ECONOMIC RETURNS FROM SPRING BROADLEAF WEED CONTROL IN HARD RED WINTER WHEAT

(*Triticum aestivum* L.)

By

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(*Triticum aestivum* L.)

Economic Returns from Spring Broadleaf Weed Control in Hard Red Winter Wheat (*Triticum aestivum*)[1]

ROBERT C. SCOTT and THOMAS F. PEEPER[2]

Abstract. Seventeen on-farm and two experiment station situated experiments were conducted to evaluate farmers decisions to apply broadleaf weed control herbicides to hard red winter wheat in February or March with or without urea-ammonium nitrate (28-0-0) fertilizer carrier. The herbicides and rates varied but all farmers applied a residual sulfonylurea herbicide and four added a phenoxy. Most farmer selected herbicide treatments controlled target weeds, but controlling weeds increased wheat yield at only two farms. Farmer selected, commercially applied treatments increased net returns at two of seventeen farms, decreased net returns at seven farms, and did not affect returns at other sites. Net returns were increased over the farmer selected treatments at two farms when half the farmer selected rate of herbicide was used. Half rate herbicide treatments controlled

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[2]Grad. Res. Asst. and Prof., respectively, Dep. Agron., Okla. State Univ., Stillwater, OK 74078.

weeds up to 25% less than farmer selected treatments. Weed control with the half rate treatments ranged from 60 to 98%. None of the farmers expected that herbicide use would increase yield. Their primary objective was to have weed free fields at harvest. Nitrogen application rates appeared to be selected without a firm basis for decision making. **Nomenclature:** Chlorsulfuron, 2-chloro-N-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]benzenesulfonamide; metsulfuron, 2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-y)amino]carbonyl]amino]sulfonyl]benzoic acid; MCPA, (4-chloro-2-methylphenoxy)acetic acid; 2,4-D, (2,4-dichlorophenoxy)acetic acid; triasulfuron, 2-(2-chloroethoxy)-N-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbony]-benzenesulfonamide; bushy wallflower, *Erysimum repandum* L. #[3] ERYRE; flixweed, *Descurainia sophia* (L.) Webb. ex Prantl, DESSO; henbit, *Lamium amplexicaule* L. LAMAM; plains coreopsis, *Coreopsis tinctoria* Nutt. CRLTI; smallflowered bittercress, *Cardamine parviflora* L. CARPA; wild buckwheat, *Polygonum convolvulus* L. POLCO; hard red winter wheat, *Triticum aestivum* L. **Additional index works:** Net returns, chlorsulfuron, metsulfuron, triasulfuron, MCPA, 2,4-D, CARPA, CRLTI, DESSO, ERYRE, LAMAM, POLCO,.

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[3]Letters following this symbol are a WSSA approved computer code from Composite List of Weeds, Revised 1989. Available from WSSA, 309 W. Clark St., Champaign, IL 61820.

INTRODUCTION

An estimated 33 to 44% of the 2.7 million hectares of wheat harvested for grain annually in Oklahoma receive an application of herbicides for broadleaf weed control (6). About 70% of these treatments are commercially applied and many are applied with UAN[4] carrier[5]. The effects on grain yield of controlling broadleaf weeds in the spring in hard red winter wheat are sometimes unreported and when reported, have been variable.

In Utah, chlorsulfuron and metsulfuron controlled winter annual broadleaf weeds 90 to 100% when applied over snow. This research confirmed that herbicides used were compatible with UAN, but effects on wheat yield were not reported (9). In Oklahoma, chlorsulfuron and triasulfuron at 9 to 18 g/ha both controlled henbit, wild buckwheat, flixweed, and cutleaf eveningprimrose (*Oenothera laciniata* Hill), but effects of these treatments on wheat grain yield were not reported (17).

In other research, controlling various densities of red horn poppy (*Glaucium corniculatum* (L.) Rudolph) in the fall or spring in Oklahoma failed to affect wheat yield in nine experiments conducted from 1989 to 1991 (1). In Michigan, experiments were conducted over three years to evaluate herbicides for mayweed (*Anthemis cotula* L.) control (16). Several herbicide treatments controlled mayweed 89% or more, but failed to increase wheat grain yield even though

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[4]Abbreviations used: UAN = 28-0-0 fluid urea-ammonium nitrite fertilizer, containing 0.36 kg of elemental nitrogen per L.

[5]Unpublished data 1991, Ciba Corporation, Greensboro, NC 27419-8300.

winter wheat was considered partially susceptible to interference from this weed. This species also interferes with harvesting grain.

In experiments conducted across Oklahoma to evaluate chlorsulfuron, MCPA, and 2,4-D for winter annual broadleaf weed control, wheat yield was increased only 5 of 29 times by controlling weeds in the spring (21). In Texas, one tansy mustard (*Descurainia pinnata* (Walt.) Britt.) per 0.09 m^2 reduced winter wheat yield 6 to 10%. However, in that same research six times as many tansy mustard plants failed to reduce yield in one year of three (26). In Northwestern Oklahoma, winter wheat yield decreased from 1717 to 1249 kg/ha as tansy mustard density increased from 0 to 22 plants/m^2 (13). However in three associated field experiments, controlling this species with herbicides in the spring failed to increase yield. In Canada, 60 wild mustard (*Sinapsis arvensis* L.) plants/m^2 reduced spring wheat yield, but in three years of on-farm research, yield reductions were not found until wild mustard density was 125 plants/m^2 (12, 19). In England, eight species of winter and summer annual broadleaf weeds reduced winter wheat yield in only 10 of 20 experiments and yield losses from broadleaf weeds were much less predictable than yield losses from slender foxtail (*Alopecurus myosuroides* Huds.) (27).

In England, the cost of broadleaf weed control herbicides for wheat were considered "relatively cheap" compared to grass control herbicides and compensating for the control of broadleaf weeds required only a 3% increase in yield (10). Herbicide applications for broadleaf weed control were considered routine and probably justified when all objectives of weed control were considered. Objectives of weed control included in this argument were a clean trouble-free harvest, uncontaminated grain for processing, preventing loss of crop yield through competition, and decrease storage and handling difficulties (11). Weed interference with wheat harvesting can be a major problem and justification for implementing weed control measures (16, 20).

Wild buckwheat, common in both winter and spring wheat, clogs sickles, threshing components, and separating components of grain combines (20). Heavily infested fields may not be harvestable and harvested grain may have an elevated moisture content (20, 27). Plains coreopsis not only interferes with grain combine operation, but also causes a strong odor in the grain and its green capitula can cause spoilage of harvested wheat.

In addition to deciding whether to use a herbicide, farmers must also decide whether to apply UAN which can serve as a carrier for spring applied herbicides. Nitrogen requirements for hard red winter wheat are well established (15). However, research in Oklahoma indicated variable effects on winter wheat yields from spring applied UAN. While UAN is expected to increase yields when nitrogen is limited, UAN applications can also burn leaf tissue and increase the potential for freeze damage to embryonic seedheads (7). Also, the optimum time for top-dressing wheat with UAN precedes the typical grazing termination date, thus the actual removal of nitrogen by grazing can only be estimated.

Commercial application of herbicides with equipment commonly in use often requires the whole field to be treated. The cost of weed control then approximates to a fixed cost and is independent of weed density (25).

Farmers need to be able to predict yield losses from weed infestations and plan for risk aversion and unpredictable events (8, 24). Farmers may find it difficult to use available data to estimate yield losses because researchers typically select or create dense weed populations for evaluating weed control that likely exceed average weed densities on farmers fields (25). Even minor changes in weed density can effect crop yield (14). Thus, farmers face a dilemma in trying to determine a system of rational pesticide use given the variations in weeds present and their densities within or between fields.

In the United Kingdom, where there has been increasing need to economically justify the use of herbicides in cereal crops, herbicide costs have been justified when weed populations exceed predetermined thresholds. However, the most important threshold factor is typically crop yield rather than risk aversion, aesthetics, or increasing harvest ease of the crop (28).

The reduction of herbicide use rates was examined as one possible means of reducing herbicide use and increasing net returns from weed control in small grains (22). Herbicide efficacy was found to be acceptable and grain yields higher in many weed-crop situations with lower than labelled rates of MCPA plus mecoprop ((R)-2-(4-chlor-2-methylphenoxy)propionic acid) or MCPA plus fluroxypyr (4- amino-3,5-dichloro-6-pyridyloxyacetic acid) combinations (23).

The objectives of this research were 1) to evaluate the effects of spring broadleaf weed control on wheat grain yields and net return on investment in production wheat fields where the farmer made the decision to apply herbicides with water or UAN carrier, 2) to determine the effects on weed control and net returns of reducing by half the rate of herbicide chosen by the farmer, and 3) to determine why these farmers decided to use herbicides.

MATERIALS AND METHODS

Seventeen small plot experiments were conducted during the spring of the 1991-92 and 1992-93 winter wheat growing seasons in north central Oklahoma to determine the economic consequences of farmers' decisions to apply herbicides for broadleaf weed control with or without UAN. The two criteria for site selection were 1) a request from a wheat grower to a cooperating commercial applicator for a herbicide application on his wheat and 2) the wheat grower then agreed to permit establishment of research plots on his farm. University personnel did not influence the farmers' decisions to spray. In 1991-92, two similar experiments were conducted on Agronomy Research Stations at Lahoma and Stillwater, Oklahoma.

Locations, planting and application dates, wheat growth stages at treatment, soils, and other site specific data are in Table 1. The experimental design at each farm was a randomized complete block with 4 replicates (3 at farm 19, 5 at farms 1 - 4, 11, and 13) depending on the available space containing a weed population representative of the whole field. Plot size was 1.8 by 7.3 m in the 1991-92 experiments and was reduced to 1.8 by 7 m area the next year to permit more rapid installation of polyethylene plot covers. The number of treatments in each experiment depended on whether the farmer selected treatment (baseline treatment) included UAN (Table 2).

At each on-farm site, immediately prior to custom application of the baseline treatment, 1.8 by 7.3 m folding polyethylene covered wooden frames were placed over all plots except those receiving the baseline treatment. The commercial applicators then applied the baseline treatment as the entire field was sprayed. Carrier volume used by the custom applicators ranged from 12 to 175 L/ha depending on the desired rate of nitrogen and the method of application. Immediately after the baseline treatment was applied the plot covers were removed and additional treatments were applied to the protected plots with a CO_2 pressurized backpack sprayer in a total carrier volume of 190 L/ha with a four nozzle boom equipped with flat fan nozzle tips spaced 51 cm apart. When the baseline treatment included UAN, these additional treatments included the herbicide(s) in water carrier and UAN without herbicide. Also a half rate of the herbicide(s) was applied with the farmer selected quantity of UAN with water added so that carrier volume was 190 L/ha, and an untreated check. In the experiments on Agronomy Research Stations, all treatments were applied with a CO_2 backpack sprayer in a total carrier volume of 190 L/ha. Herbicide and UAN rates chosen at these locations were similar to farmer selected treatments at previously established locations.

Weed density was determined by counting the weeds in four randomly selected 0.125 m^2 quadrats in each replication. In fields with low weed populations, larger areas were also visually inspected for weed presence. Growth stage of henbit and plains coreopsis was vegetative with 3 to 15 cm stems at the time of application.

Wild buckwheat density at each site was determined when plants were cotyledon to first true leaf. Growth stage of bushy wallflower, flixweed, and smallflowered bittercress was 2.5 to 8 cm rosettes at the time of application. Weeds present and their density at each location are in Table 2.

Henbit, bushy wallflower, and smallflowered bittercress control was evaluated in late March or April before they matured. Wild buckwheat control was evaluated in late May or June as the wheat matured. Plains coreopsis control was evaluated six to seven weeks after treatment. Weed control was visually estimated using a scale of 0 to 100%.

Plots were harvested using a small plot combine. The harvested samples were scalped to remove chaff, straw and large weed material. Wheat moisture content, volume weight, and grain yield adjusted to 13.5% moisture, was determined after cleaning. Grain samples from each plot were graded according to USDA standards by the Farmers COOP Exchange at Lucien, Oklahoma, to determine market value. Established grades are 1 to 5, where grade 1 is the highest quality and grade 5 (sample grade) is the lowest quality.

The cost to the farmers of each baseline treatment was obtained from the commercial applicators and was used to calculate the cost of all additional treatments had they been commercially applied. Treatment cost information and wheat selling prices were used to calculate the net return on the investment of spraying the wheat. Net return on investment for each treatment was calculated by using the equation: ((grain yield from the treated plot - grain yield from the check plot) x wheat price)-cost of treatment = net return on investment.

All data were statistically analyzed and means separated with least significant differences at the P = 0.05 level. Weed control data were subjected to arcsin transformations prior to analyses. Transformation did not affect data interpretation, thus, original data were reported. Correlation analyses were used to search for relationships between yield and weed densities, yield and application timing, and to compare yields of baseline and control treatments. Wheat grain yield at the locations where wheat was grazed was compared to wheat grain yield of the ungrazed locations using a two-grouped, t-test (P = 0.05).

Each cooperating farmer was interviewed to obtain their two main reasons for applying herbicides and to learn whether they had obtained a soil test for nutrient requirements for the field in the previous two years. The farmers were also asked what their yield goals were based on the current crop situation and the top-dressing decision made. Additional information was collected on fall seeding and fertilization.

RESULTS AND DISCUSSION

Weed control. All farmers selected herbicides from the sulfonylurea family and only four of seventeen farmers tank mixed a herbicide with a different mode of action (phenoxy). All rates applied were within the labeled rate ranges. There were no weeds present at any time at seven locations even though farmers made the decision to apply herbicides along with their spring application of UAN (Table 2). The full rate herbicide treatments all controlled their target weeds

84% or more except at three locations (Table 3). By reducing the rate of herbicide used to one half the farmer selected rate, weed control was reduced at 8 of 12 locations up to 25%.

Henbit control ranged from 85 to 99% with the baseline treatments at the nine farms where henbit was present. The herbicide only treatments controlled 10 and 8% less henbit than the baseline treatment of herbicide plus UAN at farms 5 and 10 respectively. When herbicide rates were reduced by one half, henbit control decreased at four farms by 6 to 25%. Thus, less control occasionally could be expected if farmer selected rates were halved.

Wild buckwheat control with the baseline treatments ranged from 27 to 91% at the five farms where wild buckwheat was a target weed. Poor control at farms 4 and 19 may be attributed to excessive rainfall throughout the spring of 1993. Both sites were extremely wet when sprayed and it is likely that additional rainfall was unable to move the herbicide into the soil as deep as the wild buckwheat seeds germinated. Also, because of wet conditions, aerial application was required, and the nozzle settings used to apply the 90 L/ha of UAN desired by the farmer resulted in very large droplet size. The far better control with the herbicide only treatment than with the baseline treatment at farm 19 was attributed to different application methods, ie. aerial application versus application with the CO_2 backpack sprayer.

Plains coreopsis was controlled 99% by all treatments at farm 14. At farm 16, with higher rates of the same herbicides used at farm 14, plains coreopsis was controlled only 56% by the baseline treatment which was applied in 90 L/ha of

UAN applied by a commercial truck mounted sprayer. When the same rate of chlorsulfuron:metsulfuron was applied with a CO_2 backpack sprayer in 190 L/ha of water at farm 16, plains coreopsis control increased 35%. The half rate of herbicide treatment, which was applied in a water plus UAN carrier solution at the same rate of actual nitrogen as the baseline treatment, but at a total carrier volume of 190 L/ha, controlled 20% more plains coreopsis than the baseline treatment. The lower control with the baseline treatment was attributed to less adequate coverage by the commercial sprayer, which was equipped with flooding type nozzles on 76 cm centers 150 cm above the ground. Although the commercially applied baseline treatment at farm 14 controlled plains coreopsis 99% that application was made a month earlier to much smaller weeds and in a total carrier volume of 130 L/ha compared to 90 L/ha at farm 16.

Bushy wallflower was controlled 91 to 99% by the baseline treatment of herbicide plus fertilizer at the 3 farms where it was present. The half rate treatments controlled bushy wallflower 6 and 10% less at farms 17 and 19 respectively. The herbicide only treatment controlled bushy wallflower 6% less than the baseline treatment which included UAN as a carrier at farm 17. Flixweed was controlled 99% by all treatments at location nine which agrees with research reported earlier (17). Smallflowered bittercress control was 97% with the baseline treatment at farm 10. This mustard species of small stature was a secondary target weed at this location. The herbicide only treatment and the half rate of herbicide treatment controlled 5% less smallflowered bittercress than the baseline treatment of herbicide plus UAN at this location. Flixweed and smallflowered bittercress were present at only one farm each. These results indicate that farmers could consider reducing their herbicide rates when mustard species are the main targets.

Wheat yield. Commercially applied baseline treatments increased yield at seven farms, all of which received UAN as the herbicide carrier (Table 4). Yields of the baseline treatments were not higher than yields with the UAN alone treatment at any location. Thus, adding herbicide did not further increase grain yield.

Herbicide only treatments increased yield at farm 14 which was infested with plains coreopsis and farm 19 which was infested with henbit, wild buckwheat, and bushy wallflower. Controlling six plains coreopsis plants/m^2 increased wheat yield 300 kg/ha in the 1991-92 growing season at farm 14. When plains coreopsis was sprayed one month later at farm 16 in 1992-93 yield was not affected by any treatment even though weed density was higher at this farm than at farm 14 the previous year.

At location 19, controlling weeds with the herbicide only treatment increased wheat yield 400 kg/ha. Even though some of these same weeds were present in varying densities and growth stages at 8 other locations, controlling them with herbicides did not increase yield at any other location.

The average yield of the farms where wheat was grazed was 435 kg/ha lower than the average yield of ungrazed farms. However, a two-grouped, t-test failed to reject the hypothesis that these two means were the same (probability of a > t = 0.23).

No significant relationship was found (r = -0.24, P = 0.31) between yield and the number of days after January first that the baseline treatments which included fertilizer were applied. Also, in the nine fields with henbit, yield of the untreated checks was positively correlated with henbit density (r = 0.73, P = 0.02). This may mean that henbit was more dense in more productive fields, and its density was not a major determinant of wheat yields. There was no correlation between henbit density and yield increase obtained with the herbicide only treatment (r = -0.24, P = 0.53). There was a positive correlation (r = 0.80, P = 0.005) between the yield of the check plots and the sum of the henbit plus mustard species densities. Again, this indicates that weeds were more dense in fields with higher yield potential. The lack of correlation between density of mustards plus henbit and the change in wheat yield due to applying a herbicide (r = 0.002, P = 0.996) indicates that controlling these species in the spring had no influence on grain yield of hard red winter wheat.

Wild buckwheat density ranged from 35 to 665 plants/m_2 at the five farms where it was present. Wild buckwheat density was not correlated with yield of the untreated checks (r = -0.22, P = 0.72) or the percent change in yield obtained by applying the herbicide only treatment (r = - 0.45, P = 0.44). This was not unexpected since wild buckwheat developed rapidly only after wheat leaves had began to mature and admit sunlight into the canopy.

There was a good correlation (r = 0.95, P = .0001) between yield of the check and yield of the baseline treatment. Yields of the baseline treatments averaged 2080 kg/ha, which was only 150 kg/ha higher than the average yield of the untreated checks. This indicates that the yield potential was established by factors other than weed control or nitrogen top-dressing in the spring.

Yields of the baseline treatments were 85% or more of the farmers stated yield goal at 7 of 17 farms. No particular practice seemed to be associated with the farmers' ability to produce a crop that met his yield goal. At 8 of 17 farms, yields were 66% or less than the farmers yield goal. The yield goals selected by all the farmers were 210 to 1210 kg/ha higher than the average wheat yields for their respective counties during the past five years (2, 3, 4, 5, 6). Five year average yields for 1988 through 1992 were 2080 kg/ha in Pawnee, 2190 kg/ha in Garfield, and 2260 kg/ha in Kay and Noble counties. However, the yield goals of 12 of the 17 farmers were not unreasonable since they exceeded the highest county-average yields obtained during the previous five years by 75 kg/ha or less. At five farms, yield goals were 15 to 27% higher than the highest average county yields for the previous five years.

It is doubtful that several of the wheat growers based their crop inputs on the concept of yield goals. For example, at farms 11, 16, and 19, nitrogen applications were far less than required (1 kg of nitrogen per 30 kg of grain) to produce the farmers yield goal not considering the extra nitrogen required for grazing at farms 11 and 16 (15). On the other extreme, at farms 7 and 8, wheat was not grazed and the nitrogen applied was 37 and 67% above that needed to produce grain equal to the farmers stated goal.

At farm 16 yield was only 40% of the five year county average. Soil pH was 4.7 and the cultivar seeded was Karl, which has been shown to have a low tolerance to low pH soils (18). Low wheat yields can be attributed to low pH at this location, but the farmer was unaware of his pH problems.

Net Returns. Grain samples did not contain enough inert matter or dockage to establish a grade lower than did the test weight criteria. Thus, test weight was the determinant factor for grade and selling price of each grain sample. Sample grades ranged from two to five for the 1991-92 crop and grades one to three for the 1992-93 crop. Wheat selling prices ranged from \$0.12 to \$0.11/kg for grades two through five in 1992 and \$0.10 to \$0.09/kg for grades one through three in 1993.

The farmer selected and commercially applied baseline treatments increased net returns at only 2 of 17 on farm locations (Table 5). Net return on the baseline treatment at location 10 was \$38.45/ha. Neither the half rate of herbicide plus the full rate of UAN treatment or the UAN only treatment increased net returns above the returns from the baseline treatment. However, when herbicide only was applied at this location the net return was not different from the check (zero net return). Target weeds at location 10 were henbit and smallflowered bittercress.

The net return on the baseline treatment at location 11 was \$14.40/ha. There was no difference in net returns between the baseline treatment and the half rate of herbicide treatment or the UAN only treatment at this location. The herbicide only treatment at location 11, where there were 5 henbit plants/m_2, caused a net loss of \$16.28/ha.

The UAN only treatment increased net returns \$22.10/ha at location 5. The baseline treatment and half rate of herbicide plus UAN treatment were not different from the check at location 5. The herbicide only treatment at this farm lost $32.83/ha. Farms 10, 11, and 5 were the only farms where net returns were increased by some treatments.

Baseline treatments decreased net returns at seven locations. At farms 1 and 2, baseline treatments decreased net returns $42.95 and 31.05/ha, respectively. Reducing the farmer selected rate of herbicide increased net returns by $25.82/ha at location 1 and $19.20/ha at farm 2 compared to the baseline treatment. However, net returns from the half rate herbicide treatment at farms 1 (treated with UAN) and 2 were not different from the check. Half rate herbicide treatments decreased net returns at locations 3, 4, 8, and 16. The herbicide only treatments decreased net returns at locations 3, 4, 5, 10, and 11, and never increased net returns over the check plots. The fertilizer only treatments increased net returns at only three locations, but the fertilizer alone treatment did not reduce net returns below the check at any farm.

No significant relationship was found ($r = -0.131$, $P = 0.60$) between net returns and the number of days after January first that the baseline treatments that included fertilizer were applied.

Farmer questions. Responses to questions concerning the two main reasons for using herbicides were variable (Table 6). Eleven farms received a herbicide application because the farmers desired a weed free harvest or because they had weeds last year. Five farmers felt that weeds might appear in their fields and were making a 'risk aversion' or insurance against weeds application of herbicides.

Three farmers said that they were spraying to control weeds currently in the field; however, at field 12 only a few scattered henbit plants were present and weed control in the plot area could not be visually estimated. At farms 14 and 15, the farmer was bound by a lease agreement with the land owner to apply chlorsulfuron each year. At farms 1 and 2, the farmers believed that summer tillage requirements would be reduced because of residual weed control from 8.9 and 13.3 g/ha of chlorsulfuron applied on 02-09-93 and 03-09-93 respectively. No farmers stated that increasing wheat yield was a main reason for applying herbicides. However, all farmers did state that each of the possible responses was a potential benefit of controlling weeds in their wheat.

There were nine farms in this research where no differences in net returns or yield could be detected due to either controlling weeds or the addition of fertilizer to the plots. There were also seven farms that received a commercially applied herbicide at a cost of $16.15/ha to $47.78/ha and no weeds were present at the time of application or at harvest in the check plots. At farms 4, 7, 8, 14, 16, 18, and 19 weeds were present that had the potential to cause severe harvest and/or storage difficulties.

Controlling broadleaf weeds in wheat may not provide positive net returns when only grain yield is considered. However, when dealing with the control of weeds such as wild buckwheat or plains coreopsis which can cause severe harvest and storage difficulties and price penalties, grain yield may not accurately reflect the value of weed control in winter wheat. Additional research is needed to quantify benefits of weed control in wheat other than increasing yield.

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Table 1. Dates of planting and herbicide application, wheat variety and seeding rate, amount of actual nitrogen applied in fall, days from herbicide application to rainfall, wheat tiller number at the time of application, grazing termination date, and soil information at the nineteen experimental sites.

Farm	County	Planting date	Wheat variety	Seeding rate	Nitrogen Fall	Nitrogen Sum[a]	Appl.[b] date	Appl. to rainfall	Wheat tillers	Grazing term. date	Soil Tex.	Soil pH	Soil OM
				kg/ha	kg/ha	kg/ha		d[c]	no./pl.				-%-
1	Garfield	10-03-92	2180	90	36	70	02-09-93	6	6 to 9	03-03-93	L	4.5	1.3
2	Noble	09-20-92	Karl	75	86	86	03-09-93	10	3 to 10	03-15-93	L	5.4	1.4
3	Noble	09-20-92	Karl	97	78	95	03-05-93	14	4 to 11	03-06-93	L	5.6	1.5
4	Noble	09-28-92	Tomahawk	68	64	95	03-05-93	14	5 to 13	Ungrazed	L	6.1	1.7
5	Noble	09-25-92	Karl	85	20	83	03-14-93	5	7 to 11	Ungrazed	L	7.0	1.5
6	Noble	09-02-92	2180	85	105	168	03-14-93	5	7 to 12	02-28-93	L	5.3	1.6
7	Kay	09-02-91	Thunderbird	136	150	150	03-14-92	4	6 to 9	Ungrazed	CL	5.8	2.6
8	Kay	10-22-91	2180	114	124	124	03-14-92	4	2 to 6	Ungrazed	CL	5.4	2.9
9	Major	11-27-91	Cimarron	110	108	124	03-03-92	2	3 to 5	Ungrazed	L	6.3	1.4
10	Pawnee	09-20-91	Thunderbird	68	20	68	02-21-92	13	3 to 12	Ungrazed	L	5.7	2.8
11	Garfield	09-24-92	2157	136	20	54	03-08-93	11	7 to 10	03-03-93	L	5.6	1.3

Table 1. Continued

12	Garfield	10-01-92	Karl	85	92	126	03-09-93	10	3 to 10	03-01-93	L	5.6	1.3
13	Noble	10-3-92	Karl	102	17	58	02-09-93	6	6 to 13	Ungrazed	L	5.3	1.5
14	Noble	10-10-91	2157	90	70	118	02-01-92	13	9 to 12	02-29-92	L	7.0	1.6
15	Noble	10-07-91	2180	90	70	101	02-01-92	23	5 to 15	Ungrazed	L	5.5	1.6
16	Noble	09-10-92	Karl	85	18	49	03-09-93	10	4 to 10	02-25-93	L	4.7	1.9
17	Payne	09-18-91	Cimarron	102	0	32	03-03-92	1	5 to 10	Ungrazed	L	7.1	2.2
18	Noble	09-30-91	2180	85	62	93	02-06-92	30	5 to 11	Ungrazed	L	5.8	1.8
19	Kay	10-05-92	Karl	90	17	48	03-06-93	16	4 to 10	Ungrazed	L	5.6	1.4

[a]Sum equals the total amount of nitrogen applied in the fall plus the spring.

[b]Abbreviations used: appl. = Application; term. = termination; tex. = texture; OM = organic matter; d = days; no. = number; pl. = plant; L = loam; CL = clay loam.

[c]Number of days to rainfall of 1 cm or more.

Table 2. Baseline treatments and application carrier, volume, and method, and weeds present at each farm.

	Baseline treatment		Application			Species[a]					
Farm	Herb(s)[b].	Rate	Car.	Vol.	Meth.	Henbit	Wild buckwheat	Bushy wallflower	Smallflowered bittercress	Flixweed	Plains coreopsis
		g/ha		L/ha		plants/m^2					
1	chlorsulf.	8.9	UAN	94	GRD	0	0	0	0	0	0
2	chlorsulf.	13.3	H_2O	120	GRD	0	0	0	0	0	0
3	chlorsulf.	17.7	UAN	45	AIR	0	0	0	0	0	0
4	chlorsulf.	17.7	UAN	90	AIR	21 ± 4	35 ± 9	46 ± 11	0	0	0
5	chlorsulf.	17.7	UAN	175	GRD	29 ± 6	0	0	0	0	0
6	chlorsulf.	17.7	UAN	175	GRD	0	0	0	0	0	0
7	chlor+MCPA	17.7+197	H_2O	12	AIR	4 ± 2	661 ± 63	0	0	0	0
8	chlor+MCPA	17.7+197	H_2O	12	AIR	40 ± 8	665 ± 48	0	0	0	0
9	chlor+MCPA	17.7+284	H:U	190	CO_2	0	0	0	0	13 ± 4	0
10	chlor+MCPA	17.7+284	UAN	130	GRD	43 ± 4	0	0	28 ± 4	0	0
11	chlor:met	8.9:1.8	UAN	95	GRD	5 ± 2	0	0	0	0	0
12	chlor:met	8.9:1.8	UAN	95	GRD	0	0	0	0	0	0

Table 2. Continued

13	chlor:met	11.1:1.2	UAN	110	GRD	0	0	0	0	0	0
14	chlor:met	14.8:3	UAN	130	GRD	0	0	0	0	0	6 ± 2
15	chlor:met	14.8:3	UAN	90	GRD	0	0	0	0	0	0
16	chlor:met	17.7:3.5	UAN	90	GRD	0	0	0	0	0	44 ± 16
17	chlor+2,4-D	13.3+213	H:U	190	CO_2	73 ± 8	0	174 ± 28	0	0	0
18	chlor+2,4-D	13.3+284	UAN	90	GRD	61 ± 9	138 ± 12	0	0	0	0
19	triasulf.	18.6	UAN	90	AIR	1 ± 1	68 ± 16	21 ± 10	0	0	0

[a]The number of plants/m^2 ± the standard error.

[b]Abbreviations used: herb(s). = herbicide(s); car. = carrier; vol. = volume; meth. = method; chlorsulf. = chlorsulfuron; chlor+MCPA = chlorsulfuron plus MCPA; chlor:met = chlorsulfuron plus metsulfuron premix; chlor +2,4-D = chlorsulfuron plus 2,4-D; triasulf. = triasulfuron; UAN = 28-0-0, urea-ammonium nitrate; H:U = H_2O plus UAN; GRD = ground application by high flotation commercial applicators; Air = aerial applicators; CO_2 = CO_2 backpack sprayer.

Table 3. Visual estimates of weed control at eleven locations by species.

Treatment	Henbit									Wild buckwheat					Bushy wallflower			Plains coreopsis	
Locations	4	5	7	8	10	11	17	18	19	4	7	8	18	19	4	17	19	14	16
	%																		
Baseline	86	95	85	96	96	99	81	99	92	45	84	91	90	27	91	99	93	99	56
Herbicide only	85	85	--	--	88	99	70	--	95	67	--	--	--	85	90	93	95	99	91
Half rate	77	95	60	80	90	98	68	--	83	49	75	75	--	53	89	93	83	99	86
Check	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LSD .05	4	7	22	12	2	3	14	2	6	32	17	14	4	34	3	2	6	7	11

Table 4. Grain yields at each location and farmers' yield goals.

Farm	Treatments						Farmer
	Baseline	Half rate	Herbicide only	UAN[a] only	Check	LSD (0.05)	yield goal
	kg/ha						
1	1800	2000	2000	2000	2000	NSD	2725
2	2300	2500	-[b]	-[b]	2500	NSD	2725
3	1200	1200	1100	1300	1100	NSD	2725
4	3000	3000	2700	2900	2900	NSD	2450
5	2500	2500	1900	2600	2000	200	2725
6	1600	1700	1400	1600	1400	180	2725
7	1400	1500	-[b]	-[b]	1400	NSD	2725
8	2500	2600	-[b]	-[b]	2600	NSD	2725
9	750	700	800	700	700	NSD	[c]
10	2500	2500	2000	2400	1800	270	2725
11	1900	1800	1400	1800	1400	130	3400
12	1700	1800	1700	1900	1700	NSD	2400
13	1600	1600	1300	1600	1200	130	2725
14	3100	3000	3000	3100	2700	200	3400
15	2500	2500	2300	2500	2500	NSD	3400
16	900	800	900	950	900	NSD	2725
17	3800	3700	3700	3500	3700	NSD	[d]
18	2300			2400	2200	150	2725
19	2000	2200	2000	2200	1600	270	3050

[a] Abbreviations used: UAN = 28-0-0 urea-ammonium nitrate.

Table 4. Continued.

[b]No UAN was used by the farmer at these locations. Baseline treatment is herbicide only.

[c]Experiment was conducted at the North Central Agronomy Research Station, Lahoma, OK.

[d]Experiment was conducted at the Agronomy Research Station, Stillwater, OK.

Table 5. Baseline treatments applied at 19 farms and costs of the baseline and other treatments applied to the replicated plots calculated on the basis of actual cost as if they had been commercially applied and the net return on investment for each treatment.

	Baseline treatment[a]			Treatment cost				Net return on investment[d]				
Farm	Herbicide(s)	Rate	UAN	Base.	Half rate	Herb[b]. only	Fert. only	Base-line	Half rate	Herb. only	Fert. only	LSD (.05)
		g/ha	kg/ha	$/ha				$/ha				
1	chlorsulfuron	8.9	120	27.00	23.40	12.60	19.73	-42.95	-17.13	-10.50	-14.45	19.70
2	chlorsulfuron	13.3	0	16.15	10.73	-[c]	-[c]	-31.05	-11.68			16.83
3	chlorsulfuron	17.7	57	31.53	24.20	24.90	16.88	-22.20	-19.20	-26.48	-1.65	15.43
4	chlorsulfuron	17.7	112	38.40	31.08	24.90	23.75	-35.23	-26.78	-40.65	-20.45	22.60
5	chlorsulfuron	17.7	225	47.78	40.45	20.53	33.13	-11.20	8.15	-32.83	22.10	20.65
6	chlorsulfuron	17.7	225	47.78	40.45	20.53	33.13	-26.43	-12.60	-16.93	-20.33	NSD
7	chlor+MCPA	17.7+197	0	25.62	17.00	-[c]	-[c]	-20.23	8.78			NSD
8	chlor+MCPA	17.7+197	0	25.62	17.00	-[c]	-[c]	-45.53	-27.58			20.15
9	chlor+MCPA	17.7+284	57	27.35	19.93	20.73	12.50	-20.68	-17.18	-9.73	-12.30	NSD
10	chlor+MCPA	17.7+284	170	42.40	34.23	21.83	26.25	38.45	43.30	-8.80	36.83	33.45

Table 5. Continued.

11	chlor:met	8.9:1.8	120	27.00	23.40	12.60	19.37	14.40	10.08	-16.28	16.18	9.37
12	chlor:met	8.9:1.8	120	27.00	23.40	12.60	19.37	-28.45	-10.18	-16.53	-1.10	NSD
13	chlor:met	11.1:1.2	145	31.78	27.20	14.40	22.63	11.05	8.98	-.05	17.48	NSD
14	chlor:met	14.8:3	170	42.50	34.28	22.13	26.25	6.93	-2.03	7.75	16.83	NSD
15	chlor:met	14.8:3	112	36.13	27.50	22.13	19.38	-44.53	-34.28	-46.68	-22.38	NSD
16	chlor:met	17.7:3.5	112	34.03	26.70	20.53	19.38	-29.95	-34.25	-12.43	-7.30	16.90
17	chlor+2,4-D	13.3+213	112	31.05	25.43	17.55	19.38	-9.33	-16.78	-5.50	-17.85	NSD
18	chlor+2,4-D	13.3+284	112	31.50			19.38	-20.65			6.33	17.08
19	triasulfuron	18.6	112	33.60	28.68	20.10	23.75	2.68	20.03	15.58	28.10	NSD

[a]0.25% v/v of surfactant was used on all treatments where 28-0-0 nitrogen fertilizer was not used as a carrier for the herbicide(s). Surfactant cost was $0.25/ha.

[b]Abbreviations used: Herb. = Herbicide; UAN = 28-0-0, urea-ammonium nitrate; chlor+MCPA = chlorsulfuron plus MCPA; chlor:met = chlorsulfuron plus metsulfuron premix; chlor+2,4-D = chlorsulfuron plus 2,4-D.

[c]No UAN was used by the farmer at these locations, baseline treatment is herbicide only.

Table 5. Continued.

[d]Net return on investment for the check was zero.

Table 6. Farmers' two main reasons for herbicide use and their response to our inquiry regarding whether they had obtained a soil test for nutrient requirement in the previous two years.

	Location																	
Response[a]	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	18	19	Total
For a weed free harvest			X	X		X	X	X		X	X	X			X	X	X	11
Had weeds last year			X	X	X		X	X	X			X	X	X	X		X	11
Could have weeds (risk aversion)	X	X			X	X				X								5
Have weeds currently in field									X		X					X		3
Landlord requires it													X	X				2
To reduce summer tillage	X	X																2
To increase yields																		0
Tested soil in last two years?	N[b]	N	Y	N	N	N	N	N	Y	N	Y	N	N	Y	N	N	N	4

[a]All farmers agreed that each of these reasons was a benefit of controlling weeds in wheat. The farmers were asked to pick their two main reasons at each location.

[b]Abbreviations used: N = no; Y = yes.

VITA

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