IMPROVING EFFICIENCY IN AGRICULTURAL WATER USE

by

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Colorado Water Resources Research Institute

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IMPROVING EFFICIENCY IN

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Title: SURFACE WATER

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ABSTRACT

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Management of runoff under dry land cropping was attempted by collecting precipitation from sealed surfaces 4' to 10' wide on untreated crop strips 18" wide. In the dry years of 1966 and 1968, when only six and eight inches of water were available, respectively, (soil storage plus rainfall) yields from microwatersheds were five times yields on untreated check areas. Crops grown included corn, sugar beets, and sweet corn. During the four-year study period, 1965-1969, with an average of 8.5" of moisture available, corn on the treated plots yielded 68 bushels per acre compared to 32 bushels per acre from the untreated area. In 1968 when 8" of moisture was available, sweet corn on microwatersheds yielded 924 ears per acre compared to 165 ears per acre from the check. Sugar beets yielded 9 tons per acre compared to 3 tons per acre on the check. In 1967 with 11" of moisture available, beets on the microwatersheds yielded 12 tons per acre compared to 11 tons per acre on the check.

An evaluation of several possible water proofing or infiltration reducing covers for the microwatersheds were made. The cost of concrete was $3,000 per acre. Other materials tested included polyethelyene plastic, hydrophobic chemicals, and sodium salts, none of which proved fully acceptable due to short life.

Plant growth and moisture use under controlled water stress conditions were studied. Controlling water stress by irrigation scheduling reduced evaporation 61 percent while yields were reduced only 36 percent compared to maximum yields under ideal moisture stress conditions. Other plant responses to moisture stress include leaf turgidity, stomata opening, and leaf sugar content.

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/evapotranspiration/ crop response/ growth rates/
/*irrigation effects/ *moisture stress/ moisture uptake/
/*runoff management/ water yield.

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I. Sub-project Title: Management of Water on Dry and Irrigated Lands for More Efficient Use.

II. Principal Investigators: W. D. Kemper and R. E. Danielson, Department of Agronomy.

III. Cooperators: H. R. Gardner and M. Fairbourn, USDA, SWCRD.

IV. Research Findings:

A system involving the use of elevated strips of the land surface to contribute water to adjacent cropped strips was tested and shall be called the microwatershed system in succeeding discussion. The "watershed" areas involved strips from 4' to 10' wide which were interspersed with cropped strips 18" wide which contained two rows of plants (corn, sugar beets, or sweet corn) spaced 12" apart. Since effective and durable soil sealants were not yet available, the potential of this microwatershed system was tested by covering the sheds with about 2" of concrete which, when painted, shed essentially 100% of the precipitation to adjacent cropped strips.

The best microwatershed treatments yielded an average of 68 bu. of corn/acre and used an average of 8.5" of water per year during 1965-1969 inclusive. Check treatments (rows spaced 3' apart yielded an average of 32 bu/acre using essentially the same amount of water. The yield differences were greatest in the dry years of 1966 and 1968 when only 6" and 8" of water (stored plus rainfall) were available to the crops. In these years the yields on microwatershed systems were more than 5 times the yields on the check treatments.

Yields of salable sweet corn were 9,240 ears/acre on microwatershed systems in 1968 and 165 ears/acre on the check plots.

In 1967 check plots of sugar beets yielded 11 tons per acre and microwatersheds yielded 12, using about 11 inches of water. During 1968 when only 8" of water was available to the beets, microwatersheds yielded 9 tons of sugar beets and check plots yielded only 3 tons/acre.

All yields are calculated on the basis of the total areas in the plots, including microwatershed areas.

The general conclusions are: If an economical waterproofing agent can be found for microwatersheds, yields of corn could be doubled and sugar beets could be grown in many of the dryland areas of the Great Plains. Such a cropping system would be particularly beneficial during periods of prolonged drought, since it could produce about 45 bushels of corn/acre on only 6" of water.

While the present cost (about $3000/acre) of waterproofing microwatersheds with concrete is not economical for field crops, even this system provides insurance for a highly industrialized nation which, if faced with droughts of the severity encountered in the major droughts of the Great Plains in the 18th and 19th centuries, could turn its industrial capability to the production of microwatersheds on the Great Plains and prevent starvation of its people.

The search for and evaluation of other waterproofing materials was not very productive. In general, hydrophobic agents were expensive and when applied only in thin layers on soil surfaces, were subject to mechanical breakdown by raindrop impact.

Polyethylene sheeting was effective, but the necessity of replacing it yearly makes its long-term cost about the same as that of concrete.

Sodium salts are fairly effective in breaking down the aggregate structure of soil surfaces and increasing runoff. While sodium phosphate and carbonate gave the best initial runoff, sodium chloride had a more lasting effect. A treatment of 400 lbs/acre increased runoff from 2"/year on a check treatment (bare soil surface) to 4"/year on Na-treated plots. Retreatment with the salt about every two years appears to be necessary to maintain the increased runoff. Long-term treatment (e.g. 40 years) of this type would result in soil with high runoff, but it would be difficult to confine the treatment to the watershed area. Eventually the cropped area would become salinized with the consequent negative influence on crop growth. However, the success of the runoff plots at Avdat, Israel, where fruit trees are being grown on about 4" of precipitation per year, is undoubtedly due to the fact that the soils are slightly saline with Na salts. Their dikes hold the water on the cultivated area long enough to ensure infiltration and occasional leaching of the cultivated area keeps the salt content of the root zone to reasonable levels. Development of such agricultural systems is much more likely to be accepted by the public if it is applied to low value lands in arid zones which are already saline.

Investigations directed toward the management of surface water on irrigated crop land have involved laboratory and greenhouse studies as well as field trials. Controlled laboratory studies were designed to evaluate the influence of water stress levels in plants on transpiration and growth rates in order to evaluate photosynthetic efficiency in terms of water use. Techniques for developing and maintaining plant water stress by artificial means were evaluated. Plant physiological responses and transpiration were measured under the artificial stress conditions and compared to results from plants grown in soils.

Water use and relative growth rates of bean plants were both reduced by plant water stress conditions as would be expected, but water use was reduced to the greatest extent. Thus, water use efficiency by stressed plants was significantly increased when water availability to the roots was maintained at levels below that required for potential transpiration under a specified foliar environment. Comparable results were obtained when soil cultures were used under greenhouse conditions by limiting irrigation frequency so as to develop periodic stress. The findings provide knowledge usable where irrigation water supplies are insufficient to adequately irrigate all the land available or where water is sufficiently costly to make water use efficiency of greater concern than maximum production. Field plot data has been obtained to substantiate the laboratory results. In 1968 controlled development of plant water stress through irrigation scheduling reduced consumptive use of water during the crop season by 61 percent, while yield was only reduced 36 percent as compared with irrigation systems where maximum production resulted.

The studies have provided an opportunity to measure various plant responses other than growth in relation to water stress levels. Leaf relative turgidity measurements were found to be relatively insensitive to water stress levels through the range where transpiration is significantly reduced. Measurements of stomatal aperature, however, are closely associated with transpiration and thus are related in a meaningful way to interval leaf water stress. Leaf sugar concentrations were found to increase somewhat as plant water stress increased, but the consistency of the data was not sufficiently good to recommend such an analysis as a means of measuring water stress.

Details of the experimental results are provided in publications and manuscripts prepared for publication.

V. Publications:

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Conway, J. T., W. D. Kemper, and N. Lahav. Successive Na profiles and their effect on runoff. (Manuscript in preparation for submission to Soil Sci. Soc. Amer. Proc.

Fairbourn, M. L. and W. D. Kemper. Production of sugar beets as affected by microwatersheds and ground color. (Manuscript in preparation for submission to Agron. Jour.

VI. Student Training:

Six graduate students have been involved in the research conducted under the project. These have included three Master of Science and three Ph.D. candidates.