Water Use of Field Crops in Eastern North Dakota

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Introduction

Historically, solid-seeded small grain crops have dominated production in the northern Great Plains. However, recent developments in variety selection and crop breeding have brought about an increase in the acreage planted to other crops. Several row crops have become popular. These include sugarbeet, soybean, corn, sunflower, and dry edible beans.

Efficient agricultural land management requires an understanding of crop physiology, seasonal climatic conditions, plant water and nutrient requirements, and soil resources and capabilities. It is necessary to also understand the interactions of these characteristics and to adopt cultural practices that maximize efficiency of resource use.

Crop production is dependent on many factors, including availability of moisture, temperature conditions, light intensity, and nutrients. In addition, interaction of these factors markedly influences plant growth. Various agricultural management practices can control or influence some of the environmental factors that affect crop production. Available soil moisture, as an example, can be influenced by irrigation, drainage, tillage, crop rotations, and crop selection.

The influence of available soil moisture on crop growth is well understood. Maximum yields of agricultural crops are most often obtained when the rate of water application is equal to the potential evapotranspiration, provided that fertility or other environmental factors are not limiting.

The soil moisture level necessary for maximum production of many crops has been determined. Examination of the optimum levels for several different crops suggests that there is no single optimum moisture level applicable to all crops. Many crops may produce maximum yields at unique soil water contents. For example, soil moisture levels greater than 50 per cent of the total storage capacity result in maximum production of alfalfa, tobacco, sweet potatoes, and peaches. Many other crops show little or no increase in crop yields when the soil moisture level is increased above the 50 per cent level. Similarly, several investigators have demonstrated that production of particular crops decreases as the soil moisture in increased to excessive levels. Viets (1962) and Chang (1968) have discussed the information presently available regarding crop production and soil moisture. Lack of available water during the crop growing season is often a limiting factor for crop production.

The objective of this study was to compare the seasonal water use of several field crops commonly grown in eastern North Dakota and northwestern Minnesota. Small grains have been of special interest due to their extensive production throughout the state (Davis et al, 1952; Bauer and Young, 1966). Stegman et al (1977) have determined crop coefficients for a number of crops, including sugarbeet, corn, spring wheat, soybean, potato, and alfalfa. Alfalfa has been studied by Bauder et al (1978) and several others. This water use study complements other water use studies conducted throughout the state.

Materials and Methods

Seasonal water use of several crops was compared at three sites in 1977 and at one site in 1978. All sites were located in eastern North Dakota or northwestern Minnesota, in the Red River Valley. The region is predominated by a continental climate with approximately 50 percent of the annual precipitation occurring during the frost-free period from May through September. The crops compared, locations of study sites, and soil properties are included in Table 1. Sunflower was included in all comparisons, sugarbeet and corn were included in three of the four comparisons, soybean was included in two comparisons, all other crops were studied at only one site.

Each site was fertilized before planting to meet specific crop requirements. Fertilizer applications were made on the basis of soil samples and routine analysis by the North Dakota State University soil testing laboratory.

During the 1977 study, duplicate plots of each crop studied were established within cooperator fields at three locations. Neutron probe access tubes were installed in each plot to monitor soil water depletion by the crops. Soil samples were collected for physical characterization (Table 1). Weekly measurements of soil water were made throughout the growing season. Measurements were made at 12-inch depth increments to 6 feet. An additional measurement was made at the 6-inch depth. Measurements were converted to volumetric water content and equivalent depth of water. A recording rain gauge was located at each site to measure rainfall. Total seasonal water use was calculated for each crop.

Crop yield samples were harvested from all plots at crop maturity to determine yield. The size of the sampled area varied with each crop. Grain and seed samples were dried, threshed, cleaned and weighed. Sugarbeet samples were analyzed for extractable sugar.

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TABLE 1. Crops, study site locations, and soil properties of 1977 and 1978 crop water use comparisons in eastern North Dakota.

Site number	Location	Soil type	Soil series	Depth weighted mean profile	Available soil water storage	Crops compared[3]
				g/cm³	in H_2O/6ft depth	
			1977			
1	Dilworth, MN	Sandy, mixed frigid, Aeric Calciaquoll	Ulen fine sandy loam	1.42	4.7	SF,SOY,SB, SW
2	Mapleton, ND	Fine, montmorillonitic, frigid vertic Haplaquoll	Fargo silty clay loam	1.22	16.4	SF,B,C,F, SB
3	Page, ND	Fine-loamy, mixed Pachic Udic and Udic Haploboroll	Svea-Barnes loam association	1.31	18.3	SF,B,C,DEB
			1978			
1	Fargo, ND	Fine, montmorillonitic, frigid Vertic Haplaquoll	Fargo silty clay loam	1.22	17.4	SF,C,SOY,SB

[1]0-6 ft depth, assumed effective rooting zone.
[2]Available soil water storage capacity = ⅓ bar soil moisture tension (SMT) water content-15 bar SMT water content, expressed on an equivalent depth basis.
[3]SF = sunflower; SOY = soybean; SB = sugarbeet; SW = spring wheat; B = barley; C = corn; F = flax; DEB = dry edible beans.

In 1978 water use by corn, soybean, sugarbeet, and sunflower were compared at Fargo, ND. All crops were planted in plots measuring 25 ft. × 10 ft. Each plot was fertilized separately on the basis of specific crop recommendations and routine soil analyses. Populations were established for each crop on the basis of previous crop performance for this region. Soil water depletion was determined weekly using the same procedure as in 1977. Final yield was determined by harvesting the entire plot area for each crop at crop maturity.

Results and Discussion

Seasonal water use by the crops varied significantly at each site and also from site to site. Sunflower was grown at each site and used as a standard for comparison among crops and from site to site. Sunflower water use ranged from 12.1 to 16.5 inches in 1977, and was 16.4 inches in 1978. The other crops required various amounts of water (Table 2).

Sugarbeet used the most water of all crops; seasonal water use ranged from 16.6 inches at Site 2, 1977 to 22.8 inches at Site 1, 1977. With the exception of Site 3, 1977, total water use by sunflower was less than all other row crops, i.e., soybean, corn, and sugarbeet. Seasonal water use by solid-seeded small grains, spring wheat, barley, and flax, was less than sunflower.

Consumptive water use for several crops was estimated by Davis et al (1952). Based on measurements of water use at 20 locations throughout North Dakota, small grain water use was low (16-17 inches/season), while sugarbeet, soybean, and corn (silage) were comparatively high (20-22.5 inches/season).

Several studies have identified factors which influence seasonal water use requirements. Two of these factors are the amount of exposed soil surface in relation to leaf surface and differences in plant morphology (rooting, stomatal structure, and density) among crops.

TABLE 2. Total seasonal water use, days from emergence to maturity, and daily water use rates of crops studied in 1977 and 1978 crop water use comparisons in eastern North Dakota.

Site number	Location	Crop	Total water use	Days from emergence to maturity	Daily water use
			inches		inches/day
		1977			
1	Dilworth, MN	sugarbeet	22.8c[1]	146	0.16b
		soybean	16.8b	129	0.13a
		sunflower	16.5b	97	0.17b
		spring wheat	12.0a	74	0.16b
2	Mapleton, ND	sugarbeet	16.6c	135	0.12a
		corn	15.6bc	101	0.15c
		sunflower	14.6b	127	0.11a
		barley	13.8a	99	0.14b
		flax	13.7a	102	0.13b
3	Page, ND	corn	16.0c	115	0.14b
		sunflower	12.2b	98	0.12a
		barley	11.5b	72	0.16c
		dry edible bean	10.2a	71	0.14b
		1978			
1	Fargo, ND	sugarbeet	19.6c	126	0.16c
		corn	18.2b	126	0.14b
		soybean	17.1a	126	0.14a
		sunflower	16.4a	111	0.15bc

[1]In each year and location, values for total water use and daily water use followed by the same letter(s) do not differ significantly at the 10% probability level, according to Duncan's Multiple Range Test.

Shaykewich (1974) cites length of active growing period as another significant factor in determining seasonal water use among various crops.

The number of days from emergence to maturity of the 1977 and 1978 crops is indicated in Table 2. Crops requiring the longest growing period generally had the greatest seasonal water use, i.e., sugarbeet, corn, soybean. The correlation coefficient between total water use and days from emergence to crop maturity was highly significant ($r = 0.97$, $P \leq 0.05$). It was concluded

that a significant factor in determining seasonal crop water use was length of active growing period, regardless of crop morphology.

Daily water use was determined from seasonal water use and growing season length (Table 3). Mean daily water use for the active growing season ranged from 0.13 inches/day (soybean and flax) to 0.16 inches/day (spring wheat). Daily water use was greatest for spring wheat, followed by barley, corn, and sugarbeet; lower water use rates were measured for dry edible beans, sunflower, flax, and soybean, respectively. A similar ranking of daily consumptive water use rate of spring wheat, barley, sugarbeet, and corn was reported by Sonmor (1963) in southern Alberta, Canada.

The relationship between seasonal water use, average daily water use and days from emergence to crop maturity for all crops, sites, and years are shown in Figure 1. Daily water use among the various crops decreased as the season length increased. The correlation between average daily water use and days from emergence to crop maturity was $r = -0.77$ ($P \leq 0.10$).

Water use efficiencies are presented in Table 3. These data, although of little value for direct comparison in agronomic terms, demonstrate the variability in water use efficiency for production by various crops.

TABLE 3. Mean seasonal water use, growing season length, and daily water use rates of crops studied in 1977 and 1978 crop water use comparisons in eastern North Dakota[1]

Crop	Seasonal Water use inces	Days from emergence to maturity	Daily water use rate inches/day	Water use efficiency lb/a inch H_2O used
dry edible bean	10.2a[3]	71	0.14ab	218.7
spring wheat	11.9b	74	0.16c	128.1
barley	12.6b	86	0.15b	222.1
flax	13.7bc	102	0.13a	41.5
sunflower	14.9c	110	0.14a	119.7
corn	16.3d	113	0.14b	307.3
soybean	16.9d	131	0.13a	139.2
sugarbeet	20.4e	140	0.15b	1.0

[1]Average across years and locations for each crop.
[2]English tons raw beets/a/in H_2O; equal to 0.1 tons extractable sugar/a/in H_2O.
[3]Values in the same column followed by the same letter(s) do not differ significantly at the 10% probability level, according to Duncan's Multiple Range Test.

LITERATURE CITED

1. Bauder, J.W., A. Bauer, J.M. Ramirez, and D.K. Cassel. 1978. **Alfalfa water use and production on dryland and irrigated sandy loam.** Agron J. 70:95-99.
2. Bauer, A. and R.A. Young. 1966. **Soil fertility and water relations.** North Dakota Farm Res. 24:8-11.
3. Chang, Jen-Hu. 1968. **Climate and agriculture, an ecological survey.** Adline Publishing Co., Chicago, Illinois.
4. Davis, S., N.A. Evans, and A.G. Hazen. 1952. **Estimates of irrigation water requirements for crops in North Dakota.** North Dakota Agr. Coll. Bull. 377.
5. Shaykewich, C.F. 1974. Ch. 1. "Principles of water use in agricultural production." p. 23-42. In **The allocative conflicts in water-resource management.** University of Manitoba, Winnipeg, Manitoba, Canada.
6. Sonmor, L.G. 1963. **Seasonal consumptive use of water by crops grown in southern Alberta and its relationship to evaporation.** Can. J. Soil Sci. 43:287-297.
7. Stegman, E.C., A. Buer, J.C. Zubriski, and J.W. Bauder. 1977. **Crop curves for water balance irrigation scheduling in S.E. North Dakota.** North Dakota Agri. Exp. Sta. Res. Rep. No. 66.
8. Viets, F.G., Jr. 1962. **Fertilizers and the efficient use of water.** Adv. Agron. 14:223-264.

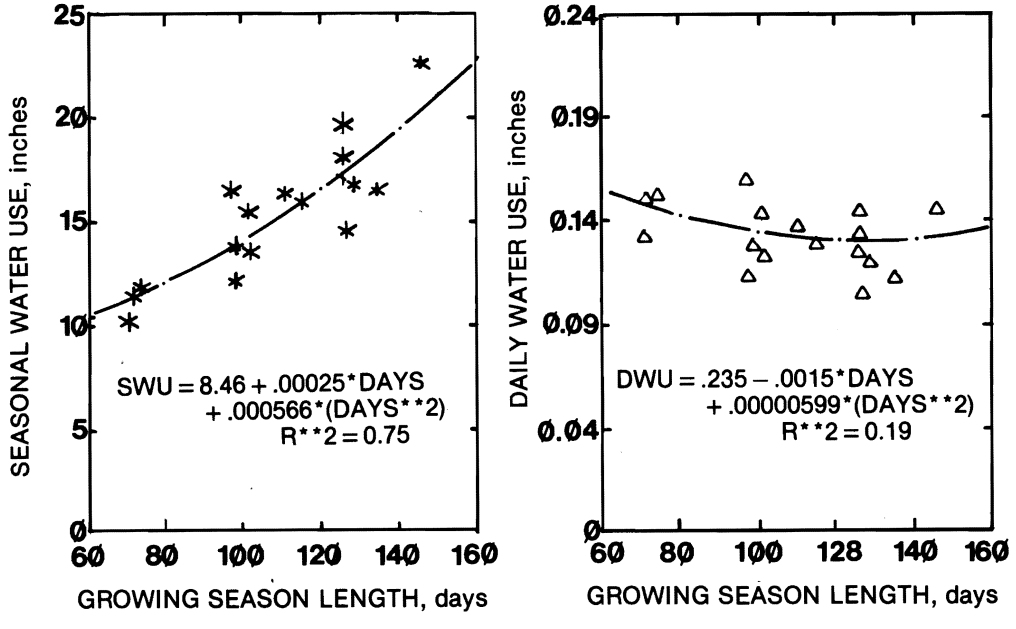

FIGURE 1. Seasonal water use and average daily water use for all crops, sites, and years, as related to active growing season length.