UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
WESTERN REGION

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September 19, 1975

TO: Interested persons of the Central Great Plains Research Station Akron, Colorado.

FROM: B. W. Greb, Soil Scientist

SUBJECT: Fall weed control in new wheat stubble.

It has been estimated that uncontrolled weed growth in the stubble fields of the Great Plains of the United States consumes more water each fall than the annual 7.5 million acre feet irrigation allotment of the entire Colorado River system. Some of this water being wasted by weeds could be profitably converted into crop units and of wheat in particular.

About three years ago a preliminary report from research conducted at the Akron station strongly suggested that fall weed control in new wheat stubble in a fallow-wheat rotation would increase wheat yields by 4 to 11 bushels per acre. These results have now been formalized in the enclosed publication. Data here includes four fallow seasons (1967-1971) and four crop seasons (1969-1972). Continuing work in 1974 and 1975 (see attached data sheet) adds to the evidence that failure to suppress weeds in new stubble is a costly economic loss; particularly at the price of wheat since 1972.

Fall application of the principles given here for the local 8-million acres of summer fallow wheat of western Kansas, western Nebraska, and eastern Colorado could add a net gain of 30 to 50 million more bushels/year to the overall economy. Hopefully the advent of new and improved herbicide technology will someday make this possible.

Sincerely,

B. W. Greb
Soil Scientist

Enclosures

Yield of Dryland Winter Wheat Resulting from Suppression of Fall Weed Growth in New Stubble
Fallow-Wheat Rotation, Akron, Colorado

Weed Control Treatment*	Fall Weeds	Grain Yield	Straw Yield	Total Dry Matter	Protein Grain
	Lb/A	B/A	Lb/A	Lb/A	%
1974 Results					
Check (Spring Disk)	1255	43.1	4380	6965	9.6
Fall Sweep (twice)	350	49.1	5510	8455	11.2
Fall Sweep + Atrazine	335	51.4	5360	8445	11.5
1975 Results					
Check (Spring Disk)	610	41.2	3370	5840	- **
Fall Sweep (twice)	30	46.8	3680	6490	-
Fall Sweep + Atrazine	30	50.3	4035	7055	-
Atrazine + Roundup	395	51.0	4230	7290	-
Atrazine + Paraquat	290	53.4	4120	7325	-

* Weed control treatments applied late July 1972 and 1973 as affecting wheat yields of 1974 and 1975 respectively.

** Awaiting analysis during winter of 1975-76.

Note: Atrazine continued to suppress spring germination of weeds until mid-June.

B. W. Greb, USDA-ARS
Dr. R. Zimdahl, Weed Research Lab, CSU

YIELD RESPONSE TO FALL WEED CONTROL IN NEW WHEAT STUBBLE IN A FALLOW-WHEAT ROTATION 1/

B. W. Greb 2/

COLORADO CROP PROTECTION INSTITUTE PROCEEDINGS

Nov. 13-14, 1974
Student Center
COLORADO STATE UNIVERSITY

1/ Contribution from the Soil, Water, and Air Sciences, Western Region, USDA-ARS in cooperation with the Colorado Agricultural Experiment Station.

2/ Soil Scientist, U.S.D.A., Akron, Colorado.

Yield Response to Fall Weed Control in New Wheat Stubble in a Fallow-Wheat Rotation

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Interpretive Summary

Six of the better fall weed control treatments, using subtillage and/or herbicides, reduced potential fall weed growth in new wheat stubble by 57% over a 4-year test period as compared with no treatment. Soil water storage was thereby increased at the end of fallow by 1.2 inches and soil nitrate nitrogen by 21 lbs/acre. These growth inputs subsequently increased wheat grain yields 6.0 bushels/acre and straw yields by 700 lbs/acre.

Overall benefits were greatest from either fall double sweep or amitrole-atrazine herbicides used at 1 lb/acre shortly after harvest. The use of herbicides decreased the need for mechanical tillage by 25 to 40%. All treatments that improved wheat yields 2.0 bushels/acre were economical. However, it is imperative that fall weed control treatments leave the stubble upright during the winter to retain blowing snow.

In the fallow-winter wheat area west of the 100^o meridian of the Central Great Plains, 4 to 8 inches of rain can be expected between wheat harvest and the first killing frost (3, 7, 9, 13). Most of this water is wasted if weeds are allowed to grow undisturbed in new wheat stubble. Samplings in nontilled stubble fields in northwestern Colorado have shown that fall weed growth can be as great as 2000$^+$ lbs/acre of dry matter.

Briggs and Shantz (4) and Shantz and Piemeisel (11) listed 10 broadleaf weed species common to the area that require an average of 515 $\pm$ 23 lbs of water per pound of dry matter produced. The value is nearly identical to the 507 $\pm$ 6 lbs of water required by wheat. In addition to warm-season broadleaf and grassy annual weed species, some cool-season broadleaf weeds, grassy weeds (downy brome), and volunteer wheat iteself can consume considerable soil water throughout the fall, winter, and early spring (4, 9, 11, 13, 15). Thus, the control of fall weed growth in wheat stubble may involve tillage, herbicides, or both.

Earlier work in Colorado, western Kansas, and northern Texas using stubble-destroying tillage implements to control weeds showed that fall tillage of wheat stubble gave little crop yield advantage as compared with fall weed control by tillage usually was lost because the tillage was done either after the weeds had already used the water or tillage had left little or no standing stubble available to catch snow. The advantage of holding snow with upright stubble for water conservation purposes has been recorded in both the Northern and Central Great Plains (2, 3, 6, 9, 12).

The concept of using herbicides in fallow is not new. A number of "chemical" fallow experiments have been conducted in recent years (1, 2, 5, 10, 13, 15, 16). These experiments varied in success depending on location, rotation, type of weeds, and herbicide used. In most cases samplings were limited to soil water storage and crop yields. Complete chemical fallow did show promise in some instances, but not at an economic level (2, 13). The most favorable results were obtained by Smika and Wicks (13) at North Platte, Nebraska with the use of a combination of a contact + preemergence herbicide early in the fallow cycle.

A study similar to that by Smika and Wicks (13) was begun in 1967 at Akron, Colorado where rainfall is less favorable than at North Platte. Complete chemical fallow was not attempted; the primary objective was to concentrate on fall weed control from date of harvest to fall dormancy. This part of the 14-month fallow period had previously received little attention in terms of effects of weed control on the conservation of soil nitrates and soil water. This report presents the results of four cycles of fallow-winter wheat involving nine fall weed control treatments.

EXPERIMENTAL PROCEDURE

The experimental site was on nearly level Sligo silt loam soil with half of the area in wheat and half in fallow during the spring of 1967. Shortly after wheat harvest, the stubble was subdivided into nine fall weed control treatments with four replications of each. Individual plots were 32 x 100 ft. as a convenient size for the use of various tillage implements, spray boom, and frequent field samplings of soil water, soil nitrates, and plant tissue. The remaining area in fallow was planted to wheat in the fall of 1967 to produce available stubble for the fall of 1968. In this manner, an alternate fallow-crop sequence was set up for both halves of the experimental area. Four fallow years (1967-1970) and four crop years (1969-1972) were completed to encompass a reasonable variation of climate, weed population, and crop yields.

The fall weed control tillage and herbicide treatments are given in Table 1. Tillage implements used were a 12-ft. one-way disk and a rod weeder with small chisel points in front of the rod. Both of these implements were operated at the 3-in. soil depth. The sweep implement used had two 6-ft. V-shaped blades. These blades were used to undercut stubble at the 4-in. soil depth for initial tillage and the 3-in. depth for secondary operations. The rod weeder was used late in July and August to control small germinating weeds and for seedbed preparation. The pull-type ground spray rig with a 32-ft. boom was used for applying the herbicides of 2, 4-D butyl ester, atrazine and amitrole. The time schedule shown in Table 1 for tillage and herbicide applications was used in all years except 1968, when one extra rod weeding was necessary early in August to control grassy weeds. At the end of fallow, wheat was planted early in September with a deep furrow drill in rows 13.5 inches apart.

Soil Measurements

Soil water samples were obtained gravimetrically by 1-ft. increments to the 6-ft. depth with three borings per plot per sampling date. Samples were taken at date of weed control applications (late July), at fall dormancy, and at the end of fallow. Samples for soil nitrate were collected at soil depths of 0-ft., 1-2 ft., and 2-4 ft., three borings per plot, at the date of treatment application, at fall dormancy, and at the end of fallow. Nitrate was determined by the phenoldisulphonic method.

Plant Measurements

Weed production in the wheat stubble was determined from samples collected from a 3-ft. x 3-ft. area, three samples per plot, at the stage of maximum maturity, usually in mid-September. The samples were oven dried at 70^{o} C before weighing.

Grain yield was determined by combine harvesting a 16- x 100-ft. area from each plot. Straw yields, protein content of grain and test weight of grain were determined from two hand-harvested areas per plot. The two hand-harvested areas, 4 rows by 4 ft. in size, each were composited and allowed to air dry 3 weeks before threshing. Protein of grain was determined by the Kjeldahl distillation method.

EXPERIMENTAL RESULTS

During the 5-year duration of the experiment, precipitation averaged 12.43 inches per season, equivalent to 24.86 inches per 2-year fallow-crop cycle. Precipitation during the 14-month fallow season averaged 14.76 inches, with an average 10.10 inches being received from date of wheat planting to date of harvest. Although annual precipitation was 4 inches below the long-term area average, there was no prolonged damaging drought. The precipitation was remarkably effective in terms of soil water storage during fallow and very timely for promoting excellent wheat growth. There was no hail damage, excessive runoff water, or presence of disease and insect pests.

Soil Water Storage (Table 2)

Where no weed control was used, fall weed growth in new wheat stubble averaged 1020 lbs/acre dry matter. The best treatments, double sweeping and the use of atrazine-amitrole, reduced potential fall weed growth 64 to 72%, respectively. At the time of fall dormancy (see Table 2), the net soil water storage increase on the weed-control treatments ranged from 0.2 inch for fall disking to 1.4 inches for the double sweep.

With flat stubble during the winter months, the fall disk treatment did not catch snow and eventually stored 1.0 inch less water by the end of fallow than did the check. The remaining seven treatments stored an average 1.1 inches more water than did the check.

Water storage was highest with the double fall sweep and the atrazine-amitrole treatments. These treatments stored 1.5 inches more water than the check which thereby increased fallow efficiency 34% as compared with 24% for the check. Even though precipitation was much below normal during the experiment, the overall fallow efficiency of 29% for all treatments is a considerable improvement over historical values of 13 to 26% for this region (5, 7, 9).

Soil Nitrate Nitrogen (Table 2)

The supply of soil nitrogen available as NO_3-N for all treatments averaged 21 lbs/acre at harvest, increased to 40 lbs/acre by fall dormancy, and to 87 lbs/acre by the end of fallow. The use of butyl ester alone did not increase the supply of nitrate above that obtained by the check. For the seven remaining treatments, the level of nitrate-nitrogen was increased about 10 lbs/acre per 300-lb/acre reduction of fall weed growth. The net gain of 27 lbs/acre nitrate-nitrogen (above the check) achieved by fall double sweeping and the atrazine-amitrole treatments is equal to an 80-lb. bag of ammonium nitrate. With the rising cost of fertilizers, increasing the supply of soil nitrate by more intensive weed control could be important in future wheat production practices.

Wheat Yields and Quality (Table 3)

Wheat grain yields were excellent, and for all treatments and averaged 39.1, 48.7, 38.7, and 34.0 bushels/acre for the 1969, 1970, 1971, and 1972 crop seasons, respectively. The average yield of wheat, both grain and straw, was significantly increased above the check by all fall weed control treatments except fall disking or the use of butyl ester alone. Increases in grain yields for the six better treatments ranged from 3.8 bushels/acre to 7.7 bushels/acre. Increases in straw yields ranged from 480 lbs/acre to 980 lbs/acre for these same treatment comparisons. For all treatments as a whole, soil water content and soil nitrate status at the end of fallow were highly correlated with grain and straw yields.

The yield response of wheat to fall weed control treatments varied from year to year in response to variations in water available for weed growth. Yields benefited most in 1970, as a reflection of very favorable water and high potential weed growth during the fall of 1968 when that fallow season began. Calculations based on weed growth data (Table 2) and yield data (Table 4) showed a consistent increase of 1 bu/acre per 100-lb/acre reduction of fall weeds. Thus, a reduction of 1 lb. in fall weeds resulted in an increase of almost 2 lbs. of wheat tissue (total dry matter).

Water use efficiency by wheat was increased nearly 9% by the better fall weed control treatments as compared with no treatment (Table 4). Increases generally were greatest in those treatments in which levels of nitrate-nitrogen were higher at the end of fallow.

With the exception of using butyl ester alone, the protein content of grain from the remaining fall weed treatments was increased 0.4 to 0.9%, compared with no treatment. The test weight of grain was influenced very little by any of the fall weed control treatments.

Economics of Fall Weed Control (Table 4)

Loss-profit estimates are usually obsolete within 24 hours of computation becuase of almost daily fluctuations in costs of labor, machinery, and herbicides, and in the value of the crop itself. Nevertheless, estimates of the economics of fall weed control are given in Table 4 as based on average costs during 1971, 1972, and 1973.

The number of tillage operations ranged from 3-1/4 per fallow season for the atrazine amitrole treatment to 6 per season with double fall sweeping. Average costs for all fallow operations, tillage and/or herbicides ranged from $7.50/acre for the check treatment to a high of $13.50/acre using atrazine-amitrole plus a sweep operation at the beginning of fallow. The cost of fallow operations for all nine treatments averaged $10.30/acre.

The average dollar net gain per acre of fall weed control (cost minus sale value of wheat) is shown on Table 4 if wheat sells at $2.00/bushel and at $4.00/bushel. At today's $4.00/bushel sale price, using the one-way disk for fall weed control resulted in a net loss of $5.20/acre compared with no treatment. Average profits over $20.00/A. were achieved by using either fall double sweep or atrazine-amitrole herbicide. Regardless of weed control method used, only a gain of 2.0 bushels/acre wheat was required to show a reasonable profit. The values in Table 4 do not include the obvious advantage of increased straw yields. Straw is considered to be worth about 2¢/lb. as a mulch to reduce soil erosion, improve water storage, nutrient content and snow catchment (6, 7, 12, 13). Thus, an increased straw yield of 500 lbs/acre by the use of fall weed control would add another $10/acre to the value of treatment. Lastly, protein content of wheat increased 0.4 to 0.9% as a result of fall weed control. An improved protein content of grain has a nutritional value even if no monetary value is realized.

Comments on Specific Weed Control Methods

Fall Disking - This method proved slightly negative because of volunteer wheat growth and the failure of the flat stubble produced by disking to hold blowing snow.

Single Fall Sweep - The maximum benefit of fall sweeping at 1 week versus 5 weeks after wheat harvest varied from year to year dependent upon the amount of weed infestation at the time of sweeping and the amount of water available. Generally, sweeping was easier if done shortly after harvest, because of mellower soil conditions, than if done later.

Double Fall Sweep - The primary objective of double sweeping was to obtain a quick kill of weeds shortly after harvest and then to reduce the growth of volunteer wheat with the second operation. Double fall sweep was more beneficial than single sweeping in the two years that water content was high for potential weed growth. In two drier years, double sweeping gave no advantage over single sweeping.

Butyl Ester - This herbicide was slower in killing broadleaf weeds than desired and was ineffective on grassy weeds. Benefits above 2.0 bushels wheat per acre was achieved in only one of four years. In that case no grassy weeds were present and butyl ester did get a good kill on young pigweeds and kochia.

Butyl Ester + Sweep - The results were about additive to these two methods used alone when averaged over the 4-year test.

Atrazine-Amitrole - Amitrole was an effective contact herbicide on grassy weeds and most broadleaf species except kochia. Atrazine, as a preemergence herbicide, was moderately effective during the fall in preventing new broadleaf weeds from emerging and in preventing volunteer wheat from rooting during the fall and winter. Atrazine was particularly effective during the next spring, keeping plots sterile of all vegetative growth until about mid-June when the atrazine was deactivated by normal organic decomposition. This method also eliminated two or three mechanical tillage operations per fallow season.

Atrazine-Amitrole + Sweep - Because amitrole killed weeds on contact, there was no advantage in also using the fall sweep treatment for the early kill of weeds.

The results of the weed control treatments tested suggest that an ideal control system would include instant complete killing of all unwanted vegetation shortly after wheat harvest and keeping the soil essentially sterile until midsummer the next year. Second, the contact preemergence herbicides necessary to accomplish this objective would have to be within economic cost to encourage use and legal from the standpoint of environmental protection acts. Although none of the treatments used in this experiment met all the above requirements, some did very well. Other treatment possibilities such as paraquat-atrazine and single sweep + atrazine are being tested.

SUMMARY

The results of this experiment showed that controlling some of the potential weed growth in new wheat stubble by subsurface tillage or herbicides significantly increased the storage of soil water and nitrate-nitrogen during fallow. With either tillage or herbicides, stubble must remain upright during the winter to hold blowing snow. Generally, elimination of 580 lbs/acre of fall weed growth resulted in a net gain of 1.2 inches soil water and 21 lbs/acre of nitrate-nitrogen. These growth inputs increased grain yield about 6.0 bushels/acre and straw yield about 700 lbs/acre. All weed control treatments tested that increased wheat yield by as little as 2 bushels/acre were economical. Furthermore, the increases were achieved with precipitation of only 12.43 inches per year (25% below normal). Within-year experimental results obtained here and by Smika and Wicks (13) strongly suggest that benefits would increase as available water and potential for weed growth increased. Thus, yield-benefit estimates of 10 to 15 bushels/acre for fall weed control would not be unreasonable in a fallow-wheat rotation in areas with an 18- to 22-inch average precipitation.

The concepts given here and by Smika and Wicks (13) may have a significant impact on the production of winter wheat in semiarid zones, not only in the United States but in other large wheat producing nations.

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Table 1 - Weed control treatments during the fallow season. Four years(1967-1971). Akron Colorado.

Weed Control Treatment	Fall Treatments: Late July	Fall Treatments: Late August	Spring and Summer Treatments: Early May	Spring and Summer Treatments: Mid-June	Spring and Summer Treatments: Late July	Spring and Summer Treatments: Late August
None	-	-	Disk	Sweep	Rod Weeder[a]	Rod Weeder
One-way Disk	Disk	-	-do-	-do-	-do-	-do-
Sweep[b]	Sweep	-	-do-	-do-	-do-	-do-
Sweep	-	Sweep	-do-	-do-	-do-	-do-
Double Sweep	Sweep	-do-	-do-	-do-	-do-	-do-
Butyl Ester	Spray[c]	-	Sweep	-do-	-do-	-do-
Ester + Sweep	-do-	Sweep	Disk	-do-	-do-	-do-
Atrazine-Amitrole	-do-	-	-	Disk	-do-	-do-
Sweep + AA	Sweep + Spray	-	-	-do-	-do-	-do-

[a] Rid weeder = rotating bar with tongs attached that lifts straw and soil clods over the bar.

[b] Sweep = 6-ft. wide V-shaped blades for undercutting stubble.

[c] Spray = 1 lb/acre active ingredient of each herbicide listed.

Table 2 - Soil water storage and nitrate nitrogen status during fallow as affected by fall weed control treatments. in new wheat stubble in a fallow-wheat rotation. Four-year average (1967-1970). Akron, Colorado.

Weed Control Treatment	Fall Weed Growth	Soil Water Status - Begin Fallow[a]	Fall Dormancy[a]	End Fallow[a]	Net Gain	Fallow Eff.[b]	Soil Nitrate Nitrogen Status Begin Fallow[a]	Fall Dormancy[a]	End Fallow[a]	Net Gain
	Lb/A	Inches				%	Lb/A			
None	1020	2.7	3.8	6.2	3.5	24	20	33	72	52
Disk (1 wk.)[c]	500	2.6	3.9	5.1	2.5	17	21	36	83	62
Sweep (1 wk.)	550	2.6	4.8	7.2	4.6	32	21	41	87	[illegible]
Sweep (5 wks.)	650	2.3	4.3	6.5	4.2	28	20	36	87	[illegible]
Sweep (1, 5 wks.)	330	2.7	5.2	7.7	5.0	34	18	44	96	78
Butyl Ester (1 wk.)	770	2.4	3.9	6.6	4.2	28	21	34	71	50
Ester (1 wk.) + Swp. (5 wk.)	470	2.5	4.6	6.0	4.4	30	25	43	92	67
Atrazine-Amitrole (1 wk.)	370	2.8	4.8	7.8	5.0	34	19	45	99	80
AA (1 wk.) + Swp. (1 wk.)	290	2.5	5.0	7.3	4.8	33	21	48	100	79
Avg. All Treatments	560	2.5	4.5	6.8	4.3	29	21	40	87	66

[a] Avg. dates = Begin Fallow, apply treatments = July 26; Fall Dormancy = Nov. 10; End Fallow = Sept. 7

[b] Fallow Efficiency = $\frac{\text{Net gain soil water X 100}}{\text{Avg. fallow season pptn. (14.76 inches)}}$

[c] Note on Treatments: (1 wk.) (5 wk.) = weeks after July 18 harvest.

Table 3 - Winter wheat yields as affected by fall weed control in a fallow-wheat rotation. Four-year average (1969-1972). Akron, Colorado.

Weed Control Treatments	Grain	Straw	TDM	Water Use Eff.[a]	Protein Grain	Nitrogen Uptake[b]	Test Wt. Grain
	B/A	Lb/A	Lb/A	Lb/A/In.	%	Lb/A	Lb/A
None	36.1	3500	5670	390	11.0	42	61.8
Disk (1 wk.)	35.3	3400	5500	365	11.6	43	61.3
Sweep (1 wk.)	39.9	3980	6350	395	11.6	49	62.2
Sweep (5 wks.)	40.4	4000	6450	415	11.4	49	62.2
Sweep (1, 5 wks.)	43.8	4300	6900	425	11.7	54	62.3
Butyl Ester (1 wk.)	38.1	3850	6150	400	11.0	44	62.1
Ester (1 wk.) + Swp. (5 wks.)	41.6	4180	6670	425	11.9	52	61.9
Atrazine-Amitrole (1 wk.)	43.2	4480	7070	425	11.7	53	62.6
AA (1 wk.) + Swp. (1 wk.)	43.1	4200	6800	420	11.8	53	61.9
Avg. All Treatments	40.1	3990	6400	405	11.5	49	62.0

[a] $$\text{WUE} = \frac{\text{Total Dry Matter (lb/A)}}{\text{Total water use (soil water + crop season rainfall)}}$$

[b] N-Uptake = Grain yields X % N in grain.

Table 4 - Economic estimates of fall weed control treatments in new wheat stubble in a fallow-wheat rotation. Four-year average (1969 to 1972). Akron, Colorado.

Weed Control Treatments	Tillage Fallow Operations	Cost Tillage + Herbicide[a]	Net Gain Grain	Net $/A Above Check Wheat Sells At	
	No.	$/A	B/A	$2/B	$4/B
None	4¼	7.50	0	--	--
Disk (1 wk.)	5¼	9.50	-.8	-3.60	-5.20
Sweep (1 wk.)	5¼	9.50	3.8	55.60	13.20
Sweep (5 wks.)	5¼	9.50	4.3	6.60	15.20
Sweep (1, 5 wks.)	6	11.00	7.7	11.90	27.30
Butyl Ester (1 wk.)	4¼	9.30	2.0	2.20	6.20
Ester (1 wk.) + Swp. (5 wks.)	5¼	11.30	5.5	7.20	18.20
Atrazine-Amitrole (1 wk.)	3¼	11.50	7.1	10.20	24.40
AA (1 wk.) + Swp. (1 wk.)	4¼	13.50	7.0	8.00	22.00
Avg. All Treatments	4-1/2	$10.30	5.3	$ 7.40[b]	$18.05[b]

[a] Based on Sweep = $2.00/A, Disk = $2.00/A, Rod Weed = $1.50/A
Herbicide + application costs = Butyl Ester = $1.80/A
Atrazine-Amitrole = $6.00/A

[b] Avg. all treatments except disk.