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Chemical Fallow in a Winter Wheat-Fallow Rotation[1]

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Abstract. Five fallow treatments in an alternate winter wheat (*Triticum aestivum* L.) fallow rotation experiment were compared over a 6-yr period at North Platte, Nebraska. During the 14-month fallow period from winter wheat harvest until winter wheat planting, plots receiving no tillage (weeds were controlled by herbicides) had the least weed growth, most soil water stored, and highest amount of surface mulch maintained. Also, the plots receiving only herbicides had the highest grain yields of all treatments. However, an average of 3.8 herbicide applications were needed to control grass weeds missed by 2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine (atrazine) during the last 5.5 months of the fallow period. Greatest weed growth during the fallow period was on plots that received only tillage and occurred during the first 3 months after harvest.

INTRODUCTION

ALTERNATE winter wheat-fallow rotation is commonly used in the Great Plains of the United States. Each tillage operation during the fallow period, irrespective of implement used, decreases the quantity of crop residue remaining on the soil surface (6). Fenster *et al.* (6) reported that the best weed control was obtained when oneway disking was included in the tillage sequence. However, the disking incorporated 45% of the remaining plant residue into the soil each time it was used (6) and soil erodibility was 63% greater than when stubble mulch tillage was used (7). Control of weeds with herbicides during the fallow period would decrease the number of tillage operations and thereby conserve more surface crop residue to decrease wind and water erosion. To reduce wind erosion during the winter months after winter wheat planting, 1100 kg/ha of plant residue is needed on the surface of fine-textured soils, 1700 kg/ha for medium-textured soils, and 1800 kg/ha for coarse-textured soils (4). Horner (9) found that on a silt loam with 30% slope soil loss was 0.6 metric ton (T) per 2.5 cm of rain from land with standing winter wheat stubble and 12.3 T per 2.5 cm of rain from land where stubble had been plowed.

Increased soil water storage by increased winter wheat residue on the soil surface has been shown in the central and northern Great Plains (8, 12), but in the southern Great Plains (16) and Pacific Northwest (10), increases in soil water storage from chemical fallow have not occurred. Weeds growing on fallow land use water intended for the subsequent winter wheat crop. Weeds should be killed as rapidly as possible since plants continue to use water until they are air dry (18). Naturally, there would be less soil water loss from young weeds than from more mature weeds. Wiese (17) showed that tansy mustard (*Descurania intermedia* Rydb), germinated in Texas in late October, did not reduce soil water to a level lower than bare soil until after March 15 when plants were 8 to 10 cm tall. Also, some weeds can develop massive root systems. Phillips and Launchbaugh (11) reported that kochia (*Kochia scoparia* (L.) Schrad.) roots penetrated to a depth of 2.4 m or more and lateral roots extended as much as 2.4 m. A few kochia plants of this size would use considerable soil water.

An experiment was initiated in 1963 at North Platte, Nebraska to determine whether chemical fallow was feasible for the alternate winter wheat-fallow rotation commonly practiced in the central Great Plains.

MATERIALS AND METHODS

Plots 4.9 by 15.2 m arranged in a Latin square were established on two adjacent land strips in July 1963. The strips were alternated between fallow and winter wheat each cropping season. The Holdrege silt loam soil of the experimental area contained 1.6% organic matter in the top 15 cm. The plots received the same treatments during the fallow seasons of 1963–1964 through 1968–1969.

The five fallow treatments were: (a) sweep tillage after harvest and spring moldboard plowing followed by sweep tillage as needed for weed control (plow); (b) sweep tillage after harvest and thereafter as needed (stubble mulch); (c) sweep tillage after harvest, atrazine at 1.68 kg/ha, plus a contact herbicide applied in late August or September, and sweep tillage thereafter as needed (stubble mulch + atrazine); (d) a contact herbicide after harvest, atrazine at 1.68 kg/ha plus a contact herbicide applied in late August or September, + a contact herbicide in fall and once in early spring, if needed, and sweep tillage thereafter as needed (atrazine + contact herbicides + stubble mulch); and (e) a contact herbicide after harvest, atrazine at 1.68 kg/ha plus contact herbicide applied in late August or September, and contact herbicides thereafter as needed (atrazine + contact herbicides). Hereafter, these treatments will be designated by terms in parentheses.

There was some modification to improve effectiveness of treatments over the years. The plow treatment was changed from after harvest to spring moldboard plowing in 1964, because of excessive soil water losses. Sweep tillage after harvest was begun in 1965 on the plow treatment and continued each year thereafter because of losses of soil water due to weeds in 1964. The application time of atrazine and sweep tillage was reversed in the stubble mulch + atrazine treatment in 1967 because there was poorer weed control with atrazine granules when sweep

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tillage followed atrazine application. Contact herbicides replaced tillage in the fall of 1967 and thereafter in the atrazine + contact herbicides + stubble mulch treatment.

Winter wheat was seeded about September 14 with a mulch-hoe drill at 50 kg/ha; rows were spaced 30 cm apart. The cultivar 'Scout' was planted in 1964 and 'Lancer' in 1965 through 1969.

Soil water was measured about July 13 (after wheat harvest), November 4, April 14, July 3, and September 14 (at the end of the fallow period). Measurements were made with a neutron probe at 30-cm intervals to a depth of 3 m in three of the five replications. Downward movement of water below the 3-m depth is doubtful as the water content at this depth was constant near exhaustion of the soil throughout the study (12).

The principal herbicides used during the fallow period were atrazine; 3-amino-*s*-triazole (amitrole) + ammonium thiocyanate (hereafter referred to as amitrole-T); and 1,1'-dimethyl-4,4'-bipyridinium ion (paraquat) + 0.5% of 80% alkylaryl polyoxyethylene glycols, free fatty acids, and isopropanol (X-77 surfactant). The spray volume used was 187 L/ha. Atrazine at 2.24 kg/ha was sprayed July 16, 1963 after harvest. Atrazine at 2.24 kg/ha did not satisfactorily control downy brome (*Bromus tectorum* L.) that emerged the latter part of August because it was hot and dry for a month after application. Amitrole-T at 2.24 kg/ha was sprayed on October 17, 1963. Atrazine granules were used in 1964 through 1967 to reduce the possible loss of atrazine by photodecomposition, volatilization, or both. Atrazine granules at 2.24 kg/ha were used after harvest in 1964, and atrazine granules at 1.68 kg/ha were used in 1965 through 1967. The granular formulation of atrazine did not satisfactorily control downy brome and volunteer wheat in 1967 because of insufficient rainfall, so plots were sprayed October 16 with amitrole-T at 1.12 kg/ha. Amitrole-T + atrazine at 0.56 + 1.68 kg/ha were sprayed after harvest in 1967 on the stubble mulch + atrazine treatment and after harvest in 1968 and 1969 on the three treatments receiving atrazine.

A contact herbicide was used to kill weeds after harvest and as needed throughout the fallow period on atrazine + contact herbicides + stubble mulch and atrazine + contact herbicides treatments. In 1968, atrazine + amitrole-T at 0.56 + 0.56 kg/ha were sprayed on April 29 to kill surviving winter wheat and to provide additional residual weed control on the atrazine + contact herbicides treatment.

Tillage and spraying (Table 1) were performed when weeds were 2 to 5 cm tall. However, wet soil sometimes delayed tillage, and wind occasionally delayed spraying.

In 1965, the winter wheat was sprayed on May 7 for control of kochia with 0.56 kg/ha of the dimethylamine salt of (2,4-dichlorophenoxy)acetic acid (2,4-D). The wheat was fertilized about April 1 with 22 kg/ha of nitrogen in 1965 and 1966, 45 kg/ha in 1967 and 1968, and 67 kg/ha in 1969 and 1970. The nitrogen rates were increased to raise the protein content in the grain.

Weeds were counted, harvested, and oven-dried from a 1-m² area before each tillage or spray operation during the fallow period. Winter wheat residue was measured by standardized procedures (14) at the beginning and at the end of the fallow period. Downy brome plants were counted in a 7.6-m² area during March each year and harvested from a 3.7-m² area when the crop matured about mid July. Plots were harvested with a plot mower in 1965 from a 3-m² area and with a plot combine in 1966 through 1970 from a 26-m² area. Winter wheat grain yields (oven-dried) were determined. Percentage nitrogen in the grain was dtermined by the Kjeldahl procedure. The density of grain was determined with a Boerner test weight apparatus and reported in kg/hl; and 100-seed weights were determined.

RESULTS AND DISCUSSION

Winter wheat residue. The amount of residue at the beginning of fallow periods before treatments were applied ranged from 5620 kg/ha in 1963 to 7690 kg/ha in 1968 (Table 2). All the residue was gone on the plow treatment each year when the wheat was seeded. During the 6-yr period, the plots tilled with stubble mulch equipment had 21 to 25% residue remaining on the soil surface at seeding. Atrazine + contact herbicides + stubble mulch treatment had a higher amount of residue remaining in 1968 and 1969 than in the previous 4 yr because the first tillage in the spring was delayed until about July 1 in 1968 and 1969. On plots that received no tillage and weeds were controlled by herbicides, 46% of the residue remained on the soil surface at the end of the fallow period. This amount of residue would greatly reduce evaporation (8) and soil temperature fluctuation compared to treatments that had less residue. There was no apparent accumulation of residue on the soil surface during this study.

Weed growth. Weed yields were about the same for all fallow treatments at the beginning of the fallow season (Figure 1). These weeds were kochia, green foxtail (*Setaria viridis* (L.) Beauv.), redroot pigweed (*Amaranthus retroflexus* L.), and stinkgrass (*Eragrostis cilianensis* (All.) Lutati) that germinated prior to harvest. Probably weed control for fallow should begin before the winter wheat is harvested. Weeds can be controlled in growing winter wheat with a granular herbicide (2).

Table 1. Average number of tillage or spraying operations during the six fallow periods from 1963 through 1969.

Fallow treatment	No. of tillage operations: Harvest to late fall	Spring to wheat planting	Total	No. of spraying operations[a]: Harvest to late fall	Spring to wheat planting	Total	Total operations
Plow	2.0	6.5	8.5	0.0	0.0	0.0	8.5
Stubble mulch	2.0	6.7	8.7	0.0	0.0	0.0	8.7
Atrazine + stubble mulch	1.3	6.3	7.6	1.2	0.2	1.4	9.0
Atrazine + contact herbicides + stubble mulch	0.3	4.8	5.1	1.8	1.0	2.8	7.9
Atrazine + contact herbicide	0.0	0.0	0.0	2.2	3.8	6.0	6.0

[a]Includes application of atrazine granules after harvest.

Table 2. Winter wheat residue on the soil surface as affected by fallow treatments.

Fallow treatment	Fallow period						
	1963–64	1964–65	1965–66	1966–67	1967–68	1968–69	Avg.
	Residue at beginning of fallow period (kg/ha)						
Average of all treatments	5620	6820	7310	6550	5670	7690	6610
	Residue remaining at end of fallow (%)						
Plow	0	0	0	0	0	0	0
Stubble mulch	15	25	19	22	24	21	21
Atrazine + stubble mulch	15	27	21	17	27	19	21
Atrazine + contact herbicides + stubble mulch	14	26	21	17	42	28	25
Atrazine + contact herbicides	56	49	39	42	54	40	46

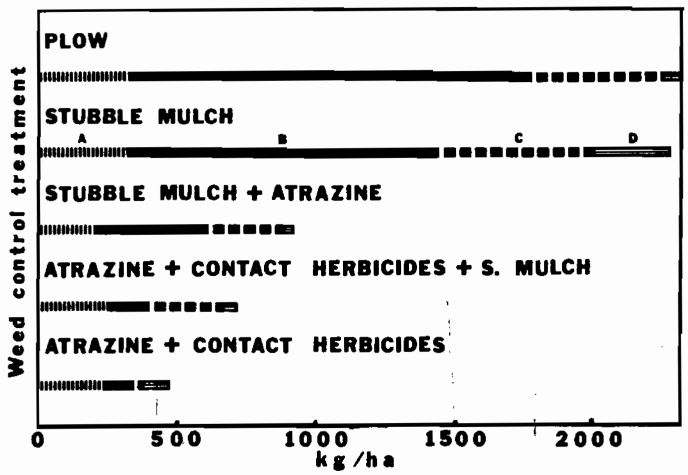

Figure 1. Weed yields during the fallow season in an alternate winter wheat-fallow rotation at North Platte, Nebraska during 1963 through 1969 fallow seasons. Weed yields are (A) in wheat stubble prior to treatments, (B) from wheat harvest to November 4, (C) from March to April 15, and (D) from April 15 to winter wheat seeding.

Total weed yields for the 14-month fallow period (Figure 1) were greatest from the plow and stubble mulch treatments, and lowest from the herbicide treatments. Half of the total weed growth from the plow and stubble mulch plots occurred during August, September, and October (Figure 1) despite an average of two tillage treatments during this period (Table 1). Sometimes tillage did not kill all of the weeds, especially if the soil was wet or it rained soon after tillage. Atrazine applications reduced weed growth to less than 450 kg/ha during August, September, and October. Much of the weed growth was volunteer wheat and downy brome. If the volunteer wheat and downy brome were not killed in the fall they were more difficult to kill the following spring.

Plowing in the spring quickly eliminated volunteer wheat and downy brome. Kochia was controlled in the early spring by timely tillage or atrazine (Figure 2) and was not a problem the remainder of the fallow period on any treatment. The principal weeds in June and July were redroot pigweed, green foxtail, and stinkgrass; in August and September, downy brome and volunteer wheat were also present. Herbicides reduced the number of weeds present during the fallow period much more than did conventional stubble mulch tillage (Figure 2). However, an average of 3.8 spraying operations with contact herbicides were needed to control grass weeds on the atrazine + contact herbicides treatment from spring until the winter wheat was seeded. The plots that received the plow, stubble mulch, and stubble mulch + atrazine treatments were tilled 6.5 times during this period. Weed populations were lower as the growing season progressed; and some weeds, such as kochia, were past peak periods of germination. Also, high temperatures during July and August caused the soil surface to dry out faster, thus creating unfavorable conditions for weed seed germination or survival.

Soil water gain. Water storage was low during the July 13 (harvest) to November 4 period, with storage in the best treatment (atrazine + contact herbicides) being only 3.4 cm of the 19 cm of precipitation received (Table 3). Rapid

Table 3. Precipitation during 1963 to 1970.

Fallow year	Portion of fallow season					Planting to harvest	Grand total
	Harvest–Nov. 4	Nov. 4–Apr. 14	Apr. 14–July 3	July 3–planting	Total		
	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)
1963–1964	28	16	7	24	75	44	119
1964–1965	14	4	31	18	67	42	109
1965–1966	24	9	18	17	68	40	108
1966–1967	20	3	35	4	62	30	92
1967–1968	7	2	25	17	51	31	82
1968–1969	23	4	18	14	59	29	88
Average	19	6	22	16	64	36	100

evaporation during the early part of this period (Table 4) reduced storage. From harvest to November 4 the soil from the plowed plots lost water (Table 5), while soil from the atrazine + contact herbicides treatment gained some water,

Table 4. Evaporation from open water surface during 1963 to 1970.

Year	Portion of fallow season					Planting to harvest	Grand total
	Harvest–Nov. 4	Nov. 4–Apr. 14	Apr. 14–July 3	July 3–planting	Total		
	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)
1963–1964	70	61*	25	99	255	98	353
1964–1965	66	63	65	52	246	78	324
1965–1966	43	46	77	47	213	90	303
1966–1967	76	41	64	58	239	99	338
1967–1968	78	41	80	59	258	98	356
1968–1969	82	50	57	69	258	93	351
Average	69	50	61	64	245	93	338

*Evaporation readings were not taken from November 1 to March 31; data are based on the average for this period of 40.6 cm for the years 1961 through 1965.

and soil water in all other treatments remained about the same. The plow plots lost 13 cm of soil water because of evaporation following plowing after harvest in 1963, and lost 8 cm of soil water due to weed growth prior to sweep tillage on September 8, 1964. In subsequent years these plots were sweep tilled after harvest and plowed in the

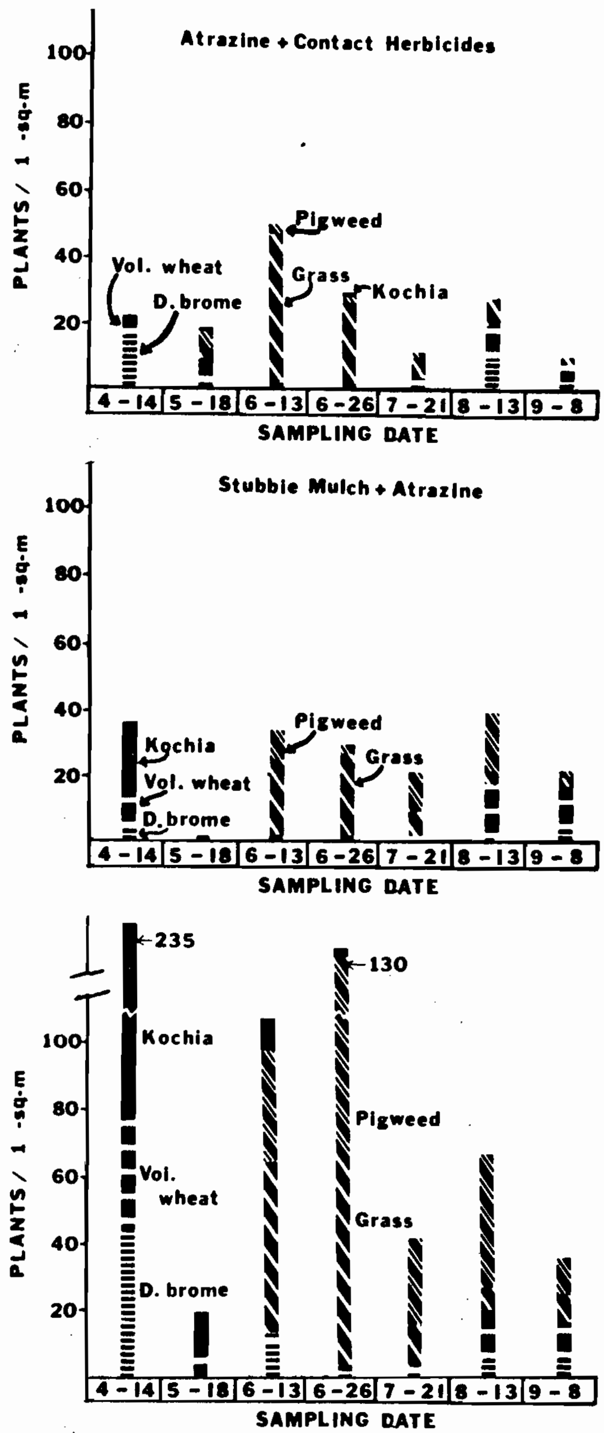

Figure 2. Weed populations during the summer fallow season from 1964 to 1969 at North Platte, Nebraska for three treatments. Sampling preceded spraying or cultivation.

spring. The increase in soil water during the period from harvest until November 4 in the plots of the atrazine + contact herbicides treatment is believed to be due to slightly better weed control, the absence of tillage to expose more soil surface for water evaporation, and conservation

Table 5. Soil water gains or losses as affected by five fallow treatments, 1963 to 1969.

Fallow treatment	Winter wheat harvest to Nov. 4	(Over winter) Nov. 4 to April 14	April 14 to July 3	July 3 to winter wheat seeding	Total
			(cm)		
Plow	−4.4	7.5	10.3	1.2	14.6
Stubble mulch	0.4	7.1	11.3	1.4	20.3
Stubble mulch + atrazine	1.2	6.8	13.7	−0.2	21.5
Atrazine + contact herbicides + stubble mulch	1.1	8.0	15.5	−0.9	23.7
Atrazine + contact herbicides	3.4	9.2	16.6	−1.8	27.4

of more wheat residue on the soil surface compared to the treatments receiving tillage.

During the overwinter period (November 4 to April 14) the plots of the atrazine + contact herbicides treatment gained slightly more water than plots that received tillage (Table 5). Apparently the non-tilled-standing stubble trapped more snow than stubble disturbed by tillage.

From April 14 to July 3 of the fallow period, soil water gain was greatest under the atrazine + contact herbicides (Table 5) and lowest under treatments receiving only tillage. About 17 cm of water were stored in the 0 to 3-m depth under the atrazine + contact herbicides treatment compared to 10 and 11 cm for the plow and stubble mulch treatments, respectively. Water storage efficiency was high since 22 cm of rain were received (Table 3) because it is probably associated with better water infiltration. Barnes *et al.* (1) reported that when weeds were controlled by herbicides in standing stubble, water intake was 216% greater than in plowed ground and 250% more than in soil subjected to subsurface tillage during the second 30 min of simulated rain. The stubble fell down by June 1 each year of this study, creating a dense mat of straw on the soil surface. This straw mat may be an important factor in reducing evaporation and thus increasing soil water storage on the atrazine + contact herbicides treatment.

From July 3 until seeding, water was stored only under the plow (1.2 cm) and stubble mulch (1.4 cm) treatments (Table 5). Prior to July 3 weed populations were greater on plots that received the plow and stubble mulch treatments (Figures 1, 2) compared to those that received herbicides. Also, tillage had exposed more soil for drying, thus the tilled soil was dried to the depth of the last tillage operation and receptive to water storage from rain. The soil in the plots treated with herbicides stored more water before July 3 than the plots that received the plow and stubble mulch treatments. However, after July 3, the soil in plots receiving the three herbicide treatments lost water because the water content of surface soil was always high, evaporation (64 cm) was high (Table 4), and precipitation (16 cm) was low (Table 3).

Soil water storage during the fallow period was greatest in plots that received the atrazine + contact herbicides treatment (Table 5). This was probably due to more residue remaining on the soil surface (Table 2), better weed control (Figures 1, 2), and lack of tillage which hastens drying of the soil.

There was little soil water stored or used by the winter wheat below the 2.1-m depth. Soil water storage efficiency for the 6-yr period was 23, 32, 34, 37, and 43% in plots receiving the plow, stubble mulch, stubble mulch + atrazine, atrazine + contact herbicides + stubble mulch, and atrazine + contact herbicides, respectively. These percentages are similar to those of the first 3 yr (12).

Downy brome in winter wheat. None of the fallow treatments eliminated downy brome since it was growing in all plots 5 months after planting (Table 6). Poor management on any of these treatments could allow sufficient downy brome to go to seed during the fallow period and a subsequent winter wheat yield might be reduced. The plots that were plowed tended to have fewer downy brome plants than the other plots. The plow has been proven to be an excellent tool for downy brome control in other studies (3, 15).

Table 6. Downy brome population and yield in wheat as affected by fallow treatments applied to the same plot every-other-year.

Fallow treatment	1965	1966	1967	1968	1969	1970	Avg.
			Downy brome plants in March in growing winter wheat (No./10m²)				
Plow	0	40	54	14	0	4	10
Stubble mulch	9	97	66	8	15	40	39
Atrazine + stubble mulch	0	55	9	4	0	16	14
Atrazine + contact herbicides + stubble mulch	0	145	27	9	1	46	38
Atrazine + contact herbicides	110	56	35	9	4	51	44
L.S.D. 0.05	85	NS	39	NS	6	28	
			Downy brome at winter wheat harvest (kg/ha)				
Plow	0	175	85	38	0	1	55
Stubble mulch	56	214	133	22	36	1	77
Atrazine + stubble mulch	0	74	13	8	0	2	16
Atrazine + contact herbicides + stubble mulch	0	138	36	26	2	3	34
Atrazine + contact herbicides	156	55	56	19	6	2	49
L.S.D. 0.05	120	NS	84	NS	15	NS	NS

Apparently, some downy brome plants died between March and July since downy brome yields at harvest were low (Table 6). Thus downy brome probably did not influence winter wheat yields but did produce sufficient seed to maintain a stable population. Burnside *et al.* (3) showed that timely tillage and herbicides can keep downy brome at low populations in an alternate winter wheat-fallow rotation.

Winter wheat yields. Yields were excellent throughout the 6-yr period (Table 7). Highest yields came from plots that did not receive any tillage and where weed control was obtained with herbicides. Yield from plots that were plowed was lowest, but not statistically different from plots that were stubble mulched. Yield from plots that received the atrazine + contact herbicides treatment was significantly higher than those that received the stubble mulch treatment in 4 of the 6 yr.

There was no difference among the treatments in which atrazine was included, even though atrazine + contact herbicides treatment had 4 to 6 cm more soil water at planting time than stubble mulch + atrazine and atrazine + contact herbicides + stubble mulch treatments. Probably no yield differences could be expected among these treatments. Smika and Whitfield (13) reported that, above a certain point, winter wheat fails to respond to added soil water stored at planting. Increasing the available soil water at planting from 21.7 to 27.5 cm increased yields only about 269 kg/ha. The expected yield difference between 16.3 and 27.5 cm of available soil water was about 470 kg/ha (13), which is about the difference between the plow treatment and the atrazine + contact herbicides treatment (Table 7).

Atrazine carryover did not affect winter wheat seeded 14 months after application. However, it did kill some volunteer seedlings in August 1968; but an additional 0.56 kg/ha of atrazine was sprayed in April. Some symptoms of injury to seedlings were found in one plot in the fall of 1966 after emergence, but these symptoms had disappeared by spring. In both instances atrazine granules were used after harvest. Injury to wheat by atrazine has been reported in the pan-handle of Nebraska on coarser textured soils with lower organic matter (5) than the soils in this study.

Table 7. The effect of five fallow treatments on yield and quality of winter wheat from 1965 to 1970.

Fallow treatment	1965	1966	1967	1968	1969	1970	Avg.
				Grain yield (kg/ha)			
Plow	3580	3170	2640	1660	3140	1980	2690
Stubble mulch	3830	3280	3080	1780	3360	1920	2880
Atrazine + stubble mulch	3660	3470	3040	2000	3210	2120	2910
Atrazine + contact herbicides + stubble mulch	3480	3730	2900	2300	3480	2330	3040
Atrazine + contact herbicides	4020	3750	3100	2240	3610	2260	3170
L.S.D. 0.05	NS	465	451	292	297	181	
				Weight of 100 seed (g)			
Plow	—[a]	—[a]	2.52	1.80	2.50	2.37	2.30
Stubble mulch	—	—	2.58	1.88	2.68	2.24	2.34
Atrazine + stubble mulch	—	—	2.44	2.00	2.54	2.26	2.31
Atrazine + contact herbicides + stubble mulch	—	—	2.33	2.04	2.69	2.17	2.31
Atrazine + contact herbicides	—	—	2.46	1.92	2.75	2.21	2.34
L.S.D. 0.05	—	—	0.22	0.17	0.12	0.13	NS
				Density of grain (kg/hl)			
Plow	44.9	48.5	47.9	43.4	48.0	46.4	46.5
Stubble mulch	45.4	48.6	47.9	44.0	48.2	46.3	46.8
Atrazine + stubble mulch	45.5	48.8	47.9	44.9	48.2	46.5	47.0
Atrazine + contact herbicides + stubble mulch	44.3	49.1	46.6	45.4	48.0	46.6	46.7
Atrazine + contact herbicides	44.6	49.0	46.8	45.3	48.8	46.7	46.9
L.S.D. 0.05	1.1	0.5	NS	1.0	0.5	NS	NS
				N in grain (%)			
Plow	2.49	2.91	2.64	3.30	2.67	3.02	2.84
Stubble mulch	2.47	2.91	2.56	3.24	2.67	3.15	2.83
Atrazine + stubble mulch	2.49	2.72	2.55	3.22	2.65	3.11	2.79
Atrazine + contact herbicides + stubble mulch	2.49	2.78	2.64	2.87	2.58	2.98	2.72
Atrazine + contact herbicides	2.53	2.69	2.71	2.89	2.71	2.97	2.75
L.S.D. 0.05	NS	0.15	NS	0.15	0.11	0.13	NS

[a] Seed were not saved to be counted.

Factors that affect winter wheat yield and quality. The weight of 100 wheat seed showed a significant treatment × year interaction but no difference among treatments when averaged over years (Table 7). No explanation is apparent for difference within years.

The density of grain also had a significant treatment × year interaction. The largest difference was in 1968 when the density of the grain from the plow treatment was 1.9 kg/hl lower than grain from the all-herbicide treatment. During the fallow season only 4 cm of rainfall were received from July 3 to seeding (September 14), and the precipitation during the growing season was low (Table 3). The low amount of precipitation caused the 1968 yields to be the lowest during the 6-yr study, and low density of grain was associated with the low yield.

The percentage of nitrogen in the grain was not significantly different among treatments when averaged over years, but it tended to be greater on treatments with lower grain yield (Table 7). However, in 1965, 1967, and 1969 the atrazine + contact herbicides treatment had both the highest grain yield and highest nitrogen percentage.

Acknowledgments

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