Soil Water Use Efficiency of Sunflowers

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Sunflower production in the United States has increased significantly within the past 10 to 15 years. Sunflower has become a crop of sizeable acreage on some of the most productive soils in North and South Dakota, Minnesota, Texas, and California. The objective of this study was to compare and evaluate yield, water use and water use efficiency of several sunflower cultivars grown in eastern North Dakota.

This study was conducted at three locations with eight cultivars in 1977, and at two locations with five cultivars in 1978. Measurements were made of harvestable seed. Water use efficiency was calculated for each cultivar as lbs seed/a/inch of water used by the crops.

Seed yield was significantly different among cultivars in 1977, and varied significantly among cultivars at one site only in 1978. Water use was not significantly different among cultivars in either 1977 or 1978. Water use efficiency closely reflected yield performance; high yielding cultivars exhibited the highest water use efficiency.

Yield performance is a good indicator of water use efficiency of sunflower cultivars. Crop managers interested in selecting water-use efficient cultivars may do so by selecting consistently high-yielding cultivars. Variability in water use among sunflower cultivars is small and statistically not significant.

INTRODUCTION

Oilseed sunflower production in the United States has increased significantly within the past 10 to 15 years. Specific states which have seen a major increase in sunflower acreage include North and South Dakota, Minnesota, Texas, and California. Research relating to all aspects of production has paralleled this upsurge in sunflower acreage. Much of this research has been directed toward identifying various agronomic practices which will result in maximum seed and oil yields. Such research has led to the development of a number of criteria that can be used in cultivar selection for maximum production.

Sunflower has been cited as a fairly drouth-resistant crop, and some researchers have observed high drouth tolerance by dryland sunflower. High sunflower seed yields have been reported with minimal growing season precipitation. Water use and yield response of individual cultivars have been studied at a number of locations. In a two-year dryland study in North Dakota, Alessi et al. (1977) found that total water use of sunflower was not significantly affected by plant population or row spacing. Cumulative water use was higher with mid-May plantings than with later plantings. In addition, a major part of soil water depletion occurred during the early part of the season, leaving little soil water available after flowering for seed development. Faulkner (1977) found total water use of sunflower unaffected by population. Yields were increased and water use efficiency was improved 45% by increasing plant population. Other studies have shown that increasing plant population from 10,200 to 30,352 and 51,000 plants/a can cause a significant increase in water use.

Total water use of sunflower was increased by increasing nitrogen fertilization of sunflower from zero to 124 lbs N/a, according to Cheng and Zubriski (1978). This addition of nitrogen fertilizer resulted in a significant increase in seed yield and a 29% increase in water use efficiency. Others have observed a positive correlation between total water use and sunflower seed yield.

Sunflower was planted on more than 4 million acres of land in North Dakota in 1980 (ND Farm Report, 1980). Most acreage was seeded to high oil sunflower cultivars. High yielding cultivars are usually selected on the basis of variety performance trials and fertilizer response studies. The effect of fertilizer and cultivar selection on sunflower water use is often overlooked. Efficiency of water use may be an important aspect to consider where limited available water restricts plant growth. The objective of this study was to compare yield, water use, and water efficiency of several sunflower cultivars grown in eastern North Dakota.

MATERIALS AND METHODS

Eight sunflower cultivars were studied at three locations in 1977, and five were studied at two locations in 1978. The study sites located in either eastern North Dakota or northwestern Minnesota are described in Table 1. Fertilizer nitrogen, phosphorus, and potassium were applied to each site as deemed necessary by routine

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soil test analyses to achieve a goal of 2500 kg seed/a for all sites in 1977, and of 3000 and 2000 kg seed/a for Sites 1 and 2, respectively, in 1978.

The 1977 cultivars (Table 2) were planted on May 9, 11, and 20 at Sites 1, 2, and 3, respectively. Each cultivar was planted in four row plots (20 ft/row × 30 in between rows) in a non-replicated block design. Plant population was approximately 18,000 plants/a.[1] In 1978, five cultivars (Table 2) were planted at each site. Planting dates and populations were May 22 at 14,100 plants/a; and May 24 at 17,000 plants/a for Sites 1 and 2, respectively. Each cultivar was planted in two row

Table 1. Location, soil classification, selected physical properties of the 1977 and 1978 sunflower cultivar study sites.

Site Number	Location	Soil type	Series	Depth weighted mean profile bulk density[1]	Available soil water storage capacity in 0-6 ft depth[2]
				g/cm³	inches H_2O
			1977		
1	Glyndon, MN	sandy, mixed frigid Aeric Calciaquoll	Ulen fine sandy loam	1.42	4.7
2	Dilworth, MN	sandy, mixed frigid Aeric Calciaquoll	Ulen fine sandy loam	1.44	6.7
3	Hunter, ND	coarse-loamy mixed Pachic Udic Hapoloboroll	Embden fine sandy loam	1.37	10.9
			1978		
1	Moorhead, MN	fine, montmorillonitic, frigid Vertic Haplaquoll	Fargo silty clay	1.22	16.4
2	Valley City, ND	fine-loamy mixed Pachic Udic and Udic Haploboroll	Svea-Barnes loam	1.31	18.3

[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.

Table 2. Descriptions of sunflower cultivars planted in 1977-1978 water use comparison studies.[1]

Cultivar Identification Number	Cultivar	Cultivar Description and Seed Source
		1977
1	'30311'	Single cross hybrid ('Cargill 205,' Cargill, Inc.)
2	'5011'	Experimental single cross hybrid (Cargill, Inc.)
3	'30312'	Experimental single cross hybrid (Cargill, Inc.)
4	'5012'	Experimental single cross hybrid (Cargill, Inc.)
5	'204'	F-1 hybrid (closed pedigree-Cargill, Inc.)
6	'894'	F-1 hybrid (U.S.D.A.)-(CMS HA89 × RHA294)
7	'8944'	3-way hybrid - (CMS HA89 × HA234) × RHA294
8	'Peredovik'	Open pollinated (U.S.S.R. Standard source)
		1978
1	'Peredovik'	Open pollinated (U.S.S.R. Standard source)
2	'NK212'	Hybrid (Northrup King)
3	'SWxW'	Experimental hybrid (Northrup King)
4	'204'	F-1 hybrid (closed pedigree—Cargill, Inc.)
5	'205'	Single cross hybrid (closed pedigree—Cargill, Inc.)

[1]Use of specific cultivar names is intended to provide clarification of explanation and does not necessarily constitute endorsement of such products or cultivars by North Dakota State University, or the authors.

plots (20 ft/row'30 in between rows).

Soil water depletion amounts and water use patterns were monitored on each site weekly from planting through harvesting. Measurements were made at 12-in depth increments to determine volumetric soil water content.

Seasonal water was calculated for each cultivar.

After physiological maturity in 1977, sunflower heads of the center 10 ft of the two middle rows of each plot were harvested, dried, threshed, cleaned and weighed to determine seed yield. Water use efficiency was calculated as seed yield/unit area/equivalent depth of total water use, i.e., lb/a/in. In 1978, sunflower heads were harvested fromt he center of each row in each experimental unit at physiological maturity, and treated the same as in 1977.

RESULTS

1977

Although the average water use was significantly different from site to site in 1977, differences in water use among cultivars at each site were not significant. Seed yield was significantly different.

[1]Cultivar selections and plantings were performed in cooperation with Cargill, Inc., Minneapolis, MN.

Mean seasonal water use for the eight cultivars at all sites was 12.8 in (Table 3). Mean seasonal water use for all cultivars was 10.0, 14.0, 14.4 inches at Sites 1, 2, and 3, respectively. The range between maximum and minimum water use for all cultivars at the three sites in 1977 was approximately 2.5 inches.

Average seed yield was 2114 lb/a (at 10% moisture). The open pollinated cultivar, 'Peredovik,' produced the maximum seed yield, 2632 lb/a. Cultivars '204,' '894,' '30311,' and '30312' did not differ significantly in yield from 'Peredovik.' The lowest yielding cultivar was '5011,' which yielded lowest of the cultivars at all three sites.

Water use efficiency ranged from 140 to 204 lb/a/in of water. Mean water use efficiency was 165 lb/a/in. Although significant differences in cultivar seed yield were measured, the same differences were not reflected in water use. Furthermore, although differences in water use efficiency were not significant, water use efficiency was generally greater for the higher yielding cultivars and lower for the lower yielding cultivars, i.e., 'Peredovik' versus '5011' in Table 3.

1978

The average soil water content in the soil below each cultivar was compared several times during the growing season. Water uptake patterns at both sites were essentially the same for the five cultivars studied in 1978. Weekly observations showed only slight differences among cultivars; these differences were attributed to variations in soil water holding properties at each site. Water available for plant uptake at various times during the season was essentially the same for all cultivars.

Table 3. Mean water use, seed yield, and water use efficiency of sunflower cultivars in 1977 and 1978 water use comparison.

Cultivar	Water Use	Seed Yield	Water Use Efficiency
	inches	lb/a[1]	lb/a/in
		1977	
'30311'	12.6a[2]	2070abc	165a
'5011'	12.0a	1686c	141a
'30312'	13.2a	2061abc	156a
'5012'	13.4a	1909bc	143a
'204'	13.1a	2516ab	190a
'894'	13.0a	2150abc	165a
'8944'	12.0a	1900bc	159a
'Péredovik'	12.9a	2632a	204a
Mean	12.8	2115	165
		1978-Site 1	
'Peredovik'	16.0a	1954b	122b
'NK212'	16.7a	1999b	125b
'SWxW'	16.5a	1312c	82c
'204'	16.1a	2677a	170a
'205'	15.9a	2605a	165a
Mean	16.2	2106	134
		1978-Site 2	
'Peredovik'	12.9a	1793a	141a
'NK212'	13.4a	2329a	174a
'SWxW'	11.4a	2150a	190a
'204'	12.0a	2132a	184a
'205'	13.0a	2186a	174a
Mean	12.5	2115	172

[1]10% moisture.

[2]Values followed by the same letter are not significantly different at the 0.05 probability level, according to Duncan's Multiple Range Test.

Total water use, representing surface evaporation and plant transpiration, was not significantly different among cultivars at either site in 1978. As sunflower approached maturity at Site 1, the soil water content at the 12 and 24 inch depths under all cultivars was lowered to below the permanent wilting point. Seed yield and water use efficiency were significantly different among cultivars only at Site 1.

The measured seed yields for the five cultivars are shown in Table 3. At Site 1, cultivars '204' and '205' produced the highest yields, 2677 and 2605 lb seed/a, respectively. Cultivars 'SWxW' and 'Peredovik' produced the lowest yields. Cultivar 'SWxW' at site 1 was infected with *Rhizopus* head rot, and yields may have been adversely affected. During cleaning of the harvested seed, an exceptionally large number of barren pericarp were observed in 'SWxW' and 'Peredovik' cultivars. Seed yield ranged from 1793 to 2329 lb seed/a at Site 2. All cultivars except 'Peredovik' exceeded the expected yield goal (2007 lb/a) at Site 2. The inconsistent ranking of cultivars from site to site within years and from year to year for sunflower is non uncommon. Mean seed yield was 2106 and 2115 lb/a at Sites 1 and 2, respectively.

Water use efficiency at Site 1 ranged from 82 lb seed/a/in water used to 170 lb/a/in (Table 3). The variation in water use efficiency among cultivars was identical in ranking to the seed yield. Mean water use efficiency at Site 1 was 134 lb seed/a/inch; in contrast, the mean at Site 2 was 172 lb/a/inch. The water use efficiency was essentially the same for all cultivars.

DISCUSSION

Seed yield during the two-year study was positively correlated with water use and water use efficiency. The correlation between seed yield and water use efficiency was better than that for seed yield and water use (Figure 1). The lower correlation of seed yield with water use is partially due to the inconsistency in cultivar performance from site to site and from year to year. The relationship of seed yield to water use and water use efficiency for all cultivars during the two-year study are shown in Figure 1. As water use and water use efficiency increase, seed yield increases.

Figure 1. Sunflower cultivar seed yield (10% moisture) as a function of seasonal plant water use and water use efficiency; observations are from 1977 and 1978 studies, all sites.

SEED YIELD, lb/a
0 500 1000 1500 2000 2500 3000
YIELD = − 4665 + 935.14*SWU
− 30.83*(SWU**2)
R**2 = 0.54
8 10 12 14 16 18 20
SEASONAL WATER USE, inches

SEED YIELD, lb/a
0 500 1000 1500 2000 2500 3000
YIELD = − 2255 + 41.91*WUE
− .0892*(WUE**2)
R**2 = 0.58
100 130 160 190 220 250 280
WATER USE EFFICIENCY, lb/a/inch

SUMMARY

In this study, water use was not significantly different among eight sunflower cultivars during 1977, nor among five sunflower cultivars in 1978. In 1977, seed yield varied significantly among cultivars. During 1978, seed yields were significantly different among cultivars at only one site. Water use efficiency of sunflower reflected yield performance; high yielding cultivars exhibited highest water use efficiency. By pooling data from various sites for the two-year study, it was possible to demonstrate that seed yield and water use efficiency increase as water use increases. The relationship between seed yield and water use can be described by a second order quadratic equation. Crop growers interested in selecting water use efficient cultivars should use yield performance data as an index of efficiency. Variability in water use among cultivars is small and nonsignificantly different.

LITERATURE CITED

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risk occupations and vulnerable groups who are injured most often are the target groups for dissemination of data gathered from this project for purposes of avoiding burn injuries and death. Both of these projects relate closely to the areas of family stability, environment and health as highlighted by the New Initiatives.

And this is just the beginning! A series of new research proposals have crossed my desk in the last six weeks—research proposed by faculty in the College of Home Economics designed to meet the needs of people in North Dakota. These projects include such proposals as: Utilization of Triticale for Human Food, Level and Bioavailability of Vitamins and Minerals, Child Abuse and Maltreatment, Needs of Rural North Dakota Elderly with Reference to Living Arrangements and Health Services, Family Violence and Abuse, Financial Counseling for Families, Buying Skills of School-Age Rural Childre, Household Expenditure Patterns in North Dakota, Effects of Past Financial Management on Economic Well-Being of the Elderly, Removal of Pesticides from Work-Clothing Fabric, Protective Clothing to Minimize Injuries to North Dakota Oil Field Employees. As you can see, there is no dearth of research ideas, and all of them are specific to improving the quality of life for individuals and families in North Dakota in their home and work environments. It is obvious that home economics, human nutrition, and family living form an integral part of food and agriculture.

The next 10 years promise to be exciting and challenging ones as NDSU prepares to celebrate its first 100 years. The College of Home Economics is proud of its past contribution to the development of NDSU as it moved from an agricultural college to a high-quality university, wide in scope. We are also committed as a college to the development of new knowledge-bases that will contribute substantively to decision-making in those areas that affect people most directly—in their homes and in their work. We are also please and gratified by the continued support of the Agricultural Experiment Station for research efforts in the many areas of Home Economics. This cooperative effort should result in continuing development and expansion as we look forward to the future.