Efficient distribution of water in

Irrigating Annual Crops

with limited supplies in drouth years

John R. Davis and Melvin A. Hagood

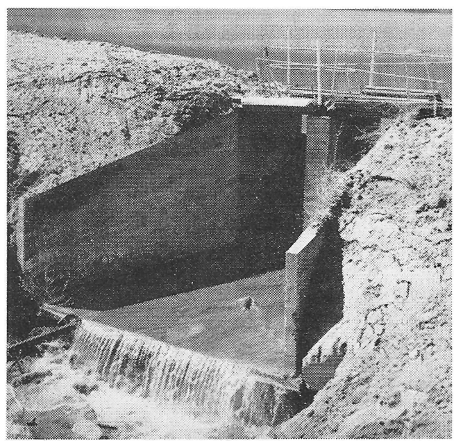
In every water-deficient year, growers are confronted with a series of decisions concerning the utilization of a limited supply of water for crop production.

Perennial crops such as tree fruits, vines and alfalfa require some minimum application of water to protect the crop and the investment for following years, thus influencing to some extent the final decisions. With annual crops, however, the flexibility and also the difficulty of decision making increases considerably, because so many factors have an influence on the end results.

In addition to the questions of how much water to apply and when to apply it, growers must decide the uniformity with which water is applied, the most economic application of water, which crops to irrigate, or even whether to irrigate at all. As individuals, growers must make decisions that are based on extremely variable and complex functions and in the face of a sometimes critical economy.

To provide information to illustrate some of the decisions that can be enacted in a farm situation, a replicated plot study of irrigation of sweet corn was initiated at Davis in 1960. Sweet corn is a fairly representative annual crop, and the findings may be applied to other crops.

In one test plot, to be used as a check, the soil was irrigated with a depth of water and a frequency according to good local practice, so that throughout the growing season the moisture content of the soil always exceeded 30% of the total available moisture. The remaining plots were irrigated at the same time on the same day, but received at each irrigation 25, 50, 75, 150, and 200% of the depth of water applied to the check plot. The objective of the six treatments was to provide conditions in the plots that might represent certain distributions of water within a field, or that might simulate results of underirrigation or overirrigation with a given frequency of irrigation.



Limited water supplies require efficient irrigation.

Golden Cross Bantam sweet corn was planted in the plots on May 2 in Yolo silty clay loam soil, a deep permeable soil with good internal drainage. Nitrogen was side-dressed on June 2, at the rate of 90 pounds per acre. All plots had been pre-irrigated to a depth of about 6′. The two inside rows of corn in each plot were harvested on July 28 and on August 2, and the weight and number of marketable ears were measured for each harvest. The yield information definitely reflected the effects of pre-irrigation, therefore the results of the study may be interpreted for those conditions where pre-irrigation is inevitable, due to winter rains, leaching operations, or the availability of cheap water. Where pre-irrigation is not possible, the information is valid but the numerical values would change.

The yield results for the six irrigation treatments are shown in the smaller graph. Although the maximum yield of about 5.2 tons per acre was attained with a depth of application of 32″ of water, the most efficient irrigation, from the

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SULFUR

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graph. At a pH of about 5.0 in the salt-free soil the average pH for all soils was 0.5 unit lower in the unleached than in the leached soil. The range of differences was 0.17 to 0.77 pH unit.

The lower graph on page 5 presents the relationship between sulfur requirement by the buffer method and by the incubation method. If the sulfur estimated by the buffer method had been added to these soils the pH—as indicated from the data obtained by the incubation method —would have been within the 4.8 to 5.4 range for all soils. Nine of the soils would have had a pH in the 5.0 to 5.2 range. Two would have had a pH between 4.8 and 5.0 and five would have had a pH between 5.2 and 5.4. Thus, the buffer method does have some reliability in predicting the sulfur requirement.

The estimated sulfur requirement as expressed in pounds per 2,000,000 pounds can be converted to pounds per acre-six-inches if the soil has a bulk density of about 1.3 to 1.4. The amount of sulfur must be adjusted proportionately for lower or higher bulk densities.

All of the soils used in this study were relatively coarse-textured with low amounts of organic matter. The buffer method seriously underestimated the sulfur requirement on an organic soil and on a clay soil but because most potato production in southern California is on coarse-textured soils, the underestimation for these two soils does not represent a serious problem.

The buffer method for the estimation of the amount of sulfur needed to acidify coarse-textured soils to pH 5.2 is rapid and requires no special equipment. The correlation between the sulfur requirement by the buffer method and by an incubation method was 0.96 with a standard error of estimate of 150 pounds of sulfur per 2,000,000 pounds of soil.

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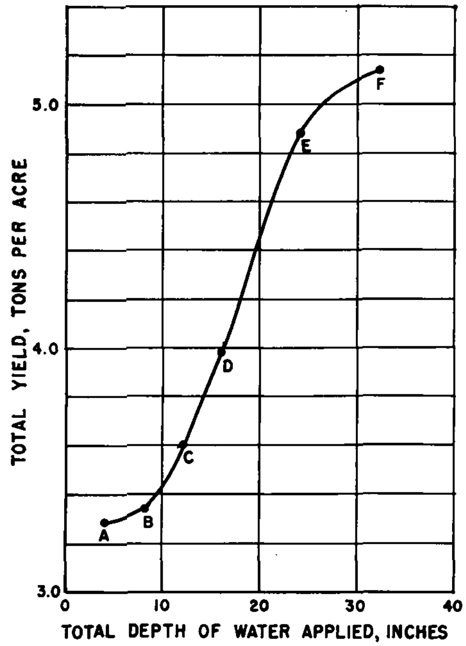
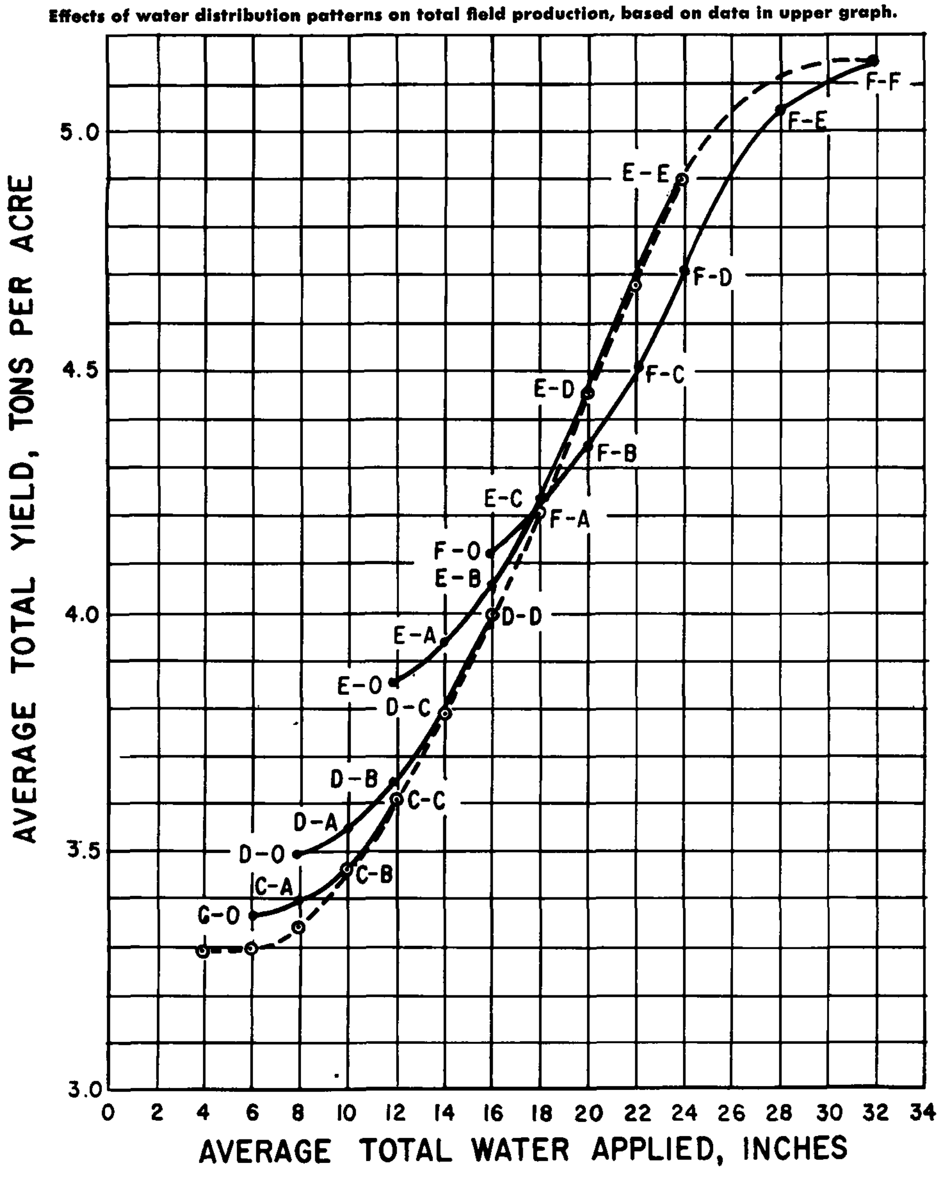


Relation between total yields of sweet corn and depth of water applied in summer irrigations.

Effects of water distribution patterns on total field production, based on data in upper graph.



standpoint of minimum water used per ton of crop production, was the *A* treatment, which produced 0.73 ton per acre per inch of water applied. Apparently, if no irrigation water had been added, the corn yield may have approached about 3.25 tons per acre. However, a conclusion that it would have been better not to irrigate at all would be erroneous, because the grower must work on an economic basis, to produce the maximum

Yields of Irrigated Sweet Corn in Irrigation Efficiency Tests

Plot designation	Treatment	Total water applied (acre-inches)	Marketable yield (tons/acre)
A	25%	4	3.33
B	50%	8	3.38
C	75%	12	3.75
D	100%*	16	4.09
E	150%	24	4.97
F	200%	32	5.23

* Good local irrigation practice selected as a standard for comparative purposes.

net return from the available resources. The grower's investment in land, physical facilities, and in cultural practices is usually a fixed value and if an added increment of water, fertilizer, insecticide, and so forth increases the value of the crop more than the cost of the added increment, the grower gains. The maximum gain from an investment of water, as shown in the graph, would occur at a depth of application of about 18″, between treatments *D* and *E*. At this point, 1″ of water applied produced about 0.13 ton of sweet corn, which has an estimated net value, after other production costs, of $4.50. If the assumption is made that this application of 1″ of water cost the grower about $2.00, then he gained $2.50 per acre.

However, if a grower attempted to achieve higher yields and applied 30″ of water, at that point he increased the net value of the crop by about $0.65 at an expense of $2.00, for each inch of water applied. Using some of the same cost figures, it can be calculated that, up to approximately 24″ of water applied, the return is larger than the cost; but that the application of an additional inch of water beyond the 24″ cost more than the return, by about $0.30 an acre. Therefore, based on such calculation, irrigation would be economically efficient only if the total depth of water for the season did not exceed 24″.

The break-even point is difficult to evaluate, as it depends on many factors, including factors which interact with water. An addition of fertilizer may change the situation enough, for example, to make a 30″ application equally as efficient. Thus the decision on whether or not an irrigation is efficient is extremely difficult and will necessarily be made on a year to year basis.

During drouth years, growers must plan to deliver water from a deficient supply to fields or areas which return the maximum benefits. The calculations used in the example established that depths of water application above 24″ were not economical and, as shown in the smaller graph, any applications up to 10″ would be uneconomical. Thus an economic or efficient range of water application exists between 10″ and 24″ of water, over and above winter rains or winter irrigation. Efficient irrigation, for this example, exists only for a range of water applications and would depend on whether or not the distributions of irrigation water in the field fell within that range.

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Behavior of short-chilling

Peach Varieties in Southern California

after warm winter of 1960–1961

J. W. Lesley and M. M. Winslow

In southern California peaches frequently are not exposed to winter chilling sufficient to break the rest period. The dormant condition of the flower and leaf buds is prolonged and symptoms sometimes known as delayed foliation appear. Flower and leaf bud growth are late and irregular; the fruit ripens irregularly and, in extreme cases, there is little or no crop. The fall and winter temperatures of the buds and twigs are critical. Pruning has a localized growth-stimulating effect and spraying at the proper time with an oil-in-water emulsion containing DNO—dinitro-o-cyclohexyl phenol—or DNC—3-5-dinitro-o-cresol may be helpful.

The exact relation to temperature and timing of chilling peaches is unknown but probably exposure to 45°F, or below, is effective. Therefore, the sum of the hours at or below 45°F from the fall to the end of February is used as a rough measurement of winter chilling. Chilling after February is relatively ineffective. For the same locality, the temperature sum is a tolerable measure of winter chilling but symptoms of insufficient chilling were far more severe at Riverside in 1961, after 738 hours, than in 1960, after 636 hours. Presumably sunshine, fog, humidity and even air movement affect bud temperature.

Peach varieties vary in winter chilling requirement and a long term study was begun in 1927 with the object of developing improved short winter-chilling varieties adapted to southern California and other subtropical climates.

At Riverside such standard relatively long chilling varieties as Elberta, J. H. Hale and Rio Oso Gem have suffered partial or total crop loss from insufficient winter chilling in 10 of the past 30 years.

In general short-chilling varieties bloom earlier than long-chilling. Extremely short-chilling varieties may bloom in mid-January and suffer seriously from frost injury to the flowers when longer-chilling varieties, still in rest, will bloom later and often over a longer period. Flower buds require less chilling than leaf buds but may drop excessively after a mild winter.

The winter of 1960–1961 in southern California was extremely mild, sunny and dry. In peaches the symptoms of insufficient chilling were the most acute of the past 30 years and made it possible to determine accurately the usefulness

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IRRIGATION

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When an available water supply is less than 24″, a decision must be made regarding not only the most appropriate depth of water to apply and area to irrigate, but also the uniformity with which water is to be applied.

The lower graph on page 7 illustrates the effect of uniformity of water application on the total yield of a field of any given size. The letters in the graph describe the type of water distribution—the first letter referring to the depth of water applied at the upper end of the field and the second letter to the depth at the lower end. An application of C-C would be a perfectly uniform application of 12″ of water, whereas E-O would represent an application of 24″ at the upper end of the field and none at the lower end. The broken line represents the yield results for uniform water distributions, for any depth of application. The graph also shows that, for applications above 18″ of water, better yields may be obtained with more uniform application to the entire field. Below the application of 18″, apparently a non-uniform distribution of water results in better yields than a uniform distribution. For an average water application of 12″, for example, a grower would gain in production by applying 24″ of water at the upper end of the field and none at the lower end, compared to spreading 12″ uniformly over the entire area. However, a closer examination of the graph indicates that non-uniform water distribution is not the true reason for the better results, but rather it is due to the proper irrigation of only that portion of the area that results in economic returns. Instead of applying 12″ uniformly, or 24″ and zero inches at the upper and lower ends, the grower could irrigate only one half of the field uniformly with 24″ and not irrigate the lower half at all. The average total yield for the entire field, which would include 4.9 tons per acre for the upper irrigated half and 3.25 tons per acre for the unirrigated half, would then be 4.1 tons per acre; or an increase of one-half ton per acre over a uniform 12″ application.

In general, a good pre-irrigation or winter rain that supplies considerable water to a short-season crop may be more beneficial than other seasonal irrigations. During drouth years when water supplies for summer irrigation are extremely limited, growers should not try to stretch that water over an entire field, but should attempt to reduce the size of the irrigated area and to apply an economically feasible depth of water.

Generally, there are economic limits to the use of water, for either high or low applications of water, and growers must establish those upper and lower limits to make effective and efficient use of water.

Efficient irrigation with limited supplies of water involves considering the value of the crop, the cost of water, the crop returns for each inch of water applied, the critical growth stages of the crop, and the distribution of water to the crop in the field.

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