CROP PROTECTION (1987) 6 (1), 61–63

Residual herbicides for weed control in proso millet (*Panicum miliaceum* L.)

R. L. ANDERSON AND THE LATE B. W. GREB

Agricultural Research Service, USDA, Central Great Plains Research Station, Akron, Colorado 80720, USA

ABSTRACT. Five triazine herbicides were evaluated for pre-emergence weed control in proso millet (*Panicum miliaecum* L.) grown in the Central Great Plains of the United States. Atrazine and propazine maintained weed-free proso millet over the entire cropping season at rates of 0·28, 0·56, and 0·84 kg a.i./ha. Proso millet grain yields and water use efficiency were increased by these weed-control treatments. Metribuzin also effectively controlled weeds, but was phytotoxic to proso millet. Cyanazine and terbutryne at 1·12 kg/ha were not as effective as the other triazines in controlling the weed population. In a 5-year experiment, the elimination of weed competition by atrazine and propazine increased the harvest index by increasing the water use efficiency of the crop. Proso millet grown in dryland agriculture under weed-free conditions can more efficiently convert limited available water into harvestable grain.

Introduction

Proso millet (*Panicum miliaceum* L.) is well adapted to dryland agriculture in the Central Great Plains of the United States, being grown annually on 115000 ha (Martin, Leonard, and Stamp, 1976). Proso millet has the lowest water requirement and the highest conversion of limited water supplies into grain of any grain crop (Martin *et al.*, 1976; Hinze, 1977); this is attributed to a low straw-to-grain ratio (1:1) and a small leaf area (Greb, 1979). Thus, proso millet can usually produce a grain crop in the drought-prone Central Great Plains. At present, proso millet is grown after winter wheat (*Triticum aestivum* L.), with a 10-month fallow period between wheat harvest and proso millet planting (Hinze and Smika, 1983). The prevalent cultural practice is to till the soil for seed-bed preparation and to eliminate existing weeds, with no herbicides used for in-crop weed control. Proso millet, however, is a relatively poor competitor with weeds and its seedling vigour is low (Hinze, 1977): thus, control of annual weeds with herbicides during the growing season may increase proso millet grain production. The objective of this study was to determine the optimum rates of selective herbicides for season-long weed control, and their effect on grain production with proso millet grown in the Central Great Plains.

Materials and methods

This experiment consisted of three studies. The first study compared atrazine (6-chloro-*N*-ethyl-*N'*-isopropyl-1,3,5-triazinediyl-2,4-diamine) and terbutryne (*N-tert*-butyl-*N'*-ethyl-6-(methylthio)-1,3,5-triazine-2,4-diyldiamine) at rates of 0·84 and 1·40 kg a.i./ha. The second study compared propazine (6-chloro-*N,N'*-di-isopropyl-1,3,5-triazine-2,4-diyldiamine), terbutryne, cyanazine (2-(4-chloro-6-ethylamino-1,3,5-triazin-2-ylamino)-2-methylpropionitrile) and metribuzin (4-amino-6-*tert*-butyl-3-methylthio-1,2,4-triazin-5-(4*H*)-one) at 1·12 kg/ha with atrazine at 0·56 and 0·84 kg/ha. The third study evaluated the effectiveness of 0·28, 0·56 and 0·84 kg/ha of atrazine and propazine (the herbicides providing the best weed control in studies 1 and 2) for weed control in proso millet over a 5-year period from 1976 to 1980. The experiment was conducted on a Rago silt loam (fine, montmorillonitic, mesic Pachic Argiustoll) at Akron, Colorado, USA (latitude 40 degrees 9 minutes N, longitude 103 degrees 9 minutes W). The soil contained 13 g/kg organic matter and the pH was 7·4. The experimental design was a randomized complete block with each treatment replicated four times. Plots were established in wheat stubble each year, being 10 m wide by 24 m long.

Herbicides were applied at $2{\cdot}8\times10^{4}$ kg/m^2 in

0261-2194/87/01/0061-03 $03.00

TABLE 1. Effect of atrazine and terbutryne on weed control, grain yield, harvest index, total water use, and water use efficiency of proso millet grown at Akron, Colorado, USA, in the first study

Herbicide treatment	Rate (kg/ha)	Visual weed control (%)	Grain yield (kg/ha)	Harvest index*	Total water use (cm)	Water use efficiency (kg/ha/cm)
Control	—	0 c**	1350 c	0·47 c	27·8 b	117 b
Atrazine	0·84	100 a	1890 a	0·50 ab	26·9 b	157 a
Atrazine	1·40	100 a	1990 a	0·51 a	27·7 b	159 a
Terbutryne	0·84	70 b	1555 b	0·49 b	30·0 a	117 b
Terbutryne	1·40	100 a	1835 a	0·49 b	30·0 a	139 ab

* Harvest index = grain biomass divided by total plant biomass above ground
** Numbers within a column followed by the same letter are not significantly different at the 5% probability level as determined by the new Duncan's multiple range test

187 l/ha of spray solution with a 4 m boom plot sprayer equipped with flat fan nozzles. The herbicide application occurred within one week of planting in late May or early June. The plot area was sweep-ploughed after wheat harvest, then the following year a seed-bed was prepared by discing and mulch treading. The herbicides were then applied to the soil surface, followed by proso millet seeding at 7·2 kg/ha in 0·3 m rows with a disc drill.

Weed control was evaluated visually 6–8 weeks after planting. Proso millet was hand harvested in early September from 12 rows 1·2 m long to determine grain and straw yields. Soil water content was determined gravimetrically before planting and after harvest to determine soil water use by proso millet. Two samples were taken per plot at 0·3 m increments to a depth of 1·2 m.

Results and discussion

Climatic records maintained for 75 years at Akron, Colorado, characterize the cropping environment of proso millet in the Central Great Plains. The average monthly temperatures for the growing season are 19·4°C for June, 22·8°C for July and 22·2°C for August. Precipitation during the growing season (1 June to 31 August) averages 180 mm, and 320 mm during the fallow season (1 August to 1 June). Redroot pigweed (*Amaranthus retroflexus* L.) is the major weed infesting proso millet in the Central Great Plains. Other weeds commonly found in proso millet include kochia (*Kochia scoparia* L.), Russian thistle (*Salsola iberica* Sennen & Pau), and witchgrass (*Panicum capillare* L.).

The first herbicide study compared two rates of atrazine and terbutryne, 0·84 and 1·40 kg a.i./ha. Atrazine at both rates and terbutryne at 1·40 kg/ha resulted in weed-free proso millet throughout the growing season, but terbutryne at 0·84 kg/ha controlled only 70% of the weeds (Table 1). The proso grain yields reflected the level of weed control. The herbicide treatments maintaining weed-free proso millet resulted in significantly higher grain yields than the weed-infested control. The weeds which terbutryne did not control at 0·84 kg/ha decreased grain yields by 18% compared with the weed-free treatments. All herbicide treatments increased the harvest index (the percentage of grain produced by the above-ground biomass). Total water use (soil water + precipitation) did not reflect the trend in grain yields, but water use efficiency was increased by completely eliminating weed competition. Atrazine at both rates increased water use efficiency by 35% compared with the weed-infested control.

In the second herbicide study, the rates of atrazine were reduced to 0·56 and 0·84 kg/ha. Propazine, terbutryne, cyanazine, and metribuzin were applied at 1·12 kg/ha. Atrazine at both rates, propazine and metribuzin provided season-long weed control (Table 2). Terbutryne resulted in 60% weed control, while cyanazine controlled only 15% of the weed population. Metribuzin was also phytotoxic to proso millet, completely eliminating the plant stand. Proso millet grain yields again reflected the level of weed control, the highest yields occurring with the atrazine and propazine treatments which eliminated all weed competition, and the lowest yield occurring with cyanazine (Table 2). The harvest index was increased by atrazine at 0·84 kg/ha and propazine, indicating the effect that weed competition has on proso millet grain production. Total water use did not reflect the yield trend, but the atrazine and propazine treatments

TABLE 2. Effect of herbicide treatments on weed control, grain yield, harvest index, total water use, and water use efficiency of proso millet grown at Akron, Colorado, USA, in the second study

Herbicide treatment	Rate (kg/ha)	Visual weed control (%)	Grain yield (kg/ha)	Harvest index*	Total water use (cm)	Water use efficiency (kg/ha/cm)
Control	—	0 c**	1900 c	0·48 b	37·3 a	120 c
Atrazine	0·56	100 a	2415 a	0·49 b	33·5 b	166 a
Atrazine	0·84	100 a	2325 a	0·51 a	34·3 b	152 b
Propazine	1·12	100 a	2365 a	0·51 a	33·5 b	158 ab
Terbutryne	1·12	60 b	2100 b	0·49 b	37·3 a	130 c
Cyanazine	1·12	15 c	1735 c	0·47 c	34·0 b	123 c
Metribuzin	1·12	100 a	—	—	—	—

*, **, as Table 1

TABLE 3. Effect of herbicide treatments on grain yield, harvest index, total water use, water use efficiency, and economic return of proso millet over five cropping seasons, grown at Akron, Colorado, USA, 1976–80

Herbicide treatment	Rate (kg/ha)	Grain yield (kg/ha)	Harvest index*	Total water use (cm)	Water use efficiency (kg/ha/cm)	Economic return (US$/ha)
Control	—	1960 b**	0·46 a	27·9 a	143 b	—
Atrazine	0·28	2260 a	0·46 a	29·0 a	167 a	15·04
Atrazine	0·56	2215 a	0·47 a	28·2 a	157 a	10·65
Atrazine	0·84	2290 a	0·47 a	27·7 a	167 a	16·14
Propazine	0·28	2125 a	0·46 a	28·7 a	156 a	3·35
Propazine	0·56	2185 a	0·46 a	27·7 a	163 a	6·72
Propazine	0·84	2225 a	0·47 a	28·2 a	157 a	8·30

*,**, as Table 1

significantly increased water use efficiency compared with the weed-infested treatments.

On the basis of the first two studies, atrazine and propazine were considered to be the most effective herbicides. Rates of 0·28, 0·56 and 0·84 kg/ha for each herbicide were evaluated over five cropping seasons to determine the optimum dose. Irrespective of rate, these two herbicides adequately controlled (>90%) the weed population over the growing season (data not presented), resulting in significant increases in grain yield compared with the weed-infested control (Table 3). Total water use again was not influenced by herbicide treatment, but water use efficiency was significantly increased. Controlling weeds resulted in more grain production with the same water supply, as weed-free proso millet produced 78·5 kg of grain/cm of water used, whereas weed-infested proso millet produced only 70·3 kg of grain/cm of water used.

An economic return for using herbicides for residual weed control was calculated based on the following values: atrazine at US$4·41/kg, propazine at $6·90/kg, and herbicide application (custom-rate) at $9·27/ha. Proso millet grain was valued at $8·82/100 kg. Atrazine provided the highest return, as increased grain yields resulting from control of weeds increased income by $15·04/ha with atrazine applied at 0·28 kg/ha (Table 3). The same rate of propazine returned $3·35. These economic results demonstrate that weeds can be beneficially controlled with residual herbicides in proso millet grain production.

The change of the harvest index along a water use gradient when weed-free proso millet (herbicide-treated) is compared with the weed-infested control is shown in Figure 1. The data for herbicide treatments, which resulted in 100% weed control over the 7-year period, and the weed-infested controls were subjected to a polynomial analysis with water use varying among the years. The results indicate that when the proso millet cropping system uses more water, controlling weeds will result in a higher percentage of grain produced by above-ground biomass. The decrease in harvest index in the weed-infested controls at higher water use levels is attributed to increased weed competition. This further substantiates the fact that reducing weed competition in proso millet will increase water use efficiency, resulting in increased grain production.

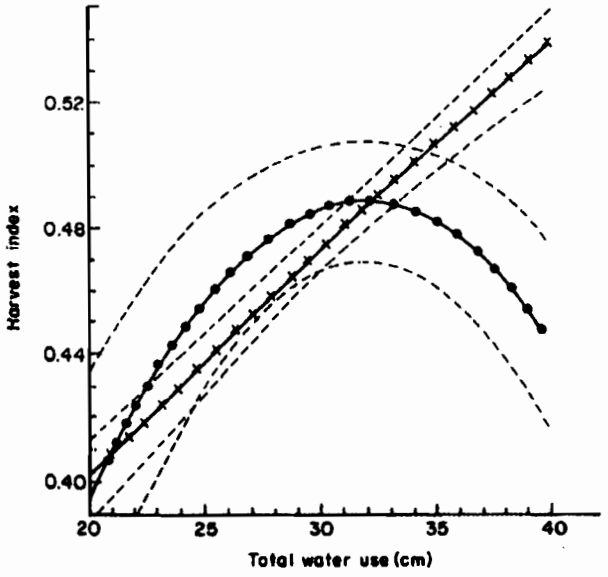

FIGURE 1. Effect of weed control on harvest index as influenced by total water use. Weed-free proso millet (×—×—×), $y=0·2208+0·0099x-0·00005x^2$; $r^2=0·99$. Weed-infested control (●—●—●), $y=0·1972+0·0430x-0·00067x^2$; $r^2=0·93$. Confidence bands (— — —) are at the 5% probability level.

References

GREB, B. W. (1979). Reducing drought effects on croplands in the West-central Great Plains. *United States Department of Agriculture Information Bulletin No. 420*, 1–31.

HINZE, G. O. (1977). Millets in Colorado. *Colorado State University Experiment Station Bulletin* 553S, 1–12.

HINZE, G. O. AND SMIKA, D. E. (1983). Cropping practices: Central Great Plains. In: *Dryland Agriculture*, pp. 387–395 (ed. by H. E. Dregna and W. O. Willis). Madison, Wisconsin: American Society of Agronomy, Inc.

MARTIN, J. H., LEONARD, W. H. AND STAMP, D. L. (1976). *Principles of Field Crop Production*, pp. 567–570. New York: Macmillan Publishing Co, Inc.

Received 6 January 1986
Accepted 30 June 1986