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Irrigation and Fertilization Practices For Seed Production From Established Stands of Side-oats Grama[1]

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Revegetation of certain marginally productive lands with perennial grasses is a part of the present-day agricultural program. Numerous grass species adapted to a wide range of conditions and planting uses are needed in the Great Plains and adjacent areas. Some of these grasses are planted in pure stands whereas others are used in complex mixtures. Diversities of soil and climate often require seed supplies of one or more strains or varieties of each grass.

Grass strains obtained from distant sources frequently fail to become established or to persist with adequate production under use. Seed supplies for successful revegetation in local areas have been obtained from natural stand harvests of prairie grasses. Harvests from a given site fluctuate in both quantity and quality from year to year, causing variations in price and supplies of seed from adapted strains. Growers and seedmen seek to stabilize grass seed supply through contracts for seed of improved varieties under the supervision of seed certification programs.

Establishment and management procedures for seed production of several grasses have been reported (1, 2, 5), as have the benefits from some cultural practices (1, 2, 4, 7). These reports pertain primarily to cool-season or introduced grasses. Less information is available on seed production potentials of grass species native to the Great Plains, notably warm-season prairie grasses.

The objectives of this study of grass seed production were to determine the response of an established stand of a warm-season grass to irrigation and fertilizer practices with regard to the specific practices needed to produce maximum quantity of adequate quality seed per acre. Side-oats grama was chosen for the study because of the availability of adapted varieties.

[1] Contribution from the Northern Plains Branch, Soil and Water Conservation Research Division, and Crops Research Division, Agricultural Research Service, USDA in Cooperation with the Nebraska Agricultural Experiment Station.

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Methods and Materials

The seed production studies of side-oats grama (*Bouteloua curtipendula* (Michx) Torr.) were conducted on a farm near Oxford, Nebraska, for three years and at the North Platte Experiment Station for one year. The field near Oxford was seeded in 1959 and the one on the experiment station in 1961. Soils at the Oxford location and at the experiment station were classified as Hall silt loam and Bridgeport very fine sandy loam, respectively. At the beginning of the experiment soil tests of the surface 6 inches of soil at both locations showed that phosphorus and potassium were adequate. Nitrogen, as ammonium nitrate, was applied at rates of 0, 40, 80, and 120 pounds per acre each year of study between May 1 and May 10.

Side-oats grama is a deep-rooted grass (6, 9), and the available-water-holding capacity of the soils of the study areas is good (1.5 to 2 inches of available water per foot of soil). The following irrigation treatments were employed: 1. no irrigation, 2. fall only, 3. fall and heading, 4. spring and heading, and 5. fall, spring, and heading. Treatments 1 through 5 were used at Oxford, but only treatments 1 through 4 were used at North Platte. Water was applied in furrows 40 inches apart. Each irrigation was sufficient to fill the soil profile to a depth of 6 feet.

A split-plot design in three replications with irrigation treatments as main plots and fertilizer treatments as subplots was used at Oxford. Main and subplots were randomized within the replicated blocks. At North Platte the three replications of irrigation and fertilizer treatments employed a factorial design without block restrictions. Each plot, however, was split for two varieties of grass. Subplots at both locations were 16⅔ feet wide (five 40-inch rows) by 40 feet long. The side-oats grama varieties used were Trailway (8) (both locations) and Butte (8) (North Platte only).

Soil moisture was determined at 1-foot increments to a depth of 10 feet with a neutron moisture probe. Determinations were made before and after each irrigation, before spring growth started, and at seed harvest of the grass.

Number of spikes per raceme were determined in the field by counting the spikes on 10 racemes at two locations per subplot. Number of culms or racemes per foot of row were determined by counting the racemes in a 3-foot length of row at two locations in each subplot. Both counts were made 30 days prior to harvest.

Seed yields were determined by hand-harvesting 20 feet of the center row of each subplot. Seed was harvested when the caryopses were in the dough stage as judged in the nonfertilized subplots in 1961 and in the fertilizer subplots in 1962 and 1963. Spikes were stripped from the racemes and weighed, processed through a small seed cleaner, and reweighed. Thus whole spike and cleaned spike weights were obtained. Seed quality determinations were made for each subplot from spikes of 10 culms taken from each of three locations not included in the area of the plot harvested for yield.

Weed and insect control practices used in this study were as follows: Weeds were controlled by late spring burning of the trash and aftermath, followed by cultivation when the grass was 6 to 8 inches high. If the aftermath had been removed, a band application of pre-emergence herbicide was made on the row, accompanied by cultivation when the grass was 6 to 8 inches high. Thrips were controlled by insecticide application at weekly intervals during the flowering period of the grass.

RESULTS AND DISCUSSION

Seed Production Measurements

Seed yield of side-oats grama was determined on the basis of the number and weight of whole spikes produced per acre.

Number of spikes per culm as determined during the three years in both the field and laboratory showed no effects of cultural treatment. Field counts averaged 45, 44, and 41 spikes per raceme for the years 1961, 1962, and 1963, respectively, and laboratory counts averaged 38, 40, and 36 spikes per culm for the same respective years at Oxford. Counts at North Platte in 1963 were 42 and 38 in the field and laboratory, respectively. Field counts were made 30 days before harvest but laboratory counts were made from mature harvested inflorescences by which time early maturing spikes had ripened and shattered. This accounted for the somewhat higher number of spikes found in the field than in the laboratory. The number of spikes per raceme appears to be a heritable characteristic of the grass which is not affected by treatment and is influenced only to a minor extent by environmental conditions and time of determination.

Raceme number per foot of row was correlated with cleaned seed yields per acre and shows the importance of the number of racemes in determining yield. With Trailway at Oxford, correlation between these two variables produced r values of .782, .843, ad .891 for the years of 1961, 1962, and 1963, respectively. Average of the 3 years was .838 which shows that 70% of the seed production potential was based on the number of racemes produced. At North Platte in 1963 the correlation gave r values of .737 and .779 for Trailway and Butte, which agreed with results the first year at Oxford. Three years of continuous treatments at Oxford revealed that both irrigation and fertilizer increased raceme numbers per foot of row, (Table 1). During the three years no increase in raceme number occurred in the nonfertilized treatment. Three-year averages revealed that the fall and

Table 1. Fertilizer and irrigation treatment averages for the number of side-oats grama racemes per foot of row in 1961, 1962, and 1963. Oxford, Nebraska.

Fertilizer treatment average				Irrigation treatment average			
Fertilizer treatment lbs. N/A.	Year 1961	Year 1962	Year 1963	Irrigation treatment[a]	Year 1961	Year 1962	Year 1963
				(1)	85 a	135 m	131 x
0	116	124 h	97 s	(2)	100 b	155 no	149 x
40	118	145 hi	189 t	(3)	140 c	151 no	189 y
80	117	151 ij	199 t	(4)	117 b	135 m	182 y
120	116	153 ij	191 t	(5)	142 c	141 mn	193 y

Values for each year accompanied by the same letter of a given group of letters are not significantly different (P .05).

[a] Irrigation treatments are as follows: (1) No irrigation, (2) fall only, (3) fall and heading, (4) spring and heading, (5) fall, spring, and heading.

heading irrigation treatment with 40 or 80 pounds of N per acre produced significantly more racemes per foot of row than any other combination of cultural practices.

Whole spike weights per culm contributes to seed yield and was affected by both irrigation and nitrogen treatments. At Oxford spike weights decreased with increasing amounts of N in 1961, but in 1962 and 1963 weights increased as rate of N increased (Table 2). In 1961 all plots were harvested when the grass seed in the nonfertilized treatment was in the dough stage of maturity. Fertilizer in the other treatments had delayed maturity, and this resulted in shrinking and loss of weight. In 1962 and 1963 seed was harvested in the fertilized plots when in the dough stage of maturity. Two or more irrigations increased spike weights in 1962 and 1963 and resulted in an average increase of slightly over 40 percent for the 3-year period when compared with no irrigation. The single irrigation in the fall gave smaller weights in 1961 and 1963 than did the no irrigation treatment, but for the 3-year period seed weights averaged the same.

Seed set (weight of caryopses per given weight of spikes) influences total weight of spikes. This is expressed in terms of milligrams of

Table 2. Fertilizer and irrigation treatment averages for the weight (gms.) of whole spikes on 10 culms of side-oats grama in the years 1961, 1962, and 1963. Oxford, Nebraska.

Fertilizer treatment average				Irrigation treatment average			
Fertilizer treatment lbs. N/A.	Year 1961	Year 1962	Year 1963	Irrigation treatment[a]	Year 1961	Year 1962	Year 1963
				(1)	1.42	1.75 m	1.40
0	1.46 a	1.79 h	1.21 s	(2)	1.31	1.99 n	1.28
40	1.39 ab	1.94 hi	1.39 t	(3)	1.43	1.98 n	1.52
80	1.34 ab	2.12 i	1.59 u	(4)	1.37	2.07 n	1.52
120	1.31 b	2.05 i	1.62 u	(5)	1.37	2.06 n	1.56

Values for each year accompanied by the same letter of a given group of letters are not significantly different (P .05).

[a] See footnote Table 1 for treatment details.

Table 3. Fertilizer and irrigation averages for production of caryopses by side-oats grama, expressed as weight of caryopses in milligrams per thousand milligrams (1 gram) of whole spikes, for the years 1961, 1962, and 1963. Oxford, Nebraska.

Fertilizer treatment average				Irrigation treatment average			
Fertilizer treatment lbs. N/A.	Year			Irrigation treatment[a]	Year		
	1961	1962	1963		1961	1962	1963
				(1)	58 a	106	241
0	70	99	208 s	(2)	57 a	102	228
40	74	104	219 s	(3)	87 b	114	226
80	59	111	234 t	(4)	80 b	100	213
120	74	103	241 t	(5)	75 b	106	220

Values for each year accompanied by the same letter of a given group of letters are not significantly different (P .05).
[a] See footnote Table 1 for treatment details.

caryopses per gram of spikes (Tables 3, 4). Seed set at Oxford in 1962 and 1963 was significantly increased, 12.1 and 12.5 percent by the 80-pound rate of N. At North Platte in 1963, when all irrigation treatments were averaged, 40 pounds of N resulted in the greatest though nonsignificant increase in seed set. At Oxford, irrigation treatments increased seed set in one of three years, with no significant difference between irrigation treatments (Table 3). Irrigation in the fall and at heading was the best treatment for the average of the three years. At North Platte the best irrigation treatment was spring and heading for both varieties (Table 4). Average percentage seed set

Table 4. Production of caryopses by side-oats grama, expressed as weight of caryopses in milligrams per thousand milligrams (1 gram) of whole spikes. North Platte, Nebraska, 1963.

Irrigation treatment	Variety	Fertilizer treatment (lbs. N/A)				Irrigation treat. ave.
		0	40	80	120	
No irrigation	Butte	102	113	104	134	113 s
	Trailway	33	60	52	73	54 j
	Ave.	67	87	78	104	84
Fall only	Butte	122	147	112	103	121 s
	Trailway	71	59	28	37	49 j
	Ave.	96	103	70	70	85
Fall and heading	Butte	188	204	203	186	195 t
	Trailway	112	134	84	148	119 k
	Ave.	150	169	143	167	157
Spring and heading	Butte	201	222	219	223	216 t
	Trailway	185	156	104	161	151 k
	Ave.	193	189	162	192	184
Ave. of treatments	Butte	153	172	159	162	162
	Trailway	100	102	67	104	93
	Ave.	127	137	113	133	

Values accompanied by the same letter are not significantly different (P .05). No significant differences between fertilizer treatments. Highly significant difference between varieties.

Table 5. Fertilizer and irrigation treatment average seed quality of side-oats grama (milligram weight per thousand caryopses) in the years 1961, 1962, and 1963. Oxford, Nebraska.

Fertilizer treatment average				Irrigation treatment average			
Fertilizer treatments lbs. N/A.	Year			Irrigation treatment[a]	Year		
	1961	1962	1963		1961	1962	1963
				(1)	517 ab	764 n	608 x
0	559	721 h	611 s	(2)	502 a	731 m	600 x
40	555	736 hi	625 s	(3)	588 c	743 mn	678 y
80	524	758 i	663 t	(4)	574 c	760 n	657 y
120	558	764 i	687 t	(5)	565 bc	725 m	685 y

Values for each year accompanied by the same letter of a given group of letters are not significantly different (P .05).

[a] See footnote Table 1 for treatment details.

(ratio of the two weights) for all treatments of Trailway at Oxford was 7.2, 10.4, and 22.6 percent for 1961, 1962, and 1963 respectively, and 9 and 16.2 percent for Trailway and Butte strains respectively at North Platte in 1963.

Number of caryopses produced per given weight of whole spikes is another measure of seed set. At Oxford neither irrigation nor nitrogen treatments significantly affected caryopses number in 1962 or 1963 and only irrigation treatments at the 10 percent level of significance in 1961. However, the number of caryopses produced per given weight in 1963 averaged 353 as compared with 132 and 138 in 1961 and 1962. Thus seed set as measured by caryopses numbers approximated an increase of 157 percent in 1963 over that in the two former years. At North Platte larger numbers of caryopses per gram of whole spikes were obtained with Butte than with Trailway, averaging 223 and 146 respectively. Seed set was increased 9, 17, and 20 percent over no irrigation with fall-only, fall and heading, and spring and heading irrigations, respectively, but was not affected by N treatments. These results are similar to findings at Oxford the second year after planting (first year of study at that location).

Seed quality (weight of a given number of caryopses), which contributes to the overall weight of whole spikes, was significantly affected by both irrigation and fertility treatment at Oxford in 1962 and 1963, but only by irrigation treatments in 1961 (Table 5). Fall and heading irrigations produced the highest quality seed for the three years of study; the fall-only irrigation produced the poorest quality. In 1962 and 1963 each increment of N fertilizer resulted in increased seed quality, but the increase between 80 and 120 pounds of N per acre was small and nonsignificant. Although a larger number of caryopses per gram of spikes was produced in 1963, the average weight was smaller than in 1962.

At North Platte seed from the fall and heading irrigation was best and that from the fall-only treatment was lowest in quality for both varieties of grama (Table 6). There was no significant difference between fertilizer treatments, but 40 pounds of N per acre increased seed quality slightly over the nonfertilized treatment and 80 pounds reduced seed quality when compared with that of the nonfertilized treatment. The application of 120 pounds of N resulted in the highest quality seed.

Differences in seed quality of samples of good and poor quality chaffy seeded grasses such as side-oats grama are difficult to determine by observation. The concept of pure-live-seed (purity percentage x germination percentage) is an important factor in the recognition of quality in chaffy-seeded grasses. To calculate pure-live-seed, the purity percentage is needed and this differs depending on whether purity determination was made commercially or for research purposes. However, a relationship between actual purity as determined for research and commercial purity percentages was determined by Harlan and Ahring (3). They reported that commercial purity of side-oats grama average 3.2 times the ratio of actual purities by weight of caryopses.

Commercial purity calculated from actual purity percentages (Table 7) showed no statistically significant differences among either irrigation or fertilizer treatments as an average of the three years at Oxford. There was, however, the same trend as noted in other measurements favoring the fall and heading irrigation treatment and the higher rates of nitrogen. Averages of all treatments show estimates on a commercial basis of a 23 percent purity in 1961, 33 percent in

Table 6. Seed quality of side-oats grama, (milligram weight per thousand caryopses). North Platte, Nebraska, 1963.

Irrigation treatment	Variety	Fertilizer treatment (lbs. N/A)				Irrigation treat. ave.
		0	40	80	120	
No irrigation	Butte	682	643	656	721	675 s
	Trailway	583	608	581	645	604 j
	Ave.	632	626	618	683	640
Fall only	Butte	580	675	675	654	646 s
	Trailway	544	500	422	626	523 j
	Ave.	562	588	549	640	585
Fall and heading	Butte	759	776	763	755	763 t
	Trailway	649	733	632	696	677 k
	Ave.	704	754	698	726	720
Spring and heading	Butte	742	765	736	772	754 t
	Trailway	672	648	616	657	648 k
	Ave.	707	706	767	715	701
Ave. of treatments	Butte	691	714	708	725	710
	Trailway	612	622	563	656	613
	Ave.	651	669	635	691	

Values accompanied by the same letter are not significantly different (P .05). No significant difference between fertilizer treatments. Highly significant difference between varieties.

Table 7. Estimated commercial percent seed purity of Trailway side-oats grama as affected by nitrogen fertilization and irrigation. Three-year average (1961–1963).

Irrigation treatment	Fertilizer treatment (lbs. N/A)				Irrigation treat. ave.
	0	40	80	120	
No irrigation	41.3	41.2	46.1	43.1	42.9
Fall only	38.7	41.4	42.2	42.7	41.3
Fall and heading	44.0	48.6	42.7	44.1	44.9
Spring and heading	38.5	40.0	41.4	48.8	42.4
Fall, spring, and heading	43.5	40.2	43.2	41.0	42.2
Fertilizer treatment average	41.2	42.3	43.3	43.9	

No significance between either fertilization or irrigation treatments.

1962, and 72 percent in 1963. These are possibly lower than would be found with field harvesting, as much of the inert material would normally be excluded in the field harvesting process. These results show again the beneficial effects of continued good culture practices.

"Pure seed" (product of commercial purity percent x weight of whole spikes, noncleaned) yields per acre are of importance for determination of pure-live-seed for a given percent germination. Estimates of "pure seed" production per acre at Oxford (Table 8) reveal that fall and heading is the most favorable irrigation treatment, followed by the three irrigation (fall, spring, and heading) and the spring and heading treatments. No difference was obtained between the no irrigation and fall-only irrigation treatments. Nitrogen treatments show a yield increase of 60 percent with 40 pounds of N per acre when compared with the no N treatment. Small but insignificant additional yield increases were obtained with 80 and 120 pounds of N.

Cleaned seed yields (whole spikes processed through a seed cleaner) per acre obtained at Oxford (Table 9) follow a pattern almost identical with those obtained with commercial pure seed yields. The only difference, but not significant, is that average yields were slightly higher from the three irrigation (fall, spring, and heading) treatment

Table 8. Commercial seed production in pounds "pure seed" per acre of Trailway side-oats grama as influenced by nitrogen fertilization and irrigation. Three-year average (1961-1963).

Irrigation treatment	Fertilizer treatment (lbs. N/A)				Irrigation treat. ave.
	0	40	80	120	
No irrigation	90	150	180	190	150 x
Fall only	80	190	150	180	150 x
Fall and heading	170	280	240	290	250 z
Spring and heading	110	170	240	260	200 y
Fall, spring, and heading	170	190	270	250	220 yz
Fertilizer treatment average	120 a	200 b	220 b	230 b	

Values accompanied by the same letter of a given group of letters are not significantly different (P .05).

Table 9. **Cleaned seed yields in pounds per acre of Trailway side-oats grama as influenced by nitrogen fertilization and irrigation. Three-year average (1961–1963).**

Irrigation treatment	Fertilizer treatment (lbs. N/A)				Irrigation treat. ave.
	0	40	80	120	
No Irrigation	110	200	180	210	180 x
Fall only	120	210	170	220	180 x
Fall and heading	160	200	270	330	270 y
Spring and heading	180	250	340	290	270 y
Fall, spring, and heading	210	310	350	300	290 y
Fertilizer treatment average	160 a	250 b	260 b	270 b	

Values accompanied by the same letter of a given group of letters are not significantly different (P .05).

than from any other treatment. Cleaned seed yields at North Platte (Table 10) show that both grass varieties at this location responded to the irrigation and fertilizer treatments as at Oxford.

Correlation between the commercial and cleaned seed yields for the three years at Oxford reveal a close relationship between these two measurements of seed production. Values of r for 1961, 1962, and 1963, all highly significant, were .782, .843, and .969 respectively with an average of .865.

Concomitant Measurements

Stubble or aftermath production for the three years at Oxford averaged slightly over 2 tons per acre (Table 11). Irrigation treatments

Table 10. Cleaned seed yields (lbs./A) of Trailway and Butte side-oats grama grass. North Platte, Nebraska. 1963.

Irrigation treatment	Variety	Fertilizer treatment (lbs. N/A)				Irrigation treat. ave.
		0	40	80	120	
No irrigation	Butte	22	26	32	46	31 s
	Trailway	16	37	21	24	24 j
	Ave.	19	32	26	35	28
Fall only	Butte	46	60	67	43	54 s
	Trailway	29	40	60	17	37 j
	Ave.	38	50	64	30	46
Fall and heading	Butte	135	215	165	206	180 t
	Trailway	94	94	107	127	105 k
	Ave.	114	154	136	166	142
Spring and heading	Butte	154	220	198	189	190 t
	Trailway	64	132	177	126	125 k
	Ave.	109	176	188	158	158
Ave. of treatments	Butte	89 x	130 y	116 y	121 y	114
	Trailway	51 a	76 b	91 b	73 b	73
	Ave.	70	103	104	124	

Values accompanied by the same letter of a given group of letters are not significantly different (P .05).

Table 11. Aftermath production in tons per acre of Trailway side-oats grama as affected by nitrogen fertilization and irrigation. Three-year average (1961–1963).

Irrigation treatment	Fertilizer treatment (lbs. N/A)				Irrigation treat. ave.
	0	40	80	120	
No irrigation	2.05	2.30	2.15	2.50	2.25
Fall only	2.10	2.55	2.10	2.50	2.30
Fall and heading	1.80	2.20	2.70	2.20	2.25
Spring and heading	1.95	2.55	2.10	2.45	2.25
Fall, spring, and heading	1.85	2.22	1.80	2.25	2.05
Fertilizer treatment average	1.95 a	2.35 c	2.15 b	2.40 c	

Values accompanied by the same letter of a given group of letters are not significantly different (P .05).
No significant difference between irrigation treatments.

did not affect aftermath production but N fertilizer significantly increased production.

Protein content of the aftermath compares well with such crop stovers as corn and sorghum or with native grass hay. Aftermath from irrigation treatments of fall and heading and fall, spring, and heading had significantly lower nitrogen content than that of the other treatments. With each increase in nitrogen fertilizer rate, nitrogen content of the aftermath significantly increased (Table 12).

Efficiency of use as well as total amounts of moisture and fertilizer utilized are of importance in evaluating the effects of irrigation and fertilization treatments on seed production.

Total moisture use in the three years at Oxford was significantly increased by two or more irrigations (Table 13). Nitrogen treatments, however, had no effect on total water use.

Water-use efficiency was significantly increased by the fall and heading and fall, spring, and heading irrigation treatments (Table 14). The fall only irrigation gave the lowest water-use efficiency. Nitrogen fertilizer significantly increased water-use efficiency over that of the non-fertilized treatment; however, there was no significant difference among the three rates of N.

Table 12. Nitrogen content of side-oats grama (Trailway) aftermath as affected by nitrogen fertilization and irrigation. Average of three years, 1961–1963.

Irrigation treatment	Fertilizer treatment (lbs. N/A)				Irrigation treat. ave.
	0	40	80	120	
No irrigation	.663	.770	.971	1.028	.858 x
Fall only	.643	.766	.839	.967	.804 xy
Fall and heading	.629	.681	.898	.945	.788 y
Spring and heading	.645	.714	.888	.964	.803 xy
Fall, spring, and heading	.582	.681	.789	.933	.746 y
Fertilizer treatment average	.632 a	.722 b	.877 c	.967 d	

Values accompanied by the same letter of a given group of letters are not significantly different (P .05).

Table 13. Inches of soil moisture used by Trailway side-oats grama as influenced by nitrogen fertilization and irrigation. Three-year average, Oxford, Nebraska.

Irrigation treatment					Irrigation treat. ave.
	0	40	80	120	
No irrigation	18.87	19.51	19.42	19.69	19.37 x
Fall only	20.41	21.11	20.74	20.32	20.65 x
Fall and heading	22.94	23.95	23.47	24.35	23.68 y
Spring and heading	25.76	25.52	25.27	25.67	25.56 z
Fall, spring, and heading	25.45	25.83	27.17	26.44	25.97 z
Fertilizer treatment average	22.69	23.18	23.01	23.29	

Values accompanied by the same letter of a given group of letters are not significantly different (P .05).

No significant difference between fertilizer treatments.

The most efficient use of the N fertilizer was made with the 40-pound-per-acre rate, which averaged 2.25 pounds of cleaned seed per acre per pound of N applied. With 80 and 120 pounds of N per acre, 1.25 and .92 pounds of cleaned seed per acre were produced per pound of N. However, with increased age of stand, the efficiency of the higher rates of N should increase, because in the first year (1961) production from the 80-and 120-pound N treatments was less than that from the no N treatment but thereafter increased each year.

The seed production potential of side-oats grama is determined by the number of seed-producing culms per unit of area coupled with degree of seed set and seed quality. These production factors can be controlled to a major extent by proper timing of water application, accompanied by an adequate level of fertility.

The necessity of timing water applications with crucial plant growth stages is apparent. Water applications either in the fall or in early spring and at heading gave equal results in cleaned seed production per acre. However, the fall and heading combination resulted in seed of slightly higher quality than that from the spring and heading irrigation. Irrigation at the time the grass is heading is critically essential in either case.

Nutrient requirements for side-oats are not excessive even with

Table 14. Water-use efficiency[a] of cleaned seed production of Trailway side-oats grama influenced by nitrogen fertilization and irrigation. Three-year average, Oxford, Nebraska.

Irrigation treatment	Fertilizer treatment (lbs. N/A)				Irrigation treat. ave.
	0	40	80	120	
No irrigation	5.7	9.9	9.8	10.7	9.0 xy
Fall only	5.8	9.5	8.1	10.7	8.5 x
Fall and heading	7.1	12.9	11.8	13.6	11.4 z
Spring and heading	6.9	9.7	13.2	11.2	10.3 yz
Fall, spring, and heading	8.5	12.0	12.6	11.5	11.2 z
Fertilizer treatment average	6.8 a	10.8 b	11.1 b	11.5 b	

Values accompanied by the same letter of a given group of letters are not significantly different (P .05)

[a] Pounds of cleaned seed produced per acre per inch of water used.

intensive production under irrigation. It is essential, however, that a balanced, nutritive condition be available for maximum production. Soil testing will indicate the nutrients needed for an optimum level of fertility. Nitrogen is likely to be needed for most soils. However, 40 to 80 pounds of N per acre should be adequate.

SUMMARY

Fertilization and irrigation requirements of side-oats grama grown in 40-inch rows for seed production were studied for three years near Oxford, Nebraska, and for one year at the North Platte, Nebraska, Experiment Station.

The number of spikes per raceme was not affected by treatments. But the number of spike-producing racemes per foot of row was altered by both irrigation and fertilization. Fall and heading irrigations and 40 pounds of nitrogen per acre resulted in the greatest number of racemes per foot of row.

Weight of whole spikes per raceme was increased 40 percent by two or more irrigations when compared with no irrigation. Nitrogen fertilizer significantly increased whole spike weights when seed of the fertilized plots was harvested in soft dough stage of maturity.

During the last two years of study at Oxford, 80 pounds of N per acre increased seed set 12 percent over that of the nonfertilized treatment. The number of caryopses per gram of whole spikes was not affected by either fertilizer or irrigation, but in 1963 the number of caryopses per gram was 157 percent greater than in the two previous years of study. At North Platte, 40 pounds of N produced the greatest increase in seed set. Butte produced a larger number of caryopses than did Trailway.

Seed quality at Oxford was best with fall and heading irrigations and poorest with fall-only irrigation. Both the 40- and 80-pound rates of nitrogen resulted in significant increases in seed quality. Seed quality of both varieties at North Platte was highest from the spring and heading irrigations and lowest with the fall-only irrigation.

Yield of commercially pure seed per acre was highest when irrigations were made in fall and again at heading. Application of 40 pounds of N per acre in conjunction with these two irrigations was the most favorable rate of fertilization. Maximum cleaned-seed yields per acre were obtained with similar irrigation and fertilizer treatments as those for commercial seed yields. Correlations of the two measurements of seed yield gave a highly significant average r value of .865.

Stubble or aftermath following seed harvest averaged slightly over 2 tons per acre for the three-year period at Oxford. Irrigation treatments had no effect, but nitrogen fertilizer significantly increased after-

math tonnage. Nitrogen content of the aftermath was highest with no irrigation and lowest with fall and heading and fall, spring, and heading irrigations. Each increment of N significantly increased nitrogen content of the aftermath.

Water use by the grass was increased when irrigated two or more times, but nitrogen fertilizer did not influence water use. Water-use efficiency was lowest when only one irrigation was applied in the fall and highest when water was applied in the fall and again at heading. Nitrogen fertilizer significantly increased water use efficiency, with the first 40-pound increment having the greatest effect.

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