can be recycled beneficially and to develop management practices consistent with the preservation of the quality of the environemnt. Research on the fate and effects of aquatic and terrestrial disposal of fly ash is, thus, essential to the electric utility industries, the environmental regulatory agencies, and to the public. This report summarizes major findings and conclusions pertaining to potential adverse and beneficial impacts of fly ash from western USA coal sources when added to agricultural lands. The data were generated during the course of a long term fly ash research program carried out at the Department of Soil and Environmental Sciences, University of California, Riverside, in cooperation with the Department of Research and Development Southern California Edison Company, Rosemead, California.

Morphological investigations of fly ash show their morphology is dominated by the spherical-shaped particles, some of which are hollow and may contain a number of smaller-sized particles within and attached to their outer surfaces. Particle size distribution analysis coupled with light and electron microscopy show that about 60% of the particles are of the silt size, 4% of the clay size, and the remainder are of the fine sand fraction size. The bulk density of the fly ash was 1.01 g/cm^3 and its moisture content at saturation is 50%. The hydraulic conductivity of water-saturated fly ash was, in most cases, $\leq 3 \times 10^{-3}$ cm/sec.

Total element analysis of bulk and varous sized frations of fly ash showed the presence of all naturally occurring elements. The relative abundance of major elements in the ash is as follows: Si>Al>Ca>Fe>K> Ti>Na>Ba>Sr. These elements form an oxide matrix which is associated with a host of minor and trace elements. Compared to soil, B, Mo, Se, Sr, and Ba are elements which exhibit greater concentration in the ash than in typical soils.

An inverse relationship between total element concentration and particle size is an important chemical charateristic of fly ash. A large number of elements, particularly those which are volatile at the prevailing temperature of combustion, exhibit significant increase in concentration as the particle size of fly ash is decreased. Important among this group are the elements Sb, Cd, Ca, Ga, Pb, Mo, Se, and Zn.

Water solutions of fly ash are characterized by elevated levels of pH($\geq$12), salinity (EC_e up to 12 mmho/cm) with Ca^{++} and OH^- ions as the dominant cation and anion, respectively. Solubility of B and SO_4^{--} was found to be inversely related to the fly ash suspension density, i.e., the amount of fly ash in solution.

Significant changes in the physical and chemical properties of agricultural soils are induced upon application of small to moderate amounts of fly ash. Growth and mineral composition of plants cultured on fly ash treated soils are also altered significantly. Addition of fly ash at rates of up to 10% by volume increased the hydraulic conductivity, water holding capacity and the modulus of rupture of several California soils Further additions of the ash produce unfavorable changes in the above mentioned physical properties of soils.

Application of up to 8% fly ash by weight to soils also increases their pH, salt content, soluble S and B. The increase in pH is diminished, however, in calcareous soils after relatively short periods of cropping. The change in pH of acid soils is, on the other hand, long lasting and indicates the possibility of the use of fly ash as a liming agent for acid soils. Laboratory and greenhouse experiments demonstrated the leachability of B and salts accumulated in fly ash treated soils.

Growth of plants on soils treated with fly ash at rates ranging up to 8% by weight was influenced by salinity, B and the S status in soil. Salt and B sensitive plants (e.g.,lettuce) showed yield reductions at levels of fly ash in soil $\leq$2% by weight, while tolerant species such as Swiss chard and bermudagrass may tolerate up to 8% fly ash in soil without showing signs of reduced yields. Alfalfa, white clover, and a number of other crop species respond quite favorably to fly ash due to increased availability of S from the ash.

Levels of Mo and Se are also elevated in plants grown on fly ash treated soils. The elevation is a function of soil reaction, plant species, and rate of ash addition to soil. In forage crops, concentrations of Mo and Se may reach levels considered unsafe for animal consumption. However, the accumulation of these two elements was found to diminish with time following ash application. As the number of clippings obtained from the forage crop was increased concentrations of the Mo and Se decreased.

The above mentioned effects of fly ash on soil and plant composition were found to be aggravated by application of small sized fractions of fly ash to soil.

It is concluded that while certain levels of fly ash applications to soil may be beneficial from the standpoint of improving physical properties of soil and increasing S availability to plants, care must be exercised in guarding against the build up of salinity, B, Mo, and Se. In situations where soils are deficient in such elements, plants may benefit from small applications of the material..

STABILIZATION OF INLAND SAND DUNES

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Inland sand dunes, as opposed to coastal dunes or beach dunes, are located away from the shore and in regions where the climate is arid. Such dunes require somewhat different stabilization methods than coastal dunes located where rainfall is usually more plentiful.

Many inland sand dunes are presently stabilized and have a vegetative cover. However, if this vegetation is removed and the sand becomes exposed to wind action, sand particles will start to move. If unchecked, the moving sand area can rapidly increase and cause problems.

Moving sand damages structures and equipment by "sanding off" paint and finish; it can also block roads and destabilize structures built on it. Because sand movement is almost continuous throughout the year, repair of sand-caused damage is expensive. For example, depending on the location, removal of a cubic yard of sand can cost from $8 to $20. And strong winds can move thousands of cubic yards of sand across a line.

Bechtel manages the construction of projects where sand dunes are occasionally disturbed. These projects include roads, pipelines, and airfields. To comply with environmental regulations and to serve a client's best interests, we need to employ cost-effective and relatively simple sand-stabilization methods. This paper presents a short outline of the steps we have found effective to achieve these objectives.

Because non-vegetative methods still the sand only temporarily, when large areas are involved, permanent sand stabilization can only be achieved by establishing a permanent vegetative cover. For example, the placement of mulches or mats, the spraying of plastic mulches and oil, or even the placement of gravel are only temporary solutions. These materials disintegrate or the sand covers them up. Therefore, the ultimate goal must be the establishment of a permanent vegetation which will persist and colonize the sand.

Vegetation stops sand movement by reducing wind speed below the critical velocity, i.e., to speeds that will not move the sand. Even a relatively sparse and low plant cover can accomplish a great deal, because wind speed must only be reduced on the immediate surface; wind moving a foot or two above the ground will not cause sand movement.

Actual techniques and materials needed to stabilize sands will vary for each site. However, at any site the following steps are necessary to stabilize the sand:

1. Steep slopes of blowouts must be reduced to a lesser grade. This reduction will prevent later sliding of sand and also enable equipment such as tractors, mulchers, and seed drills to drive over the area. Usually a 1:3 or 1:4 slope (33 percent or 25 percent) is acceptable.

In grading the area, care must be taken not to flatten the dunes, because flattening will increase sand movement, wind speed being highest over a level surface.

2. Sand movement must be stilled temporarily so that vegetation can be established. The sand can be stilled by using various mulches or by planting a fast-growing crop. However, the latter is risky: if no rain occurs, the wind will blow both the sand and the seed away. Various mulches can be used as long as they permit seeding and germination of seeds. Cereal straw is often a good material to use; it provides protection to the seedlings, increases the organic matter in the surface sand, and makes possible seeding during application or afterwards. However, the straw must be anchored to the surface by methods such as discing or sheepsfoot-rolling or by the application of a tacking compound.

   Sand stilling must be applied to the entire dune area in which the sand is moving. A strip of land across a large dune area cannot be stabilized because sand from the side tends to bury the mulch and plantings.

3. The sand area must be seeded with plants that are adapted to the site and that will thus persist for years, or until the native vegetation reinvades. Usually, it is not necessary or even possible to seed native plants or plants of the climax vegetation, since native plants will eventually invade the site and replace the originally seeded plants.

4. The area must be monitored and the plantings maintained for years. Sands contain little or no plant nutrients; therefore, fertilizers must be applied. If plantings fail, the area will have to be reseeded until vegetation is well established.

Bechtel projects are usually located far away from water sources. Because of cost, trucking or piping of water for irrigation is not practical. Therefore, the seeding must be timed prior to the season when the best growing conditions are expected. However, in arid regions rains are unreliable and droughty periods are frequent, causing planting failures and making it necessary to repeat the stabilization process. Even so, repeating the stabilization process is still less expensive than attempting to haul or pipe water from great distances.

OPTIMIZING FACTORS TO REDUCE ENERGY USE AND INCREASE CROP YIELDS

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Agriculture has evolved from a labor intensive, low output production system to its current status as an intensive, highly productive activity of an every expanding human population. This increased output by agriculture has been the result of a number of factors. Productivity of agricultural crops has been increased by enhanced agronomic management skills. Crop plants have been genetically manipulated to be responsive to mineral fertilizers and agronomic management practices. Plants have been selected for resistance to diseases and insects. When genetic solutions were not available chemicals were developed to control these pests. Many of these biological and technological improvements require inputs of fossil fuels in various forms. This has resulted in a dramatic increase in energy consumption on the farm in the last 25 years, a pattern similar for all sectors of our society. Even with this dramatic increase in on-the-farm energy consumption agriculture accounts for only 5% of the fossil fuel consumed in the US. It has been suggested that agricultural production is a method whereby man is able to transform inedible fossil fuel into forms that are palatable and nutritious to the human population. This transformation has been the basis for an unprecedented increase in productivity of agriculture and is primarily responsible for food production keeping pace with the expanding human population.

Recently, it has been observed that a number of crops which demonstrated substantial yield increases in response to energy inputs have become less responsible with further increases of these inputs. These observations were not uniform over all crops or cropping areas, but there were enough examples to provide a focus on these potentially significant trends. These observations have also stimulated concern as to the future direction and impact of existing agricultural practices. The agricultural sector in recent years has become increasingly dependent on fossil fuels, their supply and price. This trend is expected to continue. It seems appropriate, therefore, to evaluate various approaches which might alter agriculture's dependence on these energy sources and reduce the expected instability of production systems.

An energy budget for agricultural operations provides a basis for determining which operations consume what percentage of fossil fuels. For example, nitrogen fertilizers account for 30% of the energy consumed on-farm. This is justification for close scrutiny of this aspect of agricultural practices. Fertilizer use by plants, fertilizer application procedures and alternative sources of N should be evaluated.

Tillage and cultivation consumes 15% of the fossil fuels used on the farm. Chemicals have recently been substituted for mechanical cultivation and this appears to save some energy. Minimum tillage practices, however, may be an alternative to current tillage procedures and possibly save energy.

In any of these alternatives the effect on productivity and the economic tradeoffs need to be determined. The presentation will provide a series of analyses and equate the effect of energy conservation on productivity and economic well-being of California agriculture.

Environmental Factors Influencing Crop Yield

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Crop yield, whether harvested as fruit, grain, or for age, represents the ability of the plant to adapt to the environment. This assumes that a plant is never subjected to an optimum environment continually throughout the growing season. Can we apply the same approach to crop yield as is practiced in soil fertility where yield can be represented by the most limiting factor? Because of the complex interactions between factors, a simplistic approach may not supply sufficient detail in evaluating crop yields.

Crop yield can be directly related to the rate of photosynthesis, therefore, any factor which affects photosynthesis would impact on yield. In this analogy we should also consider factors which influence respiration since net photosynthesis is gross photosynthesis minus respiration. These environmental factors are solar radiation, temperature, soil moisture, and carbon dioxide concentration.

Carbon dioxide is present in the atmosphere in an assumed constant concentration, however, there are large fluctuations over an actively photosynthesizing plant canopy. It has been reported in the literature that for short periods of time during the day, CO_2 would be a limiting factor. The conditions which cause this are a very actively growing crop and low windspeeds (less than 3 ms^{-1}) are the two factors which cause this problem. The lack of adequate mixing from low windspeeds is a transient condition and one which does occur in California agriculture. During midday when solar radiation is at the highest irradiance, wind speeds tend to be the lowest;

however, other than a few samples, there has been no coordinated effort to evaluate the magnitude of the problem.

Soil moisture is regarded as being the most limiting factor on crop yield. More attention has been given to this factor in research over a wide variety of crops than any other environmental factor. It is necessary, however, to focus our discussion on the water status of the plant of which the soil moisture status is a part of the response. The atmospheric conditions and the plant itself control the moisture status of the plant. If one assumes a gradient of water potential from the soil to the atmosphere with the atmosphere having the lowest potential, then plant water potential would represent a balance between the atmospheric potential, soil potential, and the ability of the plant to extract water from the soil. We could take two extremes to illustrate this point, first, the soil is near maximum plant available water, yet the roots do not penetrate beyond 20 cm, and second, the roots penetrate down to 150 cm. Under conditions of identical atmospheric water potentials, both crops will behave the same until the upper 20 cm is depleted; and then the shallow rooted one will be subjected to stress until it grows a larger root system. There are also times in which the atmospheric water potential requires more water than the plant can physically transport, and the plant is subjected to stress even though an adequate soil moisture supply is available. For the majority of the time, the availability of soil moisture is the limiting factor; and in irrigated agriculture, we attempt to control soil moisture to be a nonlimiting variable. In nonirrigated lands, however, this option does not exist; and soil moisture supplies often limit yield.

Effects of soil moisture deficit are not uniform over the crop growth cycle, and it has been shown that the reproductive stage is less tolerant of stress than the vegetative stage. There is a balance at this point, one cannot stress a plant continually during the vegetative stage and then supply water when it begins to flower and expect the same yield as one which was well-watered continually. Recent findings show that determinate crops will adapt around stress in a variety of ways. These include a deeper growth of roots to extract soil moisture, more open canopies through reduced leaf size to allow for a better sensible heat exchange, and stomata which are less responsive to stress. These adaptations only show their benefit if the crop is then well-watered during the reproductive stage, because if left without water, yields will be reduced. The impacts of soil moisture at various phenological stages needs continued research; but in this research, we need to evaluate the crop response as well as just applying water to the soil.

Solar radiation and temperature are sort of like the weather - there are two variables which everyone recognizes as being factors which often limit yield, but how do you change them? Maximum crop yields result in fields where there is a total interception of solar radiation as early as possible in the season. In row crops, a narrow row spacing and leaf structure which captures radiation at high plant densities are two possibilities. Since radiation and more specifically the photosynthetically active radiation is one of the primary building blocks, it must be present in high irradiances to produce the maximum photosynthesis. Extended cloudy periods during grain filling on all crops have been noted to have a detrimental effect on yield.

Temperature is another factor which has been shown to be a major factor in crop growth, but it should be remembered that a better relationship would result if the actual crop temperature rather than air temperature were used. Studies have shown that foliage temperature can range from -10 to +8C respective to air temperature depending on the time of day, soil moisture conditions, and type of crop. Foliage temperature is a complex response to a number of factors which include solar radiation, air temperature, wind speed, soil moisture, crop, and stomatal resistance. Therefore, it is not possible to say directly that one factor is the limiting environmental variable. There are some good relationships between foliage and air temperature, for example, cool nights tend to reduce respiration, which increases the net photosynthesis for the day.

It is very difficult to say that one environmental factor is limiting crop yield, and we should not attempt to develop such arguments. I believe we should focus our attention on the microclimate within crop canopies and how the plant adapts to and modifies the microclimate, and as a result we have a clearer picture of the environmental factors which limit crop yield. With this understanding, we can tend to determine what makes some fields produce more than others when the soil fertility and soil moisture appear to be similar. Increasing world population demands that we continue to increase our productivity.

MAXIMIZING YIELDS OF COTTON

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SUMMARY

Upland cotton, Gossypium hirsutum L., is a perennial plant which is grown primarily as an annual crop. Like many crop plants, cotton sets and matures fruit in cycles. In the San Joaquin Valley, only one fruiting cycle is utilized for production. In the southeastern valleys of Imperial, Palo Verde, and Coachella, an extra long growing season normally permits production from two fruiting cycles. Currently, about 85% of California seed cotton is produced in the San Joaquin Valley and about 15% is produced in the southeastern valleys.

Yield and quality of lint and seed are affected by many factors including: weather, soil compaction, soil salinity, seed variety and quality, planting date, planting configuration, nutrient availability, water availability, diseases, pests, weeds, harvesting aids and methods, and ginning methods. Cotton requires a warm climate and a relatively long growing period. Adverse weather may decrease yields and/or quality by delaying planting dates, interfering with harvest, or causing serious disease and pest problems. Soil compaction may decrease root extension and proliferation and restrict nutrient and water uptake. Soil salinity may decrease growth rates.

Soil preparation activities should not be conducted when the soil is excessively wet. Planted seed should be of an adapted variety of high quality and treated to prevent seedling diseases. Seed should be planted when soil temperatures are above 60°F, at planting depth, and the forecast is for good weather for several days following planting. In fields where cotton is normally short, planting configurations, narrower than the standard 38 to 40 inches, may increase yields and shorten the date for maturing each fruiting cycle without decreasing lint or seed quality. Nutrients and water should be readily available during early periods of growth and development but excessive amounts may increase pest

control problems, promote excessive vegetative growth at the expense of fruit production, and hinder harvest. Preharvest aids, harvesting methods, and ginning methods should preserve yield and quality of lint and seed. Although a farmer has little control over weather, he may maximize yields and quality by the judicious use of factors he can control, such as high yielding-disease and insect tolerant varieties, crop rotation, and plant and soil sampling techniques to determine plant nutrient needs.

Recent Developments in Head Lettuce Production

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Lettuce production is a major agricultural industry in California ranking ninth among all commodities produced in the state in 1979. California growers produce head lettuce the year around from various districts in the state. In 1979, 90 million 24-head cartons, which was 75 percent of the U.S. supply, were produced from 157,500 acres.

Yields have steadily improved to the current level of 600-700 cartons per acre, but this is far short of the potential yield of over 1000 cartons per acre. The major factors contributing to yield loss include incomplete stand establishment, irregular growth rate, diseases and insect pests. Research programs conducted by USDA, experiment station and Extension personnel in cooperation with growers and agricultural suppliers are seeking answers to these problems and have contributed much new knowledge and improved practices to the lettuce industry in recent years. Of special significance have been the control of lettuce mosaic through the seed-indexing program, improved stand establishment through the precision planting of coated seed and the use of sprinkler systems, and the introduction of many new head lettuce varieties with disease resistance and better shipping quality.

Plant breeders are working toward improved uniformity, better color, resistance to important diseases such as downy mildew, lettuce mosaic, big vein and tipburn. Studies on seed quality and seedling growth are improving our knowledge of plant growth uniformity which has profound effects on harvest uniformity. Plant pathologists have studied and developed much new information on sclerotinia disease, tipburn, corky root, varnish spot and other diseases which take their toll in lettuce plantings. Entomologists are working on programs which will allow more prudent use of pesticides while still maintaining quality. The transplanting of lettuce is a recent innovation which offers good possibilities for more efficient stand establishment and more uniform maturity.

Major imporvements have been made in head lettuce production since the crop was first introduced about 1920, but most of the beneficial cultural changes have occurred within the past 15 years. Much new knowledge and new innovations are expected within the next few years which will contribute to the growers ability to progress toward the perfect harvest.

Measurement of Mycorrhizal Infection in Soybeans

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Mycorrhiza, a symbiotic fungus-root association, can greatly increase phosphorus utilization by the host plant when phosphorus in the soil is limiting. As most crop plants are mycorrhizal, the fungus can significantly enhance agricultural productivity. Assessment of the role of mycorrhizal fungi in influencing such important physiological parameters as photosynthesis, nitrogen fixation, biomass production, and yield depends on a quantitative determination of the intensity of fungal infection. We now report on the progress of fungal infection throughout the development of soybean plants and discuss the measurement of infection by different methods.

Infection of soybean (CV.'Kent') roots by the vesicular-arbuscular mycorrhizal fungus *Glomus fasciculatus* was assessed throughout the ontogeny of the symbiotic association. Degree of infection was evaluated by a histological method as percent infection and colorimetrically as mg chitin/g mycorrhiza. Correlation of data by the two methods was highly significant ($r = 0.99$) below 60% infection and not significant ($r = 0.62$) at higher levels. Assessment of infection by the histological method did not yield statistically distinguishable data above 60% infection. Data by the colorimetric method were statistically distinct at all levels of infection. The effects of biological and chemical contaminants on the colorimetric assay were determined. The fungal component of mycorrhizae was compared to glucosamine-HCL and purified chitin standards. Use of glucosamine-HCL or chitin for standard curves in the absence of degradation products from uninfected root materials significantly ($p < 0.05$) overstated the degree of infection. Colorimetric determination of fungal infection in mycorrhizae is recommended when high levels of infection are expected.

INTEGRATED PEST MANAGEMENT - NOW AND IN THE FUTURE[1/]

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Introduction

I feel particularly fortunate to be asked to speak on the subject Integrated Pest Management - Now and in the Future before this section of the American Society of Agronomy. My first college degree was in Plant Science with a Major in Agronomy. I took my Ph.D. in Plant Pathology and Plant Breeding and one of my major professors was Dr. D. C. Smith the Chair of Agronomy at the University of Wisconsin. Thus, I feel some kinship to you.

Far more important, however, is my conviction that crop specialists should play a much more active role in developing Integrated Pest Management programs. The focus should not be on pests but on the crop--we should be focusing on Integrated Crop Management. If this is true then those who are most familiar with all aspects of the production of a particular crop should be leaders in the development of these programs. This speaks to Agronomists, Horticulturists and other crop production specialists.

Before we pursue this further, let's look at a few basics so that all will be dealing with a common language--and hopefully from this will come a common understanding and commitment.

What Is Integrated Pest Management or IPM?

IPM can be described as "a systems approach to reduce pest damage to tolerable levels through a variety of techniques, including predators and

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1/ Presented at the American Society of Agronomy Meetings, San Francisco, California, January 28, 1981.

parasites, genetically resistant hosts, natural environmental modifications and, when necessary and appropriate, chemical pesticides." It is essentially a philosophical commitment to a new approach to pest management, an approach which abandons the eradication mentality and accepts that most pests are here to stay. Furthermore, IPM is built on a better understanding of host plant and pest phenologies and the relationship of host and pests to the ecosystems in which they occur. Finally, the philosophical commitment is supported by an array of new technologies that are being applied to agriculture including System Science, Modeling and Computer Science--none of which supercedes or displaces the excellent science which has been conducted in pest control over the last 50 years. Rather, these new technologies make it possible to more effectively integrate the research information flowing from the seemingly disparate and independent research in disciplines supporting pest management.

Characteristics of Present IPM Research and Implementation

At the present time we are in transition from the traditional disciplinary approach to pest management wherein plant pathologists concerned themselves primarily with plant diseases and the entomologists focused on the insects to a situation where interdisciplinary groups of pest specialists, supported by plant scientists, economists, mathematicians and system scientists sit down and approach pest management problems in a particular crop or agroecosystem in a holistic manner. This approach is not for all scientists--many are uncomfortable with this type of approach and will continue to pursue excellent science independently. Others, including many young scientists with good quantitative skills, knowledge of computer and system science, function effectively in a multi-disciplinary team and are not uncomfortable with the probing questions that come from team members outside of their discipline.

Thus, the present effort is to pull together disparate information within disciplines and to integrate control tactics (cultural, genetic, biological, and chemical) for single pests or to integrate strategies for two or more pests in a single crop or a series of crops in an agroecosystem (e.g. the corn, soybean and wheat system).

System science and modeling are being utilized to integrate the information to identify data gaps and to establish priorities for additional research. Data gaps identified range from lack of good understanding of pests' biologies, host growth phenologies, reliable sampling techniques to decision criteria (economic thresholds).

Implementation is not waiting on the development of complete IPM programs for crops--programs that, in a real sense, can never be complete. As new sampling techniques are developed (e.g. a phenological model of an insect that predicts a susceptible stage occurrence, a phermone or sex lure trap, or mechanical soil sampler) they are tested in the field, proven effective or modified, and then put into use where appropriate through Farm Advisors and Pest Control Advisors (PCAs). Where more complete information is available on crop phenology, susceptible stages in the plant's development, the pest/host interaction or the influence of weather on both host and pest(s), this information is packaged for delivery in several forms. Preliminary publications utilizing charts, graphs and other illustrations as well as procedures for calculating action levels have been widely used. In some crop/pest(s) situations computer programs have been developed and utilized to manage input data and to assist in development of decision criteria. In a few cases action levels (economic thresholds) are very well developed, however, in most cases they are not available or not based on the level of science one would like.

At the present time implementation of IPM programs for crops, livestock and poultry are carried out by the active participation of the public sector (e.g. Farm Advisors) and private sector (e.g. PCAs and Growers) employees. In California, PCAs outnumber Farm Advisors at least ten to one. They are tested and licensed and have to have a four-year degree in biology or agriculture. Presently, the majority are affiliated with a pesticide sales firm. Many, however, are private consultants and many have advanced degrees in some aspects of pest management.

Changing Requirements for IPM Research Scientists

Previously, I suggested that crop scientists should play a more active role in the development of IPM programs. It was suggested that integrated crop management or ICP might be a more appropriate term. This is because the central focus should be on the crop plant and how those intrinsic and extrinsic factors in the environment influence its growth and health. Therefore, all factors biotic and non-biotic that independently or together interact to influence the photosynthetic efficiency of the plant must ultimately be taken into consideration. Many of these problems are better treated by crop scientists such as plant physiologists, nutritionists and water relations experts working in interdisciplinary teams rather than by entomologists, nematologists or weed scientists. We are fortunate that many crop scientists are now joining in these efforts and working with a wide range of scientists to develop plan growth models and to assess the stress placed on plants by pests. When one considers all the interactions that can go on in an alfalfa or cotton field, the first inclination is to cut and run. However, this is an evolving process. First, we crawl, hopefully we will learn to walk, and someday we may learn to run.

The new scientists working in these programs are better skilled in quantitative techniques such as mathematics, computer science and system science. They are comfortable working in inter-disciplinary teams and having to share their skills. Hopefully, the insights provided by these persons will move pest management to a higher level of sophistication.

Changing Requirements for Implementors of IPM Programs

The application of IPM principles to real world pest management requires a level of knowledge, as well as a commitment, to ecological principles, considerably greater than that required to follow a more traditional calendar schedule of pest control practices. It requires an excellent understanding of the host plant, its normal and abnormal growth patterns and how it is influenced by climatic and edaphic factors. It requires an understanding of stress factors both biotic and non-biotic. It requires a good understanding of the biology of individual pests and how pests interact. Furthermore, it requires an understanding of how pests are influenced by climate, predators and parasites, cultural practices and pesticides. Finally, the person managing pests must know how to sample for pests, identify them properly, and to react to the numbers present. Thus, the person must be a plant scientist, biologist, ecologist, meteorologist, chemist, computer operator and farmer--in short he must be a practitioner of plant health. As indicated before, present licensed pest control advisors (PCAs) are required to have a four-year degree. Many have masters and doctorates. There are now a number of programs in U.S. Universities offering a professional masters degree in Pest Management. What does the future hold?

Is California Leading the Way and What Will the Future Look Like?

With petroleum shortly to cost 40 dollars a barrel, we can anticipate that pest management practices requiring pesticides and other energy inputs will continue to increase in cost rapidly. As little as five years ago it was cheaper to apply a pesticide than to pay someone to make a survey and recommendation as to whether the crop should be treated. I believe this is changing rapidly and that the relative cost will soon be in favor of advice. Furthermore, regulatory officials are requiring more and more information about the status of pest populations before issuing permits to use restricted pesticides. Finally, growers confounded by the multitude of complex information they must analyze for both business and crop production decision are seeking out the support of PCAs and independent consultants.

I believe that in the future many of those consultants will be Practitioners of Plant Health. Why should a sick cow or hog have the services of a Practitioner of Animal Health (DVM) and a sick walnut or citrus tree have a retreaded nematologist or entomologist? Is it not possible in the future that 10 million acres of irrigated crop land in California cannot support 2000 to 3000 independent Practitioners of Plant Health. I believe that our Universities should give serious consideration to the development of curricula for such persons. Properly trained I believe they would be the ideal implementors of IPM programs for crops. I believe California has the best "climate" socially, politically and scientifically for implementing future IPM programs.