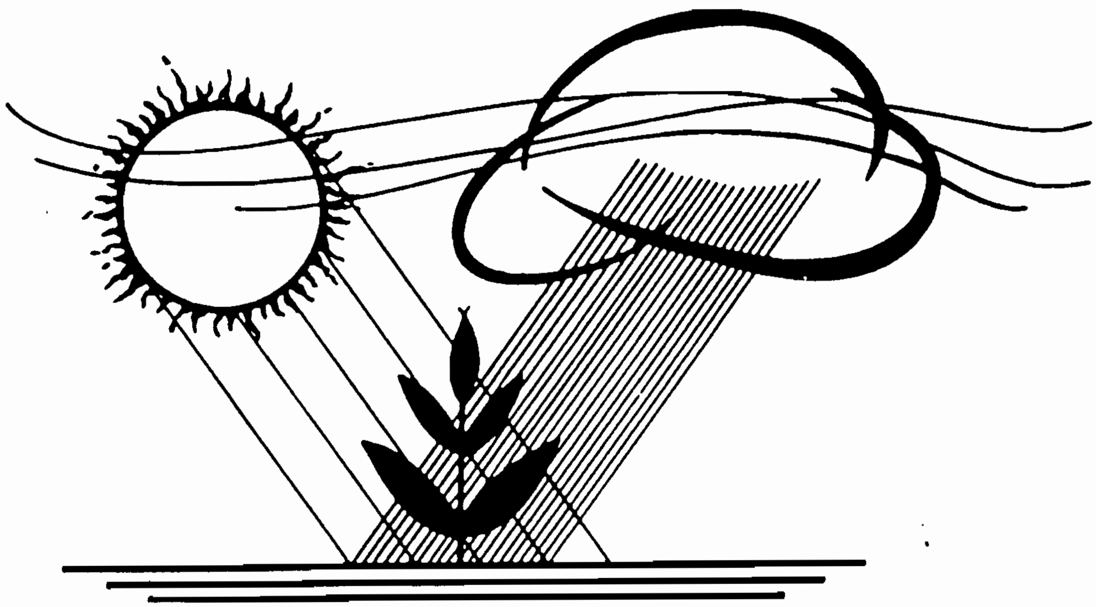
Proceedings

1985 CALIFORNIA PLANT AND SOIL CONFERENCE

Agriculture, Environment and You



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January 30 - February 1, 1985

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CONFERENCE REPORTS

SOIL FERTILITY/PLANT NUTRITION

BIOMETEOROLOGY

AGRICULTURAL WASTES AND RESIDUE MANAGEMENT

AMMONIA VOLATILIZATION FROM UREA AND UREA PHOSPHATE FERTILIZERS

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Urea and urea-ammonium nitrate solutions (UAN) which contain one-half urea N account for about 30% of fertilizer N applied in the United States. Also, a significant portion of the N applied in mixtures (25% of the U.S. N fertilizer consumption) is urea. Urea and UAN usage is increasing at the expense of ammonium nitrate because of production, transportation, storage, and marketing considerations even though ammonium nitrate is sometimes agronomically superior. Much of the urea-containing fertilizer is surface applied in reduced-tillage or topdress situations where incorporation with tillage is impractical. Even where tillage is performed after application, there may be a significant lag time between application and incorporation. In these situations, significant ammonia (NH_3) loss from urea-containing fertilizers can occur.

The increased use of urea-containing fertilizers coupled with the growing importance of surface application without immediate incorporation prompted the National Fertilizer Development Center (NFDC) to initiate a program to reduce NH_3 loss from urea-containing fertilizers. One approach under study is to cogranulate urea with phosphoric acid to produce fertilizers with typical grades of 39-13-0, 34-17-0, 28-28-0, and 17-44-0. The 17-44-0 material is an adduct formed from a 1:1 mole ratio of urea and phosphoric acid and is called urea phosphate (UP). The other products are produced by cogranulating additional urea with UP to form urea-urea phosphate (UUP). Because of their acid reaction before urea hydrolysis in the soil, these fertilizers show promise for reducing NH_3 loss from urea.

The objective of this presentation is to review results of recent studies designed to determine (1) the significance of NH_3 loss from urea-containing fertilizers applied on the soil surface and (2) the effectiveness of phosphoric acid in UUP for reducing NH_3 losses from surface-applied urea. Reported results are from laboratory research at the NFDC and the International Fertilizer Development Center (IFDC) and laboratory and field research from cooperative NFDC-university projects.

Direct Measurements of Ammonia Volatilization

Laboratory Studies

Adding phosphoric acid with urea to form UUP granules (3:1 to 2:1 $N:P_2O_5$ ratios) reduced NH_3 loss from broadcast urea between 35 and 70% in soils with calcium carbonate content between 0 and 2.6%. With broadcast applications on these soils, the phosphoric acid in UUP did not delay urea hydrolysis significantly, and therefore, reduced NH_3 loss mainly by reducing soil pH near granule application sites. With surface band applications, the phosphoric acid component of UUP significantly delayed urea hydrolysis. In calcareous soils with > 14% calcium carbonate, the reduction in NH_3 loss with UUP relative to urea ranged from 0 to 20%. The minimal reduction in NH_3 loss with UUP in highly calcareous soils was due to rapid precipitation of calcium phosphates near granule sites and diffusion of urea away from granule sites, followed by urea hydrolysis and NH_3 loss. Because of these results, field evaluation of UUP was conducted mainly on noncalcareous soils. Urea and UUP (34-17-0) broadcast on a Cecil sandy loam soil (pH 5.4) from Georgia gave 66% lower NH_3 loss from a bare than from a mulched soil surface; NH_3 losses were 82 to 93% lower from UUP than urea with the mulched soil and were 47 to 91% lower from UUP than urea with the bare soil.

Field Studies

Ammonia loss was measured from urea, UUP, and ammonium nitrate surface applied on orchardgrass sod in Indiana (spring and late summer) and on soil mulched with wheat straw in Georgia (June). A forced-draft technique with intermittant sampling of NH_3 loss was used for these field measurements. Ammonia loss from urea ranged from 8 to 37% and averaged 24% whereas NH_3 loss from ammonium nitrate was not significant. Ammonia loss from UUP ranged from 2 to 22% and averaged 12%. Peak NH_3 loss during a particular 24-hour period generally occurred from mid-morning to early afternoon and was associated with increasing temperatures following dew formation. Ammonia losses were lower from bare than from mulched soils and were relatively low when soils were dry at the soil surface for prolonged periods. In the Georgia study, measurements of NH_3 loss were 1.5 to 3.5 times higher with the forced-draft technique than with an ^{15}N recovery technique. Relatively high values with the forced-draft technique apparently resulted from use of an air-flow rate of 0.06 meters/sec which is considered nonlimiting on NH_3 loss, whereas ambient wind velocity during NH_3 loss measurements was frequently < 0.06 meters/sec.

Indirect Measurements of Ammonia Volatilization: Nitrogen Source Comparisons Based on Yield

Yield response to surface-applied urea, UUP, and ammonium nitrate and in some cases UAN was measured over 23 site-years as an indirect indication of NH_3 loss from these N sources. All sites were east of the Mississippi River and involved noncalcareous soils. Crops followed by number of site-years observed were as follows: no-till corn (7), fescue sod (7), grain sorghum (3), wheat (3), orchardgrass (2), and cotton (1). Yield response was detectably higher (0.05 probability level) with surface applications of ammonium nitrate than with urea or UAN in 10 site-years, suggesting notable levels of NH_3 loss from the urea-containing N sources. In 6 out of the 10 site-years, UUP gave detectably higher yield responses than urea or UAN. The detectable yield differences due to N source generally represented substantial differences in the N rate required to achieve a given yield level.

Conclusions

Significant NH_3 loss from urea and UAN applied on the soil surface occurs with great enough frequency to justify measures for reducing these losses. Particularly severe NH_3 losses from urea-containing fertilizers can be expected with heavy crop residues on the soil surface and from moist soils that are drying. The phosphoric acid component of UUP has little effect on NH_3 loss from surface-applied urea in calcareous soils; in noncalcareous soils the phosphoric acid component generally reduces NH_3 losses to intermediate levels between those from urea and ammonium nitrate.

POTASSIUM NUTRITION OF COTTON

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Use of potassium in California cotton production has been the subject of considerable discussion and debate over the past 30 years. Many soils in the San Joaquin Valley have been identified as having high potassium fixing capacities.

Differences have arisen due to observations that potassium like deficiency symptoms develop on plants where soil tests indicate response to fertilizer potassium would be unlikely. However, when these tissues are analyzed, they are low in potassium, and recent fertilizer trials indicate yield response to potassium generally occurs. The picture has been further complicated by the observation that varieties respond to the problem differently.

Approximately 250,000 acres of cotton in the San Joaquin Valley have this problem and have some loss of yield. Up to 50,000 acres may be true potassium deficiencies as determined by soil tests. The remainding acreage responds to potassium but symptoms are not totally corrected by potassium fertilizer.

Before reviewing results it may be helpful to review potassium usage by the cotton plant. Bassett et al. (1970. Agron. J. 62:299-303) documented the uptake and distribution of potassium. Only about 15 percent had been taken up prior to July 1 (Figure 1). For the next six weeks uptake was rapid. Stems and leaves showed a gradual decline in tissue potassium; seed remained rather constant; while burs (boll carpel walls) increased dramatically in potassium. Burs represent approximately 25 percent of the final mature boll dry weight. At the end of the season approximately 40 percent of the potassium taken up during the year was in the bur (Figure 2). This is consistent with observations that deficiency symptoms in California generally do not become apparent until after a boll load has accumulated.

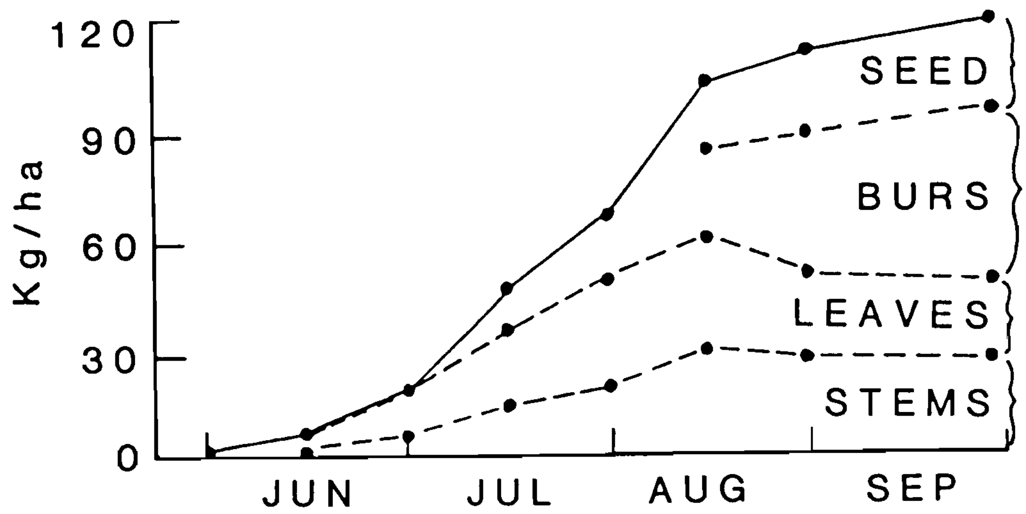

Figure 1. Accumulations of K in the various plant parts at different stages of development. Basset et al. 1970. Agron. J. 62: 299-303.

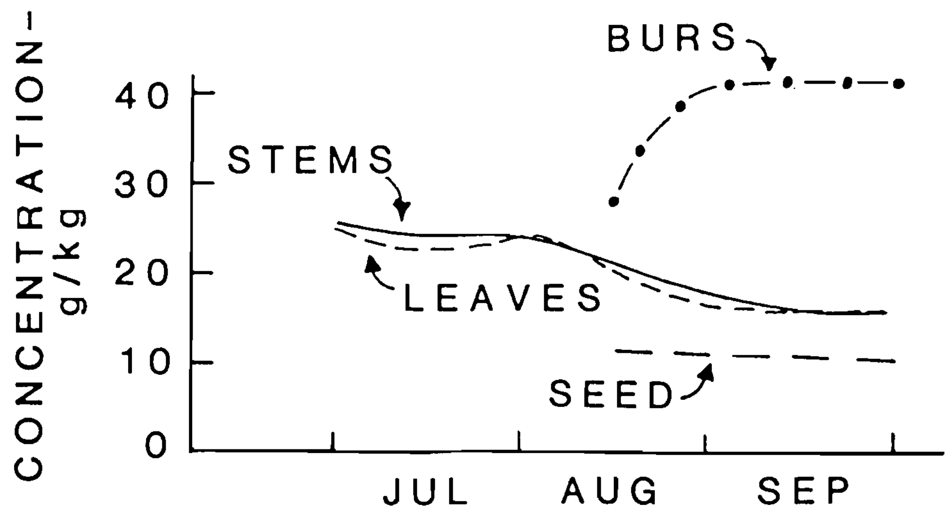

Figure 2. Potassium concentration in various plant parts at different stages of development. Bassett et al. 1970. Agron. J. 62:299-303.

A reason frequently cited to support the theory that these symptoms are not real potassium deficiencies is that other crops such as corn and alfalfa do not show symptoms. Cope (1981, Soil Sci. Am. J. 45:342-347) recently reported that cotton was more sensitive to potassium deficiencies than was corn, soybeans, vetch, or wheat (Table 1). This study was conducted at five test locations in Alabama over a 21 year period. Cotton was the most sensitive crop at every test location. Our prior conclusions as to how good an indicator crop cotton is for potassium deficiency could be in gross error.

Table 1. A Comparison of Relative Yield of Cotton with Other Plant Species in Long-Term Rotations (1958-1978) in Alabama

	Relative Yield of "No K" Treatment†				
Soil Series	Cotton	Corn	Soybean	Vetch	Wheat
Benndale fsl (Typic Paleudult)	0.38	0.85	0.64	0.75	0.92
Dothan fsl (Plinthic Paleudult)	0.58	0.86	0.95	0.67	1.00
Hartsells fsl (Typic Hapludult)	0.24	0.61	0.40	0.42	0.90
Lucedale fsl (Rhodic Paleudult)	0.65	0.92	0.91	0.75	0.98
Lucedale scl (Rhodic Paleudult)	0.41	0.83	0.76	0.56	1.01
Five Test Average	0.45	0.81	0.73	0.63	0.96

†Yield of "No K" treatment divided by maximum yield with K added.

Cope, J.T., Jr. 1981. Soil Soc. Am. J. 45:342-347.

It is generally recognized that soil test levels required to avoid deficiencies varied according to the cation exchange capacity of the soil. Around the world, sufficiency levels have ranged from 0.16 to 0.24 cmol/kg (62 to 94 ppm) for sandy soils and 0.32 to 0.38 cmol/kg (125 to 149 ppm) for finer textured soils.

Established sufficiency levels for petioles or blades has not been as successful. The standard practice in California has been to select the same petioles as are used for nitrate-N testing. Other cotton growing areas generally select old petioles or blades as the sample tissue. Tissue levels decline from July 1 through mid-September as potassium is translocated to bolls (Figure 2). We believe that non deficient plants should have petiole concentrations at least 2.5% August 1 and 1.5% September 1.

Fertilizer rate trials on soils in the San Joaquin Valley where deficiency like symptoms have developed indicate that yield increases occur when potassium fertilizer is applied (Table 2). Responses have been greatest where soil test

Table 2. Effect of Variety and K Rate on Lint Yields Under Varying Levels of Soil K and Verticillium Wilt. (1982-1983. Unpublished data of B. Weir, T.A. Kerby, and D. Mikkelsen. Univ. of California).

	Location 1		Location 2		Location 3	
K-Rate	SJ-2	SJC-1	SJ-2	SJC-1	SJ-2	SJC-1
kg/ha	kg/ha					
0	478	685	651	898	756	866
280	679	827	822	960	821	834
560	710	824	782	1007	746	916

Location 1 is an average of three 1982 experiments conducted on a soil high in Verticillium wilt containing 0.30 cmol K/kg; Location 2 is an average of two 1983 experiments conducted on a soil high in Verticillium wilt containing 0.49 cmol K/kg; and Location 3 is an average of two 1983 experiments conducted on a soil low in Verticillium wilt and containing 0.77 cmol K/kg and fertilized with 45 Mg/ha dairy manure.

levels have been lowest (but not considered deficient). Acala SJ-2 has been more susceptible to the deficiency symptom but both Verticillium tolerant varieties and Acala SJ-2 respond to applied potassium.

Application of 10 to 20 tons per acre manure generally alleviates the symptom and yield responses from additional potassium fertilizer do not occur. Bruce Roberts, Kings County Farm Advisor, observed when barley was used as a winter cover crop and turned under as a green manure, symptoms were greatly diminished. Furthermore, he has shown that cotton grown on plots with the green manure maintained petiole potassium levels approximately one percent higher than other plots. Substantial yield increases are also being observed.

Oenes Huisman and Bill Weir have also made new observations this year. With only one exception, when symptoms were expressed some type of restrictive layer to deep rooting was observed. This was due to either soil compaction or sandy layers which restricted moisture movement to lower soil profiles.

It is too early to claim we know what is causing the problem, or how it can be cured or avoided. However, new ideas are being explored and our understanding of the problem is increasing.

A current working hypothesis is: Where the symptoms occur and the soil test indicates potassium deficiency is not likely, we believe the symptoms result from massive redistribution of potassium in the plant to bolls. The activity of the root system at this time is less due to (a) less photosynthate movement to the roots due to boll development; (b) a restriction of root development due to soil physical conditions; and/or (c) a restricted root zone due to pathogen activity resulting from soil physical conditions. This occurs at a time when potassium demand by developing bolls increases.

Research is moving forward in 1985 with emphasis on cropping systems, deep tillage effects, soil solarization to eliminate pathogens, root function, and potassium uptake and distribution. Until causes are clearly identified and economics of correction are determined, our suggestion continues to be that if symptoms have been present in the field, 250 pounds per acre potassium should be applied. This does not totally correct the problem, but it does decrease symptoms and results in yield increases which make fertilizer applications cost effective.

Development of a Soil Nitrogen Test for Cotton

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There is a narrow window of optimum nitrogen fertilizer rates for cotton production. The optimum rate varies with the year, the yield potential, and the amount of residual soil nitrogen which is available throughout the growing season. Typical rates of nitrogen fertilization vary between 75 and 200 lbs/ac, with tradition and experience being the primary method of determining the specific rate for a field.

Insufficient nitrogen will reduce lint yields and excess nitrogen can cause difficulties in defoliation, harvest, and a reduction in lint yield. Excess nitrogen can also lead to pollution of the groundwater if water is applied in excess of crop requirements. Growers typically spend between $25 and $100 dollars/ac for nitrogen fertilizer, and the development of a soil test which would assist in the selection of the optimum fertilizer rate would be beneficial from many standpoints.

Many growers use petiole sampling as a guide in fertilization, but by the time a representative petiole sampling can be obtained, water running the nitrogen fertilizer is usually the only method of application available. Therefore, a soil test for residual soil nitrogen, which could be taken early in the growing season would be of added value in determining the optimum rate of fertilizer at a time when a choice of application methods is still available.

Procedure

In 1982 a trial was initiated at the University of California Westside Field Station with the objective of developing a reliable soil nitrogen test for cotton. The trial involved establishing different residual soil nitrogen levels by applying different rates of nitrogen to small plots in the winter. The plots were sampled to four feet and the soil samples were analyzed for nitrate, ammonium, and total nitrogen. A nitrogen rate trial was then established on each of the small plots by applying between 0 and 250 lbs N/ac. Petiole samples were collected throughout the year and normal cultural practices were used so as to not limit yield. In November the plots were harvested and a determination of the response to fertilizer was made for the different levels of residual soil nitrogen.

The trial was repeated in 1983 and 1984 to help refine the relationship between residual soil nitrogen and optimum fertilizer rate. In 1984 ten nitrogen rate trials were conducted at various locations throughout the San Joaquin Valley to help validate the model. The Westside Field Station trial and an additional ten trials throughout the valley will be repeated in 1985.

Results

To develop the test an evaluation of which form(s) of residual soil nitrogen would provide the best correlation with predicted yields was required. Therefore, the soil samples from the 1982 trial were analyzed for nitrate, ammonium and total nitrogen. The results are presented as the percent change over no winter applied nitrogen versus the amount of winter applied nitrogen, (fig. 1). There was no relationship between the amount of total nitrogen or the amount of ammonical nitrogen and the rate of winter applied nitrogen. The amount of nitrate nitrogen, however, did show good correlation with winter applied nitrogen. These results are to be expected since the amount of winter applied nitrogen (between 50 and 200 lbs N/ac) was minuscual relative to the total nitrogen in the soil, and though the winter applied nitrogen was 75% ammonium (urea ammonium nitrate solution 32% N), the rate of nitrification would be sufficient to convert nearly all of applied nitrogen to nitrate.

An analysis of the optimum depth to sample was performed in 1982 and 1983 by sampling in the following increments; 0-6, 6-12, 12-24, 24-36, and 36-48 inches. The total amount of residual nitrate nitrogen to each depth was then regressed against lint yield. The results, (table 1), indicate that sampling to two feet would provide the best relationship between residual soil nitrogen and estimated lint yield. Though sampling to two feet was best for the 1982 and 1983 Westside Field Station trials, it is currently recommended that the soil be sampled to three feet. It is felt that there is little extra effort required for sampling this additional foot, and the possibility of encountering a substantial amount of nitrogen in the third foot warrants sampling this deep. Further analysis of the information collected in the 1984 and 1985 field trials may provide some estimate of the frequency with which there would be an advantage to three foot sampling.

The relationships between residual soil nitrate nitrogen and lint yield for the 1982, 1983, 1984 and a combination of the 1982 and 1983 data are presented in table 2. There is good correlation for the 1982, 1983, and the 82-83 combination, but a poor correlation for the 1984 data. The reason for the poor correlation in 1984 is not clear, but may be related to insect pressure, (which was known to be moderate), or weather, (which was unseasonally hot during much of the fruit setting period). Irrespective of the reason, it can be concluded that some factor, other than residual soil nitrogen, was more limiting to yield. For this reason the data from 1984 was not included in the model. The experience in 1984 is, most likely, not uncommon, and must be remembered when evaluating the accuracy of the model.

Preliminary equations which estimate lint yields in the absence of post-plant nitrogen fertilization are plotted in figure 2. These equation were developed by using the yield response information from both the 1982 and 1983 Westside Field Station trials. Over the range of observed values there is little difference between the linear or the quadratic forms. The quadratic equation probably describes reality slightly better than the linear, (especially when extrapolating beyond observed values), so it was chosen as the model equation.

To use the model an estimate of the response of cotton lint yields to fertilizer nitrogen at different residual soil nitrogen levels is needed. To develop this estimate the linear component of the response to fertilizer nitrogen at residual soil nitrate nitrogen where a response was most likely, (less than 150 lbs NO_3-N/ac-3 ft) was used. The amount of fertilizer required to give an additional bale of lint per acre was found to be 175 lbs of N. If the amount of residual soil nitrogen was higher than approximately 200 to 225 lbs NO_3-N/ac-3 ft there was no response to added fertilizer nitrogen.

Conclusion

A soil test for nitrate nitrogen was correlated with cotton lint yield at the University of California Westside Field Station. The test was used to develop a model which predicts optimum nitrogen fertilizer rates for cotton. The model is currently undergoing validation for other location and soil type throughout the San Joaquin Valley.

The steps involved in the model are presented below.

1) Determine estimated yield based on;

$$Y_{est} = 0.5895 + 0.0144(N_s) - 0.0000156(N_s^2)$$

Y_{est} = estimated lint yield (bales/ac)

N_s = residual soil nitrate nitrogen (lbs NO_3-N/ac-3 ft)

2) Determine yield potential (Y_{pot}) for field

3) If $Y_{est} > Y_{pot}$ then nitrogen fertilizer requirement (N_f) = 0

4) If $N_s > 225$ then $N_f = 0$

5) Calculate N_f by;

$$N_f = (Y_{pot} - Y_{est}) * 175 \text{ lbs N/bale}$$

Table 1. Relationship between depth of sampling and coefficient of Determination for lint yield versus soil nitrate nitrogen

	Year		
Depth	1982	1983	1982 & 83
feet	Coefficient of Determination		
Quadratic			
0 - 1	.238	.602	.751
0 - 2	.498	.593	.781
0 - 3	.450	.575	.738
0 - 4	.509	.575	.738
Linear			
0 - 1	.195	.555	.706
0 - 2	.300	.566	.732
0 - 3	.307	.567	.725
0 - 4	.331	.564	.750

Table 2. Linear and quadratic regression equations and coefficients of determination describing the response of cotton lint yields to residual soil nitrate nitrogen.

		Coefficients			
Year	Form	A	B	C	r^2
1982	Linear	2.41	3.84E-3		.315
	Quad	- .349	2.24E-2	-3.01E-5	.456
1983	Linear	1.53	5.40E-3		.567
	Quad.	1.12	9.90E-3	-1.11E-5	.575
1982 & 83	Linear	1.40	6.80E-3		.725
	Quad.	.590	1.44E-2	-1.56E-5	.756
1984	Linear	3.35	-5.02E-3		.109
	Quad.	-3.98	7.99E-2	-2.44E-4	.196

Fig. 1 Relationship of various residual soil nitrogen forms to winter N rate

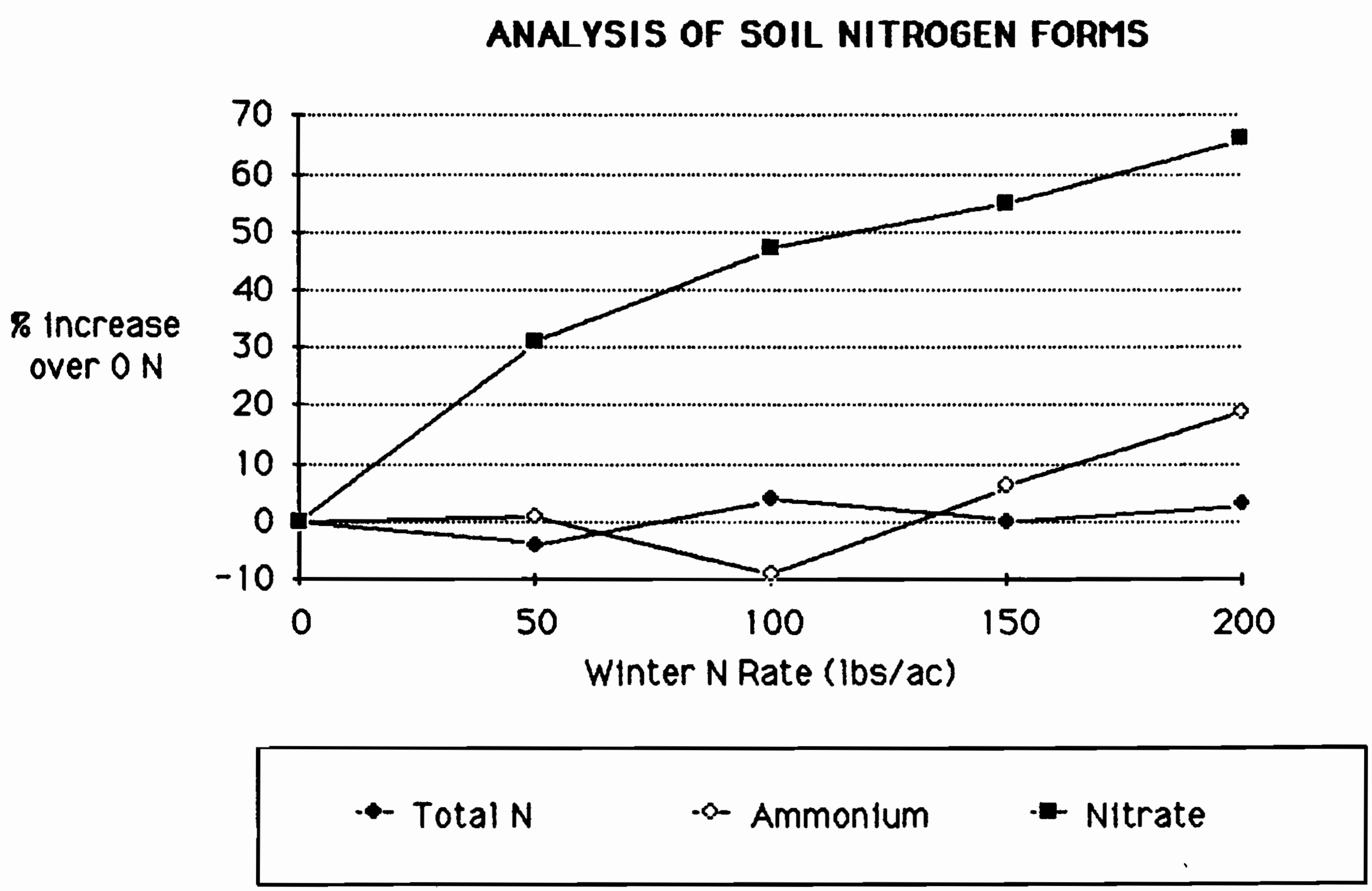
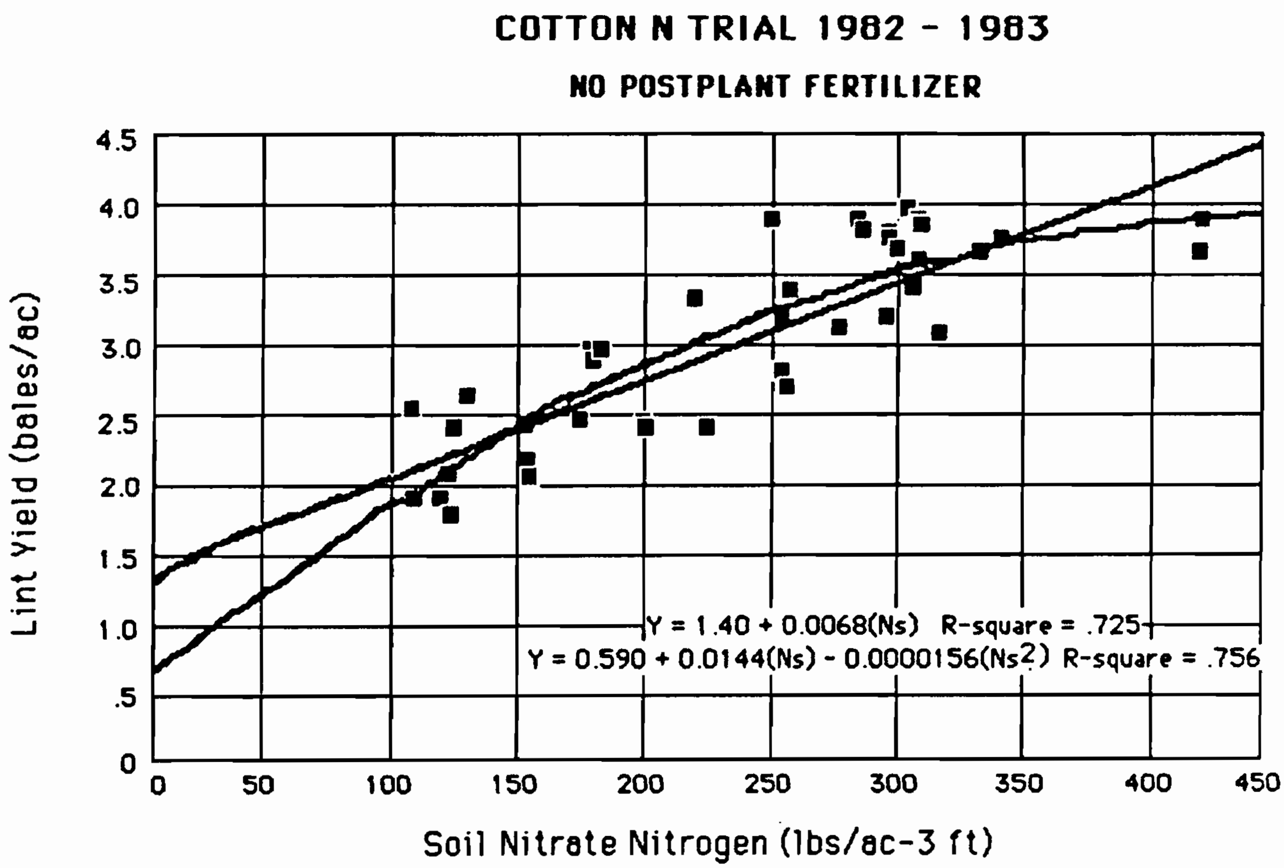


Figure 2. Relationship between cotton lint yields and residual soil nitrate nitrogen



RAPID FIELD TISSUE TEST METHODS

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Plant tissue analysis is used for three purposes: (1) identifying nutrient deficiencies; (2) predicting future nutrient deficiencies and responses to mid-season fertilizer applications; and (3) assessing the adequacy of a fertilizer application after the fact, e.g. in lieu of a fertilizer field experiment. Particularly for the first and second purposes, rapid field tissue testing may be useful.

Advantages and Disadvantages

Fresh tissue "quick tests" are no longer as popular as they once were. In the past, quantitative analytical methods were more expensive, perhaps more difficult, and turn-around times were not as short. As wet chemistry methods have improved, quick tests have fallen into disfavor. However, there are still reasons to use rapid, semi-quantitative methods. First, in spite of improvements in speed, it still is sometimes desired by a farmer or field scout to obtain an immediate reading, e.g. when weather is changing rapidly and no delay can be tolerated. Second, rapid field tests can be used to identify extremely high or low values. A more accurate and precise laboratory analysis can be used for samples that are not clearly above or below the critical level. Third, quick field test methods may be less expensive, depending on number of samples in a batch, number of determinations per sample and such factors as value of the labor used to collect the sample. Precision and accuracy of rapid field methods used on fresh tissue are less than for standard quantitative laboratory methods. It should be remembered that the sampling variability and uncertainty in interpretation - and not the analytical procedure - set the limits on reliability of a fertilizer recommendation. In many situations a quick test is probably good enough.

Some of the potential disadvantages of rapid field methods are the following: (1) Dyes used are not sensitive in the range of concentration needed; (2) product quality control is poor; (3) fresh tissue varies in water content; (4) individual judgement is required in reading the color; and (5) the ease of use and low initial cost may encourage incompetent persons to make diagnoses and fertilizer recommendations. Other disadvantages of particular reagents are mentioned below.

Development of Quant Strips

Nitrate tissue criteria for deficiences have been developed in California for sugarbeets, cotton, sorghum, corn, wheat, grapes, melons, tomatoes, potatoes and many vegetable crops (1). For some grass forages, levels of nitrate toxic to animals have been defined (2,3).

Rapid field methods for nitrate currently in use include diphenylamine and Bray powder. Diphenylamine is dissolved in sulfuric acid and thus is corrosive and can carbonize plant tissue, making a reading difficult. Bray powder is difficult to use on small pieces of plant tissue such as cotton petioles, and color development is often slow and uneven. An ingredient of Bray powder, alphanaphthylamine, is highly carcinogenic. Bray powder and diphenylamine share the disadvantage of being highly sensitive to nitrate at concentrations well below the critical levels for many plants.

Nitrate Quant Strips, marketed by EM Science have been used for soil and plant analysis in Germany, Great Britain, and New Zealand among other places (4, 5, 6). We have developed these for use in wheat in California. The strips appear to have potential for use in other crops as well. The product consists of a small paper square fixed to a plastic strip. The paper square is impregnated with a compound that reduces nitrate to nitrite and a dye, N-(1-naphthyl) ethylenediamine, that produces a red-violet color in the presence of nitrite.

The strips share a disadvantage of Bray powder and diphenylamine, that of oversensitivity to nitrate. But they are much easier to read because of the uniform background provided by the paper square. Only a very small amount of liquid squeezed from the tissue is needed, so a smaller amount of tissue is required compared to the other two methods. And the reagents are bound to the paper so any potential problems from toxicity or corrosivity are nearly eliminated.

To counter the sensitivity to low levels of nitrate, we have used the "time to full color" (in seconds) rather than take a direct reading of concentration. (A color standard is provided by the manufacturer. "Full color" is considered to be the 500 ppm NO_3^- color standard.)

A fairly good relationship between time to full color and dry stem tissue NO_3^--N concentration has been observed for wheat (Figure 1). Based on these data and previous work done to identify a critical level for wheat, the following recommendation is made for use of EM Nitrate Quant Strips or laboratory analysis in wheat:

Stem nitrate-N (dry wt. ppm)[a]	"Time to 500" (sec)	Recommendation
>6000	<10	No N top dressing
4000 - 6000	10 - 20	N top dressing may be needed
<4000	<20	N definitely needed

[a] Nitrate-N of bottom 5 cm at full tillering to first joint stage (Feekes 4-6) of Anza or Yolo wheat.

A critical level for the other popular wheat variety in California, Yecora Rojo, has not been established but may be as high as 8000 ppm NO_3^--N in the lower stem (7).

Some limitations of the strips, (in addition to those inherent in all quick test methods) are the following: (1) The product has a limited shelf life especially if subjected to heat and/or moisture; and (2) Cost appears to be higher than for the diphenylamine or Bray powder methods but is still not significant compared to the value of the sampler's time.

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Acknowledgements

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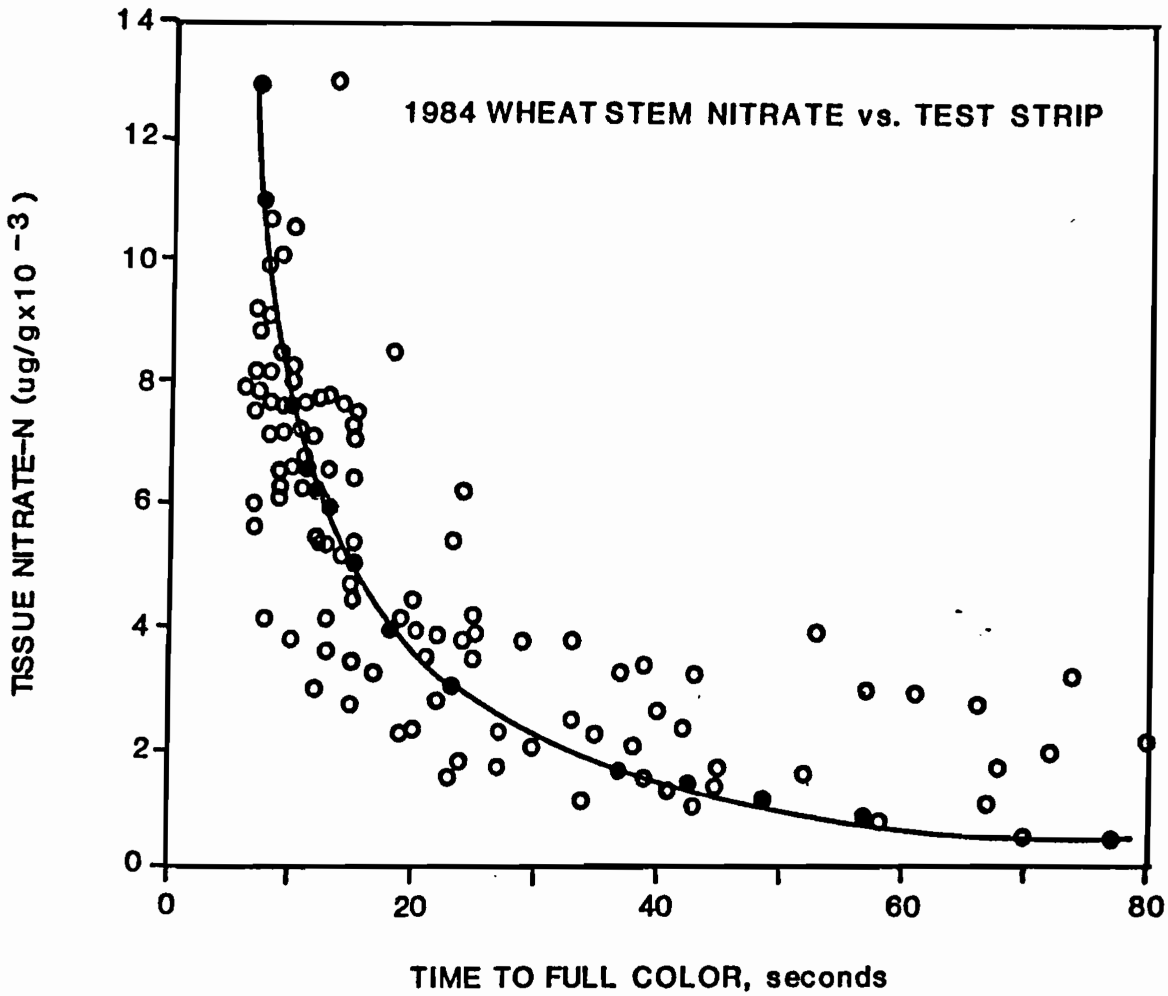

Figure 1. Relationship of wheat stem nitrate-N and "Time to Full Color" of EM Nitrate Quant Strips. Samples were collected from two nitrogen fertilizer experiments and several commercial fields planted to cv. Anza or Yolo. Stage of growth was not controlled.

CROP MONITORING

by R. E. Whiting

Cotton represents approximately 2 million acres of intensive cropping in California and Arizona, requiring heavy nitrogen use.

Increases in costs of production necessitates high yields to insure profits by decreasing unit costs of production. Based on 2 bale yields in Pinal County Arizona, the 1981 break even price was 64.5¢ per pound of lint while growers were receiving 50-55¢ per pound. 1980 break even point was 58.5¢ per pound. 1982 projected break even price was 71¢ per pound. While break even cost will vary from year to year, lower operating costs are not likely in the future.

To insure higher yields at lower unit cost, the farmer must utilize all the technical assistance available. One technique cotton farmers and others are turning to is crop monitoring systems to insure maximum efficiency in use of inputs.

Crop monitoring of cotton will help in the efficient use of water and nitrogen and possibly guard against cut-out. Cut-out occurs in cotton when fruiting rate succeeds the ability of the cotton plant to provide adequate nutrition for both fruiting and vegetative growth. Vegetative growth ceases and internode space is reduced so that fruiting branches are no longer produced.

This seriously reduces fruting structures and generally results in lower yields. By monitoring cotton petioles for nitrate and phosphorus the relationship between these factors and soil moisture can be programmed to resist plants going into cut-out. Computer assisted reporting of this data provides a rapid and visually emphatic suggestion to compensate early in plant growth for heavy nitrogen use and possible avoidance of cut-out.

Union Chemicals' experience in 1981, and PureGro Companys modified use for 2 years of the cotton monitoring system developed by Wiley & Maples at the University of Arkansas indicates this procedure is effective in maintaining surveillance and predicting nitrogen use. Several observations have shown that foliar nitrogen applied prior to onset of cut-out has kept plants growing enough vegetatively to ensure proper fruiting sites and maximum yields. Benefits of this system and others which may be designed for lettuce, sugarbeets and potatoes will accrue for growers and his agricultural support team.

The payoff from the use of these systems will be financially sound growers, knowledgeable dealers, and a solvent Ag Chemical Industry.

27790

BENEFITS OF COTTON MONITORING SYSTEM

BENEFITS TO GROWER

1. Prevent cut-out
2. Efficient N use
3. Foliar supplement of N
4. Reduce cost
5. Increase yields

BENEFITS TO DEALER

1. Customer relation
2. Full season contact
3. Competitive edge
4. Nitrogen product diversification
5. Data access

BENEFITS TO UCD

1. Maintain nitrogen market position
2. Customer dependence on UCD expertise
3. Product development climate
4. Increased urea use as foliar
5. Maintain technical leader role

MEASUREMENT OF MICROCLIMATES

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Introduction

The term microclimate conveys different messages to different people. Restricting ourselves to agricultural problems, microclimate can refer to the distinction between the average conditions at a specific location that may be influenced by terrain slope, aspect, elevation or soil type, and the climate that would be more representative of the general area, perhaps on the scale of a county. Vintners, for example, may make claim to the particular microclimate of specific vinyards. At the other end of the scale, crop canopies or components of a canopy can create unique conditions within their bounds to which the plants or parasitic or accompanying organisms respond. For example, a grape cluster may restrict ventilation and retain high humidity levels to the extent that fungal diseases are problematic. Identification of specific microclimates involves measurement at appropriate times with appropriate means but the design of a measurement system (instrumentation and data storage) must be guided by the overall purpose in collecting the information. Because of the wide range of possible objectives, this paper aims only to show the extent of techniques available and is not in any way intended to present a universal approach to measurement of "microclimate". Here, the topic is treated according to meteorological variable: air temperature, atmospheric humidity, wind speed and direction, and radiation. Ancillary measurements often considered as contributing to or components of the microclimate are soil and plant temperatures.

While this discussion is confined to transducers for monitoring environmental variables, perhaps the greatest advances made over the past decade have been in areas of analog-to-digital conversion, and data manipulation and storage devices. There is now a wide range of excellent systems available with varying degrees of flexibility for environmental measurement. Costs are reasonable, size and power requirements are small, sampling rates usually impose no limitation, data storage capacity in high, and data retrieval is convenient.

Temperature

Air temperature is generally considered to be one of the easiest of environmental measurements, although absolute accuracy is usually less than anticipated. The principal source of error is the result of the solar or terrestrial radiation field to which the thermometer may be exposed. Thermal lag of a thermometer may also be of concern if rapid temperature fluctuations are to be monitored.

If one can accept relatively large absolute errors (of the order of, say, 1°C) it is necessary only to be consistent in the height of the instrument and in the manner of exposure. This is the philosophy behind the unventilated mercury or alcohol in glass thermometers frequently exposed in white painted, louvered shelters (cotton belt shelter or Stevenson screen). Relative differences in maximum and minimum temperatures between locations can easily be found with reasonable accuracy, at least where long term averages are concerned.

When continuous recording is required, glass thermometers may be replaced by a thermograph with pen and ink display on a rotating drum actuated by a bimetallic strip. However, if greater accuracy or better spatial resolution is desired sensors that respond by changing electrical impedance (resistance thermometers and thermistors) or voltage output (thermocouples) can be used along with electronic recording and data storage.

Thermocouples have the distinct advantages that calibration is usually not necessary and temperature coefficients remain stable. Those features are used to greatest advantage when operated in a differential mode to measure temperature differences between levels or between an object and the surrounding air. If absolute measurements of temperature are required, however, a reference temperature, either physical or electrical, must be created. Thermocouples can be made extremely small (e.g., from wires $<$ 0.001 inch diameter) such that thermal inertia is negligible and radiation errors are small even without radiation shielding and artificial ventilation. The primary disadvantage of thermocouples is the small output (e.g., 40 μV/°C for copper-constantan junctions) necessitating amplification and increasing the possibility of noise, especially with long leads.

Resistance thermometers, generally made of platinum wire or film, have greater sensitivity than thermocouples and absolute measurements can be made without a reference temperature. Sensors must be calibrated but their output is reasonably linear. They can be constructed of very thin wire to avoid the need for radiation shielding and ventilation, or can be manufactured in encapsulated form for general convenience in handling and ruggedness.

Thermistors have relatively large temperature coefficients and can provide the largest output signals. This advantage is offset somewhat by their non-linear response making linearization essential. Thermistors are generally encapsulated in epoxy but can be sub-millimeter in size, although not so small that radiation shielding is unnecessary.

Humidity

The measurement of humidity presents more serious problems than that of temperature. There is currently no humidity instrument that is consistently accurate, reasonably small, rapid in response, rugged, linear, and able to operate unattended for relatively long periods of time. Most instruments fail on several of these accounts.

Five basic classes of sensor are in relatively common use, the simplest of which is the hair hygrometer which relies on the expansion of hair or other natural or artificial fibers with increasing relative humidity. The relationship between hair length and relative humidity is not linear and is contaminated somewhat by temperature, but the non-linearity is mostly corrected by appropriate design of the mechanical linkage to the pen of a drum recorder.

Principles of psychrometry have been utilized for a long time to determine the moisture content of the air from wet- and dry-bulb temperatures. With proper exposure and the correct amount of forced ventilation a psychrometer can yield accurate results. Psychrometers can also be made very small by utilizing thermocouple sensors for the wet and dry bulbs, but the inherent problem is maintaining the wick in a saturated state. The need for data reduction by reference to psychrometric tables has been superseded by digital computation using microcomputers.

Electrical hygrometers depend on the change in electrical conductance induced by the absorption of moisture by an electrolytic solution such as lithium chloride held in an organic binder. Sensors are generally calibrated in terms of relative humidity but do not function well at high humidities and are damaged if condensation occurs on the sensing element. Otherwise, the instruments are convenient to use and would be an appropriate choice if a reasonably small sensor (a few centimeters in dimension) is needed to obtain mean relative humidity levels.

Dew point hygrometers, relying on the change in optical properties of a thermoelectrically chilled mirror, generally provide the greatest accuracy. The temperature of the mirror is electronically controlled to a level very close to the dew point (or frost point) at which a small amount of condensate (or sublimate) is formed. Mirror temperature is monitored by a thermocouple, resistance thermometer, or thermistor element embedded behind the surface. This is a direct measurement of dew point but the instrument is hard to miniaturize, is generally expensive, requires ventilation of the air across the mirror for greatest accuracy, and the mirror must be cleaned regularly.

Finally, the attenuation of certain wavelength bands of electromagnetic radiation has been used in the design of closed or open path instruments for the measurement of absolute humidity. The instruments are generally expensive and are suitable for laboratory use (closed path) or for field experiments (open path) in which rapid sensor response is needed, rather than for more routine longer term humidity measurements.

Wind speed and direction

Devices for measuring wind speed and direction can be broken down into four basic categories: mechanical systems dependent on the creation of a dynamic force, those that measure dynamic pressure directly, heat transfer anemometers, and instruments that measure the rate of travel of a sound pulse. Selection of a particular measurement system should be based on consideration of a need for directionality, for rapid time response, or for small spatial resolution, as well as on cost and compatibility with available data collection systems.

The most common mechanical devices are the cup anemometer and the wind vane giving, separately, the horizontal component of the wind and the wind direction. They are manufactured in various sizes but the more rugged and durable the instruments the greater are the problems with threshold speed and with "overspeeding" due to the inertia of heavy cups. For special situations, propeller anemometers either vaned or in a two- or three-dimensional array offer advantages, while drag force anemometers based on the strain gauge measurement of the force on a body exposed to the wind have been used recently in field studies of turbulence.

The pitot tube has been the standard measuring device where the direction of air flow is well defined and stable such as in a wind tunnel. Modifications have resulted in vane-mounted anemoclinometers and pressure-sphere anemometers which are capable of turbulence measurements in the atmosphere. Because they rely on very sensitive pressure transducers, these instruments are not suited to routine, long term measurements.

Heat transfer devices, specifically hot wire or film, and heated thermocouple or thermistor anemometers are based on the nonlinear relationship between convective heat transfer from a heated element and the air flow past the element. They are superior to any other system of anemometry where spatial resolutions is important, for example to measure the air motion in the vicinity of a fruit or leaf cluster. Hot wires and films also have very high frequency response; generally much higher than needed to examine the smallest scales of turbulence in the atmosphere.

The final category of wind sensing, sonic anemometry, relies on the accurate measurement of the time of passage of a pulse of ultrasound or of the Doppler shift of a wavetrain of ultrasound between two transmitters/receivers spaced 10 to 20 cm apart. Each transmitter/receiver pair gives the wind speed along its axis and can be used in an array to examine two- or three-dimensional flow patterns. This measurement of wind is absolute and because frequency response is generally of the order of 20 Hz, it has become the standard in low level, atmospheric turbulence research. Unfortunately, sonic anemometers are generally expensive and are "fair weather" instruments.

Radiation

The most important sensors for solar (shortwave) and terrestrial (longwave) radiation are of the thermal response type in which a radiant flux warms an exposed blackened surface. The temperature rise is measured using a thermopile and the millivolt output is calibrated in terms of the irradiance.

Pyrheliometers measure direct beam solar radiation while pyranometers measure global solar radiation from a complete hemisphere. Pyrgeometers are radiometers designed to measure only terrestrial radiation and to exclude the short wavelengths with a suitable filter opaque to solar radiation.

Of special interest in the examination of local energy balances is the direct measurement of the difference between total downwelling and upwelling radiation streams. This is accomplished using a net radiometer which detects a temperature difference between two blackened surfaces facing upwards and downwards, and usually protected by domes of thin, clear polyethylene. These instruments are relatively simple to manufacture, to maintain, and to operate. The main precaution is to prevent condensation on the polyethylene domes, and to keep them clean.

Solid state sensors such as those that employ silicon, cadmium sulfide, or germanium photocells have particular spectral responses that can be optically filtered to approximate the response characteristics of the human eye, the photosynthetic process, or the energy content of solar radiation.

Surface temperature

Often the crucial factor that distinguishes two microclimates at nearby locations is a surface temperature measurement either of a plant organ or of the soil. The objective is to obtain a measurement appropriate to the skin temperature without in any way affecting that temperature. It is possible with infrared thermometry to obtain remote sensing of surface temperatures to an accuracy better than 1°C with a resolution of a small fraction of 1°C and over a surface area smaller than 1 cm^2. While infrared thermometers are suitable for hand held spot measurements, they are not suitable for forming long term averages by automatic data collection. They are also quite expensive.

Great care is needed if thermocouple, resistance thermometer, or thermistor probes are to be placed on a surface for the inference of surface temperature. Excellent thermal contact is essential and the thermal mass of the sensor must be small relative to that of the body to which it is in contact. Potential problems to which attention must be paid include conduction of heat via the sensor leads, alteration of the radiative environment of the surface, and alteration of the evaporative properties of the surface perhaps by the use of a gel to improve thermal contact. In general, sensors must be very small and in the natural environment it is usually difficult to maintain contact, particularly on flapping leaves, for significant periods of time.

MICROCLIMATES OF PLANT CANOPIES

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Introduction

The microclimate within plant canopies is considered quite important by many growers, farmers, foresters, ecologists, and agricultural scientists. Applications of plant microclimatology include improved methods of frost protection, mulch usage and integrated pest management, along with development of methods for decreased water use for a given yield, and prediction of yields.

The principal variables which make up the plant canopy microclimate are air temperature, humidity, carbon dioxide concentration, radiation, wind speed and direction, and surface temperature. Associated with these variables are fluxes of gases to and from plant canopies; photosynthesis represents a transfer of carbon dioxide from the air to plants and evapotranspiration represents a transfer of water vapor from the plant to the atmosphere. Dew formation and leaf wetness duration, which could be associated with fungal disease, are caused by the condensation of water vapor on plant surfaces, and are heavily dependent on the plant canopy microclimate.

Radiation

Solar radiation fuels photosynthesis and thus all agricultural production; solar radiation is for the most part visible. The solar radiation used in photosynthesis represents only a small part of the radiation impinging on a crop surface; much of radiation heats up the crop instead. As solar radiation passes through a crop canopy, from the top to the bottom, it is absorbed by leaves, resulting in shading of the lower canopy and the ground below.

The crop surface and the soil below emit radiation; this radiation is in the "longwaves" and is invisible. Longwave radiation generally cools the plant surface, especially at night. It is longwave radiation that is responsible for 'radiative frosts' which occur on clear, low wind nights. Slope, aspect, elevation, time of day or night, season, overall geography and air pollution influence the radiation characteristics of a field.

Air and Surface Temperature

Plant growth has been related to plant temperature; in general, growth increases with temperature until some high temperature limit, at which point growth levels off or decreases. Plant temperature is controlled by radiation, air temperature, and humidity within the plant canopy and immediately above it. The concept of a yield-'growing degree days' relationship is based on air and plant temperature being equal or at least air and plant temperature being different by some special amount.

During the day, if there is much evapotranspiration due to available water, plant canopies are cooler than the air, by more than 10°F at times. If insufficient water is available, the plant canopies may be warmer than the air. At night, under low winds and clear skies, the plant leaves may be cooler than the air, and dew may form before the relative humidity is 100%. Growing degree days-yield relationships may be inaccurate because of differences between plant and air temperature.

Humidity

Humidity is the concept of water vapor concentration in the air. It is most commonly expressed as 'relative humidity'; at 100% relative humidity, fog may form; 0% relative humidity means there is absolutely no water in the atmosphere. The humidity within a plant canopy is important because it controls evapotranspiration and condensation on plant leaves.

During the day, relative humidity is high in the canopy and lower above it. At night, when the temperatures of both plant leaf and air drop, the relative humidity climbs. Condensation or dew may form on the plants before 100% relative humidity is reached, because the leaves may be cooler than the air (in much the same way that condensation forms on a cold can of soda or a cold glass of water). The water on the leaves may remain until well after sunrise, until the leaf is warmed and the water evaporated off the leaf. At high relative humidities the evaporation rate will be low, and the leaf wetness duration longer; if sun is partially or totally obscured by clouds, the evaporation rate will even be lower and the leaf wetness duration longer still.

Wind Speed and Direction

Wind speed may be important in deciding when to spray chemicals or when to irrigate, and extremes in wind speed may be associated with lodge in crops or other damage in orchards. In general, the wind speed is highest at the canopy top and decreases greatly within the canopy. Near the bottom of the plant canopy, the wind speed is usually quite low, and sometimes it is difficult to measure with typical instruments such as cup anemometers. With low wind speeds near the canopy bottom, and also low solar radiation and high humidity, the canopy bottom is usually wet for a longer time than the canopy top, and is a likely location for initiation of fungal infection.

Wind direction may change slightly within a canopy, but in general there is no significant difference in wind direction between the top and bottom. Wind direction may determine whether it is prudent to apply chemicals such as pesticides or herbicides, and whether aerial irrigation should be scheduled.

Carbon Dioxide Concentrations

During the day, most plants absorb carbon dioxide from the air in the photosynthetic process. Generally, the higher the concentration of carbon dioxide in the atmosphere, the higher the photosynthetic rate. It has been postulated that the observed slow increase of carbon dioxide in the atmosphere (due to human activities involving combustion of materials for energy) will increase the yield of some plants and possibly change the ecological relationships between various plant types.

During the day, carbon dioxide in the air is depleted within the plant canopy by photosynthesis, and produced below the canopy by plant, root, and microorganism respiration. The carbon dioxide concentration is therefore smaller within the canopy than below or above the canopy, in the day. During the night, the plant canopy is also respiring as are the plant components and other organisms near the ground and underground, resulting in high levels of carbon dioxide below and within the canopy and lower levels above the canopy.

Soil Microclimate

The soil microclimate may be examined in the same manner as the plant microclimate. Microclimatic analysis aids in such decisions as choosing mulches for moisture conservation and modifying the temperature environment near the soil (for germination purposes or protection of short crops from extremes in temperature - frosts or high temperatures). All of the variables mentioned above are affected by mulches, so that a careful analysis must be made for each mulch type before the best one can be picked, and the most efficient time to mulch is chosen. Microclimate analysis also helps in predicting overwintering of insects in the soil.

Conclusion

The microclimate of plant canopies may be described by considering several variables such as air and surface temperature, wind speed and direction, humidity, radiation, and carbon dioxide concentrations. Analysis of the patterns of these variables in the canopy and with respect to time can lead to several applications in agriculture, such as the identification of the most vulnerable location and time for fungal infections and the improved prediction of crop yield.

USING CLIMATOLOGY ON THE FARM

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In 1979 the Panel on the Effective Use of Climate Information in Decision Making was formed by the Climate Board of the National Research Council to (1) examine the present system of providing climate information in the United States; (2) study the process of decision making with the information; (3) review possibilities for improving the information system and decision-making process; (4) make improvement recommendations; and (5) develop educational materials and recommend a process for their distribution. The results of the panel study were published in 1981. Functions of an ideal climate-information system were described and the first mentioned, and perhaps the most important function, is to supply users with "probabilistic climate information tailored to particular circumstances and consistent with climatological theory and practice." In addition, the panel recommended that the data used to provide information be sufficient "in both space and time to ensure reliable probabilistic estimates and minimal sampling errors." Currently there is very little probabilistic climate information available in the United States and that which is available is unknown to most California growers and/or is in a form that is not useful.

The objective of this research is to determine how to manipulate minimum temperature data to provide probabilistic climate information that can be used by California growers to make management decisions. This information can be used to determine the probability of temperature falling below a specified minimum for any given time interval during a calendar year. Cost-benefit studies can be performed using the generated probabilities, yield loss functions, and design and management costs. Decisions on frost protection insurance, investment on frost protection systems, and cropping patterns can then be made from the cost-benefit relationship.

Currently the only probabilistic minimum temperature information available in California are the dates when 10, 20, 30 . . . 90 percent probabilities of the first 28° and 32° F minimum in the fall and the last 28° and 32° F temperatures occur in the spring. This information is available for selected climatic stations throughout California. The information is somewhat useful for the determination of when to plant and harvest annual crops, but is of little value for determining cost benefits of various management schemes. Yield-loss functions must be applied with probabilities of damaging temperatures during the time interval of concern to determine the benefits of a management decision.

The first step in determining probabilities of rare minimum temperatures is to identify a probability density function that describes the data distribution. Several studies have shown that minimum temperatures often fit a normal or Gaussian distribution. The shape of the normal distribution depends on the mean and standard deviation of the sample space which depends on the period of record and time interval of interest. The probability of a random, minimum temperature (X) falling below a specific minimum temperature (x) can be calculated as the area under the curve from $-\infty$ to the minimum temperature as:

$$P(X \leq x) = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{x} e^{-(\nu-\mu)^2/2\sigma^2} d\nu \qquad (1)$$

where ν are the minimum temperature values, μ is the mean, σ is the standard deviation, and e is the exponential function. Generally, the probability of the temperature falling below a specified minimum is greater when the time interval of the sample space is increased during colder seasons.

Equation 1 gives the probability of the temperature falling below a specified minimum on a given year, but the probability of this event happening during the design life of a management decision is needed to determine the cost over time. Because an event either does or does not happen in any given year, the probability that an event occurs at least once over a design life can be determined using a binomial (Bernoulli) distribution where:

$$P(X = \text{at least 1 in } n) = 1 - P(X = o \text{ in } n) \qquad (2)$$

and

$$P(X = o \text{ in } n) = \binom{n}{o} P^{o} (1 - P)^{n-o} \qquad (3)$$

Once the probability of an event is known over a design period the expected cost for a management practice can be determined from a yield-loss function for the sample space time interval. The solid line in Figure 1 illustrates a hypothetical yield-loss function. If a management practice can reduce the initial loss to 28° F but has no effect below 28° F then the dashed line represents the yield loss. The dotted line is for a management practice that protects down to 26° F.

If the probability of the minimum temperature falling below 26° F for the time interval with the yield-loss function in Figure 1 is 0.5 percent, and the probability of this event happening at least once in 10 years is 5 percent, a protection system designed to eliminate yield loss down to 26° F would carry a 5 percent risk of having a temperature falling below 26° F at least once in 10 years and 0.5 percent probability of the event happening in any given year. A grower who is willing to accept this risk can then determine the benefits obtained and costs required to protect to that level.

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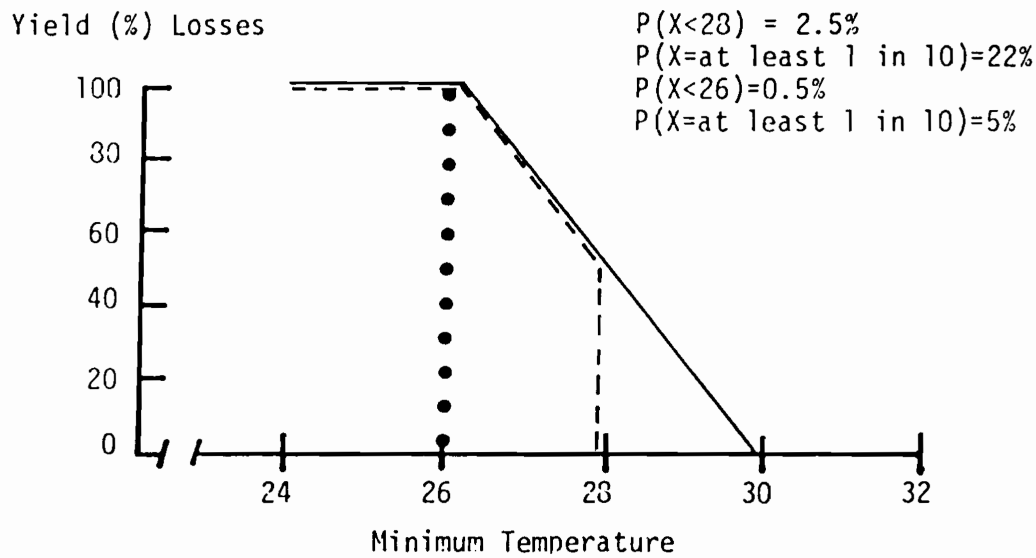

Figure 1. Hypothetical yield-loss function for a crop that is (1) unprotected (solid line), (2) protected to 28° F (dashed line), and (3) protected to 26° F (dotted line).

Short Range Weather Forecasting:
A Triumph of Applied Science

by Leonard Myrup

Introduction.

It might seem presumptuous or to be tempting fate by using the word "triumph" in connection with that perennial butt of jokes, the weather forecaster. All of us whose living depends on the weather and its seeming vageries knows that forecasting is an imperfect tool, one that fails at times. Nevertheless, meteorology as a science has progressed an enormous amount since World War II. Since we tend to remember best the worst forecast, it will be necessary to become analytical in order to demonstrate this progress on the practical level that most of us are interested in. In this paper I will present a brief "prehistory" of Meteorology, a look at the impacts of World War II on the discipline, a concise outline of modern weather forecasting and, finally, I will return to my theme in "triumph" of short range weather forecasting.

Before continuing, however, the expression "short term" should be defined. For the purposes of this paper short term refers to forecasts from, say, one hour to about six days in the future.

Prehistory of Weather Forecasting.

There is neither sufficient time nor space here for a comprehensive review of human efforts to foresee future weather. The effort probably began very early in our prehistory. Undoubtedly farmers were the first systematic observers of sequences of weather events that could be used for forecasts. The principle is known to anyone who lives in, say, the Sacramento Valley: In the wintertime, when the clouds grow dark and the south wind picks up, it's going to rain pretty soon so you better get your bike home in hurry. That kind of weather forecasting has been going on for thousands of years and about the same degree of sophistication. For it's purpose, providing a warning of some impending weather phenomena in time that a practical action can be taken, these do-it-yourself forecasts are fine.

However, ultra-short term forecast are usually severely limited to what can be seen on the horizon, say roughly thirty miles away. It happens that thirty miles per hour is also a rough estimate of how fast cloud and rain clouds move. So our personal ability to foresee the weather is limited to about one hour. Consequently, without additional information, the kind of practical preventative actions we might take are limited to those we can do in less than about an hour. A severe limitation.

In order to progress beyond this state, it is necessary to know what is going on over the horizon in some systematic way, that is collect together meteorological observations, taken at the same time, over a large area. This is called the synoptic method. As far as is known, Benjamin Franklin was the first synoptic meteorologist. From rain reports in his friend's letters, Franklin was able to deduce that winter rainstorms extended beyond the horizon and were quite large scale in nature, extending for hundreds of miles. In addition, Franklin saw that these storms moved, roughly from west to east.

These bare facts provided the basis for large-scale weather forecasting for the most of the next two hundred years.

About a hundred years later, the invention of the telegraph made daily weather maps a reasonable endeavor. Synoptic charts were first introduced in England by Admiral Fitzroy in 1861 and two years later in France by the astronomer Leverrier. With the daily weather maps available, meteorologists were able to develop forecasting techniques based essentially on the phenomena, first noted by Franklin, that the motion of weather systems is reasonable constant from one day to the next. That is, extrapolation of past motion into the future often produces a good estimate of the actual motion. Extrapolation-based forecasts remained the heart of synoptic meteorology for most of the next hundred years.

Synoptic experience during this period showed that weather phenomena was not randomly distributed but, instead, showed distinctive patterns that could be used in forecasting. In 1887, the Scottish meteorologist, R. Abercromby published a "cyclone model" which summarized twenty years experience of studying daily weather maps. Abercromby's model is shown below as Fig. 1.

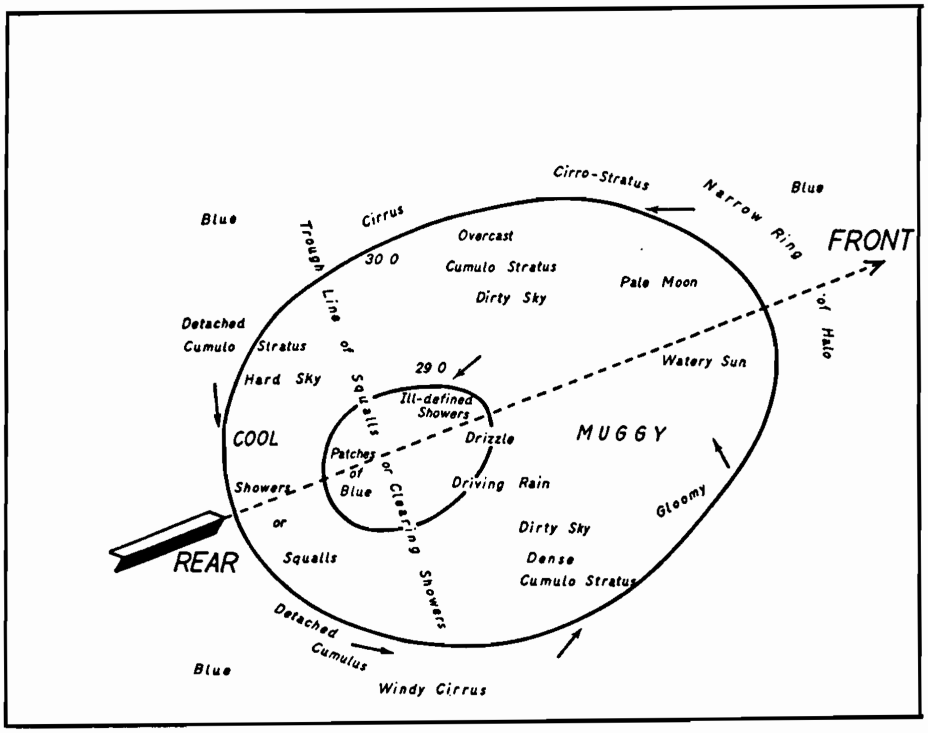

Fig. 1 The cyclone model of R. Abercromby.

This diagram asserts that there is a typical distribution of clouds, precipitation and other weather phenomena. Furthermore, these are distributed with respect to the overall motion of the cyclone. The application to forecasting was clear. Forecast the cyclone by extrapolating its past motion into the near future and then forecast the resultant weather distribution from Abercromby's model. Abercromby's model was eventually superceded by others but same basic forecasting technique was still being taught in universities in the early 1950's.

The last figure from the meteorological prehistory to be discussed here is Jacob Bjerknes, the son of the illustrious founder of theoretical meteorology, V. Bjerknes. During World War I, the scandanavian meteorological services were cut off from their usual European sources of data. For this reason, among others, they greatly increased the density of meteorological stations. Careful analysis of this information revealed the existence of "fronts" (so called by analogy to newspaper war maps) separating different air masses. Furthermore, distribution of clouds, precipitation and pressure changes were found to be highly correlated with the location of the fronts. As a result, a new frontal model of the distribution of weather phenomena was developed by Bjerknes and his collaborators which quickly became the standard method of analysis for the next 30 years. The Bjerknes system, augmented by modern research, is still widely used today. Fig. 2 shows a typical diagram of a frontal cyclone and the closely associated weather distribution.

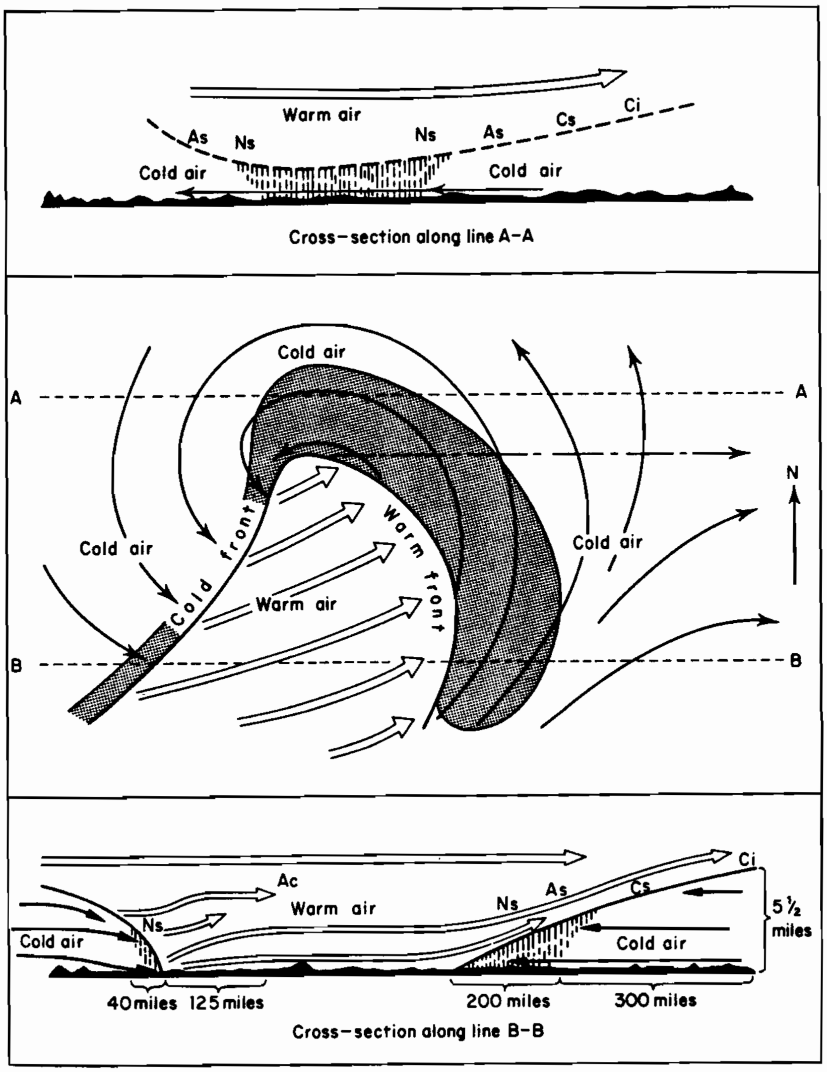

Fig. 2 Distribution of precipitation in the polar front model.

The polar front model was the culmination of 50 years of practical experience and research and it proved to be enormously valuable to subsequent generations of meteorologists. However, it should be remembered that the polar front model was entirely empirical and contained no quantitative method of dealing with the physical processes responsible for the frontal phenomena. During World War II, Allied meteorologists stationed in the tropical Pacific learned, to their dismay, that the mid-latitude polar front model was almost totally inapplicable in that region. In addition, the polar front model provided little information for the most interesting forecast of all: the development of a new storm.

Finally, it should be remembered how incomplete our knowledge of the atmosphere was in 1940. Upper air observations were made at scattered locations only in North America and Europe which means that the great mass of the atmosphere was virtually unknown. This fact was brought home in 1943 when American B-29s discovered the jetstream while attempting to bomb Japan.

The Impact of World War II on Meteorology.

As in almost all of science and technology, World War II produced a profound change, a revolution, in meteorology. Technology was an important component of this change. During the war the upper air observing network was greatly expanded in many parts of the world primarily because of the requirements of military aviation. This meant that, for the first time, synoptic charts of the upper air could be prepared for some regions, allowing study of the relationship between surface weather and the upper flow. This data base, while still sparse by modern standards, was one of the essential steps necessary before weather forecasting could be tackled as a problem in physics.

The second technological component of the meteorological revolution is well known. From its birth in World War II as a technology to control and direct weapon systems, the modern digital computer is now a revolutionary influence throughout the industrialized world. Meteorology was one of the first sciences to benefit from the new computational technology. Although the basic numerical techniques for numerical solution of the meteorological equations were essentially known at this time, the shear volume of the calculations necessary would have doomed any attempt without the new machines. This point is particular important for the extensive research necessary to develop and improve the new weather forecasting methods.

Important though technology was in this period, it is probable that human and intellectual factors were paramount. The period just before World War II had been one of much intellectual ferment in Meteorology. Led by such innovative thinkers as J. Bjerknes and, especially C-G. Rossby, meteorologists were beginning to believe the atmosphere might be governed by far simpler dynamical theorems than had been believed in the past. This simpler approach to dynamics was well adapted to computer solution.

In addition to the change in the way that the fundamental dynamics of the atmosphere was viewed there was also an important change in the scientists entering the discipline. There were many more of them and they now tended to persons with powerful quantitative skills, physicists, mathematicians, scientists eager to use the new computer techniques. It was this new generation that carried out the meteorological revolution.

Toward the end of the war John von Neuman, one of the leaders of scientists and engineers who developed the computer and an immensely influential man in science and public policy, decided that meteorology was ideally suited to benefit from the new technology. After the war, von Neuman formed a group of brilliant young meteorologists and computer scientists, including Jules Charney and Ragnar Fjortoft, at Princeton. Using the newly installed ENIAC computer, this group laid the ground work and produced the first computer weather forecasts based on basic physical principles. These first theory-based forecasts proved superior to those produced by the old extrapolation based techniques. We shall discuss these modern forecasts in the next section.

In the years immediately after the war the various factors we have mentioned acted to produce very rapid change and by, say, 1950 many of the characteristics which now characterize meteorology, or any modern science, were already in place. Of these characteristics perhaps two were of greater importance. First, meteorology was now a theory-based rather than empirical science. The indisputable basic laws of physics were now the successful basis of the discipline. Second, the discipline was thoroughly committed to using the latest and highest technologies to solve it's problems including one of the oldest known to man, weather forecasting.

An Overview of Modern Weather Forecasting.

It should be emphasized at the start that modern short-term forecasting of large-scale weather events is now completely based on the basic laws of physics. The revolution initiated by Rossby, von Neuman, Charney and others has long since been completed. It may not be obvious watching the evening weather show on television but almost all forecasts nowadays start with weather charts prepared by computers which have been programmed to solve the physical equations using current data to establish the initial conditions. Weather forecasts are treated as an initial value problem in physics.

What physical principles are used to prepare short range forecasts? The list is surprisingly short and contains nothing that is not treated in first year physics. (1) Newton's second law of motion (F=MA). Since the vectors dealt with in this equation are three-dimensional, Newton's second law is used three times to generate three equations. The result is three partial differential equations. (2) The law of conservation of energy. In the atmosphere, this universal principle is formulated as the first law of thermodynamics, another partial differential equation. (3) The law of conservation of mass produces still another partial differential equation. This basic principle simply states that if there is net convergence of mass into a region then the density must increase. These equations amount to 5 equations and 6 unknowns. To make them solvable, the gas law is added to the set, making 6 equations and as many unknowns. We not discuss the solution process here except to note it consists of finding the single flow pattern and distribution of pressure and temperature that "satisfies" the governing 6 equations. Another way to look at the problem is that each physical law establishes a strong constraint on the system that delineates what is possible and what is not. The final result is the single solution or forecast which obeys all constraints.

Needless to say computer techniques are required to find solutions to the governing equations. Before the days of computers, approximate numerical methods for solving differential equations but the labor involved was enormous and progress was slow. The chief contribution of computers to solving the weather forecasting problem has been to provide a quick and accurate means to solve the difficult governing equations. In addition, computers also provided the means to manage the large data sets required by the new forecast models as initial conditions.

The particular set of equations used to make a forecast usually incorporate various special assumptions concerning physical processes. These are called modeling assumptions and the resultant equations, a forecast model. The model represents a simplified version of the original set. The simplifications are made for a variety of reasons, the most important being computational efficiency and lack of knowledge of how a particular physical process works in the atmosphere. Modeling is a distinctive feature of modern science and an essential component in the progress achieved by modern weather forecasting. The first person to attempt a weather forecast along the lines described here was the British scientist, L. F. Richardson, failed for a variety of reasons. Richardson "model" was more in the way of an attempted complete simulation of the atmosphere using all that was known at the time of World War I. It has been proposed that the root cause of Richardson's failure was his lack of a modern modeling approach to the problem.

The first computer model used to forecast the weather using current weather data for initial conditions was the barotropic model. The barotropic model, developed from theoretical work by C.-G. Rossby just before World War II, was a highly simplified version of the basic set of governing equations. The barotropic did little more than provide a physical basis for extrapolation forecasting. The model moved weather systems along from west to east much as they are observed to move. The barotropic model is incapable of describing development or decay of weather systems, a grave defect. Nevertheless, the first barotropic forecasts proved to be superior to forecasts prepared by the extrapolation and qualitative techniques then used by operational agencies. That so simple a model should be successful meant that computer techniques would dominate weather forecasting in the future.

The subsequent history of weather forecasting is partly that of a sequence of models, each more sophisticated in terms of physics included than the previous model. The barotropic models were superseded the baroclinic models which could represent the processes associated with weather fronts and could predict the growth and decay of storms. Although more complex and containing more physics than the barotropic model, the baroclinic model was still relatively simple. The combination of simplicity and reasonable good physics made the baroclinic model the favorite for both operational forecasting and theoretical analyses for over a decade. At the present time a combination of bigger and faster computers, better physical knowledge and better numerical techniques for solving the equations has made it possible to use the basic equations in a relatively pure form, with fewer special and often questionable modeling assumptions. Such models are called "primitive". At the present time, meteorologists are working to improve the primative equation models by decreasing the data grid so as to be able to represent smaller scale features and improving the representation of phenomena known to be important to weather forecasting, such as cloud formation.

How much has short term weather forecasting improved in the years since World War II? Figures 3 and 4, below, show some standard statistics for weather forecasts at Chicago and Salt Lake City.

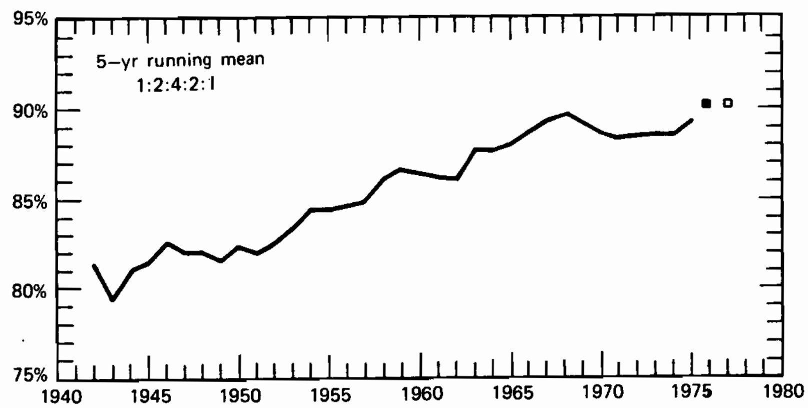

Figure 3. Percentage of correct weather forecasts, Chicago, Illinois, 1942-1977 (Shuman).

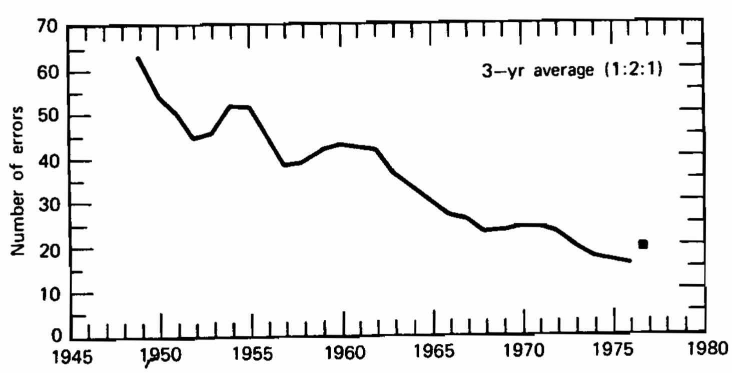

Figure 4. Temperature forecast errors >= 10 deg. F, Salt Lake City, 1948-1978 (Shuman, 1978).

As can be seen, these data suggest a modest but continual increase in forecast accuracy and decrease in error during the period studied. Similar statistics can easily be compiled for any meteorological station in North America or Europe. The analysis shown in Figures 3 and 4 are for surface-measured quantities. In meteorology, the basic forecast is now for the upper air, and therefore, it is more enlightening to examine upper air statistics. Figure 5 displays a statistic, called the "skill score" for the 36 hour forecasts of the National Meteorological Center from 1953 to 1976. During this period, the forecasting technology progressed from the traditional qualitative-extrapolation methodology, to the barotropic model, to the baroclinic model and the primative equations model. In addition, during this period the hemispheric data base increased permitting forecasts over a larger and larger area. The diagram shows a more or less continual increase in accuracy and the introduction of each improvement in terms of model sophistication or data coverage seem to be reflected in corresponding forecast improvement. The marked improvement which appeared after the introduction of the barotropic model is particularly noteworthy.

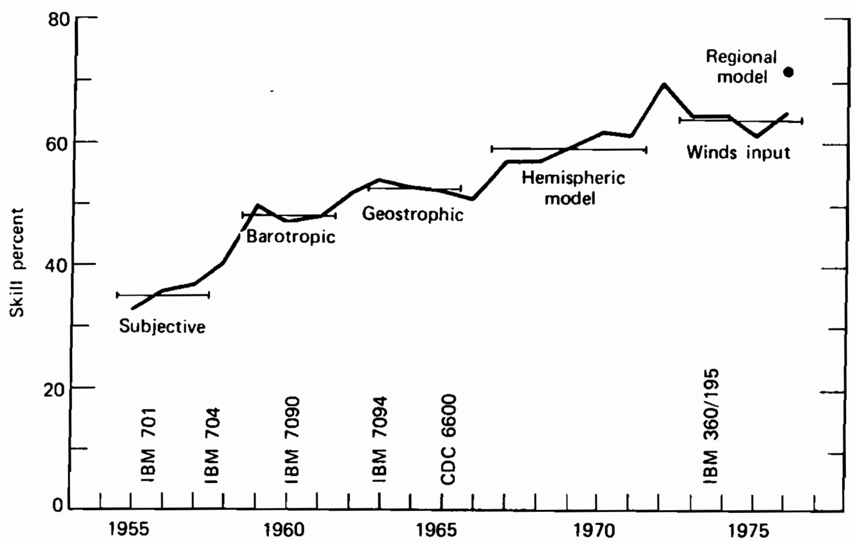

Figure 5. Record of forecast skill, averaged annually, of the National Meteorological Center's 36 hour 500 mb (5.6km) forecast.

Probably any reasonable person would agree after examining such evidence that there has indeed been progress in short term weather forecasting. The percentage of good forecasts has steadily increased and the fraction of "busts" has decreased. Nevertheless, it would also be reasonable to ask at this time why can't the progress be faster? What are the limiting factors? It should be remembered, at the start, that the weather forecasting problem is a very difficult one. At the time he was helping launch the effort to make weather forecasting scientific, John von Neuman said that weather forecasting was "second most difficult problem that had ever been formulated". As far as is known, von Neuman never revealed what the most difficult problem was. The factors which limit the accuracy of forecasts may be put in three general categories: (1) Data, (2) Physics and (3)

Computers and computer techniques. Regarding data, it should be remembered that even today, in the age of satellites, there are vast areas of the earth where no meteorological measurements are made at all. This is partly an economic problem. Is the cost of additional data worth it in terms of better forecasts? In the opinion of most forecast scientists, problems with model physics has been and remains the most important factor limiting forecast accuracy. The problem with physical processes occurring on scales too small to be resolved by the large-scale observing network is especially severe. The growth of disturbances too small to be resolved is thought to be define the fundamental limit of the length of time that future weather may be forecast from current data. This fundamental limit is thought to be from two to three weeks. Great progress has been made in the computer side of this problem, probably more in this area than in the others. There still remains a large potential benefit in larger and faster computers. This is because of the importance of representing smaller scale processes.

Is Modern Weather Forecasting a Triumph?

The distinguished american sociologist, Daniel Bell, has said that the second half of the twentieth century is the age of the primacy of theoretical knowledge. Bell meant by this that many of the great, revolutionary changes in this period, such as the introduction of semiconductors or computer technology or the bases of literally dozens of disciplines, were derived from a theoretical base rather than found by trial and error. We live in a theory-based society. Why is this so? Henry Ford, an unlikely spokesman for theory, got the essence when he said there is nothing so practical as a good theory. The reason that a "good" theory is so powerful, even in a practical context, is that the theory applies to a tremendous variety of situations, whereas the empirical approach requires information or data for every situation. Condensed problem-solving information is the key to the rest of the century.

In the context of modern, short range weather forecasting, we see that meteorology "joined the revolution" about 1950 when it became clear that the crudest form of a theory-based forecast was superior to more than fifty years of accumulated empirical weather map information. In one stroke, meteorology joined the twentieth century. In the years that followed, meteorology rapidly became a modern, theory-based technological science with a good record of steady progress in it's outstanding application area: weather forecasting.

It's worth a minute of reflection on what was achieved in meteorology in the decade after World War II. For thousands of years we humans had lived at the mercy of the weather and had sought means to foresee its vageries. Shrewd men and women have been able to deduce practical, very-short term forecasting rules which apply to a particular valley or island. Such lore provide last minute wornings but little time for the kind of planning that is characteristic of our century. During the entire sweep of the thousands of years of empirical meteorology, the most profound discovery was what we might call the synoptic principle of Ben Franklin.

Finally, a small group of scientists, in less than a decade, showed that weather phenomena could be completely explained and forecast with the basic laws of physics. Within the context of all of human history, this was a momentous event. What had been the domain of the empiricists, the wizards, the tribal warlocks, the qualitative weather forecaster, was now in the domain of rational thought and experiment. I submit that this is indeed a triumph of the human mind.

What of the future? Will the steady improvement in forecast accuracy continue? There is every reason to believe so. The basic governing equations are incredibly condensed, one of the advantages of the theoretical approach. Those equations, which could be written on four lines in their most basic form, contain the physics of the great majority of the processes important to the short term. As the data base improves, as we learn better how to represent those small-scale processes unresolved by our large-scale observing network and as the computers continue to improve in speed and memory, forecasts will improve. At the present time, the triumph is in how far we have come. Hopefully, in the near future, the triumph will be what we have achieved in accurate forecasts.

Prospects for Long-Range Forecasting

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Introduction

Accurate long range forecasting (longer than a week) would greatly benefit agriculture, public utility, transportation, construction and other industries. Of these, agriculture has by far the greatest potential for savings.

Short term forecasts of a week or less have been shown to have a high degree of skill, at least for the first few days. The models used for short term forecasts succeed by keeping track of how the details of the weather patterns evolve after the observations are taken. Refinements in these models have improved the forecast accuracy. It is tempting to conclude that further improvements will produce skillful forecasts of longer and longer duration. Unfortunately, this conclusion appears to be incorrect. Three independent estimation schemes have all indicated that 2 weeks is a fundamental limit for models like those used for short term forecasting. This limit arises from physical properties of the atmosphere; the detailed evolution of the weather is inherently unpredictable after 2 weeks.

One can draw two basic conclusions. First, detailed long range forecasting appears to be impossible. Instead only general forecasts seem feasible. For example, the average precipitation for a large area over a month may be predictable, but not the amounts at a given locale on given days of that month. Second, successful long range forecast models must use different approaches than short-term models. In practice this means searching for longer period, more predictable processes that may cause predictable atmospheric responses. Due to the complexity of the atmospheric responses, these models tend to be based upon past statistical behavior of the atmosphere rather than physical laws.

Table 1 gives a list of some current long range forecast models. For clarity, these models will be labelled "human forecasters". In the remaining discussion we will focus upon the first 4 of the models listed in this table. These models forecast whether temperature and precipitation will be above, below or near normal.* Specific examples of temperature anomaly forecasts for five winter seasons are shown in Figure 1. Figure 1 subjectively compares the forecasts by the National Weather Service (NWS) and J. Namias with the actual observed anomalies. Clearly, the most important question is whether any of these models have skill.

Measuring Forecast Skill

In order to properly evaluate forecast skill one needs to establish benchmarks that define forecasts with no skill. There are several types of forecasts that require no skill. These are summarized in Table 2. In order for a forecast model to have skill it must be better than all 5 of these "no skill" forecast schemes.

Unfortunately, it is common practice to only compare one's forecast with the result of random chance. This gives the models in Table 1 an unfair advantage since many random distributions are not possible in nature. For example, temperature fields tend to have a rather large-scale structure; i.e., they tend to smoothly vary across the United States. The modelers in Table 1 know this and adjust their forecasts commensurately. Random forecasts will include many examples with unrealistically rapid variations. Precipitation is different; it often does have rapid, small-scale variations and so it is more randomly distributed. Comparing the human forecasters in Table 1 with the first 4 "no-skill" forecasters in Table 2 avoids some of this bias. Unfortunately it also changes one's conclusions about the skill of the human forecasters.

* In 1983, the NWS categories were changed for precipitation to probabilities of "light" or "heavy" amounts.

Table 1. Some publicized long-range "human" forecast models.

	Name of Forecaster	Type of Long Period Phenomena Used
1.	National Weather Service (NWS)	Long wave motion extrapolation, Teleconnection patterns, Pacific Sea-Surface Temperatures
2.	J. Namias	Pacific Sea-Surface Temperatures
3.	A. Douglas	?
4.	T. Barnett and R. Preisendorfer	Historical analogs
5.	R. Bryson	Volcanic aerosols, Chandler wobble of earth orbit
6.	Old Farmers Almanac	Solar variability (sunspots)

Table 2. Forecasting methods that have <u>no</u> skill.

	Name	Description
1.	PERSISTENCE	use same anomaly pattern for next season as is observed for current season.
2.	CLIMATOLOGY	assume next season will be normal.
3.	pure ANALOG, persistence ANALOG	look for past pattern which is closest to pattern of current season. Take next season analog after the analog or just use the analog for forecast
4.	empirical MARKOV, probable MARKOV	use past frequency of transition from current above, below or normal to other categories at each station independently. Use random numbers with same probability distribution or take most probable transition.
5.	CHANCE	random chance distribution, each category equally likely, all stations assumed independent.

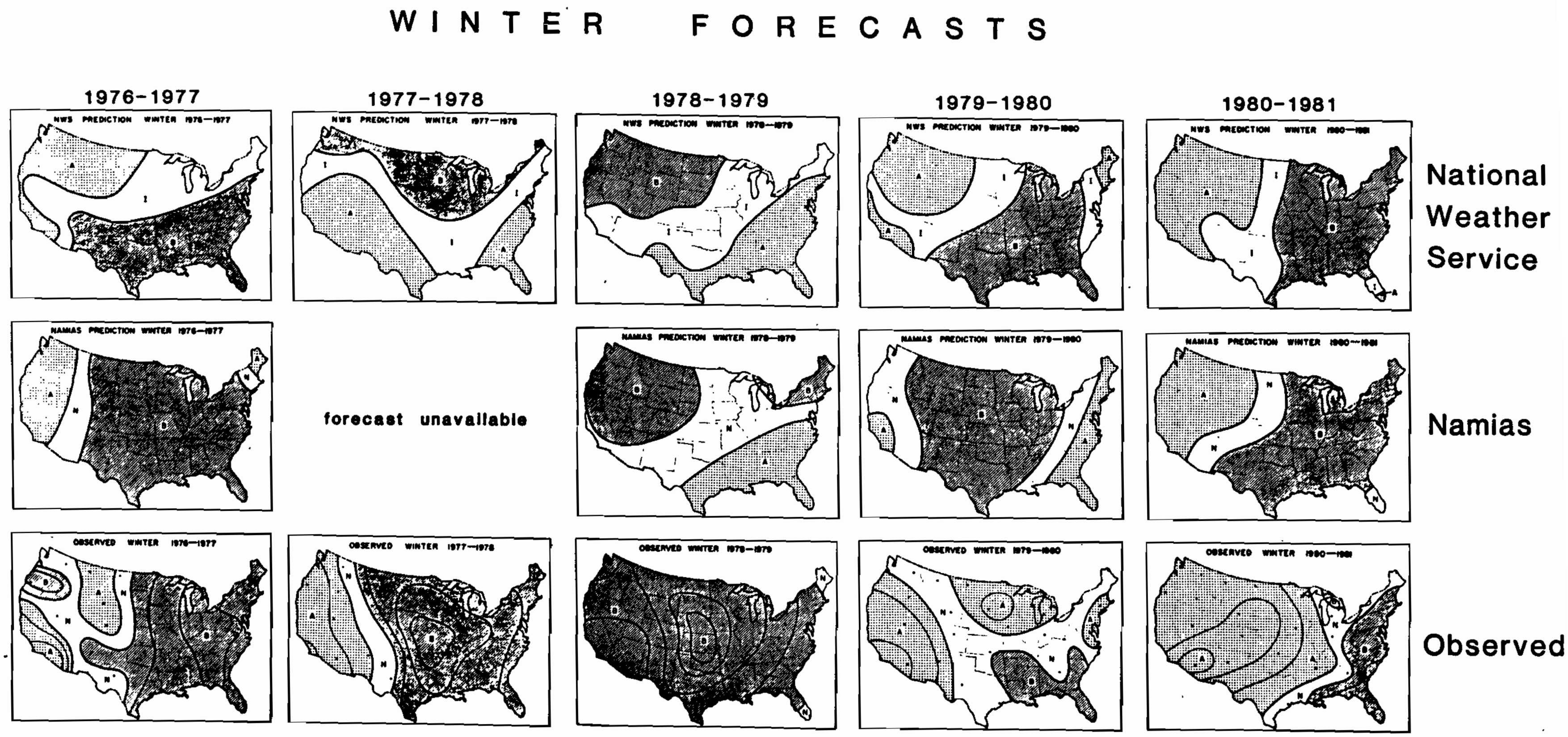

Figure 1. Seasonal temperature forecasts for five recent winters. The temperatures are grouped into three equally-likely categories: above, below, and indeterminate or near normal; marked with A, B and I or N, respectively. Dark hatching denotes above, and light hatching denotes below normal. Figure adapted from Bettge, Baumhefner and Chervin, 1981, *Bul. Amer. Meteor. Soc.*, 62, 1654-1665.

The Skill of Human Long-Range Forecasters

When considering individual forecasts, each human forecaster has had an occasional spectacularly good forecast. However each human has had spectacularly bad forecasts, as well. In order to distinguish statistically significant skill from luck it is necessary to have as large a sample of seasonal forecasts as possible. Recently, Preisendorfer and Mobley (hereinafter called PM) compared forecasts by the first four human forecasters in Table 1 with observations. PM chose the 37 seasons from the 73-74 winter through the 82-83 winter.

PM found that seasonal temperature forecasts by the human forecasters had some apparent skill when compared to random chance forecasts. However, none of the humans performed any better than the other "no-skill" methods in Table 2. The "skill" appeared to result from the lack of randomness in temperature patterns mentioned above. Note that the first 4 "no-skill" methods in Table 2 are based upon observations; hence they incorporate some observed tendency for larger scale temperature variations. The other "no-skill" methods all did better than random chance and at least as well as all of the humans. The apparent skill is quite modest. For example, one of the best NWS forecasts is that for the 77-78 winter; compared with chance, this forecast has considerable skill; but a subjective comparison (see Figure 1) does not confirm that evaluation.

PM found that seasonal precipitation forecasts by the human forecasters had no measurable skill. The humans did no better than any of the "no skill" approaches.

Overall, the best forecast model over the 37 seasons turned out to be a modified "probable Markov" model. So on average, a "no skill" model did slightly better than all of the human forecasters. To be fair, this model was not derived from an independent dataset. (One was not available) and that introduced an unfair advantage. The probable Markov method did have some compensatory flaws: 1) no seasonal stratification and 2) each station treated independently.

When grouped by season, the winter forecasts were better than the other seasons; the fall forecasts were the worst. One might conclude that fall bears little relation to summer and winter bears some relation to fall except that even the winter forecasts have only marginal skill. Finally, the forecast skill was grouped by geographic region. The temperature forecasts were poorest for the Gulf, Atlantic and Pacific Coasts. The precipitation forecasts were poorest for the Gulf and Atlantic Coasts and the Northern Plains.

Conclusions

The human forecasters listed in Table 1 are aware of the "experimental" nature of their forecasts. However, this qualification is sometimes lost when their forecasts are presented to the public. This is especially true when considerable excitement is generated by a particularly successful forecast. This has led the public to form unrealistic expectations of current long-range forecasting. It has also led some other forecasters (not listed in Table 1) to falsely conclude that their method is sound on the basis of one good forecast. The truth is that all forecasters presently have only a marginal amount of skill. The skill seems too small to have any economic benefit at this time. This view is reinforced by the forecasters typical lack of information about: 1) the magnitude of the anomalies and 2) the confidence limits of their estimates.

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AGRICULTURAL WASTES IN CALIFORNIA: AN OVERVIEW

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California, the most populous of the United States, produces a wealth of agricultural and forestry based products. Forested land comprises nearly half of California's land mass. A third of the land is devoted to farming of one sort or another, and there are over 80,000 farms in the state. California is a major producer of lumber, pulp and paper, cotton, fruits, dairy products, wines, vegetables, and rice. It is not surprising, then, that California is a leader in the production of biomass that is potentially useful as fuel.

Biomass, in this context, means most organic materials that could be combusted, gasified, digested anaerobically, i.e., in the absence of oxygen, to produce a methane rich gas, or converted into alcohol fuels such as methanol or ethanol. Biomass by this definition, included wood and wood waste, agricultural industry wastes, field crop wastes, chaparral, urban wood waste, and manures. This definition is meant to exclude from biomass only fossilized organics, e.g., coal, oil, and natural gas, and municipal solid waste.

Estimates of the total quantity of various forms of biomass produced in California have been made by numerous authors. These estimates have been compiled and analyzed by the Biomass and Cogeneration Office of the California Energy Commission and its technical support contractor, Envirosphere. They have been converted to a common basis: tons of dry matter, i.e., dry tons. This compilation is presented in Table 1. It includes all biomass that is amenable to direct combustion and/or gasification and occurs in sufficiently concentrated form to warrant collection and utilization. It does not include materials being processed into primary product, e.g., lumber, pulp, canned fruits and vegetables, cotton lint, wine, etc. Further, it does not include all the biomass residues generated from every crop or fruit type in the state.

For the purpose of this presentation, we will focus on:

Agricultural Industry Biomass - pits, shells, hulls, trash, and selected high moisture content residues;

Field Crop Biomass - field crop, fruit and nut crop, and citrus crop residues; and,

Manures - all dry collected manure.

AGRICULTURAL INDUSTRY WASTES

The agricultural industry in California produced 45,527,980 tons of cotton, fruits, vegetables, grains, berries and nuts in 1982 from some 8,895,400 acres of agricultural land. Vast quantities of residues are produced with these commodities. These residues are divided here into two general categories: low moisture content and high moisture content. The division between the two is based upon 55 moisture content (green basis). This moisture content is selected since material with much more than 55 percent is incapable of sustaining combustion.

Approximately 200,000 tons per year of the low moisture content agricultural industry residues are used for energy purposes. High moisture residues are generally not used for energy purposes because their moisture content makes use in direct combustion or gasification infeasible (although they may be suitable for anaerobic digestion and alcohol production) and many of these residues have higher value uses as cattle feed and fertilizers.

Based on the moisture content of their residue, the commodity's end use, and whether or not the commodity is processed (canned, crushed, or frozen or dried), the following crops have been selected as the likely resource base of low moisture biomass residue from the agricultrual industry: rice, cotton, almonds, walnuts, olives, peaches, apricots, and prunes. Table 2 presents their estimated residues for 1982. For high moisture content residues it was decided to concentrate on commodities that are produced in relatively large quantities, are processed at some central facility, and have residues that show some potential for thermochemical conversion applications. As a result of these factors, four high moisture residue sources have been identified: grapes, tomatoes, sugar beets, and cheese whey. Their estimated residues for 1982 are presented in Table 3.

AGRICULTURAL CROP WASTES

Agricultural field crop residues include the plant materials that remain after crops are harvested for their marketable product and prunings from tree and vineyard crops. Because their are so many different field, fruit, and nut crops, this presentation focuses on a select few:

Field Crops - barely, wheat, rice, field corn, and cotton, and

Fruit, Nut and Citrus Crops - almonds, walnuts, grapes, apricots, cherries, peaches, plums, lemons, oranges, grapefruit, tangelos, tangors, and tangerines.

The five field crops were selected because their residues are not currently being used to any measurable extent for fuel and they are produced in large amounts on a annual basis. A total of 5,860,000 tons of potentially collectable residue was calculated (See Table 4a) for these five in the crop year 1982. Wheat straw comprised 26.7 percent of the residue available, next came rice straw with 24.7 percent and corn stover with 20.6 percent. Although corn had the fewest number of acres harvested, the total tonnage of residue available was high because of the field density of corn stover, 4.7 tons/acre/year (See Table 6).

The potential energy available for the field crops selected is presented in Table 4b. Rice and wheat straw have the greatest potential for oil displacement with 50 percent (41 trillion Btu's) of the total potential heat content available from field crops and, likewise, 50 percent (5.4 million equivilent barrels of oil) of the potential oil displacement values for field crops.

The fruit and nut crops cited above were selected because, either singly or as a group, growing them produces significant amounts of residue annually. The specific residue of interest for all these crops is prunings (also called "brush"). Almost 1.4 million tons per year of potentially collectable residue were calculated for 1982 (See Table 5). Of this tonnage, almonds, walnuts, and grapes accounted for 74 percent (997,983 tons), citrus accounted for 13.8 percent, and stone fruits for 12 percent (163,097 tons).

The potential energy available for the fruit and nut crops examined is presented in Table 5b. Almond prunings are the only residue currently being used in any appreciable quantities for biomass fuel. Grape prunings show the greatest annual potential energy availability with almost 49 percent of the total Btu's available. Almond prunings are second with nearly 23 percent. Stone fruits as a group (apricots, cherries, peaches, and plums) have nearly 15 percent while citrus crops (grapefruit, lemons, oranges, and tangerines including tangors, tangelos, etc.) have over 14 percent of the Btu's available for energy.

TABLE 1

BIOMASS RESOURCES IN CALIFORNIA

Biomass Resource Type	Dry Tons Available
Forestry Related Biomass	12,600,000
Agricultrual Industry Biomass	
Low Moisture Content	952,000
High Moisture Content	368,000
Agricultural Crop Residues	
Field Crop	5,860,000
Fruit and Nut	1,350,000
Chaparral and Non-Commercial Wood	7,600,000
Urban Wood Waste	3,940,000
Manure	5,351,000
Total	38,021,000

TABLE 2

LOW MOISTURE RESIDUES GENERATED FOR SELECTED COMMODITIES

Residue	Dry Tons Produced
Almonds	
Shells	119,700
Hulls	187,800
Walnuts	117,300
Cotton Gin Trash	265,510
Rice Hulls	220,650
Peach Pits	38,185
Prune Pits	12,500
Apricot Pits	10,300
Olive Pits	21,825
Total	993,770

TABLE 3

HIGH MOISTURE RESIDUES GENERATED FOR SELECTED COMMODITIES

Residue	Dry Tons Produced
Grapes	
Pomace	136,400
Stems	83,600
Tomatoes	35,000
Sugar Beets	
Pulp	210,000
Molasses	31,080
Cheese Whey	75,000
Total	571,080

TABLE 4a

FIELD CROPS: GROSS POTENTIALLY COLLECTABLE RESIDUES

Selected Crop	Acres Harvested Statewide (1)	Residue Generated (Tons/Acre/ Year) (2)	Maximum Percent Collectable (3)	Factor: Wet to Oven Dry Weight (4)	Potentially Collectable Residue (Gross Tons/ Year)
Barley Straw	620,000	1.3	85	0.86	589,186
Wheat Straw	1,125,000	1.9	85	0.86	1,562,512
Rice Straw	535,000	3.5	90	0.86	1,449,315
Corn Stover	330,000	4.7	90	0.86	1,200,474
Cotton Stalks	1,370,000	1.5	60	0.86	1,060,380
		Total			5,861,867

(1) California Crop and Livestock Reporting Service. 1983. 1982 Field Crop Statistics.
(2) Knutson and Miller. 1982. Agricultural Residues (Biomass) in California...Factors Affecting Utilization.
(3) California Energy Commission. 1980. Biomass Handbook for the Biomass Conversion Demonstration Program.
(4) Ibid., Knutson and Miller. Based on 14 percent moisture content, 100% - 14% = 86% X 1/100 = 0.86.

TABLE 4b

FIELD CROPS: POTENTIAL ENERGY AVAILABILE

Crop Residue	Potentially Collectable Residue (Gross Tons/ Year)	Competing Uses (Tons/ Year)	Net Residue Available for Energy (Tons/Year)	Heat Content (Trillion Btu's/Year)	Potential Oil Displacement (Bbl Oil Equivilant)
Barley Straw	589,186	0	589,186	8.484	1,118,617
Wheat Straw	1,562,512	156,251 (2)	1,406,261	20.250	2,669,899
Rice Straw	1,449,315	100 (3)	1,449,215	20.868	2,751,451
Corn Stover	1,200,474	0	1,200,474	17.286	2,279,196
Cotton Stalks	1,060,380	0	1,060,380	14.433	1,903,049
Totals	5,861,867	156,351	5,705,516	81.321	10,722,212

(1) Assumes higher heating value of 7,200 Btu's/lb for all except cotton stalks which is 6,806 Btu's/lb.
(2) Feed, bedding and soil stablization; estimated 10 percent of gross.
(3) Extimated total used for research purposes.

TABLE 5a

FRUIT AND NUT CROPS: GROSS POTENTIALLY COLLECTABLE RESIDUES

Selected Crop	Bearing and Non-Bearing Acres (1)	Residue Generated (Tons/Acre/ Year)	Maximum Percent Collectable (2)	Factor: Wet to Oven Dry Weight (3)	Potentially Collectable Residue (Gross Tons/ Year)
Almonds	419,729	1.0 (4)	98	0.75	308,501
Walnuts	199,525	1.0 (4)	98	0.75	146,650
Grapes	738,549	1.0 (4)	98	0.75	542,833
Apricots	24,445	1.5 (2)	98	0.75	26,950
Cherries	12,204	0.4 (2)	98	0.75	3,588
Peaches	70,964	1.7 (2)	98	0.75	88,670
Plums	42,652	1.4 (2)	98	0.75	43,889
Citrus	266,575	0.95 (5)	98	0.75	186,136
		Total			1,347,217

(1) California Crop and Livestock Reporting Service. 1983. California Fruit and Nut Acreage. Figures shown are for 1982 crop year.

(2) California Energy Commission. 1980. Biomass Handbook for the Biomass Conversion Demonstration Program.

(3) Knutson and Miller. 1982. Agricultural Residues (Biomass) in California...Factors Affecting Utilization. Based on 25 percent moisture content: 100% - 25% = 75% X 1/100 = 0.75.

(4) Magaletti and Lew, California Energy Commission staff.

(5) California Energy Commission. Biomass Handbook. Grapefruit = 1.0, lemons = 0.9, oranges = 1.0, tangerines, etc. = 1.0. Average for this calculation is 0.95.

TABLE 5b

FRUIT AND NUT CROPS: POTENTIAL ENERGY AVAILABLE (4)

Crop	Potentially Collectable Residue (Gross Tons/ Year)	Competing Uses (Tons/ Year)	Net Residue Available for Energy (Tons/Year)	Heat Content (Trillion Btu's/Year) (1)	Potential Oil Displacement (Bbl Oil Equivilant)
Almonds	308,501	54,000 (2)	254,501	4.327	580,000
Walnuts	146,650	300 (3)	146,350	2.487	328,000
Grapes	542,833	0	524,833	9.228	1,216,000
Apricots	26,950	0	26,950	0.458	60,000
Cherries	3,588	0	3,588	0.060	8,000
Peaches	88,670	0	88,670	1.507	198,000
Plums	43,889	0	43,889	0.746	98,000
Citrus	186,136	0	186,136	3.164	417,000
Totals	1,347,217	57,300	1,289,917	21.928	2,905,000

(1) Assumes higher heating value of 8,500 Btu's/lb.
(2) Based on 60,000 tons/year (20-30 percent moisture) for Superior Farms, Bakersfield, CA; and 12,000 tons (25 percent moisture) from Golden By-Products, Turlock, CA.
(3) Based on 0.15 tons/hour input X 90 days/year operation at Yuba River Farms Nut Dryers, Marysville, CA.
(4) Based on 1982 crop data.

TABLE 6

COMPARISON OF DENSITY FACTORS (TONS OF RESIDUE PER ACRE)

Crop Residue	K and M (1)	ARB (2)	CEC (3)	Used in This Paper (4)
Barley straw	1.3	1.7	1.4-1.5	1.3
Wheat straw	1.9	1.9	1.5-1.6	1.9
Rice straw	3.5	3.0	3.0-3.7	3.5
Corn stover	4.7	4.2	4.0-4.5	4.7
Cotton stalks	1.5	1.7	1.5-2.0	1.5
Almonds prunings	1.3	1.6	1.3-2.0	1.0
Walnuts prunings	1.0	1.2	0.9-1.5	1.0
Grape prunings	2.0	2.5	2.0-2.5	1.0
Apricot prunings	2.0	1.8	1.5-2.0	1.5
Cherry prunings	0.4	1.0	0.4-1.5	0.4
Peach prunings	2.0	2.5	1.7-2.5	1.7
Plum prunings	1.5	1.7	1.4-2.0	1.4
Citrus prunings	1.0	1.0	0.9-1.8 (5)	(6)

(1) Knutson and Miller. 1982. Agricultural Residues (Biomass) in California...Factors Affecting Utiliztion. Cooperative Extension, USDA, Univ. of Calif., Davis, Ca.
(2) Air Resources Board. Cited in Knutson and Miller. 1982. (See Footnote 1.)
(3) California Energy Commission. 1980. Biomass Energy Handbook.
(4) All values used were those suggested by CEC staff except for stone fruits and citrus.
(5) Values given are the lowest and highest range of lemons and limes (0.9-1.0), grapefruit (1.0-1.2) and oranges (1.0-1.8 tons/acre).
(6) Values correspond to those given in Footnote 5.

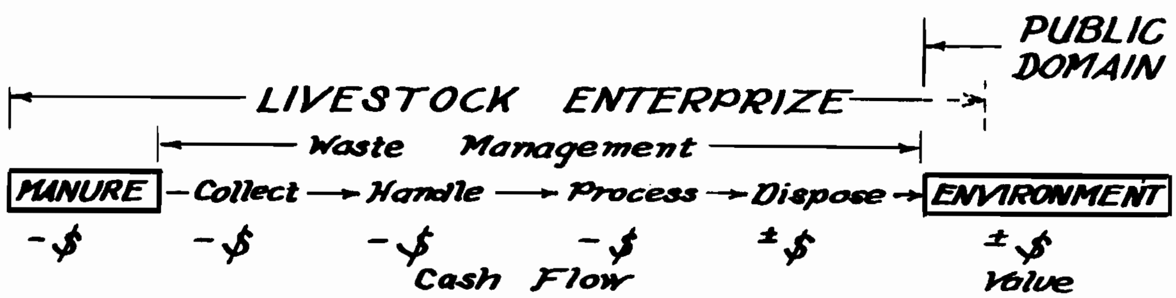
ALTERNATIVES IN MANAGING LIVESTOCK WASTES

W. C. Fairbank

It is estimated the confined livestock in California produce annually over four million tons of air-dry manure. It should go without saying this byproduct of producing our favorite foods is usually under control or we wouldn't be so comfortable in this room. The public nose, however, is not very considerate of agriculture and thinking farmers know better than to challenge in court a manure-offended community. Producers and users of manure are well advised to keep abreast of waste management alternatives for both cost effectiveness and public appeasement.

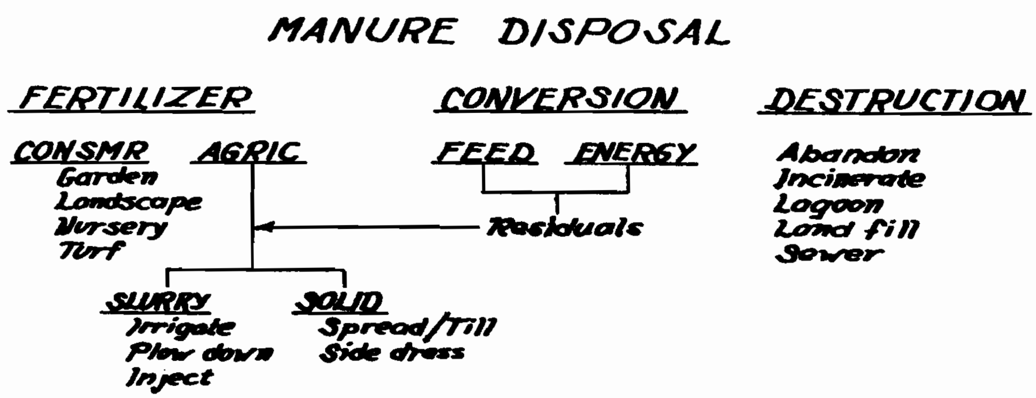
Ultimately all collected manure solids that are not deliberately diverted to feed and energy recovery are returned to the environment. With the highly developed science of plant nutrition and the use of available machinery manure handling and disposal needn't be the problem it was two decades ago. *Do-nothing* manure management and hap hazard handling have, in fact, become the more costly schemes.

One flow chart can outline the physical operations, credit and debit expectations, and societal constraints as enforced by the regulatory agencies.



The producer must manage from left to right but society is looking from right to left and ready to crowd the producer back to his dung heap whenever an environmental insult occurs. Disposal is the key element as it determines profit or loss for the producer and is usually the first and only concern of the public. The disposal plan will determine all proceeding operations back to the source.

Manure disposal is diagramed to show interrelationships between physical condition of the product and its utility (costs and returns not considered.)



Dry handling is usually favored for simplicity and nuisance control. Dry manure is relatively stable, does not generate odors or attract flies, and can be stockpiled until the best time for fertilizer use. The notable exception to dry handling in California is the liquefied waste from flush-cleaned cow and swine confinement facilities which is a daily flow of rich sewage. Dairies and hog farms are, then, committed to ponding systems and to fields set aside specifically for wastewater recycling. As a general rule, liquefied manure loses about half of its initial N if it is stored for several months. A ponding system must be considered a waste management expedient more than a fertilizer recovery plan.

There are no new ways to manage manure--just better application of the common sense practices of natural drying, aeration, runoff control, and soil-plant recycling.

MANAGING PLANT PATHOGENS IN AGRICULTURAL WASTES

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Crop residues are often a primary source of inoculum for plant diseases. Managing crop residues to reduce inoculum density or to eradicate plant pathogens is important in plant disease epidemiology and control. Burning (3, 9), composting (1, 5, 7), deep plowing (6) or avoidance of accumulations of crop wastes such as potato dumps (4) are the usual ways crop residues are managed.

Burning crop residues has been effective for controlling the stem rot disease of rice caused by *Sclerotium oryzae* (9). Sclerotia of this pathogen form in infected rice tissues and continue to increase in crop debris under favorable environmental conditions. Burning of rice straw and other residues is common in rice culture to improve seed bed preparation; it effectively reduces the inoculum density of *S. oryzae*. Other examples where burning of crop residues has been useful involve perennial grass seed crops in the Pacific Northwest (3). Composting of crop residues such as grape pomace and cotton gin trash and the use of the compost to improve fertility and structure of agricultural soils is an important practice in the San Joaquin Valley (1). Not only does composting provide a product useful in crop production, but for cotton gin trash, it also can eradicate pathogens such as *Verticillium dahliae* and kill weed seeds (2). The recent discovery that the Fusarium wilt pathogen (*Fusarium oxysporum* f. sp. *vasinfectum*) is carried in cotton gin trash (5) elevated this disease to the number one problem in cotton production in California in 1982 and 1983. It is imperative that gin trash is treated to kill pathogenic organisms before it is spread back onto cotton fields (2, 5). Composting increases temperatures of crop residues to levels sufficient to kill most plant pathogens and weed seeds (2, 7). Recent interest has been shown by large cities to compost agricultural wastes such as cotton gin trash with domestic sewage to improve the composting process and to achieve higher and more uniform temperatures in compost. Deep plowing of cotton crop residues was used to eradicate angular leaf blight of cotton in California (6). The causal bacterium, *Xanthomas campestris* pv. *malvacearum*, dies in nonsterile soil when separated from living host tissues for more than one season. The pathogen is also seed-borne but all California cotton planting seed is now free of the bacterium. Cotton seed shipped into California is tested for the absence of *X. campestris* pv. *malvacearum* by the State Department of Agriculture before planting. The use of deep plowing or turning under crop residues for controlling other plant diseases has met with only limited success. For example, when residues of rice were incorporated in soil rather than burned, inoculum densities of *S. oryzae* increased with corresponding increases in stem rot severity.

Accumulations of agricultural wastes such as in potato dumps (4) or in conservation tillage cropping systems (8) are often sources of primary inoculum of viral, bacterial and fungal pathogens. Insects and mites are commonly associated with these agricultural wastes and are often vectors of the pathogenic organisms to crop plants. Wind and splashing rain dissemination of sporangia of *Phytophthora infestans*, the cause of late blight, from potato dumps has been recognized as the most important source from which late blight infections become established in the field. Management of these agricultural wastes by avoidance of dumps is an effective practice for controlling late blight.

In regard to conservation tillage for grass crops such as wheat, serious diseases are less likely to result if the stubble mulch is pathogen-free, if pesticide control is possible, if a resistant variety is grown, or if the environment is not favorable for infection or disease development (8). An awareness of the high potential of agricultural wastes as reserviors of plant pathogenic organisms and their vectors is the first step in developing effective management programs.

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MANAGEMENT OF ALMOND TREE PRUNINGS

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California's almond industry generates approximately 320,000 tonnes of almond wood each year through pruning and orchard removal operations. The majority of this wood is burned in the field for disposal. The adverse environmental impacts of burning and the potential economic loss of a fuel resource have resulted in development of systems to harvest tree prunings for utilization. Markets for almond wood include use as fuel for cogeneration of power and heat, mushroom compost, greenhouse heating, and firewood. The brushy material produced during pruning is difficult to handle. Collecting, processing, and transporting almond brush economically requires well engineered and well managed systems.

Two major categories of systems to collect almond brush have developed in recent years. Field side collection systems take the brush after it has been moved out of the orchard in the conventional manner by the grower. In-row systems collect the brush from between the trees. Conventional buckraking is not done. Operators of in-row systems may charge the growers a field sanitation fee to offset the cost of collection. Capacities of the in-row collection equipment must be high, due to the low yield of prunings (approximately 2.5 t/ha).

An experimental field side collection system was developed under a joint project by the University, the Almond Board of California, and the California Energy Commission. The system uses modified cotton moduling equipment. The objective of the project was to develop a low-cost method for handling brush.

Almond Brush Moduling System

The almond brush module system was developed to use existing equipment as much as possible. A module cutter was developed at the University to complete the system.

Prunings are buckraked from the orchard in the conventional manner. The prunings are loaded into a modified cotton module builder and compacted. The module measures nominally 2.1 m wide, 2.1 m high, and 5.5 m long. The design configuration of the system calls for transport of the module to a storage site located no more than five to ten miles from the orchard. The module is cut into two or three sections by the module cutter. Cut sections are loaded into a tub grinder for size reduction. Chips are transported to the utilization facility in chip vans.

Moduling has several advantages compared to handling loose brush. The density of the brush in the module is increased as much as six times. As a result, storage space requirements are reduced, as are transportation costs. Throughput capacities of tubgrinders with cut modules are as much as five times greater than with loose brush. Wood in modules dries very well. Chips do not dry well in unventilated storage.

When the system was initially proposed, no satisfactory method existed for cutting the modules. Hand operated chain saws proved extremely hazardous and time consuming. A large bow type chain saw with an unsupported span of 3 m was designed and fabricated at the University to solve this problem.

Standard cotton module builders proved too light to handle the brush. A heavy duty module builder was constructed by Taylor Manufacturing, Visalia, CA. This module builder, plus the cutter, were operated for two years by Weaver Tree Service, Fresno, CA as a test of the system concept.

Field Trials of the Module System

Actual equipment time and capacity data were collected during the first five months of operation of the system. A total of 578 modules were made. The module builder capacity was 7.2 t/h dry basis. The module cutter was evaluated over 100 cuts. Capacity was 11 cuts per hour, including resharpening after 50 cuts. Estimated chain life was 200 cuts.

Economic Analysis of Module System

Total costs for collecting almond brush with the module system were estimated at $26.60/t dry basis. This cost includes loading the module builder, compacting, transporting modules to a storage site, cutting, grinding, and delivering chips 50 km.

Discussion

The cost of harvesting almond brush with the module system is approximately the same as the current market price for fuel chips offered by cogenerators. A good market is developing for fuel chips for greenhouse and process heating. The delivered cost of the almond brush fuel is $1.66/GJ, or about one third the cost of natural gas and oil. The low cost of wood fuel compared to fossil fuels is a significant incentive for biomass heating systems. High capacity in-row systems being developed commercially also show good potential economic feasibility for brush handling and utilization. Field sanitation fees charged by custom operators of in-row equipment may be lower than current costs of conventional disposal.

Conclusions

The module system can be used successfully to collect and process almond brush for utilization. Other systems are also being developed and appear to have good potential for handling brush. Improvements in brush collection and handling systems need continued investigation for system optimization.

MANAGEMENT OF AGRICULTURAL INDUSTRY WASTES

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Considerable attention has been given to the subject of wastes by the legislative and regulatory bodies in California during the past few years. Other states and the federal government have been very active, also. One only has to pick up his local newspaper to see how the press focuses on the subject. The agricultural industry has been in the forefront of this attention, particularly as it involves pesticides, and it appears that this situation will not change in the foreseeable future.

Management of waste in California is beset by many overlapping state agency activities. At least twelve state agencies have some role in California's program. This multi-agency responsibility is compounded by a plethora of county and regional agencies which also function in the management program, even though the attorney general of California issued an opinion that the California Hazardous Waste Control Act preempted local ordinances and regulations pertaining to handling, processing and disposal of hazardous waste. On top of these state regulatory programs are those of the federal government under the Environmental Protection Agency (EPA). The specific federal law governing wastes is the Resource Conservation and Recovery Act (RCRA) which was revised and reauthorized in 1984, although other laws provide regulations pertaining to this subject.

There are many designations of waste in the California regulatory scheme which trigger certain management actions. The ones which concern us most are those which impose certain restrictions on storage, transportation, handling and disposal. The Department of Health Services has the primary responsibility of classifying wastes with regard to hazard and standards for such classification are established in the California Assessment Manual (CAM). Additionally the State Water Resources Control Board (SWCRB) has a classification scheme which determines the handling procedures for wastes which it classifies.

A new piece of legislation that took effect January 1 of this year will have a major impact on the management of agricultural wastes. It is known as the Toxics Pits Cleanup Act of 1984 and will require any person discharging hazardous wastes to or through a surface impoundment to file a hydrogeological assessment report and comply with new construction and operating requirements. If the impoundment is within one-half mile of a potential source of drinking water it will require closure by a specified date. Surface impoundments include sumps and evaporation ponds. The impact of this legislation will fall upon those whose wastes are classified as hazardous and the criteria used to designate a waste as hazardous will directly include pesticide rinse waters.

It is imperative that those who are involved in any agricultural operation that produces wastes which may be designated as hazardous become familiar with the laws governing the handling of such wastes. Special permits and noticing are required along with agency inspections. Also there are specific laws and regulations governing the construction and management of waste facilities. Failure to comply will bring enforcement activity and the penalty provisions are particularly onerous. Probably the best advice one could give to a facility operator is for him to seek professional help from a reputable consulting firm.

Some specific case examples will illustrate what action is being taken by the various agencies in regard to agricultural industry wastes. These examples will show how the agencies are interpreting the law. These examples are drawn from the actual experiences of the past. Some information will be given concerning the new legislation and how these laws are being interpreted.

Conclusions

An extensive array of laws and regulations have been established in California to assure that so-called hazardous wastes are not adversely affecting our environment. Many state agencies have jurisdiction in this area and there seems to be overlapping authority that leads to some confusion. The recent legislative and regulatory documents requiring certain compliance procedures will impose a severe economic impact upon the agricultural dealer-distributor of pesticides and perhaps less severe on the fertilizer dealer. Failure to comply will bring serious penalties. Some case studies will be presented to illustrate the points made.

COLLECTION OF GERMPLASM AND ITS APPLICATION

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1. Sources. Many sources of germplasm are available to investigators:

a. Seed companies -- sources of modern and standard cultivars.

b. Germplasm banks -- for example, the U. S. National Germplasm System.

c. Curatorial collections, like the Tomato Genetics Stock Center.

d. Other specialists in the area of research, who can often provide advanced breeding lines.

e. Botanical gardens, which often maintain seed supplies for exchange, usually consisting of wild species.

f. Local expeditions in regions of crop antiquity. As examples, Yeager's "heirloom beans" in New Hampshire and Esquinas-Alcázar's local melon cvs. of Spain contain unexpected genetic variation. As a variant on this theme, specific variants can be sought to advantage in local commercial plantings. As examples, such scanning successfully yielded resistance to brown blight in lettuce, monogerm beets, and male-sterile tomatoes. Effective screening devices are essential to the success of this method.

g. Exploration in primary or secondary centers of variability usually provides the richest store of genetic variability. Such enterprises - of a private, institutional, or international character -- are generally well known are are the form of activity most popularly associated with germplasm acquisition.

An important aspect of collecting in the native areas that is often neglected is recording features of the habitat. In our experience with *Lycopersicon* spp,, such observations have led to utilization of germplasm that might otherwise have been overlooked. Examples include tolerance of such stresses as low temperature, drought, waterlogging, salinity, and insect attack. Another critical aspect of collecting is to obtain samples adequate to represent native variability: clearly much larger sampling must be done for highly outcrossed species than for inbreeders.

Acquisition of germplasm is only the start of a series of activities to be performed if the germplasm bank is to fulfill its purposes.

2. Maintenance. It is necessary to increase and preseve each accession. The original genotype(s) should be preserved as faithfully as possible, and and storage conditions should permit the longest possible viability of propagules.

3. Basic studies. Botanical identification of accessions is essential to their proper classification. Genetic, cytogenetic, biochemical, and morphological studies can provide information useful to the breeder.

4. Evaluation. A highly important, yet often neglected activity is evaluation of the collections. It is clear that unless accessions are properly evaluated, their traits cannot be fully utilized. Yet, in spite of general acknowledgement of this fact, most germplasm collections have not been satisfactorily evaluated. One reason for this dilemma is the large labor requirement of evaluation. Changes in the spectrum of disease and insect pests and in crop management practices may require future reevaluation of accessions; thus, evaluation can be a never-ending task.

5. Correlated activities. Prebreeding ranks high in importance amongst these activities. 'Prebreeding' refers to controlled introgression of wild traits into the genetic background of the cultivated species in order to provide breeders with more useful germplasm than the original wild sources. A prime

example of prebreeding and its benefits is the conversion of the sorghum collection conducted by the USDA in cooperation with the Texas Agricultural Experiment Station and the Tropical Agriculture Research Station in Puerto Rico. Until this collection of some 500+ lines was converted to dwarf, daylength-insensitive types, it was impossible to evaluate their respective characters. Investigating the genetic determination of desired traits and breeding improved cultivars are additional, logical correlated activities.

6. Distribution. An important responsibility of any germplasm unit is to distribute samples to *bona fide* investigators. This function can be fulfilled effectively provided justice is done to the aforementioned list of germplasm bank responsibilities.

The presentation will be illustrated primarily with examples from the writer's experience with *Lycopersicon*.

PLANT BREEDING PROBLEMS NEEDING SOLUTIONS--
CONVENTIONAL OR BIOTECHNOLOGICAL!

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Most of the significant problems facing plant breeders fall into one of four broad categories: breeding for increased yield, breeding for resistance to diseases and insects, breeding for improved quality, and breeding for stress tolerance. These problems are attacked by assembling appropriate sources of variability and then recombining desired attributes into improved varieties. Major sources of variation are world or country collections of strains of the cultivated species of the crop, related weedy or wild species, induced mutation, and genetic engineering. Many plant breeders are routinely using the first three sources of variation, and are contemplating what genetic engineering has to offer. The plant breeders' expectations of genetic engineering are that it will either permit the accomplishment of gene transfers which are otherwise impossible, or at least allow faster accomplishment of traditional transfers. Examples of how plant breeders have utilized, or would like to utilize, the different sources of variation are illustrated in Table 1 for a self-pollinated cereal crop, rice.

In breeding for yield, world collections clearly have been the mainstay for plant breeders in this crop. Thus most of the yield advances to date have resulted from direct selection or from recombining lines from world collections. Two useful yield-related characters, semidwarfism and early maturity, have also come from induced mutation, and cytoplasmic male sterility for hybrid rice came from a wild species in China. However, rice yields are now plateauing in California, and plant geneticists and breeders are searching for new ways to increase yield. One such way would be through use of F_1 hybrids, which are grown on 6 million hectares in China, and are reported to show 15-20% heterosis for grain yield. In the US, however, high cost of hybrid seed (10x normal) and difficulty of obtaining satisfactory grain quality in heterotic combinations make the use of the Chinese source of hybrid rice unlikely. An interesting opportunity to economically capture the increased yield of hybrids would be through use of apomixis (asexual seed production). Apomixis offers the potential for production of true-breeding F_1 hybrids with permanently fixed heterosis. Though widespread in forage grasses, citrus, berries, and guayule, apomixis has been found in only two cereal grains, sorghum and pearl millet. To find and utilize this unusual form of reproduction in rice probably will take all the tools and sources of variation available to plant geneticists and breeders.

To date adequate sources of disease and insect resistance have been found in world collections and/or weedy species of rice. However, because of heavy reliance on vertical resistance, rapid shifts are occurring in races and biotypes of major diseases and insects, raising the specter that natural sources of resistance will one day be exhausted. Should this happen, rice breeders will look to genetic engineers for creation of new genes. Even at the present time, sheath blight disease, caused by the fungus Rhizoctonia solanii, is providing stiff challenges to conventional plant breeding. In the southern US, this organism attacks both soybeans and rice, and satisfactory resistance is available in neither crop. In fact sheath blight appears to attack almost anything green, though fortunately not at disastrous levels (yet?). Control mechanisms for this disease, from any source, are eagerly awaited.

Sufficient variability for two grain quality components, physical appearance, and amylose/amylopectin fractions, have been found either in world collections or through induced mutation. The latter source has been particularly useful in California, where Dr. H. L. Carnahan and his associates at the California Cooperative Rice Research Foundation induced a waxy mutant in the best-yielding standard variety at the time, and thus conducted a successful breeding program for this minor crop use with relatively little effort. The other principal component of grain quality, protein quantity and quality, has proven rather intractable to conventional breeding techniques. In fact, most rice breeders of the world have abandoned attempts to change protein in this primarily energy-source crop. A few years ago, Dr. Gideon Schaeffer, USDA-ARS at Beltsville, MD, used feedback-inhibition techniques to select high lysine lines from rice cell culture. Early generations of regenerated lines seemed to have increased lysine and protein levels. This type of selection is being undertaken at additional laboratories, and may yet provide the needed increases.

Stress tolerance usually has been found in world collections, but large environmental effects have slowed conventional genetic selection progress. Genetic engineering techniques, especially tissue culture, would seem to offer great advantages for rapid and reproducible selection for stress resistance, although at the final stages it is necessary to go back to field testing in variable environments to measure the progress.

Table 1. Sources of variation which have provided (X) or expected to provide (e) solutions to rice breeding problems. Blanks indicate that the source of variation has not been investigated for, or has failed to provide, the needed solution.

Problems	Sources of Variation			
	World collections	Weedy species	Induced mutation	Genetic engineering
Yield				
-adaptation	X			
-early maturity	X		X	
-biomass	X			
-photosynthetic effic.				e
-semidwarfism	X		X	
-F_1 heterosis	X	X		
-apomixis	e	e	e	e
Disease and Insect Resistance				
-diseases	X	X		e
-insects	X	e		e
Grain Quality				
-physical appearance	X			
-starch	X		X	
-protein				e
Stress Tolerance				
-cold	X			e
-iron toxicity	X			e
-salinity	X			e
-herbicides	X		e	e

Tissue Culture and Crop Improvement

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Plant tissue culture techniques are being more widely used now in industry for plant propagation and crop improvement. Micropropagation of plants via shoot cuttings is well established for the orchid and ornamental industries and will soon be a major propagation method for potato plant production. Plant propagation using somatic (asexual) embryogenesis has reached a semi-commercial stage for oil palm. Micropropagation is also being used in forestry to produce clones used for progeny tests. The creation of haploid plants from anther culture followed by diploidization to produce homozygous parents for breeding has reached the stage for some crops such as tobacco, wheat, and rice where extensive field tests have been accomplished and commercialization begun (in China). Several chemical companies and other groups have produced elite plants selected in vitro either with or without mutagenesis treatment. Unique hybrids not available through traditional breeding methods have been produced following protoplast fusion. In some cases, the hybrid plants have been intergeneric. Finally, in a few instances, plant genes from one species have been inserted into a different species using recombinant DNA methods.

In all the examples presented, a regeneration event is an essential requirement for use of the selected or modified plant material. Although plant regeneration is a phenomenon reported for a wide variety of species, the overall quality of a population of tissue culture propagules (such as somatic embryos) has not been examined in most instances. This is a critical aspect for recovering plants and maintaining fidelity of the selected or modified plant material for either breeding or propagation purposes.

A second problem is the actual propagation and delivery of elite plants to the greenhouse or field. Micropropagation has been proven to be useful for high unit-value crops such as orchid but is unsuitable for most vegetable and field crops because the technique is so labor intensive and expensive. An alternative for micropropagation is the use of somatic embyros, since the cost of producing embryos is substantially less than that for micropropagation. By subsequently encapsulating the somatic embryos, a discrete delivery package can be produced to serve as a substitute or analog of true, botanic seed.

MATERIALS AND METHODS

Alfalfa (Medicago sativa L.) callus was produced on SH agar medium (Shenk and Hildebrandt 1972) containing 25 uM naphthaleneacetic acid and 10 uM kinetin. The callus was placed in SH liquid medium with 50 uM 2,4-dichlorophenoxyacetic and 5uM kinetin for a three-day induction period. The callus was collected, sieved, washed, and placed in hormone-free SH liquid medium containing 50 mM proline and 25 mM ammonium for somatic embryo regeneration. After three weeks in the regeneration medium, the embryos were placed on half-strength, SH agar medium for embryo-to-plant conversion, which took 3-5 weeks.

Newly regenerated somatic embryos of 3-8 mm length were mixed in 3.2% w/v BDH (Gallard-Schlesinger Company) sodium alginate (a seaweed hydrogel) and dropped singly into a 50 mM calcium chloride solution to form 4-5 mm diameter, hydrated, calcium alginate beads. After 30-60 minutes incubation, the encapsulated somatic embryos were washed and placed on half-strength SH medium for plant conversion.

RESULTS AND DISCUSSION

Initially, liquid-produced alfalfa somatic embryos, although produced in high numbers, were of poor quality. The shape of the embryos was spherical and the frequency of conversion to plants was less than 0.5% of the random-picked embryos of 1 mm size or greater. Although plants could be produced, the frequency was far too low to be of value as a propagation system. By changing the regeneration conditions such that the embryos were collected after two weeks, washed, sized, and placed back in fresh regeneration medium for an additional two weeks, the quality or convertibility of the embryos was markedly improved. The embryos were now bipolar and conversion was increased to 8% of random-picked embryos. A $4^{o}C$ cold storage treatment of the harvested embryos for 3-5 weeks (prior to conversion plating) further improved the quality of the embryos, increasing subsequent conversion to 30%. Despite the equally high numbers of embryos produced using the various conditions, gains in quality and conversion were achieved by modifying the regeneration and conversion steps. The conversion frequency of these high quality somatic embryos is now sufficiently high enough for use in plant propagation.

Encapsulation of alfalfa somatic embryos using alginate was not detrimental to the embryos. Complexation occurred at room temperature in a low molar salt solution without the need for damaging, cross-linking agents such as glutaraldehyde. The encapsulated somatic embryos could be stored at $4^{o}C$ for at least one month without adverse effects. The conversion of alginate-encapsulated somatic embryos was equal to that for non-encapsulated controls. The capsules did slightly slow the conversion rate of the embryos but not the frequency. The alginate served as a useful substrate for containing the embryos and allowing rough handling of the capsules without damage to the fragile embryos.

The production of high-quality somatic embyros that convert to plants at a high frequency has not been an issue for most researchers, since the recovery of a single plant or a few plants from somatic embryos has previously been a major accomplishment. Much more attention is required in this area for somatic embryos to be a useful tool for recovery and propagation of elite material. The encapsulation method using the hydrogel sodium alginate was very successful and more useful than other types of hydrogels such as carrageenan, locust bean gum, or guar gum. The calcium alginate capsules provided a mechanism for handling tissue culture propagation in a manner analogous to that for seed.

CONCLUSIONS

The quality of embryo-to-plant conversion of alfalfa somatic embryos was substantially increased from less than 0.5% to 30% of random-picked embryos. By varying the tissue culture conditions (media, timing, handling of material), this frequency should continue to increase. Such high-frequency conversion is required for using somatic embryogenesis as a propagation system for elite plants.

Alginate was very useful for encapsulating somatic embryos in hydrated capsules. The gel capsules may also serve to contain and deliver nutrients, plant growth controlling or promoting compounds or microorganisms, pesticides, and other active adjuvants. A major requirement now is to transfer the current *in vitro* conversion requirement of encapsulated somatic embryos to a greenhouse or field conversion situation where the utility of artificial (somatic) seeds can be more fully assessed.

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BIOTECHNOLGY & CROP IMPROVEMENT

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There are many forms of crop improvement that generally fall into one of three categories. The first is to increase crop yields by increasing resistances to pests or environmental conditions or by developing more productive plants. The second is to improve crop quality by enhancing such features as nutritional value, flavor, or processability. The third is to reduce agricultural production costs by reducing a crop's dependence on chemicals or by making harvesting easier.

During the last century, plant breeders have been efficiently and successfully addressing all of these goals. Thus, the use of biotechnology in crop improvement is not a new beginning, but an extension of previously evolved skills. Biotechnology alone will not produce better crop plants, but combined with knowledge from other plant science and microbiological disciplines, biotechnology will develop techniques that could be very powerful in improving agriculturally important crops.

The power of biotechnology, using recombinant DNA technology, lies in its precision and diversity. The ability to precisely identify and specifically transfer genetic information into a plant will decrease the traditional breeding time. Instead of crossing two compatible plants for a particular trait and then backcrossing to the desirable parent, recombinant DNA technology allows a specific gene to be transferred to a plant without it carrying any unwanted traits.

The diversity of genes that can be transferred to plants is the other major benefit of biotechnology. With traditional plant breeding, only genes in sexually compatible plants can be transferred. Using recombinant DNA technology, however, genetic material from any plant, bacterium, or animal can be used, thus vastly expanding the pool of genetic traits that can be engineered into important crops. Biotechnology, therefore, shortens time frames for introducing new, marketable varieties by combining the precise transfer of genes with the diverse sources of these genes.

To create a new variety of plant using biotechnology, an agronomically useful gene is identified and isolated using recombinant DNA technology. This gene is spliced to appropriate DNA regulatory sequences and to a DNA vector, which will promote the transfer of the foreign gene into plant cells. The vector-gene construct is introduced into cultured plant cells. These cells are then regenerated into whole plants, where each cell of these plants contain the new gene.

The biggest problem facing plant biotechnologists now is the lack of knowledge of genes that are likely to improve plants. Due to the amassed knowledge of plant genetics, many characteristics are known to be encoded by one or a few genes. But, in most cases, they are only identified by their phenotypic expression. Some examples include herbicide tolerance, disease resistance, and production of some secondary metabolites. Plant biotechnologists are tackling what appears to be the simplist systems first. It will be longer before they have potentially marketable results with multigenic traits, such as yield, photosynthetic efficiency, and nitrogen fixation.

Even though the application of recombinant DNA technology to plants is relatively recent, the science has proceeded very rapidly. Biotechnology will certainly be important both in understanding plant function and in developing new crops.

PYDRIN® ULV: EFFECTS ON BENEFICIAL AND PEST INSECTS IN COTTON

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Interest has grown in the use of vegetable oils as carriers for application of pesticide. During 1982 the California Department of Agriculture granted label approval for use of three pyrethriod insecticides to be applied to cotton in vegetable oil at reduced or ultral low volumes, less than one gallon of mixture per acre. These pyretrhoids are Pydrin® which is fenvalerate, Pounce® and Ambush® which are both permethrin.

Reports from other states, especially Arizona, concerning the use of pyrethroid insecticides in cottonseed oil were favorable, but information on efficacy and safety were still concerns of the Imperial County Agricultural Commissioner, growers and pest control advisors. Growers and agricultural consultants were particularly interested in a potential use of a cotton product by the cotton industry, and by reports of greater product efficacy, longer residual activity, better coverage of crop surfaces from oil spreading, reports that oil doesn't wash off the crop and reports of better canopy penetration. Also, the growers were anticipating lower cost of application.

The reduction of spray volume allows for greater acreage coverage from a single fill of the aircraft spray tank. This is especially important to the aerial applicators requiring fewer landings for tank refill. Fewer landings and refills saves time and labor costs from which growers anticipate lower charges for insecticide applications.

Ultimately the goal of most aerial applications is to distribute the desired amount of materials at the precise target site with a minimum loss to the environment. One of the most significant problems facing plant protection and pesticide users is worker-applicator safety, and reduction of pesticide contact with non-target crops while maintaining target contact efficiency.

Though some objectives concerning measurement of droplet size and drift will be mentioned, but only results of the impact on pest and beneficial insects of Pydrin® applied in cottonseed oil versus conventional application of Pydrin® in water will be reported. The preliminarly and ongoing studies of agricultural engineering from the University of California, Davis, have helped set the parameters for aerial application treatments used in these studies.

Objectives

The evaluation of advantages and disadvantages of ULV applications of cotton insecticides in cottonseed oil carrier was the primary objective. Research was conducted to determine the efficacy and drift hazards for different drop size spectra, volumes of oils and water carrier for insecticide applications in the southern desert valleys of California.

Pest control efficacy studies were primarily for Heliothis spp. larvae and pink bollworm. Evaluation of the effects on other pests (when present) were also of interest. Further, it was of interest to determine the effects of insecticide applied in oil or water at various droplet sizes and volumes on beneficial insects and spiders in cotton fields.

Measurements of the impact spray drift downwind from one and two quart per acre cottonseed oil diluted insecticide and from an optimum nozzle system based on wind tunnel studies were other objectives.

Procedures

Field efficacy tests were necessary to select the optimum drop size spectrum and total insecticide oil volume which will minimize drift without seriously changing efficacy for insect pest control or the economics of this method of application.

The insecticide efficacy tests and effects on beneficials were evaluated during three years from 1982 through 1984 in the Imperial Valley. Use of cotton fields was acquired through cooperation with a local grower and pest control advisor. Pydrin® 4L insecticide was applied three times in 1982 and Pydrin® 2.4EC six times in 1983 and 1984 during the middle to later part of the cotton growing season. During 1983 Pydrin® 4 OS was also evaluated since it is a formulation specifically for oil sprays.

Large blocks of cotton were used for each treatment to minimize contamination between treatments due to drift. All treatments were applied with a fixed-wing aircraft. Plots were arranged in a randomized complete block design with three replications. The treatments for the three years were as follows:

1982 Pydrin® 4L in 1 qt CSO (cottonseed oil) at 0.125 lb ai/Ac using 8002 flat fan nozzles 90^{O} to the air stream with 25 psi pressure. Vmd 175-200 microns.

Pydrin® 4L in 5 gal of water at 0.125 lb ai/Ac using D6-46 nozzles 90^{O} to the air stream with 32 psi. Vmd 200-300 microns.

1983 Pydrin® 4OS (oil spray concentrate) in 1 qt CSO at 0.125 lb ai/Ac using 8001 flat fan nozzles 90^{O} to air stream with 25 psi pressure. The swath width was 60 feet using 28 nozzles. Vmd 175-200 microns.

Pydrin® 4OS in 2 qt CSO at 0.125 lb ai/Ac using 8004 flat fan nozzles 0^{O} to the air stream with 25 psi pressure. The swath width was 50 feet using 14 nozzles. Vmd 275-300 microns.

Pydrin®2.4EC in 1 qt CSO at 0.125 lb ai/AC using 8001 flat fan nozzles 90^{O} to the air stream with 35 psi pressure. The swath width was 60 feet using 30 nozzles. Vmd 175-200 microns.

Pydrin®2.4EC in 5 gal of water at 0.125 lb ai/Ac using D6-46 nozzles 90^{O} to the air stream with 40 psi pressure. The swath width was 50 feet with 12 nozzles. Vmd 200-300 microns.

1984 Pydrin® 2.4EC in 1 qt CSO at 0.125 lb ai/Ac using 8001 flat fan nozzles 90^{O} to the air stream with 35 psi pressure. Swath with 60 feet. No. nozzles 30. Vmd 175-200 microns.

Pydrin® 2.4EC in 1 qt CSO at 0.125 lb ai/Ac using 8002 flat fan nozzles. 45^{O} to the air stream with 35 psi pressure. Swath with 60 feet. No. nozzles 15. Vmd 275-300 microns.

Pydrin® 2.4EC in 2 qts CSO at 0.125 lb ai/Ac using 8002 flat fan nozzles 45^{O} to the air stream with 35 psi pressure. Swath with 60 feet. No nozzles 30. Vmd. 275-300 microns.

Pydrin® 2.4EC in 5 gal H_2O at 0.125 lb ai/Ac using D8-6 nozzles 90^{O} to the air stream with 40 psi pressure. Swath with 50 feet. No. of nozzles 30. Vmd 275-300 microns.

Treatment and sampling dates for the three years were as follows:

1982	Treatments	September 28, October 8 and 18
	Sampling	October 1, 6, 12, 15, 22, and 25
1983	Treatments	August 19 and 29, September 9, 19 and 26, and October 1
	Sampling	August 22 and 26, September 2, 6, 12, 16, 21, 30, and October 4
1984	Treatments	August 7, 13, 18, 24, 30, and September 5
	Sampling	July 27, August 10, 17, 23, 27, September 3, 10, 14 and 20

Sampling consisted of collection of susceptible (14 to 21 day old) bolls from each treatment in each replicate. During 1982, 100 boll samples were taken; 50 boll samples in 1983 and 30 boll samples in 1984. The susceptible bolls were taken to the laboratory where they were cracked open and carefully picked apart in search for pink bollworm (PBW) larvae. All PBW larvae were counted and the numbers recorded for each treatment.

Further sampling was examination of cotton terminals for *Heliothis* spp. eggs and larvae. For each of the three years 50 cotton terminals from each treatment in each replicate were randomly selected and examined for *Heliothis* spp. eggs and larvae. The eggs and larvae were counted and the numbers recorded for each treatment.

All other samples were taken with a D-vac insect vacuum. Vacuum samples of 100 suctions per treatment during 1983 and 50 suctions per treatment in 1984 were taken from each replicate. The D-vac samplies were kept cool during transportation to the laboratory where insects were extracted using Berlese funnels. The insect samples were then examined under binocular disecting microscopes. Counts of the following insects were recorded.

Beneficials:	Predators	Parasitic wasps
	minute pirate	*Encarcia* spp.
	damsel bug	*Erotmoscerous* spp.
	assassin bug	*Trichogramma* spp.
	lady beetles	
	lacewings	
	spiders	
Pests:	sweetpotato whitefly	
	bandedwing whitefly	
	lygus bug	
	leafhoppers	

The data compiled was summarized and analyzed using analysis of variance for randomized complete block design. Means of significant difference were seperated using Duncan's Multiple Range test.

Results and Discussion

During 1982 the PBW larval population was found to be at a very low level through the study. The pre-treatment larval means of one and two larvae per 100 susceptible bolls were not statisically different at 0.05 level of significance (Table 1). This indicated that the PBW population was homogenous throughout the cotton fields prior to treatment with Pydrin®. The number of PBW larvae in susceptible bolls was not found to be statistically different after two applications of Pydrin ten days apart for any of the four sampling dates (Table

2). The PBW population in susceptible bolls was at such a low level that further samples were not taken. Monitoring of the PBW male moths using pheromone traps was not used as a sampling technique; however, through communication with the pest control advisor and cotton grower, it was learned that the PBW moth pressure had been light throughout the season.

Pre-treatment egg and larval means for Heliothis were found not to be statistically different at the 0.05 level of signficance (Table 3). Here again, the population for this insect was also found to be homogenous throughout the fields. Furthermore, the egg deposition was found to be statisically the same for both the Pydrin in oil and Pydrin in water-treated areas. This would indicate that the female Heliothis moths were equally attracted to both treatment areas (Table 4).

The most interesting results are found in Table 5, the efficacy of control for Heliothis spp. larvae being statistically different for the two treatments. The total number of Heliothis larvae per fifty cotton plant terminals was lower in the Pydrin® in oil treated areas for each sampling date. A controlled check area without insecticide treatments was not made available by the grower and thus percent control data could not be generated.

For 1983 analyzing the data on all dates resulted in a significant difference in the number of Heliothis spp. larvae found in cotton terminals between the Pydrin® 2.4EC applied in five gallons of water and the Pydrin® 2.4EC applied in one quart of cottonseed oil, Duncan's at 5% level. This was the same result found in a similar ULV study conducted north of Westmorland in 1982. There was no significant difference between larval counts for any of the other treatments, Table 6.

There were no significant difference in the number of Heliothis spp. eggs deposiited in the terminals of cotton plants in the four treatments. This was also the case in 1982. The whitefly and beneficial insect populations were not significantly different between any of the treatments in 1983.

The Heliothis spp. egg distribution across the treatments was fairly uniform suggesting that there was no repellancy or moth kill differences between any of the treatments. It also appears that the beneficial insect populations are no more susceptable to kill by Pydrin® in oil than they are to kill by Pydrin® in water. There was no difference in beneficial insect kill between the one and two quarts of cottonseed oil per acre applications of Pydrin®.

During 1982 and 1983 the PBW population in the fields under study were moderately to very low. The opposite was true for 1984 it being a year with severe wide spread PBW infestations. Thus 1984 provided a stronger test for ULV oil applications of Pydrin for pinky control than the two previous years.

The pinky data was summarized in two manners. Firstly, the number of PBW larvae per 30 bolls was recorded for each treatment in each replicate. Analysis of this summary results in the one quart CSO treatment using 8002 flat fan nozzles having the poorest control of PBW with a mean of 6.1 larvae per 30 bolls which was significantly more than other treatments at the 0.01 level of significance. The mean number of pinky larvae for the other treatments were as follows:

	Mean # of PBW larvae/30 bolls
Pydrin® 2.4EC in 1 qt CSO using 8001 flat fan nozzles	2.7
Pydrin® 2.4EC in 5 gal water using D8-46 hollows cone nozzles	2.6
Pydrin® 2.4EC in 2 qt CSO using 8002 flat fan nozzles	2.6

Reporting the number of PBW larvae per 30 bolls does not indicate the percentage of bolls that were infested with PBW since one treatment may have a boll with six larvae and another treatment six boll with one larva each. For this reason percent infested bolls for each treatment was based on the number of infested bolls per 30 cotton bolls regardless of how many larvae were in an infested boll. As a result the Pydrin® in one quart of CSO using 8002 flat fan nozzles was again the most infested with an overall mean of 12.2 percent infested bolls which was signficantly worse than the Pydrin® in one quart of CSO using 8001 flat fan nozzles with a mean of 6.5 percent infested and the Pydrin in 5 gal of water using D8-46 hollow cone nozzles with a mean of 6.2 percent infested bolls. The Pydrin® in two quarts of CSO using 8002 flat fan nozzles had a mean of 7.1 percent infested bolls which was not significantly different from any of the other treatments at the 0.01 level of significance. The overall means and means of each sampling date for the percent infested bolls is summarized in Table 7.

Prior to the treatments used in the study the PBW boll infestation was found to be statistically homogenous across all areas to be treated using the 0.01 level of significance.

The distribution of Heliothis spp. eggs among the different treatment plots was homogenous as indicated by the lack of signficant differences among the treatment means at the 0.05 level of significance. The treatment means overall had a very narrow range from 2.8 to 2.1 as indicated in Table 8.

Heliothis spp. larvae remained at very low levels through the duration of the study. Treatment means ranged from 0.7 to 0.3 larvae per 50 cotton terminals. This resulted from low numbers of eggs having been layed through the study period as evidenced in Table 8. The egg lay was very low on later sampling dates. The rapid succession of Pydrin® applications for PBW control and possibly predation by bigeyed bugs, minute pirate bugs, lacewing larvae probably also were partly responsible for the low number of Heliothis spp. larvae as indicated in Table 9.

The sweetpotato whitelfy (Bemisia tabaci Gennadius) population was very high through the study. The population also remained homogeous among the treatments indicating no differential effects on the population as a response to the different treatments. Treatment means overall ranged from 3901 to 5057 adults per 100 D-vac suctions with no signficant differences between any of the treatments. Other pests such as the bandedwinged whitefly (Trialeurodes abutilonea Haldeman) and leafhoppers such as Empoasca solana Delong remained at low levels through the study and no significant differences amoung treatments resulted. This was also true for lygus bugs, mites, and flea beetles.

Beneficial insect populations were small throughout the study. Populations of parasitic wasps such as Encarcia spp. and Erotmoscerous spp., both whitefly parasites, were very low, as were Trichogramma spp. wasps which are egg parasites of lepidopterous insects such as Heliothis spp. Analysis of the data collected indicated no significant differences among treatment means. This was also true for lacewings, lady beetles, and spiders, all predators.

The populations of predacious bugs (minute pirate bug, damsel bug, bigeyed bug, and assassin bug) were at low levels resulting in no significant differences between treatments. It should be noted that these results for the beneficial insects, whiteflies, lygus, and leafhoppers are consistant with the results obtained in 1983.

Conclusions

In preliminary studies using Pydrin® applied to cotton in low volumes it appeared that this method of application provided superior control of Heliothis spp. larvae as compared to the standard application of Pydrin® in three to five gallons water. This result was consistant for 1982 and 1983 study years for the Pydrin® in one quart of CSO applied at 0.125 lbs. ai/Ac using 8001 flat fan nozzles placed 90 degrees to the air stream flowing past the boom resulting in a droplet spectrum with a vmd of 175-200 microns. The 1984 Heliothis population was at too low a level for a meaningful analysis.

The PBW population during 1982 and 1983 was low in the study plots, but meaningful data was collected during 1984. It is interesting to note that the Pydrin® in oil applications provided equal control of pinkies with the exception of the one quart CSO treatment using 8002 flat fan nozzles.

The 1983 and 1984 data suggests that it may be in the best interest of cotton growers to use the two quarts of cottonseed oil per acre application of Pydrin® with a droplet size spectrum of 275-300 microns vmd in order to minimize drift. Studies by Akesson and Yates at UC Davis and by Dr. George Ware at UA Tucson, indicate up to 30 percent loss of the insect mixture in one quart of cottonseed oil applications with a vmd of 100-200 micron droplets. That is 30 percent of the insecticide mixture is not deposited in cotton fields treated, but is lost as drift.

Drift may lead to several serious problems. Drift onto crops adjacent to cotton may cause illegal residues and crop confiscation. If Pydrin® or other insecticides registered for oil application on cotton, drift into adjacent alfalfa fields, beneficial insects may be killed. Drift may complicate or accelerate insect resistance to pryethroids or other insecticides. Water may also become contaminated with insecticides due to drift.

More research has been conducted on insecticide drift in relation to droplet size and oil application by Akesson, Yates, and Brazelton. Some of the research was conducted in the Imperial Valley. From drift studies and further efficacy studies, we hope to be able to minimize drift from insecticide applications in oil and yet maintain good insect pest control.

Table 1 Pretreatment Count of Pink Bollworm

Larvae on Cotton, Imperial Valley, 1982

Insecticides[1/] to be Applied	Rate lb ai/A	Replicates	Sampling Date 9/28/82	Mean # Larvae
Pydrin® 4L In 1 qt oil Per Acre	0.125	I	2[2/]	
		II	1	1 A[3/]
		III	0	
		Total	3	
Pydrin® 2.4E In 5 gal of Water/A	0.125	I	5	
		II	1	2 A
		III	0	
		Total	6	

1/ Insecticides were applied between 5:00 and 7:00 p.m. September 28, 1982.

2/ Number of pink bollworm larvae per 100 susceptible bolls, means from 3 replicates.

3/ Means followed by the same letter are not statistically different at the 0.01 or 0.05 level of significance; Analysis of Variance and Duncan's Multiple Range Test.

Table 2 Chemical Control of Pink Bollworm Larvae on Cotton

Comparison Between Pydrin® in Oil and Pydrin® in Water, 1982

Treatments[1/]	Rate lb ai/A	Replicate	Sampling Dates 10/1	10/6	10/12	10/15	Total of all Samples	Mean # Larvae
Pydrin® 4L In 1 qt oil per Acre	0.125	I	3[2/]	0	3	0	6	
		II	3	0	0	0	3	3.7 A
		III	0	1	1	0	2	
		Total	6	1	4	0	11	
Pydrin® 2.4E In 5 gal of Water/Acre	0.125	I	1	0	1	2	4	
		II	1	0	0	0	1	1.7 A
		III	0	0	0	0	0	
		Total	2	0	1	2	5	

1/ Insecticides applied: 9/28,10/8, and 10/18/82.

2/ Number of pink bollworm larvae per 100 cotton bolls, means from 3 replicates.

3/ Means followed by the same letter are not statistically different at the 0.01 or 0.05 level of significance; Analysis of Variance and Duncan's Multiple Range Test.

Table 3 Pretreatment Count of Heliothis spp. Eggs and Larvae on Cotton, Imperial Valley, 1982

Insecticides[1/] to be Applied	Rate lb ai/Ac	Replicates	Sampling Date 9/28/82	Mean # Eggs + Larvae
Pydrin® 4L	0.125	I	28[2/]	
In 1 qt oil		II	17	23 A[3/]
Per Acre		III	24	
		Total	69	
Pydrin® 2.4E	0.125	I	14	
In 5 gal of		II	30	24.7 A
Water/Acre		III	30	
		Total	74	

1/ Insecticides were applied between 5:00 and 7:00 p.m. September 28, 1982.

2/ Number of Heliothis eggs and larvae per 50 cotton terminals, means from 3 replicates.

3/ Means followed by the same letter are not statistically different at the 0.01 or 0.05 level of significance; Analysis of Variance and Duncan's Multiple Range Test.

Table 4 Egg Counts of Heliothis spp. on Cotton

Comparison of Treatments with Pydrin® in Oil and Pydrin® in Water, 1982

Treatments[1/]	Rate lb ai/Ac	Replicate	Sampling Dates 10/1	10/6	10/12	10/15	10/22	10/25	Total of all Samples	Mean # Egg
Pydrin® 4L	0.125	I	13[2/]	13	14	15	3	14	72	
In 1 qt		II	13	17	14	19	6	10	79	75 A[3/]
Oil Per		III	24	19	11	8	6	6	74	
Acre		Total	50	49	39	42	15	30	225	
Pydrin®	0.125	I	25	22	20	16	6	10	99	
2.4 E In		II	10	11	18	16	13	7	75	77 A
5 gal of		III	19	14	5	14	1	4	57	
Water/Acre		Total	54	47	43	46	20	21	231	

1/ Insecticides applied: 9/28, 10/8, and 10/18/82.

2/ Number of Heliothis spp. eggs per 50 cotton terminals, means from 3 replicates.

3/ Means followed by the same letter are not statistically different at the 0.01 or 0.05 level of significance; Analysis of Variance and Duncan's Multiple Range Test.

Table 5 Chemical Control Comparison of Heliothis spp. Larvae:

Comparison Between Pydrin® in Oil and Pydrin® in Water, 1982

Treatments[1]	Rate lb ai/Ac	Replicate	Sampling Dates 10/1	10/6	10/12	10/15	10/22	10/25	Total of all Samples	Mean # Larvae
Pydrin® 4L	0.125	I	4[2]	9	1	1	3	1	19	
In 1 qt oil		II	9	13	4	4	0	1	31	35 A[3]
Per Acre		III	11	18	2	3	0	1	35	
		Total	24	40	7	8	3	3	85	
Pydrin®	0.125	I	10	47	17	5	6	20	105	
2.4E In 5		II	17	27	14	15	11	9	93	85.7 B
gal of		III	15	31	9	3	1	5	64	
Water/Acre		Total	37	105	40	23	18	34	257	

1/ Insecticides applied: 9/28, 10/8, and 10/18/82.

2/ Number of Heliothis spp. larvae per 50 cotton terminals, means for 3 replicates.

3/ Means followed by the same letter are not statistically different at the 0.01 level of significance; Analysis of Variance and Duncan's Multiple Range Test.

Table 6 Mean Number of Heliothis spp. Larvae/50 Cotton Terminals

Pydrin®-ULV, Imperial Valley, 1984

Treatments	Means for Sampling Dates # Heliothis Larvae/50 Cotton Terminals 8/22	8/26	9/2	9/6	9/12	9/16	9/21	9/30	10/4	Overall Means # Heliothis Larvae/50 Cotton Terminals Duncan's 0.01 level
Pydrin® 2.4EC In 1 qt CSO Per Acre Using 8001	1.3	1.0	0.5	0.2	2.3	2.0	3.0	3.2	3.2	1.8 A
Pydrin® 4 OS In 2 qt CSO Per Acre Using 8004	0.8	1.7	0.5	1.2	2.0	1.3	3.8	5.3	2.7	2.1 AB
Pydrin® 4 OS In 1 qt CSO Per Acre Using 8001	0.2	0.8	1.0	1.0	3.2	2.3	6.0	5.0	3.3	2.5 AB
Pydrin® 2.4EC In 5 gal water Using D8-46	1.3	1.2	1.5	0.5	3.0	2.0	5.5	7.5	3.2	2.8 B

Table 7 Percent PBW Infested Cotton Bolls

Pydrin®-ULV, Imperial Valley, 1984

Treatments	Means for Sampling Dates % PBW Infested Bolls 8/17	8/23	8/27	9/3	9/10	9/14	9/21	Overall Means % PBW Infested Bolls Duncan's 0.01 level
Pydrin® 2.4EC In 1 qt CSO Using 8001	2.2	2.2	0	10.0	16.7	8.9	5.5	6.5 B
Pydrin® 2.4EC In 1 qt CSO Using 8002	8.9	5.4	4.5	20.0	16.7	26.7	3.3	12.2 A
Pydrin® 2.4EC In 2 qt CSO Using 8002	4.4	6.5	2.2	12.2	4.4	15.6	4.5	7.1 AB
Pydrin® 2.4EC In 5 gal water Using D8-46	5.4	2.2	0	4.4	20.0	6.7	4.4	6.2 B

Means followed by the same number are not statististically different at the 0.01 level of significance.

Table 8 Number of <u>Heliothis</u> spp. Egss/50 Cotton Terminals

Pydrin®-ULV, Imperial Valley, 1984

Treatment	Means for Sampling Dates # Heliothis Eggs/50 Cotton Terminals 8/10	8/17	8/23	8/27	9/3	9/10	Overall Means # Heliothis Eggs/50 Cotton Terminals Duncan's 0.01 level
Pydrin® 2.4EC In 1 qt CSO Using 8001	4.3	5.3	1.7	1.0	0	0	2.1 A
Pydrin® 2.4EC In 1 qt CSO Using 8002	4.0	5.7	3.0	1.7	0	0.3	2.4 A
Pydrin® 2.4EC In 2 qt CSO Using 8002	3.7	7.7	1.7	1.3	1.7	0.7	2.8 A
Pydrin® 2.4EC In 5 gal water Using D8-46	5.0	6.0	1.0	1.0	0.3	2.0	2.6 A

Means followed by the same letter are not statistically different at the 0.01 level of significance.

Table 9 Number of *Heliothis* spp. Larvae Per 50 Cotton Terminals

Pydrin®-ULV, Imperial Valley, 1984

Treatment	Means for Sampling Dates # Heliothis Larvae/50 Cotton Terminals 8/10	8/17	8/23	8/27	9/3	9/10	Overall Means for # Heliothis Larvae/50 Cotton Terminals Duncan's 0.01 level
Pydrin® 2.4EC In 1 qt CSO Using 8001	0	2.3	0	0	1.0	0.3	0.6 A
Pydrin® 2.4EC In 1 qt CSO Using 8002	1.3	1.3	0.7	0	0.7	0	0.7 A
Pydrin® 2.4EC In 2 qt CSO Using 8002	0	2.3	0.3	0	0.7	0	0.5 A
Pydrin® 2.4EC In 5 gal water Using D8-46	0.3	1.0	0	0	0.7	0	0.3 A

EVALUATION OF DROP-SIZE DISTRIBUTIONS PRODUCED BY AGRICULTURAL AIRCRAFT

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During the past few decades the use of agricultural aircraft has emerged as an important tool in agricultural production. Agricultural aircraft are frequently used to apply seeds, fertilizers, and a host of pesticide materials. The application of pesticides poses the most difficult problems. Selection of the atomization system is probably one of the most important parameters that affects both the potential hazard of drift out of the target area as well as the type of coverage in the target area.

The atomization process is complex and most commercial systems produce a relatively wide drop-size spectrum. Also, the drop-size spectrum is affected by many variables such as nozzle type, operating conditions, and spray formulations. Precise drop-size spectra data is required to evaluate and predict the behavior of spray released from an aircraft. For example, NASA has developed an extensive computer code that can be used to calculate the trajectories of specific size particles released at various points on an aircraft. Thus, the drop-size spectra data can be used to estimate the percentage of spray that may drift out of the target area. In this manner, the potential drift hazard of different nozzles can be evaluated from the drop-size data. In addition, the grower is vitally concerned about the type of coverage and deposition in the target area. The volume median diameter is frequently used to specify the atomization required to attain optimum efficacy. Further research is needed to correlate the drop-size spectra chacteristics with deposition, coverage, and overall biological efficacy of specific treatments.

The objective of this paper is to illustrate some of the modern drop-size measurement techniques, present some results from a few typical atomization systems, and discuss how the results can be utilized.

Methods

A digital image analyzing system, Particle Measuring System Model OAP-2D-GA1 probe and PDPS 11C computer system, was used to measure the drops that pass through a He-Ne laser beam. The probe can measure drops from 28 to 2062 um in diameter and classifies them into 62 size classes. The unit was mounted in the test section, 2' x 2' x 8' long, of a wind tunnel. The nozzle was mounted on a x-y scanning mechanism which moved the nozzle spray pattern through the laser beam in the probe. The scanner mechanism was controlled with a microprocessor and automatically moved the nozzle through a specified number and length of passes that ensured the entire spray pattern was sampled. A series of cone, fan, and jet nozzles were tested with water to simulate atomization from nozzles used for 5 to 10 gal/acre applications. Also, fan and rotary nozzles were tested with a mixture of cottonseed oil and Pydrin blank to simulate atomization for applications of 1 - 2 qt./acre.

Results and Conclusions

Table 1 shows a summary of the drop-size data. In general, an increase in nozzle size produced a larger volume median diameter and an increase in nozzle angle relative to the airstream decreased the volume median diameter. The smaller nozzles and rotary atomizers commonly used for low volume applications of insecticides produced the smallest volume median diameter. Table 1 also shows the percent volume less than 154 um. This volume is an estimate of the potential volume that may drift out of the target area. In general, a decrease in volume median diameter increases the potential drift hazard. Thus, it is apparent that the common nozzles used for low volume applications may increase the drift hazards. A series of additional nozzles and angles were tested with the cotton-seed-oil mixture. The combination that produced the lowest volume <154 um with the cotton-seed-oil mixture was an 8002 nozzle at 45°.

Table 1

Volume Median Diameter and Percent Volume

that may drift. Airspeed = 100 MPH, Noz. Pressure = 40 psi

Nozzle Type	Nozzle Angle Relative to Airsteam degrees	Fluid*	Volume Median Diameter um **	Volume <154 um ** percent
D8-45	0	H_2O	320	7.8
	90	H_2O	261	13.4
D8-46	0	H_2O	455	3.7
	90	H_2O	304	8.7
D6	0	H_2O	927	1.1
	90	H_2O	304	10.1
8010	0	H_2O	518	4.2
	90	H_2O	260	14.6
8020	0	H_2O	651	3.5
	90	H_2O	295	11.7
8001	90	CSO	201	26.0
8002	45	CSO	277	13.1
	90	CSO	236	19.6
Micronair AU500	(5200 RPM)	CSO	170	39.7
	(8900 RPM)	CSO	145	63.1

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*CSO = 85% Cottonseed oil/15% Blank Pydrin

** um = drop diameter in micro-meters

Abstract

Rice Field Tests with Propanil/Cottonseed Oil Formulations

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We have worked for many years trying to control the drift losses of propanil both during the application and following when the propanil crystals blow off the treated rice fields and can cause symptoms on nearby sensitive horticultural crops, primarily prunes.

We have had two years of field and greenhouse testing of new formulations of propanil including use of cottonseed oil both as an additive and as a total carrier. The use of cottonseed oil was designed to "glue on" the propanil to the rice and weeds. In this respect we have seen a significant reduction in "lift off" when two gal. to full carrier CS oil was used. In order to reduce losses at the time of application we need primarily to increase the average drop size. This can be done by using the jet stream nozzle with no whirl plate, directed with the airstream on a fixed wing aircraft or across the airstream with a helicopter flown under 60 mi/hr. The use of the polymer additives is not recommended because these roughly double the drop size but do not reduce the production of the small driftable drops. With the loss of Ordram and Bolero as alternatives for rice weed control herbicides the need for propanil has become even greater than before. We hope a sound and careful program to re-introduce limited use of propanil will be successful in the northern California rice areas.

SAN LUIS OBISPO COUNTY, 2,4-D DRIFT STUDIES

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INTRODUCTION

In all probability the first complaint of 2,4-D drift damage occurred approximately one day after the first 2,4-D application. At that time the only one that heard the complaint was the wife of the farmer who suffered the damage, and there was little else that he could do about it. Times have changed -- repeated incidents of wayward phenoxy applications, and resulting damage to sensitive crops, prompted the need for regulatory action. This action came in the form of "Restricted Material Permits" regulations enacted by the California Department of Agriculture and enforced by the various County Agricultural Commissioner's Offices about the state.

The use of Restricted Material Permits, along with cutoff dates, specified environmental conditions, and regulated types of application equipment, have done much to minimize "non-target" contacts by phenoxy herbicide applications. This control has not been without cost however. The largest agricultural users of phenoxy herbicides in the state, and in San Luis Obispo County, are producers of grain crops. These traditional approaches to regulation often make effective broadleaf weed control very difficult, particularly for dryland producers.

One area where it appears that the regulations have not kept pace with technology is that of application equipment. The regulations governing application of phenoxy herbicides state that the nozzle used must have an orifice size of at least 1/16 inch diameter. This poses at least two problems in the dryland grain producing area of San Luis Obispo County. The use of a standard nozzle of this size at 30 - 40 psi pressure and operated at 5 MPH means that up to 39 gallons of water must be applied to every acre. Even when using a "low-pressure" (LP) nozzle of like size at 15 psi and operated at 5 MPH it is necessary to apply approximately 19 gallons of water to every acre. The logistics of covering thousands of acres at these rates, along with the fact that there are often long distances between water sources, can be a cause of great frustration and difficulty for a grower. The other main problem is that this single stipulation in the regulations precludes the use of one the newer technologies in herbicide application - the "Controlled Droplet Applicator", or CDA. Because this applicator does not use an orifice to actually dispense spray material it falls outside the letter of the regulations.

SUMMARY OF PAST TRIALS

Over the past three years I have been involved in a cooperative effort, with the San Luis Obispo County Agricultural Commissioner's Office, various U.C.C.E. Specialists, and Cal Poly SLO, to evaluate a number of spray applicator nozzles, including two CDAs, for drift potentials. Our intent is to determine whether it might be possible to safely amend current nozzle orifice regulations.

Results from 1982 trials indicated that *Tee-jet 8004 LP "flat-fan" nozzles reduced drift enough over Tee-jet 8004 "flat-fan" nozzles that ground applications to within one-half mile of sensitive crops was possible. The 8004 series nozzles meet present orifice regulations.

> * The use of trade names is in no way meant to be an endorsement of one product over any other similar product, and is used only for convenience and ease of reporting.

Based on the finding that LP nozzles substantially reduced drift problems another trial was conducted in 1983 to evaluate a larger series of nozzles, including two "flood-jet", two standard "flat-fan", one LP "flat-fan", and one CDA. These nozzles included orifice sizes well within regulation (TK-5 "flood-jet"), much smaller than regulation (80015 "flat-fan"), and totally outside the regulation (CDA).

The overall results from the 1983 trial, while exhibiting no mathematically significant differences, strongly indicated that the 8002 LP "flat-fan" nozzle was well within a safe range of allowable drift -- no symptoms were observed on tomato indicator plants beyond 400 feet down-wind from the end of the spray boom. Results of that trial were the basis of a report presented at the 1984 California Weed Conference by Richard D. Greek, San Luis Obispo County Agricultural Commissioner.

Due to the lack of significant differences and other deficiencies in the 1983 trial we decided that we would do a repeat in 1984, after making the appropriate adjustments.

METHODS AND MATERIALS

The express purpose of this trial was to determine drift potential of six spray nozzle designs mounted on a ground delivery system.

Nozzles tested:

(1) Tee-jet TK-5 "flood-jet".
(2) Tee-jet TK-3 "flood-jet".
(3) Tee-jet 8004 LP "flat-fan".

(4) Tee-jet 8002 LP "flat-fan".
(5) Micro-Max, at 1600 RPM, to produce 300 micron droplets.
(6) Giro-Jet, at approximately 2000 RPM, producing 250 micron droplets.

A bioassay method was used to evaluate damage and distance of drift, using tomato plants as indicators. The plot design used was a Randomized Complete Block, with three replications. A standard Analysis of Variance was used to determine significant differences between treatments (nozzles).

The tomato plants were grown under controlled conditions in greenhouses at Cal Poly SLO, and were maintained in air conditioned conditions, except for the approximately 20 minutes that they were actually in the trial area.

On April 9, 1984 the plants were taken to the trial site near Shandon, California, where stations were set up at distances of 25, 50, 100, 200, 400, and 600 feet down-wind from the end of the spray boom, and perpendicular to the direction of travel (see figure 1).

Plants for each treatment (nozzle) and test station were maintained in isolation, in closed boxes, for the duration of the trial, except for the time in the trial area. At no time were plants from one treatment allowed to touch plants from any other treatment.

Five plants were assigned to each station during each treatment. In addition to treatment groups, two sets of checks were utilized. One set of 30 plants was assigned to the stations, prior to spraying any phenoxy, and a mixture of water and surfactant was sprayed along the trial path to evaluate possible effects of the surfactant. A second set of 30 plants was set outside the air conditioned van for 20 minutes to evaluate any environmental effects not related to phenoxy damage.

The spray rig made three passes along the 400 foot path for each treatment, perpendicular to the stations and wind direction, for a total area equivalent to 1/2 acre for the conventional nozzles and 1/4 acre for the CDAs. Plants were allowed to remain in the field for ten minutes after the spraying was completed for each treatment. Two separate sprayers were used for this trial, one for the conventional nozzles and one for the CDAs. The conventional sprayer used a 20 foot boom, while the Micro-Max used a 12 foot boom and the Giro-Jet covered a 10 foot swath. Materials, rates, and nozzle parameters are shown in Table 1.

In addition to scoring plants for symptoms and damage, wind speed and wind direction data were also collected for analysis. After all nozzles were tested, the plants were returned to the Cal Poly greenhouse benches. Again care was taken to prevent plants from the various treatments and stations from contacting one another.

Plants were scored for phenoxy symptoms and damage for four successive days beginning April 10, 1984. Plants were scored on a 0 to 10 scale, 0 equaling no visible phenoxy symptoms, 10 equaling total collapse of the plant. All plants were independently scored by three separate observers and the resulting raw scores were averaged to determine a mean symptom score. The results of these observations are shown in Figures 2 and 3.

Figure 4 shows the results of two years trials for those nozzles common to trials in both years.

RESULTS AND CONCLUSIONS

Figure 2 gives an overview comparing each nozzle for drift based on the number of plants showing any phenoxy symptoms, converted to a percentage, at each of the trial stations. It can be seen, as indicated by the solid line labled "ws" to the right of each set of bars, that wind speeds of 6 MPH and under tended to result in much less drift regardless of which nozzle was being tested. It is also important to note that, with two exceptions, phenoxy symptoms were not observed beyond 400 feet, well within the current SLO County, 1/2 mile limit established for 8004 LP "flat-fan" nozzles.

Figure 3 shows the severity of symptoms vs. nozzles based on a 0 to 100 scale, converted from the raw data 0 to 10 scale. It should be kept in mind when comparing figures 3. and 4. that overall ratings of symptom severity were much lower than the ratings based solely on numbers of plants showing symptoms. The fact that symptom severity ratings were so much less (approximately 50 %) necessitated revising the graph scale so that the two figures are not directly comparable. The level of symptoms for the TK-5, 8002 LP, and 8004 LP appear to be within tolerable limits of symptoms to easily fit within the current 1/2 mile sensitive crop application limit. The Micro-Max CDA, in 1984, appeared to be well within safe tolerances also, however, due to a poor showing in 1983 trials we feel that further evaluation of both CDAs is in order.

The 8004 LP nozzle did show a low level of symptoms, less than 1%, over the 600 foot trial course; however, by the end of the four day rating period all of the indicator plants in this treatment had recovered. The 8002 LP nozzle showed a relatively high symptom rate, 19%, at the 25 foot station, but dropped rapidly to 0 between 50 and 100 feet; again, these symptoms had disappeared by the end of the rating period.

The 8004 LP and the TK-5 nozzles, while scoring very well in both numbers of plants showing symptoms and low symptom severity, necessitated the application of 21 gallons and 18 gallons of water per acre respectively. The 8002 LP, on the other hand, while showing drift to approximately 100 feet with 19% damage at the 25 foot distance, required only 12 gallons of water per acre.

The TK-3 "flood-jet" nozzle, while operating in the 11 to 13 gallon range tended to show too much drift of too severe nature, even at wind speeds of less than 8 MPH, to be considered safe.

Figure 4 shows a two year average of numbers of plants showing symptoms, as a percent, for the TK-5, TK-3, Micro-Max, and 8002 LP nozzles. It can easily be seen that the 8002 LP had a drift potential that was substantially less than the TK-3 or the Micro-Max, particularly in view of the wind speed conditions for the various nozzles.

You will note that I used the term substantially less rather than significantly less drift potential. At no time have we been able to show significant differences between nozzle treatments in our trials. I believe that this is at least in part due to the difficulty in using field studies to gather this type of information. It appears that there are just too many uncontrollable variables to develop totally reliable data.

This figure also points out graphically why we feel that the CDAs need further testing. In all fairness it must be pointed out that conditions during the 1983 trials were less than optimal and the CDA applicator by weight of its position in the trial could have been put at a disadvantage compared to other treatments.

In conclusion it appears that, based on the trend of two years data, re-evaluation of existing orifice regulations for the application of phenoxy herbicides should be considered. Further testing of the 8002 LP "flat-fan" and CDA types of nozzles is probably in order; however, these tests need to be conducted under conditions which are more strictly controlled. Such testing is beyond the scope of resources available to us at the county level. Results of this type of research and the ramifications of possible changes in regulations goes far beyond the borders of San Luis Obispo County.

We in San Luis Obispo County have addressed the problem and taken the testing as far as our limited resources can carry us. CDFA has charged the University of California and Cooperative Extension with the responsibility of determining whether these nozzles can be used safely, before the regulations can be changed. Perhaps assistance of a financial nature might be forthcoming from the California Department of Agriculture to help finance needed research at the University level.

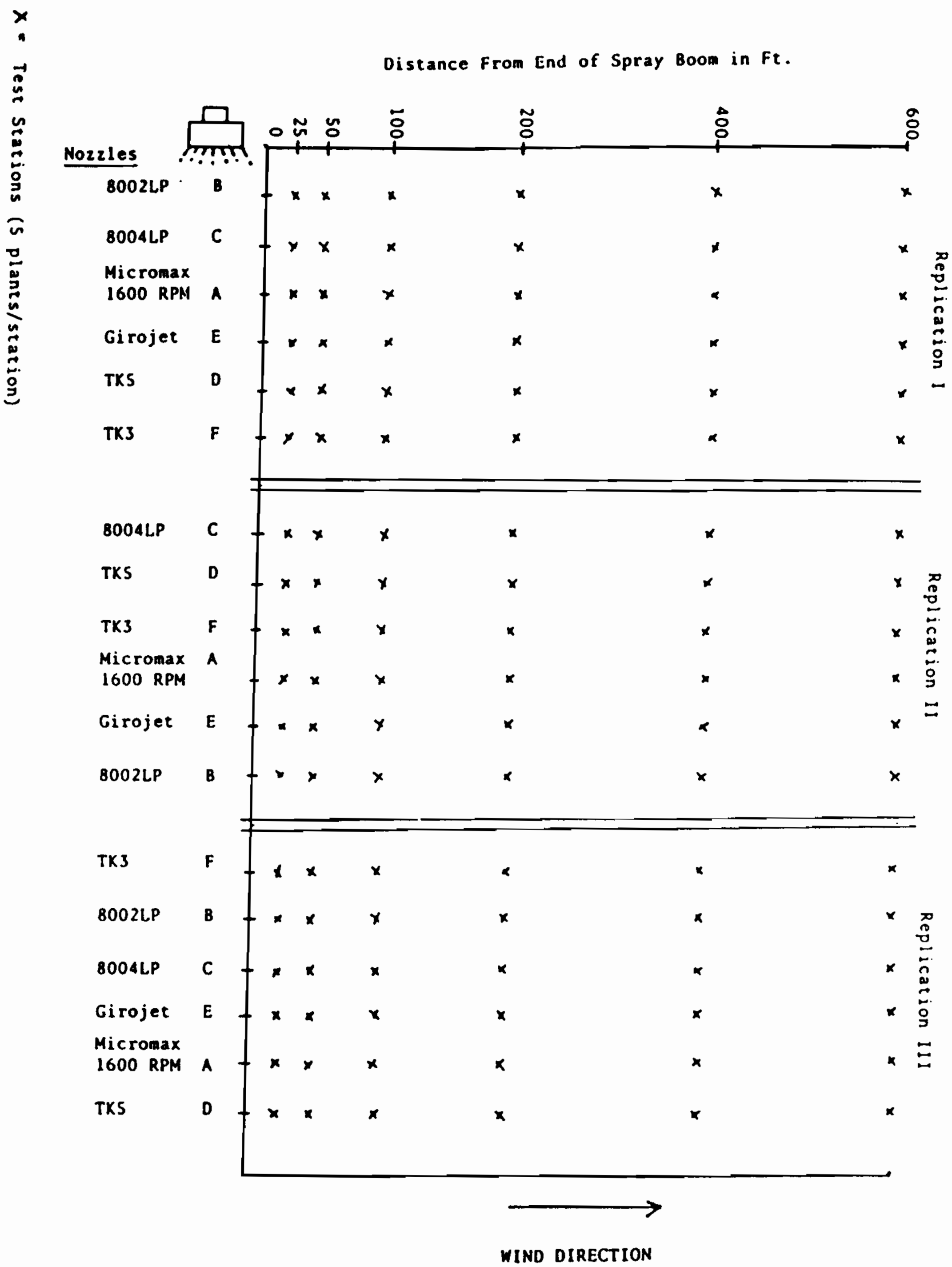


FIGURE 1
FIELD SETUP FOR REPLICATIONS, TREATMENTS AND TEST STATIONS

TABLE 1

Materials : Clean crop 2,4-D amine at 3.8 lbs a.i. per gallon. No Foam B Spreader.

Rates : 1.5 pints 2,4-D per acre (.75 lbs a.i. per acre) equates to 14 oz. 2,4-D per trial (.42 lbs a.i. per trial). spreader at .5% by volume.

Spray Area : .55 acres (3 passes on a course 20' X 400").

Nozzle parameters:

NOZZLE	HEIGHT	SPACING	ORIENTATION	PRESSURE	SPEED
8002LP	24"	20"	Down, perpendicular to ground	15 psi	5 mph.
8004LP	24"	20"	Down, perpendicular to ground	15 psi	5 mph.
TK3	24"	60"	Inverted, pointing back, parallel to ground	30 psi	5 mph.
TK5	24"	60"	Inverted, pointing back, parallel to ground	30 psi	5 mph.
Micromax	28"	48"	Umbrella pattern	NA	4 mph.
Girojet	28"	60"	Down perpendicular to the ground.	NA	4 mph.

FIGURE 2

1984 DRIFT STUDY
SYMPTOM SEVERITY vs. NOZZLE

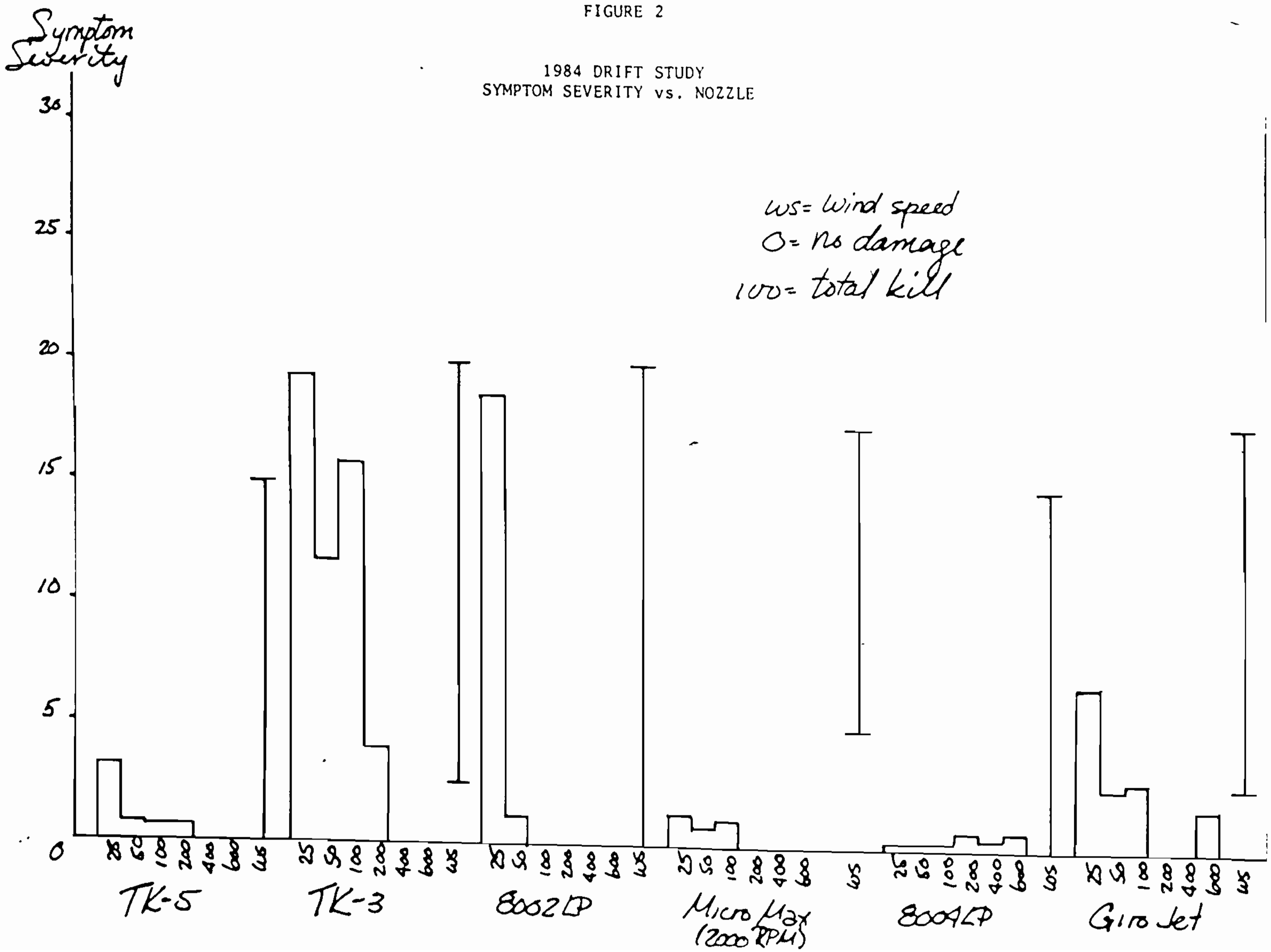


FIGURE 3

1984 DRIFT STUDY
PERCENT PLANTS SHOWING SYMPTOMS vs. NOZZLES

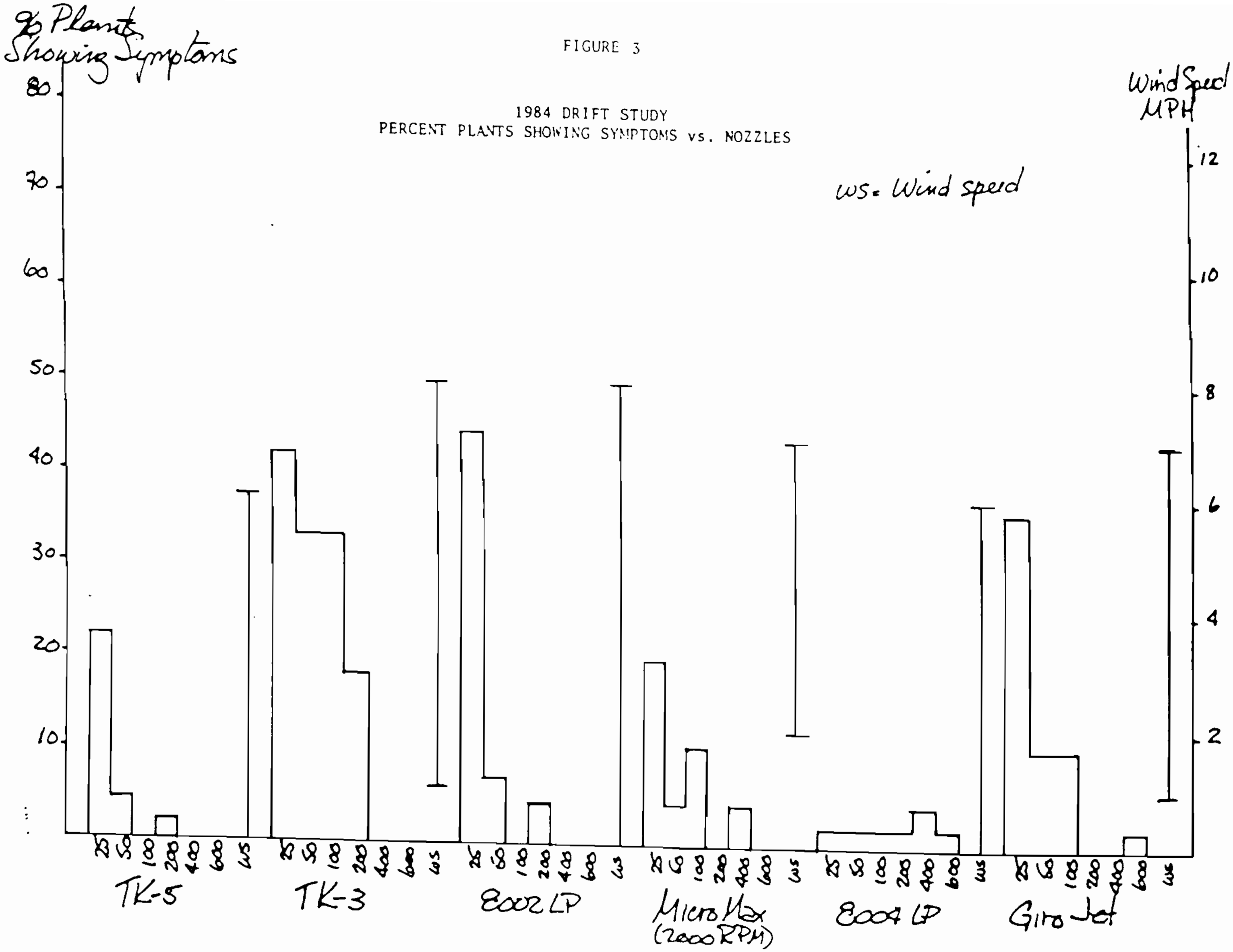
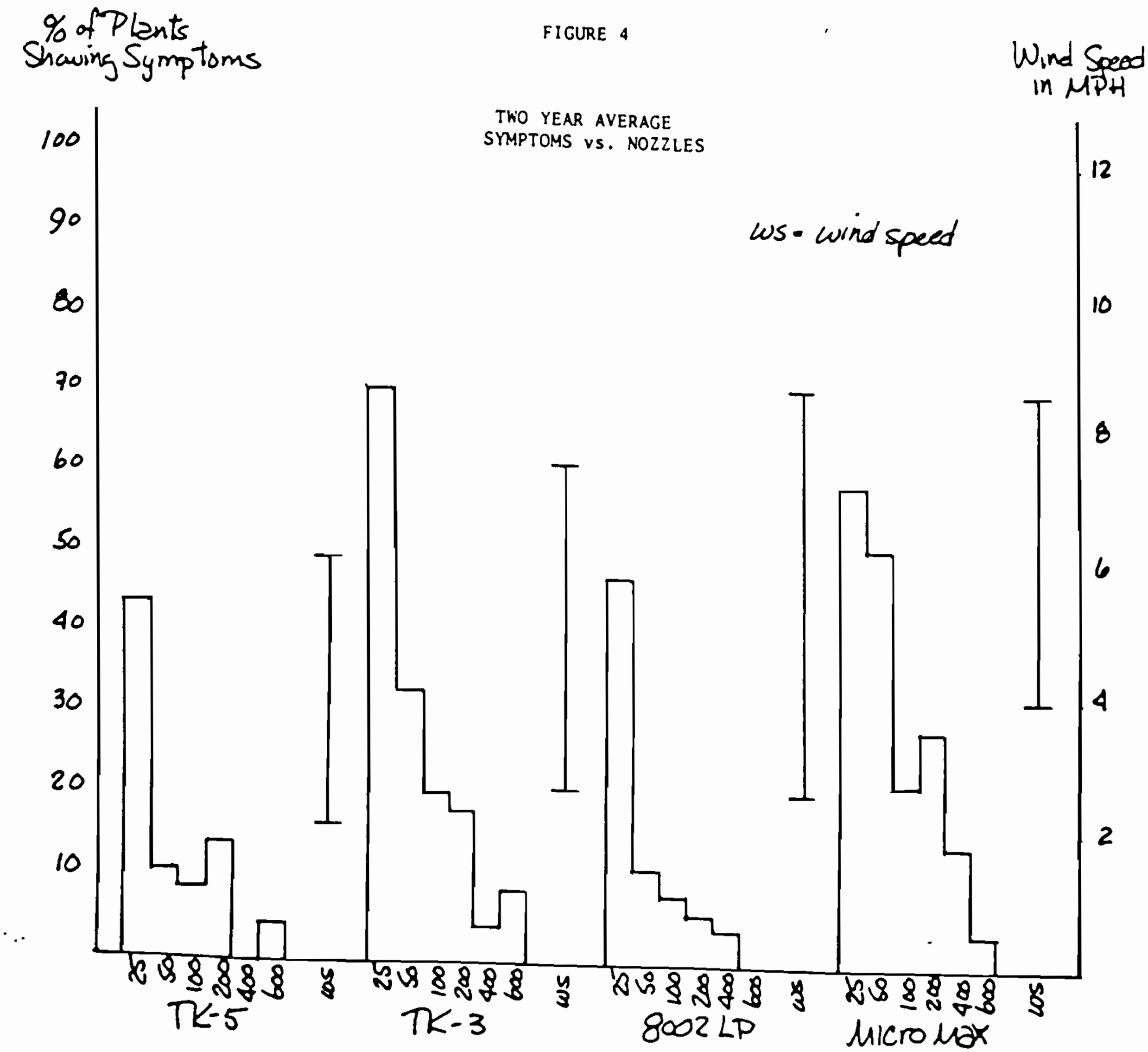


FIGURE 4

TWO YEAR AVERAGE
SYMPTOMS vs. NOZZLES



PESTICIDE RINSE WATER DILEMMA - "CATCH 22"

Albert Troglin
Hazardous Waste Committee Chairman
California Agricultural Aircraft Association
San Joaquin Air, Inc.
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With the passage of Resource Conservation Recovery Act 1976 (RCRA), began the dilemma of compliance with hazardous waste regulations. Prior to 1976, there were few laws regulating the disposal of any kind of toxic waste, let alone the rinse water generated by cleaning of agricultural application equipment. The 1976 RCRA was somewhat broad in scope, covering the total problem of toxic waste, and left some question as to who and what was covered. Many chose to ignore it altogether. In 1980, several amendments were added which became more specific as to who was regulated, what was necessary for compliance, and the penalties for noncompliance.

These 1980 changes began to get the attention of many people throughout the ag chemical industry, from manufacturer to the end user, because all of them were regulated under RCRA.

One of the biggest problems facing anyone trying to comply with hazardous waste regulations is that the regulations are changing so rapidly; what is a good sound solution today will put you in legal and financial jeopardy tomorrow. As an example, the basic intent of this regulation is containment and safe disposal of hazardous waste.

For the application industry, containment was usually accomplished with a concrete wash rack facility. Once you have the toxic waste on the wash rack, what do you do with it? Until 1982, most people would consider a surface impondment or evaporation pond as a good and legal solution. In 1982, it became mandatory that any ponds be double lined with a leak detection system and ground water monitoring wells around the perimeter. The financial responsibility for closure and post closure requirements had to be met. Basically, this required you to demonstrate through insurance, bond, trust fund, or money in the bank that you could clean up the site when it was no longer in use. These financial requirements run into the millions of dollars. No small businessman could afford them. I know of no applicator who could qualify.

So, anyone who had a pond in operation after January, 1982, has a real legal and financial problem on his hands. It is quite possible that within the next 3 to 5 years all surface impondments will have to be closed and sites cleaned, as new regulations, both State and Federal, all point in that direction.

If you considered a surface impondment a bad idea, what did you do? Most of the agrichemical dealer applicators opted for above-ground storage in large tanks. But then what happens when the tank is full? Some have tried evaporation from the tanks by way of sprinklers, etc. To my knowledge, none have been successful, as water accumulated faster than it was evaporated. As of now, most are having it hauled by certified hazardous waste haulers, taking it to a certified Class I dump for liquid waste disposal.

The cost of disposal can reach the financial limit of a small applicator very quickly, as it usually costs 25 to 45 cents/gallon for the transportation, depending on distance to the disposal area. The typical applicator will generate 2000 to 5000 gallon/month. And some applicators would have much more. So the disposal cost can get out of sight very quickly.

Should an applicator decide he can live with the cost of transportion and disposal, there is a new problem which makes the option a short term solution to the problem. In California, there are only three sites where liquid hazardous waste may be disposed. At this time, two of the sites are about to be closed or have been closed, leaving only the site in Central Valley still open. I have been told they are not accepting any new customers as they are fast running out of space. Even if you contained the rinse water in above-ground tanks, you could very well be left without a disposal site.

With the pressure of law and regulation on one side forcing us to do something and the realization that most dump sites were becoming full, we began to look for a way of reducing or detoxifying the rinse water generated.

In January, 1984, California Agricultural Aircraft Association in conjunction with Western Ag Chemical Association and Canonie Engineers began exploring the possibility of using carbon filters to clean up the rinse water and greatly reduce the volumn of toxics to be disposed of. From January to June, several meetings were held to look at all the variables that would be required to make the program work.

These are a few of the challenges we had to meet. Devise an economical chemical test procedure to test the effectiveness of the system. Determine how to prevent the oil and solvent in the chemicals from masking the carbon beds. Determine how to get the carbon in containers which minimized worker exposure while changing them and also be a legal DOT container for shipping. We had to develop the physical engineering of the facility. And we had to make the operation simple enough so the average worker could operate the system safely and efficiently.

As proposed, the system would be a closed-loop filtration whereby the same water could be used over and over for washing equipment, so no new waste would be generated. The large volumn of rinse water usually disposed of would be reduced to three to five 55-gallon drums of carbon which could be disposed of once or twice a year. Cost of operation would be reduced from $20,000 to $30,000/year to possibly $3,000 to $4,000/year. The projected cost of installation would be on the order of $20,000 to $30,000 per facility. So there was every reason to push ahead with this program. If the system worked as proposed, it would be an economical means of handling rinse water that any applicator could afford to build and to operate.

By June, 1984, we felt most of the theoretical problems had been resolved and only an operating facility could prove us right or wrong. So in July, we met with the Department of Health Service, Water Quality Control Board, and Department of Food and Agriculture. We presented our proposal and asked for their review and permission to put in two test facilities to be operated for one year under their supervision to determine the proof of the concept.

At this meeting, all were in general agreement that the concept looked workable. Since the DOHS must issue the necessary permits to allow construction and operation, they wanted an indepth review by their people. They promised a reply by August 1, 1984, noting any changes they might require. WACA and CAAA were to respond by August 15, 1984. Construction was to begin on November 1, 1984, with operation to begin January, 1985.

Well, it is now October 27, 1984; we have not had one response from DOHS on this program. The CAAA has been told by people in DOHS that new enforcement mandates and regulations will force 50% of the aerial applicators out of business by the fall of 1986. Time is running out.

Water Quality Effects on Infiltration

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Extension Soil and Water Specialist

The salt content of the soil water, or soil salinity, and the amount of adsorbed sodium on soil surfaces, or soil sodicity, influence water intake and penetration. The principle mechanisms are clay swelling and soil particle dispersion (Shainberg and Letey, 1984; Oster and Singer, 1984). When water is applied to a soil, hydration and swelling of expandable clay minerals reduce the cross sectional area of soil pores. The beating (water drop impact) and sorting action (flowing water) of applied water causes aggregate breakdown and particle dispersion. Dispersed particles within the soil become lodged in small pores blocking water and air movement. Dispersed particles suspended in the irrigation water tend to settle on the soil surface where they can form a dense, thin layer of soil. Both swelling and dispersion increase with increasing sodicity, or decreasing salinity , or both.

For irrigated soils, soil sodicity and salinity are determined to a large extent by the chemical composition of the irrigation water. At the soil surface during an irrigation, the chemical compositions of the soil solution and the irrigation water are nearly the same. Within the soil, physical and chemical effects on dispersion are more limited than at the soil surface because of the reduced kinetic energy of the water after it enters soil, the presence of a continuous soil matrix, and increased soil salinity due to dissolution of soil minerals such as silicates, soil lime (calcium carbonate) and gypsum. These considerations led to the conclusion Shainberg and Letey, 1983) that water quality guidelines, based on the chemical composition of irrigation water, for surface and subsurface soil should be significantly different.

WATER QUALITY PARAMETERS

The electrical conductivity of the irrigation water is the quality parameter used to estimate potential levels of soil salinity. The parameter used to predict adsorbed sodium, specifically the exchangable sodium percentage, is the sodium adsorption ratio $[C_{Na}/(C_{ca} + C_{mg})^{0.5}]$ where C represents ion concentration expressed in mol/m^3 or $mmol/l^1$. Numerically, it approximately equals the exchangable sodium percentage. Laboratory and field data show that the exchangeable sodium percentage of surface soils and the sodium adsorption ratio of the irrigation water are about equal provided the latter is properly corrected (Suarez, 1981; Wescot and Ayers, 1984) for calcium carbonate dissolution or percipitation.

Recent water quality guidelines (Rhoades, 1977; Ayers and Tanji,

1981) for water intake and penetration divide the salinity-sodium adsorption spectrum into two categories (Fig.1). Small chemical effects on water intake and penetration are expected for combinations of salinity and sodium adsorption ratios located above the line. The reverse is expected for those below the line. Two features of Fig. 1 need to be emphasized: 1) for a sodium adsorption ratio of zero, a salinity less than about 0.3 dS/m is unfavorable, and 2) as the sodium adsorption ratio increases, the salinity required to maintain favorable chemistry increases.

Water penetration problems resulting from irrigation with Friant Kern Canal water are consistent with the first feature of Fig. 1. If irrigation with San Joaquin Valley drainage water results in water penetration problems during the rainy season, this would be consistent with the second feature of Fig. 1. Since I believe gypsum plays an important role in the use of either water, this paper deals primarily with management options related to gypsum. However, several comments about calcium carbonate chemistry in relation to soil salinity and sodicity are appropriate.

Irrigation with Friant-Kern canal water causes dissolution of calcium carbonate and soil silicates. The dissolution of either increases soil salinity and decreases soil sodicity at the soil surface. However, the net effect is often not sufficient to generate favorable chemistry for water infiltration. The reverse can be the case for well waters particularly if bicarbonate is the predominant anion. The decreased salinity and increased sodicity due to calcium carbonate precipitation can be sufficient to cause unfavorable chemistry. The saturation index and associated mathematical procedures used to calculate the "adjusted sodium adsorption ratio" (Bower et al., 1965) results in values which are generally too high by a factor of two (Oster and Rhoades, 1977). An adjustment procedure (Westcot and Ayers, 1984), based on a method proposed by Suarez (1981), results in improved adjusted values which are consistent with the solubility of calcium carbonate in mixed salt solutions.

MANAGEMENT ALTERNATIVES WITH GYPSUM

Gypsum application to irrigation water or to soils which contain little sodium,to improve water intake of nonsaline water is an old and well established practice in California and Australia (Oster, 1982). Under these circumstances, the beneficial effect of gypsum results from increased soil salinity. Gypsum addition to Friant Kern water [Salinity = 0.1 dS/m; sodium adsorption ratio = 0.8 $(mol/m^3)^{0.5}$], or to soils irrigated therewith, was a common practice in the 1950's and still is today. In Australia, between 1963 and 1965, gypsum was applied to about one million acres of fallow, non sodic soils to improve water penetration and consequent dryland wheat yields. Some of the earliest research work related to gypsum usage to reduce crusting and improve water infiltration was conducted in Australia between 1921 and 1933. The agricultural use of gypsum as a source of salinity to improve water flow into (irrigated or nonirrigated) soils is well established.

Irrigation with saline waters which contain a high proportion of sodium is also well established. For example, in southeastern Colorado, irrigation of about 200,000 acres with Arkansas river water [salinity from 2 to 5 dS/m; sodium adsorption ratio from 4 to 10 $(mol/m^3)^{0.5}$] has occurred for the past 100 years (Miles, 1984). Chemically, it is a gypsiferous water: the predominant anion is sulfate. Soil textures vary from sandy to clay loams. Rainfall[120 to 360 mm (5 to 15 in.)] usually occurs after March 15 during the growing season. Infiltration problems occasionally develop during a period of rainfall of several days particularly if the amount exceeds 50 to 100 mm (2 to 4 in.) The lack of widespread infiltration problems as a result of rainfall is partially due to the gypsiferous chemistry of the irrigation water and the consequent presence of gypsum in the profile. Gypsum dissolution during rainfall increases soil salinity and provides a source of calcium to replace adsorbed sodium; it reduces the drop in soil salinity during rainfall and increases the reduction in sodium adsorption ratio. In terms of Fig. 1, instead of moving straight down from any given initial level of soil salinity, the approximate case during leaching of a nonsaline soil which doesn't contain gypsum, both salinity and sodium adsorption ratio are reduced. Consequently, better soil chemical conditions are maintained.

Saline-sodic well waters [salinity from 3 to 6 dS/m; sodium adsorption ratio from 8 to 26 $(mol/m^3)^{0.5}$] are used to irrigate silt loam soils in the northeastern Negev Desert of Israel. The predominant anion is chloride: evapotranspiration of this water does not result in gypsum deposition in the soil profile. The climate is similar to that of Fresno; winter rainfall of 250-500 mm (10-20 in.) is common. The salinity of the well water counteracts the harmful effects of adsorbed sodium during the irrigation season. However, during the rainy season, the salinity of the surface soil is reduced, crusting occurs and water penetration is reduced. In a replicated field trial, fall application of 10 Mg/ha (4.5 tons/acre) of phosphogypsum followed by discing to a depth of 10 cm (4 in.) resulted in a total runoff of 36 mm (1.4 in.) from seven rains (182 mm of total rainfall) over a period of three months. Runoff from untreated control plots averaged 64 mm (2.5 in.). However, the lowest runoff, 19 mm (0.6 in.), occurred from plots where the gypsum was spread over a freshly tilled surface (Keren et al., 1983).

Many saline-sodic drainage waters in the San Joaquin will have favorable quality in terms of their potential effect on water infiltration. Many will also be gypsiferous. The concentrations of calcium and sulfate often may be the highest that can be achieved in the presence of gypsum. Chemists refer to such a situation as a saturated gypsum solution. Irrigation with such a water will result in gypsum precipitation in the soil. This will reduce the deleterious effects of adsorbed sodium during the rainy season in much the same way as occurs in Colorado. If poor water penetration becomes a problem, there are several management alternatives. Surface application of gypsum before the rainy season, tillage to destroy crusts which develop, or changing the water composition by adding gypsum or by blending dilute surface waters with the more saline-sodic drainage waters.

CONCLUDING COMMENTS

Gypsum application to the soil or to irrigation water is one of several management techniques used by farmers to improve infiltration. Tillage, more frequent irrigation, substituting a more saline well water for a less saline canal water for one or more irrigations, and addition of SO_2 to irrigation water are also commonly done in California. Organic matter additions (Meek, 1982) and use of cover crops can also be effective (Christensen et al., 1968; Meyer, 1962). The cover crop protects the soil surface against the beating and sorting action of irrigation water and provides a source of fresh organic matter which increases aggregate stability.

When comparing the inorganic and organic chemical aspects of infiltration, I believe more is known in the area of inorganic chemistry. Figure one summarizes the effects of soil salinity and sodicity, inorganic chemical parameters, on infiltration: there is a threshold salinity level required for favorable chemical conditions independent of the exchangeable ion composition, and the salinity level increases as soil sodicity increases. This is consistent with the effects of salt concentration and exchangeable sodium on clay flocculation and mobility (Shainberg and Letey, 1984). However there are knowledge gaps in the inorganic chemistry of infiltration. A partial list follows: 1) Double layer theory probably doesn't describe the degree of soil clay swelling for the combinations of salinity and sodium adsorption ratio along the line in Fig. 1 unless arbitrary assumptions are made to correct for the lack of interlayer swelling of calcium smectite minerals. 2) Cementation of soil particles by the hydrous oxides of iron, aluminum and silica is not well understood. 3) Very little work has been done on the effects of temperature on cementation, swelling, dispersion and soil water infiltration. 4) The same is true for particle size distribution and intra and inter particle swelling effects on soil pore size distribution which can develop in confined (subsurface) and unconfined (surface) soil.

The organic matter content of a soil and its state of oxidation is expected to have significant effects on the location of the line in Fig. 1. Aggregate stability decreases and crust strength increase with decreasing organic matter. Fresh organic matter promotes microbial activity and is considered to be effective in stabilizing structure because of the production of polusaccharides and polyuronides. These materials either provide a coating or enter into various types of bonding (Harris et al., 1966). The number of experimental measurements relating organic matter content to infiltration are limited and difficult to obtain. Organic matter and microbial populations vary through the season and from season to season. Maintenance of a higher level of fresh decomposing organic matter for the purpose of raising infiltration rates are difficult in California because the high temperature results in rapid decomposition.

Although much remains to be learned about soil-water interactions, water quality criteria for water infiltration based on Fig. 1 are consistent with farming experience with non-saline and saline-sodic waters and with laboratory research. The new Kearney Foundation research mission (1985-1990), Water Penetration Problems in Irrigated Soils, K. K. Tanji, director, should stimulate new basic and applied research which should fill some of the knowledge gaps and increase the degree to which the criteria can be generalized. However, in addition to a thorough diagnosis to define the nature and probable cause of specific water infiltration problems, I suspect considerable subjective judgement and local farming experience will always be useful in the application of water quality criteria to specific field--irrigation water combinations.

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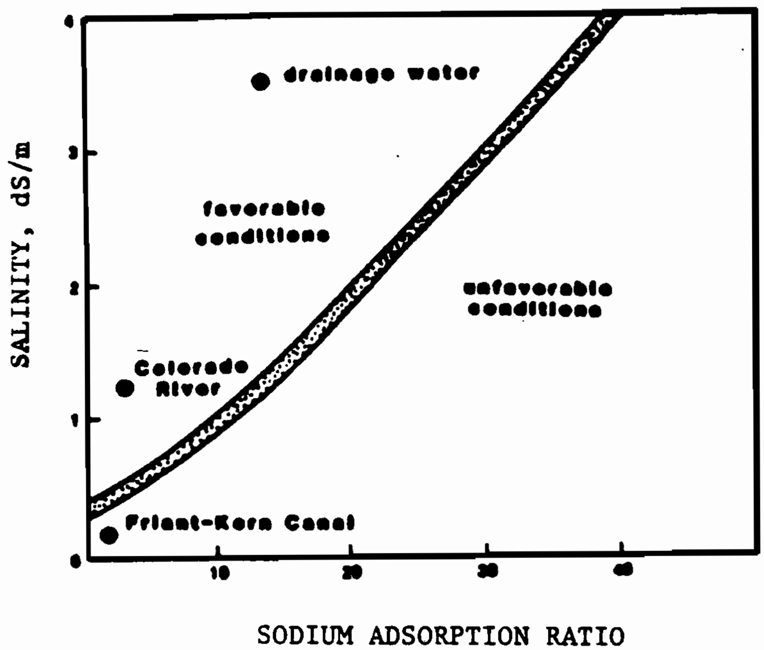

Figure 1. Salinity and sodium adsorption ratio boundary that divides combination of both measures into two categories; those which promote good permeability and those which do not. The graph can be used for both irrigation water and soil saturation extract composition.

CYCLIC STRATEGY FOR USE OF SALINE WATER FOR IRRIGATION

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Considerable saline water is available, including drainage waters from irrigated projects and shallow ground waters, in various places in the world, including California, USA. It can be used to aid California in its water conservation efforts and for the development of new water supplies for irrigation.

Estimated water demands in the San Joaquin Valley, for example, are 18km^3/year, and firm normal-year water supplies average only about 15.9km^3/year. The deficiency, 2.1km^3, represents the average annual groundwater overdraft, about three-fourths of which occurs in the southern part of the valley.

Annual water demands are projected to grow to 20.7km^3 by the year 2000. Without new supplies, the imbalance between annual supply and demand will increase to 4.4km^3, doubling the groundwater overdraft.

Paradoxically, while a serious water deficit exists in the lower San Joaquin Valley, there is an excess of drainage water and a disposal problem.

A serious shallow water table problem is developing in a number of basin locations. The volume of drainage water requiring disposal from these areas has been projected to be about 1.2km^3/year by the year 2000. The average salt concentration of this drain water ranges from 4,000 to 5,000mg/l.

The San Francisco Bay is the only outlet from the San Joaquin Valley. Disposal to the bay of this drainage will not only be expensive but also controversial. If this drain water could be reused for irrigation, the volume of water needing disposal, and the size of the main drainage conveyance system, would be reduced. It would also reduce the need for imported water and/or the groundwater over draft.

In Imperial Valley, California, drainage water amounting to about 1.85km^3/year is discharged to the Salton Sea, a large inland lake well below sea level. The rising level of the Salton Sea has inundated adjacent agricultural and recreational lands and is the source of much current controversy and concern. The average salt concentration of this drain water is about 3,500mg/l. If this water could be reused for irrigation, not only would the "disposal" problems be reduced but the acreage under irrigation could be expanded.

Many brackish waters, like the drainage waters of the Imperial and San Joaquin Valleys, not now used for irrigation because they are deemed too salty, can be used effectively for irrigation if properly adapted management methods are applied.

The ultimate goal should be to maximise the use of an irrigation water supply in a single application with minimum drainage, though there are practical constraints which now prevent this, as well as economic disincentives. To the extent that the drainage water still has value for crop use, it should be used again for irrigation.

In fact, whether inadvertent or planned, such reuse is common in many places. However, it could be carried much further by successively irrigating a sequence of crops of increasing salt tolerance.

This has little appeal to most farmers because they do not want to be restricted to growing only salt-tolerant crops nor do they want to have to deal with the special management practices or invest in the special equipment involved in obtaining good "stand" required to grow crops on saline land.

The receptivity and practicality of using saline waters (such as drainage waters) for irrigation will be appreciably enhanced if these limitations can be circumvented.

Concept of the Cyclic Strategy

A strategy to make brackish water use more appealing is to substitute saline (drainage) water for normal (low salinity) irrigation water when irrigating certain crops in the rotation when they are in a suitably tolerant growth stage; the normal water is used at other times. The timing and amount of substitution possible will, of course, vary with the quality of the two waters, the cropping pattern, the climate, certain soil properties and the irrigation system.

Any salt build-up in the soil from using the brackish water can be alleviated in the subsequent cropping period when a more sensitive crop is grown using the normal (low-salinity) water for irrigation. A soil will not generally become unduly saline from use of a saline water for a part of a single irrigation season and often not for several seasons. The maximum soil salinity in the root-zone resulting from continuous use of brackish water will not occur when such water is used for only a fraction of the time.

Furthermore, the yield of the sensitive crop should not be reduced if proper preplant irrigation and careful management are used during germination and seedling establishment to leach salts out of the seed area and shallow soil depths. Subsequent "in-season" irrigation will leach the salts farther down in the profile ahead of the advancing root system and "reclaim" the soil in preparation for the next time when the brackish water will be used again to grow a suitably tolerant crop.

This cyclic use of "low" and "high" salinity waters prevents the soil from becoming saline, while permitting, over the long period, substitution of a brackish water for a better quality water for a substantial fraction of the irrigation water needs.

Experimental Tests of Strategy

The above described strategy for using brackish waters for irrigation is under evaluation in three experiments. One is a 16ha field experiment which was begun on a cooperator's farm in the Imperial Valley in January 1982, in which two cropping patterns are under test.

The first is a two-year successive crop-rotation of wheat, sugar beets, and melons. In this rotation Colorado River water (900mg/l tds [total dissolved solids]) is being used in the preplant and early irrigation of wheat and sugar beets and for all irrigation of melons. The remaining irrigation is from the Alamo River (drainage water of 3,500mg/l tds).

The other pattern is a block rotation of cotton (a salt-tolerant crop) for two years followed by wheat (a crop of intermediate salt tolerance) and then by alfalfa (a more sensitive crop) for a block of several years. Drainage water is being used for a large part of the irrigation of cotton; then for the wheat crop only Colorado River water will be used.

Wheat should withstand the salinity initially present in the soil achieved from irrigating the cotton with the brackish water and yield well when irrigated with Colorado River water. Sufficient desalination of the soil is expected to occur during its irrigation with Colorado River water to permit alfalfa to be grown subsequently without loss of yield.

To date, two wheat crops, one sugar beet crop and one melon crop have been grown, i.e., one cycle plus has been completed in the successive-crop rotation, and two cotton crops and one wheat crop have been harvested, in the block-rotation, using the proposed "cyclic" crop/water management strategy. No loss in yields occurred in any of these crops where the Alamo River water was substituted for the Colorado River water following seedling establishment.

The percentages of substitution of Alamo River for Colorado River used in the test were 76 for wheat, 82 for sugar beets and 54 for cotton. Melons (a salt-sensitive crop) were grown on the same land farmed to wheat and sugar beets with substitution of Alamo River water without yield loss (compared with the control, i.e., use of Colorado River water only for all crops and irrigations).

A second field experiment has been under way near Lost Hills in the San Joaquin Valley of California for six years. In this case a very saline water (6,000mg/l tds) has been successfully used to irrigate cotton following seedling establishment with California aqueduct water (300mg/l tds) for four consecutive years. Wheat was then grown with aqueduct water for desalination purposes. Sugar beets were next grown with the "cyclic" strategy, to be followed by cotton. This is a demanding test since a very saline (saltier than sea water) groundwater has existed beneath the test area at a depth varying between 0.5m and 1.2m for the last three years, eliminating the opportunity for leaching and causing the soil salinity to increase to abnormally high levels.

In spite of these problems, 1982 cotton lint yields were good: 2.8 bales per acre (0.4ha) with aqueduct water only and 2.3 bales per acre with drainage water after seedling establishment. Excellent yields of sugar beets (~28 tons/acre) were obtained with no loss in yield from use of the highly saline drainage water. This experiment, upon completion, should provide appropriate data to evaluate the long-term effects of the strategy.

These results support the credibility of the proposed strategy, but it cannot be claimed that its validity has been established because the long-term consequences have not yet been fully evaluated.

A new experiment has just been initiated to simulate the two field conditions in a controlled lysimeter facility. A computer model is being developed to predict the chemistry of the soil water with cyclic crop/water use within the root zone and over time for a variety of cropping situations. It will be tested with the empirical data obtained. The model will be used to help evaluate the long-term consequences of the strategy and its suitability for various water quality combinations and cropping situations.

Caution Against Blending of Saline and Non-Saline Waters

Frequently, drainage water is inadvertently recovered and used for irrigation elsewhere because drainage often returns by diffuse flow to the water supply system. This often has deleterious effects on water quality without adding to the amount of the water supply that contributes to crop production.

A plant must expend bio-energy (that would otherwise be used in biomass production) to extract water from a saline (low osmotic potential) soil solution. When a water of excessive salinity for crop production is mixed with a low-salinity water and used for irrigation, the plant can only remove the "good water" fraction from the mix before the salinity again becomes excessive, i.e., until the fraction of the mix made up of the excessively saline portion is left.

This fraction is just as unusable at this point as it was before mixing, because it requires more energy to separate the pure water from such a low osmotic potential solution than the plant can muster. Thus, diluting excessively saline water with less saline water does not stretch the water supply for crops which could not use the water prior to dilution. This "saline water" component is only usable on crops that are sufficiently salt-tolerant to use the water undiluted.

Mixing saline water back with a receiving water can increase the latter's salinity sufficiently to limit its usability for sensitive crops and other uses as well. One has, in this process of mixing, simply mixed the usable and unusable waters into one blend which must be separated again during the use by the plant.

Greater flexibility and opportunity for crop production results if the two water types are used separately and cyclically in the crop/water management strategy described herein. Once the waters are mixed, this alternative is lost.

Of course, it may not always be feasible or practical to prevent such natural mixing. However, intentional mixing should be carefully evaluated for benefit before undertaking it, and the opportunity to prevent mixing and implement the cyclic crop/water management strategy should be pursued wherever practical.

SALT TOLERANCE POTENTIAL OF CROPS FOR THE SAN JOAQUIN VALLEY

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The San Joaquin Valley has 4.8 million acres of cropland which includes 1.3 million acres affected by drainage, high boron and salinity problems. Present estimates indicate that crop yields are at least 10 percent decreased as a result of poor drainage and salinity. By the year 2000, the drainage and salinity problem is expected to involve at least 2.3 million acres with projected crop losses of $321 million annually. About 64% of the Valley's croplands are planted to row crops, 22% to fruits and nuts, 10% to pasture, and 4% to vegetables. In 1983, cotton, wheat, barley and alfalfa were planted on about 58% of the row crop acreage and grossed almost $1.2 billion in sales. Most of the fruit and nut acreage consisted of grapes (56%) and almonds (26%) and grossed $354 million. Processing tomatoes grossed $164 million and were planted on just over half of the acreage involved in vegetable crop production. Based on these estimates, current cash losses caused by salinity would be about $243 million annually for these crops alone and could be well over $500 million for all crops combined. These estimates emphasize the tremendous economic benefits for improving the salt tolerance of crop plants, not at salinities that affect survival but, at the relatively low salinities at which economic yields are affected by only 10 to 15%.

Salt tolerance is quantified in terms of the threshold salinity and the yield reduction per unit increase in salinity (slope). Salinity is measured as the electrical conductivity (dS m^{-1}) of a saturated soil extract. Salt tolerant crops like cotton, barley, wheat and sugarbeet have threshold values between 6 and 8 dS m^{-1}. In other words, they can tolerate salinity in this range without significant reduction in yield. Slope values for these crops are around 5 to 7, meaning that yield will be reduced 5 to 7% for each dS M^{-1} increase in electrical conductivity of the soil extract beyond the threshold. Other Valley crops like alfalfa, almond, grapes and tomatoes are less salt tolerant. Threshold salinities of these crops range between 1.5 and 2.5 dS m^{-1} and yields can be reduced by 7 to 19% per unit increase in salinity beyond the threshold. Crop production in the San Joaquin Valley can benefit substantially from relatively modest gains in the increase in salt tolerance in crops. Goals can be set forth for improvements in salt tolerance that would maintain yields at the salinities that now reduce yield by 10%. These goals can be met with improvements in salt tolerance that affect either the threshold or slope.

Even without complete knowledge of the basic physiological mechanisms of salt tolerance, it is possible that salt tolerance of most crops can be improved by 10%. Salt tolerance has been evaluated in several different cultivars and varieties in the aforementioned crop species currently produced in the San Joaquin Valley. The potential for 10% improvements in salt tolerance in most of these species seems to be within the range of the available germplasm resources; however, factors concerning local adaptation and total yield potential have not been evaluated.

A plant breeding program for the development of salt tolerant species adapted to the Valley would include three major steps. Varieties with superior salt and boron tolerance would be identified and crossed with high-yielding, adapted varieties. Early segregating generations would be screened for increased boron and salt tolerance in controlled stress conditions in the greenhouse. Finally, advanced generations would be field tested in different locations under controlled boron and salinity treatments. An intensive program of this nature could be successful within five years. The anticipated capital expenses for such a program would only be a fraction of the value of the potential benefits over a single year. Several crops could be simutaneously selected for salt tolerance to improve efficiency.

Conclusions

The development and use of salt tolerant crop varieties could alleviate much of the economic loss that will occur until adequate drainage and leaching can be developed in the Valley. Estimates indicate that the development of salt and boron tolerant crops is technically feasible and economically justifiable. However, the facilities and resources needed to exploit this approach are not presently available. Breeding crops for salt tolerance should not be considered as an alternative to providing drainage for the San Joaquin Valley.

SOLAR PONDS: A SOLUTION TO AGRICULTURAL DRAINAGE WATER DISPOSAL?

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In broad terms, California's San Joaquin Valley has two water problems: A need for more irrigation water and a growing accumulation of salty agricultural waste water.

The water supply problem is related to limitations of the California Water Project, the federal Central Valley Project and ground water supplies. New imports of water depend on solutions to the cross-Delta transfer problem and development of new storage facilities.

The agricultural waste water carries salts leached from the soil, imported with irrigation water, and added to the system through farming practices such as use of soil amendments. Direct agricultural losses due to salt accumulation in the San Joaquin Valley are now estimated to be about $31 million per year. By 2000 we expect there will be as much as 370,000 acre-feet of waste water from 560,000 acres of land each year. If it is not disposed of, an increasing amount of low-lying Valley lands will be lost to farming.

The California Department of Water Resources is exploring what we hope will be at least a partial or interim solution to the problems: In-Valley desalting of the agricultural drainage water. The work is being done at Los Banos, where a large demonstration facility was completed in mid-1983. It will be operated for another two to three years to determine best methods and overall feasibility of units that would desalt about 25,000 acre-feet of brackish drainage water per year.

In addition to the direct desalting studies, the facility also includes demonstration of energy recovery from salt-gradient solar ponds charged with waste brine from the desalter.

A long-discussed 'ultimate' solution to the agricultural waste water problem is a drain that would discharge it to the San Francisco Bay Delta. This proposal has recently grounded on the issue of selenium that has been found at toxic concentrations in some of the drainage water. Inevitably, the selenium issue has relevance to what we are doing at Los Banos.

What will happen to selenium in the desalting process? The manufacturers of the reverse osmosis membranes predict that some will pass through to the product water, although -- depending on the levels in the feed water -- it probably would not present a hazard.

The brine, however, would have to be treated as a hazardous waste. Since it would be held in salt-gradient solar ponds, which because of the high concentration of brine would in any event require impervious bottom or lining, it presumably would be safe. Thus the solar pond element of a desalting solution to the drainage problem adds the possible benefit of avoiding what may be a potentially serious chemical waste problem.

Aside from that, the prospect of being able to use the 'waste' brine from desalting in solar ponds is an especially intriguing one. There are some potential problems -- none of which look fatal at this point -- but before I go into that let me describe these devices in a little more detail.

Salt-gradient solar ponds occur in nature. Only in the past 20 years or so has there been extensive work -- mostly in Israel --- on creating and using such systems as solar collectors. As shown schematically in Figure 1, such a pond consists of three layers -- a very salty convective bottom layer, a middle non-convective layer composed of a gradient of decreasing density of salt concentration, and a thin convective top layer of relatively fresh water.

Los Banos

Solar Pond Generation System

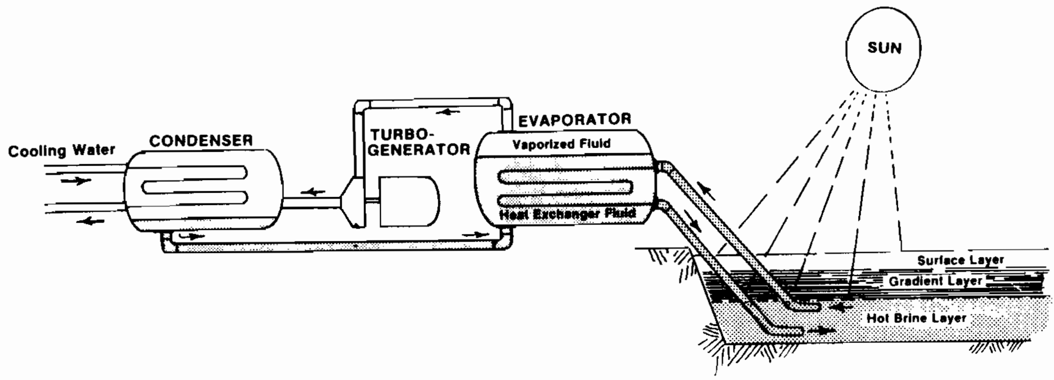

Figure 1

The non-convective gradient layer serves as an insulating blanket, trapping solar energy stored in the bottom layer. The top layer must be flushed with relatively fresh water to make up for evaporative losses and to remove salts that migrate to the surface.

We have two abutting ponds of about one-half acre surface area each at the Los Banos site. Each pond is about 12 feet deep and has an associated shallow evaporation-holding pond of the same area. All are lined with impermeable plastic membranes underlain by drainage and gas release systems. Sensors measure soil temperatures to a depth of 30 feet below the solar pond bottoms.

Heated brine (at about 185 degrees Fahrenheit) will be pumped from the bottom layers of the ponds to a heat exchanger where a low boiling point fluid (Freon) will be vaporized to drive a Rankine-cycle turbine coupled to an electrical generator. After passing through the heat exchanger the brine will be returned to the bottom layers of the ponds. We expect that the solar ponds will provide an annual average electrical power output of 12 or more kilowatts.

The present schedule --- subject to the vagaries of starting up and operating experimental systems --- will allow stratification of the first solar pond in the fall of 1985.

While in principle solar salt-gradient pond systems are well understood, a number of operational questions related to obtaining optimum performance remain.

Ours is one of the few attempts outside of the Israeli efforts near the Dead Sea to use natural salt mixtures, and the only one known to use high magnesium and sodium sulfate brines. In theory, any salt -- or mixture of salts -- can be used in a salt-gradient pond but some questions remain about performance of the mixture, particularly in relation to gradient stability. Another problem is that the drainage water -- at Los Banos, at least -- has a respectable concentration of organic materials that makes it yellowish in color, which would mean loss of pond efficiency.

If the scheme being tested at Los Banos proves successful, what are the implications of operating a 25 million gallon per day system?

Figure 2 shows one result of projections based on two modes of solar pond operations --- one with a minimum salt configuration and the other with the goal of maximum salt storage in a minimum area -- over a 30 year operating period. The vertical axis is the number of acres of drained land served, based on a rough average production of about one acre-foot of water per acre of land per year. If the low-salt pond configuration is used the eventual drain water consumption -- and therefore land served -- is eventually considerably greater.

In either configuration, the system will require large amounts of land. Figure 3 shows projections of total land consumed over a 30-year period for the high-salt pond configuration --- about 3,000 acres at the end of the period. The low-salt pond system would require a maximum of about 6,250 acres. Both estimates include 750 acres of land devoted to artificial marsh ponds, an element of the desalter that we hope will be a low-cost pretreatment step.

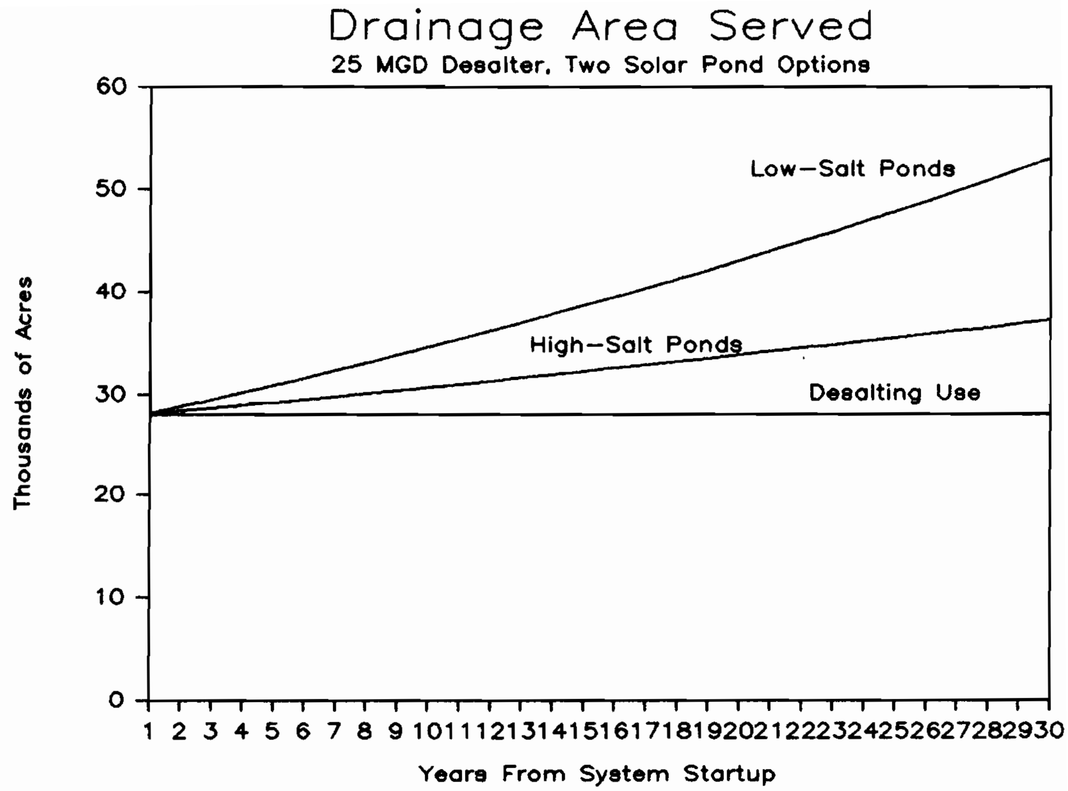

Figure 3

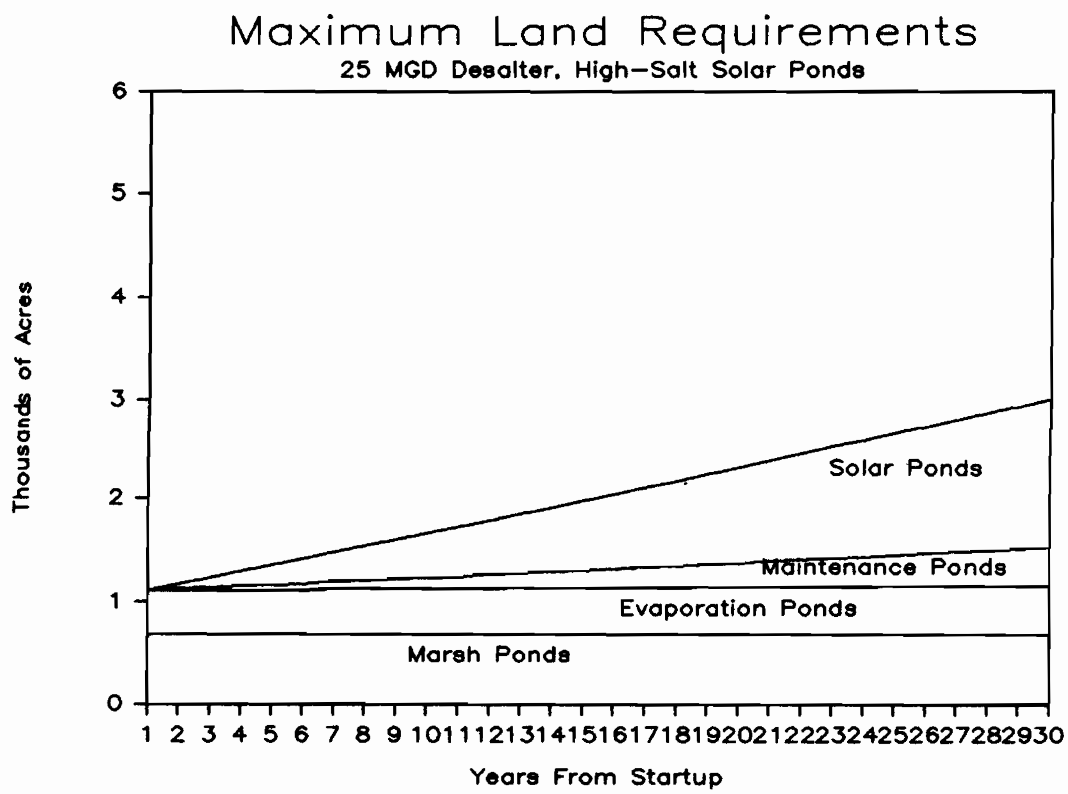

Figure 4

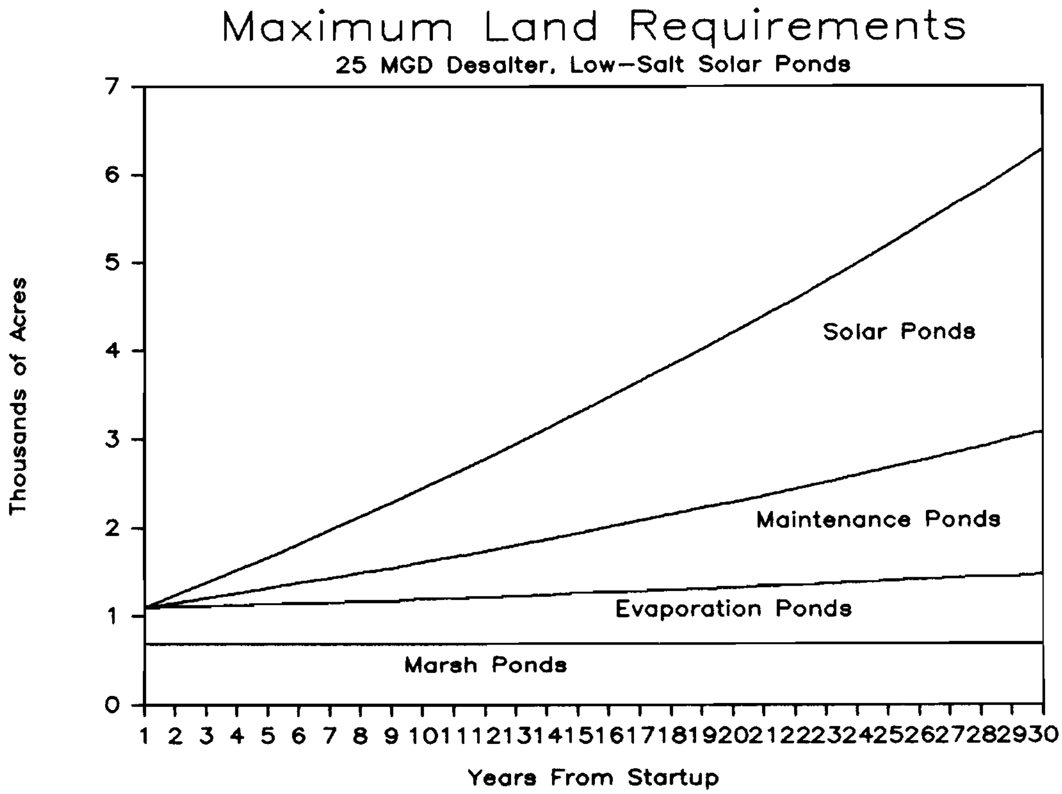

Figure 4

One way to look at the energy situation is on an annual basis. Figure 4 shows that the annual rate of production from the low-salt configuration ponds becomes greater than the desalter consumption about six years after startup. The break-even point for the high-salt system comes about 10 years after startup.

We do not yet have enough information about our proposed system to discuss technical or economic feasibility with any great confidence. In general, however, it looks as if problems that might arise can be solved and that we can make fresh water and reduce the drainage volume in a useful fashion.

If it also turns out that we can do this at a cost competitive with other supplies, taking into consideration the value of drainage disposal, then large desalting plants may play a strong role in solving the major water-related problems of the San Joaquin Valley.

Economic Analysis of On-Farm Solutions to Agricultural Drainage Problems

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Our research is concerned with the on-farm management of agricultural drainage water in the San Joaquin Valley. Specific questions addressed include the efficient management of farms when the natural drainage and off-farm drainage facilities are limiting and the economic benefits accruing to farmers from construction of off-farm facilities. These issues are important since off-farm facilities for transportation and disposal of drainage water are limited in many areas and permanent solutions in the form of a valley drain or other alternative are not likely to be available in the near future.

Options for Reduction and Disposal of Drainwater on Farms

Several options are available for reducing the quantities of drainwater produced on a farm and disposal of remaining flows. These include:

(1) Construction of evaporation ponds.

(2) Reduction in quantities of water applied per acre.

(3) Changing the cropping patterns.

(4) Reuse of drainage water from one crop for growing other crops.

(5) Improving the efficiency of the irrigation system.

Each of these management alternatives has advantages and disadvantages. Evaporation ponds can dispose excess drainage water but will require productive cropland in most areas. Applying less water per acre reduces drain water quantities but may result in lower yields. Different crops have different evapotranspiration requirements and salt tolerances. Cropping patterns can therefore be adjusted to reduce the impacts of high water tables and salinity levels, and to reduce the quantity of drainage water being produced. In many cases, however, this may imply shifts from relatively high-valued crops to relatively low-valued crops. Reuse of drainage water reduces the build-up of underground water and saves on fresh-water. However the salt concentration of the drainage water is likely to be significantly higher than that of the irrigation water so higher soil salinities and reduced yields may result. Improvements in application efficiency mean that less water is needed to ensure that all parts of the field receive adequate supplies. Although this reduces the total quantity of drainwater produced while maintaining yields, it is also likely to imply increased expenses in the form of new or refurbished irrigation equipment and more intensive managment.

Model and Data

These alternatives were evaluated with a linear programming model. The model is for a representative farm in the southern San Joaquin Valley. There is a fixed quantity of land available for growing crops and constructing an evaporation pond (1000 hectares). For farms with limited natural drainage we assume that all drainwater produced on the farm and not reused must be evaporated in the pond on an annual basis. The pond must be large enough for this purpose. For comparison purposes we also consider farms with unlimited natural drainage or unlimited access to external drainage facilities. In these cases no evaporation pond is required. Alternatives are chosen to make profits as large as posible subject to restrictions on land, drainwater accumulations, area of the evaporation pond, and cropping patterns. Only the first four alternatives were evaluated. The fifth alternative was not considered due to data limitations.

Prices, production costs, and maximum yields from 1980 UC Cooperative Extension crop budgets were used. Production functions relating yields, quantity and quality of drainwater to quantity and quality of irrigation water were specified using steady-state soil salinity relations, Maas and Hoffman yield relations, and variable ET. The salt concentration and cost of the (good) irrigation water are .7 dS/m and $.81/hectare-centimeter respectively. Constraints on individual crop acreages reflect crop rotations and other factors.

Results

Results are presented in Table 1. Area of the evaporation pond, quantity of good water, and weighted average yield are given in the first three rows. Profits are defined here as returns to land and management. They are calculated as revenues from sale of the crops minus nonland production costs (fixed and variable) and costs of installing and maintaining drain tiles. Costs of salt removal from the pond and installation costs for a reuse system are not included due to data limitations. Crop areas are expressed as percentages of available cropland.

Results under uniform water applications are given in the first three columns of Table 1. Without reuse an evaporation pond of 20 hectares is required to dispose all drainwater produced during the year. Total water applications are reduced slightly compared to a farm with unlimited natural drainage, but this reduction results from a decrease in planted acreage, not water applications per acre. In both instances sufficient water is applied to maintain maximum yields. Compared to a farm without drainage problems, profits are reduced by $73/hectare when drainage is limiting. There is no change in the cropping pattern. In the uniform case drainwater reuse has a relatively small impact. The evaporation pond is reduced by 11 hectares and total water use is reduced by 1%. Profits are increased by $17/hectare. When installation costs are considered it is quite likely that reuse will not be profitable in the uniform case.

Nonuniform water applications are considered in the last three columns of Table 1. Without reuse an evaporation pond of 42 hectares is required for disposal of drainwater produced annually. In this case it pays to significantly reduce water applications per acre. Maximum yields are maintained on the farm with unlimited drainage but yields average 90% of maximum on the farm with limited drainage. Total water use is reduced by 56% compared to the farm with unlimited drainage. This reflects reductions in crop acreage and quantities applied per hectare. The reduction in profits from limited drainage is also significant, amounting to $214/hectare or almost 20%. There is a slight change in the cropping pattern with wheat replacing sugarbeets. As in the uniform case the impact of drainwater reuse is small with respect to the evaporation pond, quantity of good water used, and average yield. The increase in profits from reuse is more significant, amounting to $59/hectare/year. This figure does not include installation and maintenance costs so the actual increase will be smaller.

Another issue is the economic value to farmers of access to off-farm drainage facilities. Some rough estimates can be made by comparing profits in Table 1 under limited and unlimited drainge and subtracting pumping costs. Using a drainwater pumping cost of $.24/ha-cm, benefits from access to external facilities are $55-72/hectare/year in the uniform case and $140-199/hectare/year in the nonuniform case. The actual amount in either case depends on the cost of installing a reuse system.

Conclusions

The results provide insights into efficient managememt and benefits from external facilities for farms with limited natural drainage. In both the uniform and nonuniform cases a small evaporation pond (5% or less of total area) is required to dispose of drainage flows produced during the year under optimal management. Maximum yields are maintained in the uniform case, however in the nonuniform case it pays to reduce water applications significantly. This reduces average yields but increases the area available for growing crops. Drainwater reuse reduces the size of the evaporation pond and potentially increases profits however the impact is likely to be significant only in the nonuniform case. No major change in cropping patterns was found. For the cases considered here, benefits from access to off-farm facilities range from $55-199/hectare/year depending on uniformity and costs of installing a reuse system. The conclusions reached here should be interpreted cautiously since the analysis is based on production functions and other parameters which are not known with certainty.

Table 1. Pond areas, water quantities, yields, profits, and cropping patterns for a 1000 hectare representative farm under various conditions.

	Uniform Applications (CUC=100)			Nonuniform Applications (CUC=72)		
	Unlimited Drainage (No Reuse)	Limited Drainage (No Reuse)	Limited Drainage (Reuse)	Unlimited Drainage (No Reuse)	Limited Drainage (No Reuse)	Limited Drainage (Reuse)
Pond Area (hectares)	0	20	9	0	42	19
Quantity of Good Water (ha-cm/yr)	62,746	61,499	60,800	153,022	67,524	67,917
Weighted Average Yield (%)	100	100	100	99.4	90	93
Profits ($/ha/yr)	1,194	1,121	1,138	1,097	883	942
Alfalfa (%)	20	20	20	20	20	20
Wheat (%)	0	0	0	0	10	10
Sugarbeets (%)	10	10	10	10	0	0
Cotton (%)	70	70	70	70	70	70
Barley (%)	0	0	0	0	0	0

Limited Drainage assumes drainwater disposed on farm.
Unlimited Drainage assumes drainwater disposed off-farm.
CUC = Christianson uniformity coefficients.
Crop areas as percent of available crop land.

CONSIDERATIONS IN MAKING ON-FARM DRAINAGE SYSTEMS WORK

by
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In order for an on farm drainage system to work many factors must be considered. They include soil and water characeristics, the farm managers' goals concerns and abilities, and as well as economic, political and enviormental concerns. The purpose of this paper is to review those concerns and how they relate to each other. They must all be considered in formulating a drainage plan that "works." The emphasis will be on puting all the elements together. The point of view is not technical but that of a consultant assisting a client.

Clients request consultation because they have concerns or problems. Yields may have been slowly declining, and a client may or may not be aware of the cause. The connection between symptoms and drainage are not always clear. A low salt ground water with high nitronen content can produce rank, non-fruitful cotton; just the opposite of what may be expected. Areas with water stress symptoms may not respond to irrigation as they have in the past. Instead of being reclaimed with irrigation, salt spots may become worse until the crop fails to germinate and only salt tolerant weeds will grow. Symptoms of a disease such as phytophthora associated with wet conditions may appear. Salt visibly acculułating at the surface, spots remaining wet long after other areas are dry enough to cultivate, and water standing above the soil surface are other symptoms of poor drainage. The symptoms or poor drainage will vary with in a season and between seasons as conditions change. In every case profit potenial declines.

The client concerned with one or more symptoms of poor drainage may not connect them with the causes of the problem. One of the most difficult steps in planning a system is convincing the client to spend money on evaluation at a time when yields and profits are declining. But it is necessary so that the cause of the problems can be determined and the most cost effective system designed. Evaluation must include determining chemical and physical properties of both soil and water, the economic situation, croping patterns, and enviormental conditions.

People are a vital part of the system and must be considered in the design. The client's goals, perceptions, understanding, skills and willingness to change are considerations as or more important than other factors. The clients perception of "what works" can range from water coming out of the drain pipe to the complex process of maximizing profits by using all of the knowledge and skill available. It is the client who defines "what works." What will work for a client is affected by the his understanding of the system, his management skills and willingness to change. One client may change to get the most out of the best design while another may get the most out of a system only if it is designed around current practices People off the farm who will be affected or who percieve they will be affected by the system must also be considered.

The quality and quantity of available irrigation water are the most important factors to be considered in planning a system. Quality ranges widely and is directly related to salinity, sodium and toxic ions and also to the amount of drain water that will require disposal. Water from the Kings river with an EC of 0.1 dS/m has few restrictions on use and would produce little unusable drain water. Water from the California Aquaduct (1.0 dS/m) would not be much more restrictive, however it would produce considerably more unusable drain water. Quality of both ground and drain water vary widely. Quality and quanity of pearched water percolating into the property from off farm sources must also be considered. The amount of water from each source and the resulting weighted average quality, are more important than the quality of each individual water.

Information concerning chemical and physical properities of the soil must be collected. Salinity and the concentration of toxic ions have a bearing on which crops will grow and the amount of water required to reclaim the soil. Exchangeable sodium and EC are indicitive of permeability problems. Lime and gypsum content of soils influences the selection of amendments. Stratification and limitations of permiability due to physical or chemical factors determine the rate at which the soil can be reclaimed and if profile alteration would be of value. Depth to the the impermeable layer determines the amount of soil that can be reclaimed and the depth at which drains should be placed. Particle size distribution must be known so that an envelope material can be selected to prevent soil from leaching into and pluging the drain line. Undulations of the restrictive layer andvariability of other features which can not be economicly altered also limit what can be done.

Crop selection is approched from three points of view. The enviroment that results from installing and using a drain will determine the type of cropping system to be used. Croping patterns can be changed as conditions change as indicated by using soil sampling and analysis. Within limits managment practices and the drainage system can be designed for particular crops. In any event design of the system will be influcnced by the crops to be grown. Considerations include the clients preference, the best mix of crops with respect to salt tolerance, soil conditions, economics, flexibility, and farm operations.

Several alternatives can be considered as possible solutions to drainage problems. Cost effectiveness of the system selected will depend upon the price of land, the price of water, the cost of disposal and the value of products produced.

Not farming is an alternative, but may not be a choice. Selecting an alternate farming site may be a viable alternative. Whether the grower rents or owns the property in question will determine if this choice is viable.

Farming without drainage has the advantage of low cost. A high level of skill is required to accumulate salt in the subsoil and to match water applications to use without limiting crop production. To be sucessful, water quality must be very good and the restrictive layer must be situated so that salt can be accumulated above it while leaving ample room for root development. Drain water may move laterally into another field or a neighbors property causing more than agronomic problems. High risk, short project life potential, very limited flexibility and choice of crops are disadvantages. Careful management may minimize the problem but is a short term stop gap solution at best.

Designing and operating a drainage system that maintains a salt balance favorable for the most sensitive crop in each field will result in maximum flexibility, ease of management, low risk and long project life. Large water requirements, large quantities of effulent for disposal and high cost are disadvantages.

A drainage system designed to produce a salt balance matched to the most tolerant crop will requires less water and produces less effluent. A high level of management skill is required. Cropping flexiblilty is lower and risk higher.

The drainage system can be designed so the salt balance can be varied from field to field to match a range of salt tolerances. Individual fields are dedicated to crops with a specific narrow range of salt tolerances. Drainage from fields dedicated to low tolerance crops is used in fields where more tolerant crops are grown. Some croping flexibility is maintained. Water requirements and the amount of effluent is held to a minimum. Higher skills and good coordination are required. Some flexibility is lost and there is a higher element of risk.

Large savings occur when this system is used to concentrate the final effluent to the 50 dS/m given as maximum salt concentration of drainage water from salt talorent crops. It is my understanding that drainage systems are being designed to acomodate 0.5 feet of effluent per acre. Five hundred acre-feet of drain water per year requiring 125 acres of evaporation ponds would result from a 1000 acre farm . Use of irrigation water with 0.1 dS/m and concentrating the final effluent to 50 dS/m would reduce the effluent to about seven acre-feet per year requiring only 2 acres of pond. Savings would include the value of the water more efficient use, reduced cost of a smaller collector and disposal system, and value of land not required for ponds. Use of medium salt waters on some fields could maintain soil permiability reducing the need for amendments. Increased cost of management and the possible reduced value of the crop produced will offset the savings.

Several management changes would be required for such a drainage system to work. In this context management practices are considered an integral part of the system. An evaluation of soil, water and other factors must proceed careful planing of the system and its management. The manager would have to implement and develop the latest technology. Use of soil and water analysis as a management tool will be required to reduce risk to acceptable levels. Irrigation systems would be evaluated, and posibly changed so that irrigation efficiency and leaching fractions can be managed. The latest irrigation technology would be mastered inorder to match consumptive use to need while avoiding risk due to drought or salt injury.

Public concerns with respect to effluent must be considered. Effluent results from any of the alternatives. Off-farm disopsal is the most desirable. No land is encumbered and the problems are delegated to someone else at the property boundry. On or off farm, enviormental concerns must be considered in drainage system evaluation. Social concerns and fears must be considered and will not be easy to deal with.

Many factors must be considered and decesions made before an engineer can design asystem that "works." The clients concerns, goals, perceptions, expectations and level of skill can not.be under-emphasized and limitations must be incorporated into the plan. Physical and chemical properties of soil and water togather with economic and enviromental factors and social concerns must be in incorporated into a drainage system. If all the expectations of the system can not be reached it may be considered a failure. The client must understand the limitations of the system including his own or the system must be designed around the client's perceptions and abilities.

January 31, 1985
PROPOSED
CONSTITUTION AND BY-LAWS OF THE
CALIFORNIA CHAPTER OF THE AMERICAN SOCIETY OF AGRONOMY

NAME

Article I, Section 1. The ~~name of the~~ organization shall be ~~known as~~ the California Chapter of the American Society of Agronomy as authorized under Article ~~XI~~ XII, Section 5 of the 1984 Revised By-Laws of the American Society of Agronomy, Inc.

OBJECTIVES

Article II, Section 1. The objectives of the California Chapter shall be generally those of the American Society of Agronomy, Inc., an educational and scientific corporation qualified for exemption under Section 501 (c) (3) of the Internal Revenue Code of 1954, as amended or a comparable section of subsequent legislation.

The California Chapter shall strive to promote human welfare through advancing the acquistion and dissemination of scientific knowledge concerning the nature, use, improvement and interrelationships of plants, soils and environment. ~~To this end~~, The California Chapter, like its parent society, shall (1) promote effective research, (2) disseminate scientific information, (3) foster high standards of education, (4) strive to maintain high standards of ethics, ~~(5) promote advancements in the profession~~, and ~~(6)~~(5) cooperate with other organizations having similar objectives.

The California Chapter supports the efforts and objectives of the Western Society of Soil Science and the Western Society of Crop Science and will operate in a manner consistent with their purposes.

MEMBERSHIP

Article III, Section 1. The membership of the California Chapter of the American Society of Agronomy shall consist of individuals actively interested in the objectives of the Chapter as outlined in Article II and who have paid dues for the current year.

Section 2. ~~Members of~~ Membership in the American Society of Agronomy, the Soil Science Society of America, ~~or~~ the Crop Science Society of America, ~~shall be entitled to~~ the American Society of Horticultural Science or similar professional societies is encouraged, but not required, ~~to~~ for full membership in the California Chapter of the American Society of Agronomy.

~~Section 3. A person not a member of the organization set forth in Section 2 may be a member of the California Chapter and be entitled to all the privileges of members qualifying under Section 2, except that they shall not be eligible for an elective office in the California Chapter.~~

OFFICERS AND STANDING COMMITTEES

Article IV, Section 1. The governing board of the Chapter shall be constituted by an Executive Committee and a Council of Representatives.

Section 2. The Executive Committee shall consist of the Past President, President, First Vice-President, Second Vice-President and Executive Secretary-Treasurer. The term of office with the exception of the Executive Secretary-Treasurer shall be for one year. The Executive Secretary-Treasurer shall serve for a three-year term.

Section 3. The representation on the Executive Committee shall be split as evenly as possible between (1) industry and (2) university, ~~-Experiment Station-Extension-State~~ college and government groups, and evenly between the broad groupings of soils and crops. ~~The objective would be that,~~ For example if the President comes from ~~the~~ a university~~-experiment station~~-extension, ~~state~~ college or government agency grouping and ~~was~~ is considered to be from the ~~a~~ soils or irrigation discipline ~~man,~~ the First Vice-President would be from one of the crops disciplines ~~a crops man from~~ representing industry. The normal order of progression would be President to Past President, First Vice-President to President, Second Vice-President to First Vice-President, and ~~with the election of~~ the Second Vice-President ~~coming~~ elected from present or past ~~the~~ Council Representatives.

Section 4. The Council shall consist of nine elected representatives, 4 or 5 from industry groups and 4 or 5 from ~~University-Experiment Station-Extension-State Colleges-Government~~ public sector groups and shall represent a broad range of disciplines. ~~The nine areas of representation are:~~

~~1. Agronomy and Range Science.~~
~~2. Water Science and Agricultural Engineering.~~
~~3. Soils and Plant Nutrition.~~
~~4. Vegetable Crops.~~
~~5. Viticulture, Horticulture and Ornamental Horticulture.~~
~~6. Fertilizers and Other Agriculture Chemicals.~~
~~7. Plant Breeding, Seed Production and Technology.~~
~~8. Environmental Quality.~~
~~9. Advisory and Regulatory Agencies.~~

Section 5. Each Council Representative will be elected to serve a three-year term. The terms will be staggered so that three Representatives will be elected each year. When a vacancy occurs on the Council because of death, resignation or other cause, appointment to fill the vacancy will be made by the Executive Committee and the appointee will serve until the next election.

~~Section 6. All Council Representatives and Members of the Executive Board must be Members of the American Society of Agronomy.~~

Section ~~7~~ 6. The Council Representatives will be elected by the membership assembled at the time of the Annual Business Meeting. The Nominating Committee will be the Executive Committee. They will distribute the list of nominees prior to the annual meeting. Additional nominations may be made from the floor at the Annual Business Meeting in which case elections shall be by secret ballot of those in attendance and voting.

Section ~~8~~ 7. The Council Representatives and Members of the Executive Committee will elect the President, First Vice-President, Second Vice-President and Executive Secretary-Treasurer.

Section ~~9~~ 8. The duties of the Past President, Vice-President, Second Vice-President and Executive Secretary-Treasurer shall be those which usually pertain to such offices of similar organizations. The Past President shall serve as the chairman of the Awards Committee. The President and First Vice-President shall serve as program co-chairmen for the Annual Meeting. The Second Vice-President shall serve as chairman of the Membership and Dues Committee, and publicity.

Section ~~10~~ 9. The President, with the approval of the Executive Committee, shall annually appoint such committees, their members and chairman, as ~~he~~ the President or the Executive Committee deems necessary to assist in carrying out the objectives of the Chapter.

ANNUAL MEETING

Article V, Section. The California ~~Section~~ Chapter of the American Society of Agronomy will hold an Annual Meeting at such a time and place as shall be advantageous to the members. The program as developed by the Program Committee shall include ~~both invitational and non-invitational~~ papers on subjects of wide interest to educators, scientists, farmers and others ~~those~~ who serve agriculture. Emphasis will be on the applications of scientific developments. Sectional meetings, special symposia, joint or cosponsored meetings with other groups may be arranged by the Executive Committee and may be held separately from or in conjunction with the Annual Meeting.

DUES

Article VI, Section 1. Annual membership dues shall be set by the Executive Committee and shall be assessed and collected as provided for in the By-laws.

Section 2. Fees or dues associated with the operation of the California Chapter will be held to a minimum.

~~Section 3. Members in arrears for Chapter dues will be dropped from the rolls in accordance with the By-laws.~~

AMENDMENTS ~~AND BY-LAWS~~

Article VII, Section 1. The constitution and By-laws may be amended by a two-thirds (2/3) majority vote of the members present at the Annual Meeting, providing such amendments have first been presented, in writing, to the Executive Committee for consideration not less than sixty (60) days prior to the Annual Meeting.

~~Section 2. Amendments to the By-Laws may be proposed to the Executive Committee by ten or more members of the California Section. Such amendments must be presented, in writing, to the Executive Committee for consideration not less than sixty (60) days prior to the Annual Meeting. A simple majority vote of the members present at the meeting is required for a change in the By-Laws.~~

BY-LAWS

PUBLICATIONS

Article I. The publications of the California Chapter may consist of proceedings made up of abstracts of submitted ~~and individual~~ papers, reports of committees, minutes of the Annual Business Meeting and such other items as shall have general interest to the members. The Executive Committee is authorized to charge for publications in such a manner as to reclaim actual costs.

DUES

Article II. The annual dues to the California Chapter shall be ~~two ($2.00)~~ three dollars ($3.00). ~~Dues in arrears for more than one year shall be cause for automatic exclusion from membership.~~

PAYMENT OF EXPENSES

Article III. The Executive Secretary-Treasurer shall be authorized to pay all routine expenses. Expense items other than of an operational nature shall require the approval of the Executive Committee.