



CIRCULAR 267

AUGUST 1983



**Comparisons
of
Methods of
Application
for
Pendimethalin
(Prowl 4EC)
in
Combination
with Other
Selected
Herbicides
for
Weed Control
in Cotton**

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FIRST PRINTING 4M, AUGUST 1983

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COMPARISONS OF METHODS OF APPLICATION FOR PENDIMETHALIN (PROWL 4EC) IN COMBINATION WITH OTHER SELECTED HERBICIDES FOR WEED CONTROL IN COTTON

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INTRODUCTION

COTTON IS VERY SENSITIVE to weed competition during the early portion of the growing season. In Alabama, plots infested with mixed populations of annual broadleaf and grass weeds yielded less than 15 percent as much as weed free checks. In addition, maximum yields were obtained when the crop was maintained weed free for approximately 8 weeks after emergence.³

Tremendous change has occurred in weed control since hand hoeing and mule-powered cultivation were the only alternatives. Substituted ureas were among the earliest herbicides to be widely used for preemergence weed control in cotton. Monuron (CMU) became available in 1952. Diuron (first called Weed Killer D, and later Karmex) was introduced as a more effective replacement in 1956. Chloro-IPC or chlorpropham, a phenyl carbamate introduced in 1956, was also used for preemergence weed control. In general, these early herbicides were most effective in controlling annual grasses

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²The authors acknowledge the assistance of W. B. Webster and Vaughn H. Calvert II of the Tennessee Valley Substation in this project.

³Buchanan, G.A. and C.G. McWhorter. 1971. Weed Control & Cotton. FAO Conference Weed Science Society of America Monographs 1:63-183.

and small-seeded broadleaf weeds. Rainfall was a prerequisite for activation; consequently, performance was often variable among years.

Consistency of weed control was markedly improved with the introduction of trifluralin (Treflan), the first dinitroaniline (DNA) herbicide. Several other DNA herbicides entered the market soon thereafter. These herbicides are characterized by negligible water solubility and rapid loss due to volatilization from the soil surface. Consequently, incorporation into the soil is usually necessary. Weed seed germinating within this treated soil generally absorb lethal amounts of herbicide. Crop injury is minimized by planting the crop seed beneath or near the bottom of the treated soil layer, allowing developing roots to pass quickly into untreated soil.

Preplant incorporated (PPI) applications of DNA herbicides provided more consistent performance compared to earlier materials. Annual grasses and other weeds, including seedling johnsongrass and small seeded broadleaf weeds such as pigweed, purslane, and carpetweed, were effectively controlled. Application of twice the normal use rate was also effective in reducing rhizome johnsongrass infestations.

Subsequent to introduction of DNA's, other herbicides have been added to the weed control arsenal for use in cotton. Some of these provide effective preemergence control of large-seeded broadleaf species. For example, fluometuron (Cotoran), introduced in 1965, provides acceptable control of common cocklebur and annual morningglories.

A herbicide to control all weeds with no adverse effect on cotton has not yet been developed. Achieving optimum control with current technology invariably requires that combinations, or systems, of herbicides be used which are more or less specific for the predominate weed species. Systems in which a DNA herbicide is first applied preplant incorporated (PPI), followed by a preemergence application of a second herbicide, are very popular. While this practice (termed overlay) provides a good weed control, two separate herbicide applications are required. It would be economically advantageous if both materials could be applied as a single PPI or PRE treatment.

Within the DNA herbicides currently registered in cotton, pendimethalin (Prowl) has one of the highest water solubilities, and is one of the least susceptible to vapor loss.

Therefore, comparable weed control should be achieved with or without immediate incorporation. The objective of this study was to compare weed control as provided by pendimethalin in combination with several other commonly used herbicides, applied as either a single PPI or PRE treatment or as separate applications in the manner of an overlay.

METHODS AND MATERIALS

Trials were conducted at the Tennessee Valley Substation, Belle Mina, Alabama, between 1978 and 1980. Soil type was a Decatur clay loam. The test site was turned with a moldboard plow each winter and subsequently disked and smoothed during early April with a Lely Rotera R. Pendimethalin alone and pendimethalin combined with each of five herbicides, table 1, were applied three ways: (1) PRE, (2) PPI, and (3) as an overlay (OL) in which pendimethalin was applied PPI and the other material applied PRE. Rates used were those which the manufacturers recommend for the soil type. Untreated checks were also included.

Herbicide treatments were assigned to plots which were four rows wide and 20 feet long, and replicated four times in a randomized complete block design. All treatments were applied broadcast in 15 to 18 gallons per acre of water with a tractor-mounted compressed air sprayer. When necessary, incorporation was accomplished with two parallel passes with a Lely Roterra R which provided uniform incorporation to a depth of 1½ inches. Cotton (Stoneville 213) was planted between April 10 and 20 of each year.

Two rows in each plot were cultivated and hand weeded as necessary to provide complete weed control. Therefore, any reduction of yield within a plot could be attributed to crop injury due to herbicides. The remaining two rows were not

TABLE 1. HERBICIDES WHICH WERE EVALUATED FOR WEED CONTROL IN COTTON AT THE TENNESSEE VALLEY SUBSTATION, BELLE MINA, ALABAMA, 1978-1980

Common name	Trade name	Rate active	Rate product	Herbicide family
		<i>Lb./acre</i>	<i>Per acre</i>	
Pendimethalin	Prowl 4EC	0.75	1.50 pints	Dinitroaniline
Fluometuron	Cotoran 80WP	1.50	1.88 lb.	Substituted urea
Cyanazine	Bladex 80WP	1.25	1.56 lb.	Triazine
Diuron	Karmex 80WP	1.00	1.25 lb.	Substituted urea
Perfludone	Destun 50WP	3.00	6.00 lb.	Unclassified
Norflurazon	Zorial 80WP	1.50	1.88 lb.	Unclassified

TABLE 2. PREDOMINANT ANNUAL WEED SPECIES IN COTTON, TENNESSEE VALLEY
SUBSTATION, BELLE MINA, ALABAMA

Weed	Type
Redroot pigweed (<i>Amaranthus retroflexus</i> L.)	Small seeded broadleaf
Pitted morningglory (<i>Ipomoea lacunosa</i> L.)	Large seeded broadleaf
Prickly sida (<i>Sida spinosa</i> L.)	Large seeded broadleaf
Fall panicum (<i>Panicum dichotomiflorum</i> Michx.)	Grass
Large crabgrass [<i>Digitaria sanguinalis</i> (L.) Scop.]	Grass

cultivated so that any weed control achieved could be attributed solely to the herbicide treatment. Fertilization and insect control measures were based on soil test results and the recommendations of field scouts, respectively.

Ratings on the level of crop injury and control of the pertinent weed species, table 2, were taken 6 to 8 (early) and 12 to 14 weeks (late) after planting. A rating of 80 or above is generally considered to be commercially acceptable; 90 and above is considered excellent. All plots were mechanically picked twice and the total yield determined.

RESULTS

Performance of all herbicide treatments in terms of weed control was sufficiently uniform over the 3 years of evaluations (as indicated by statistical analysis) so only the 3-year-average ratings needed to be examined. Both cultivated and noncultivated yield for all years are presented.

Pendimethalin (Prowl 4EC)

Fall panicum was the only weed for which pendimethalin applied alone provided "excellent" control through the final rating, table 3. Control of this weed was not affected by method of application. Early season control of large crabgrass was excellent applied PPI, but only "good" if applied PRE. Pendimethalin provided good early season control of redroot pigweed. However, control fell below 80 percent by the second rating.

Control of pitted morningglory and prickly sida was poor with pendimethalin alone, indicating its lack of activity on large-seeded broadleaf species.

No crop injury could be detected with pendimethalin alone. Noncultivated yields, table 4, were significantly lower in all years than yields from some of the more successful combinations (i.e., pendimethalin + fluometuron). In all years, cultivation markedly enhanced yields due to improved weed control.

TABLE 3. WEED CONTROL¹ AND CROP INJURY² RATINGS FOR PENDIMETHALIN AND PENDIMTHALIN COMBINATIONS AS AVERAGED OVER ALL METHODS OF APPLICATION 1978-1980 AVERAGE

Herbicide(s)	Percent weed control by species ³											
	Redroot pigweed		Pitted morningglory		Prickly sida		Fall panicum		Large crabgrass		Crop injury	
	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late	Early	Late
Pendimethalin	85b	78b	62c	15d	43d	11d	95b	93bc	*88d	71c	1a	0a
Pendimethalin + fluometuron	99a	98a	96a	93a	93a	*90a	99a	98a	*98ab	94ab	3a	0a
Pendimethalin + cyanazine	96a	*83b	88b	*39bc	88b	48b	100a	96ab	96bc	*85b	3a	0a
Qendimethalin + diuron	98a	93a	86b	27c	*79c	33c	98ab	*89c	*94c	*75c	3a	0a
Pendimethalin + norflurazone	*99a	96a	88b	46b	*96a	86a	99a	*97ab	100a	*97a	*7b	0a
Pendimethalin+ perfluridone	99a	95a	90ab	33bc	*86b	*28c	*97ab	95ab	100a	96a	*29c	*8b
Checks	0c	11c	0d	0e	0e	0d	8c	4d	3e	7d	0a	0a

¹Rating of 80 or above is generally considered commercially acceptable, and 90 or above is considered excellent.

²0-19 = none to slight, 20-69 = moderate, 70-99 = severe, 100 = death. Means within a column followed by same letter are not significantly different at the 5 percent probability level.

³Means within a column followed by same letter are not significantly different at the 5 percent probability level.

*Signifies that method of application resulted in significant differences in this average value.

TABLE 4. HERBICIDE COMBINATIONS FOR WHICH METHOD OF APPLICATION PRODUCED SIGNIFICANT DIFFERENCES IN CONTROL OF CERTAIN WEEDS AS INDICATED BY LATE SEASON RATING, 1978-1980 AVERAGE

Method of application	Percent weed control ^{1, 2}						
	Pendimethalin + fluometuron	Pendimethalin + cyanazine		Pendimethalin + diuron		Pendimethalin + norflurazon	
	Prickly sida	Redroot pigweed	Large crabgrass	Fall panicum	Large crabgrass	Fall panicum	Large crabgrass
Preemergence	97a	72b	82b	92a	75a	100a	99a
Overlay	93ab	89a	94a	97a	91a	98a	100a
Preplant incorporated	79b	88a	79b	79b	59b	93b	93b

¹Rating of 80 or above is generally considered commercially acceptable and 90 or above is considered excellent.

²Means within a column followed by same letter are not significantly different at the 5 percent probability level.

TABLE 5. SEED COTTON YIELDS ACHIEVED FROM PENDIMETHALIN AND PENDIMETHALIN COMBINATIONS AS AVERAGE OVER ALL METHODS OF APPLICATION

Treatment	Seed cotton yield ¹ /acre							
	1978		1979		1980		Average	
	Cult.	Noncult.	Cult.	Noncult.	Cult.	Noncult.	Cult.	Noncult.
	<i>Lb.</i>	<i>Lb.</i>	<i>Lb.</i>	<i>Lb.</i>	<i>Lb.</i>	<i>Lb.</i>	<i>Lb.</i>	<i>Lb.</i>
Pendimethalin	2,130ab	1,410c	2,430a	1,510d	2,080b	1,110c	2,210b	1,340d
Pendimethalin + fluometuron	2,050b	2,290a	2,530a	2,580a	2,310a	2,360a	2,300ab	2,410a
Pendimethalin + cyanazine	2,240a	*2,010b	2,580a	*2,210b	2,210ab	1,800b	2,340a	2,010b
Pendimethalin + diuron	2,280a	1,900b	2,600a	*1,830c	2,280a	*1,850b	2,390a	*1,760c
Pendimethalin + norflurazon	2,230ab	2,120ab	2,550a	2,250b	2,190ab	2,030b	2,320a	2,130b
Pendimethalin + perfluradone	1,300c	1,110d	*1,670b	*1,630cd	1,250c	890c	1,410c	1,210d
Check	2,150ab	710e	2,350a	620e	2,080b	490d	2,190b	600e

¹Means within a column followed by same letter are not significantly different at the 5 percent probability level.

²Signifies that method of application resulted in significant differences in this average value.

Pendimethalin + fluometuron (Prowl 4EC + Cotoran 80WP)

This combination provided excellent (90 percent) full season control of all pertinent weeds, table 3. PRE and OL applications were generally rated superior to PPI. However, only in the late season rating of prickly sida was the PRE application measurably superior ($p \leq 0.05$) to the PPI, table 5. Overlay application provided intermediate control. Slight (although statistically unmeasurable) early season crop injury was detected primarily with the PRE and OL applications. The crop quickly recovered and no injury was visible by the later rating regardless of method of application.

Yields from this herbicide combination were consistently among the highest of the entire experiment, table 4. The 3-year-average seed cotton yield with and without cultivation was nearly identical, reflecting the wide range weed control and excellent crop safety of this combination. Under no circumstances could a difference in yield be attributed to the method of herbicide application.

Pendimethalin + Cyanazine (Prowl 4EC + Bladex 80WP)

This combination provided excellent early season control of redroot pigweed, fall panicum, and large crabgrass regardless of the means of application, table 3. Control of fall panicum remained excellent through the late rating regardless of method of application. Late season control of crabgrass remained in the excellent category only with OL application; with either PPI or PRE application, control dropped significantly over the course of the season, table 5. Likewise, control of redroot pigweed dropped substantially between the early and late ratings. Drop in control was greatest with preemergence application. These results were expected since

TABLE 6. HERBICIDE COMBINATIONS FOR WHICH IN SOME YEARS METHOD OF APPLICATION PRODUCED SIGNIFICANT DIFFERENCES IN NONCULTIVATED YIELD OF SEED COTTON

Method of application	Seed cotton yield ¹ /acre				
	Pendimethalin + cyanazine		Pendimethalin + diuron		
	1978	1979	1979	1980	1978-80 av.
Preemergence	<i>Lb.</i> 1,870b	<i>Lb.</i> 2,010b	<i>Lb.</i> 1,710b	<i>Lb.</i> 2,080a	<i>Lb.</i> 1,880a
Overlay	1,810b	2,610a	2,200a	2,180a	2,120a
Preplant incorporated	2,350a	2,000b	1,580b	1,280b	1,570b

¹Means within a column followed by same letter are not significantly different at 5 percent probability level.

cyanazine is a short-lived herbicide. In general, the OL application provided greatest longevity of control.

Noncultivated seed cotton yield, averaged over all 3 years, was 2,010 pounds per acre, which is significantly lower than what was achieved with pendimethalin + fluometuron. This reflects limited control of the total weed spectrum and the short duration of activity of cyanazine. In 1978, yields resulting from PPI were significantly greater than other OL or PRE applications, table 6. OL application produced the highest yields in 1979. However, in the 3-year average no yield differences could be attributed to method of application. In all years, cultivation enhanced yield.

Pendimethalin + Diuron (Prowl 4EC + Karmex 80WP)

This combination provided excellent season-long control of redroot pigweed, fall panicum, and large crabgrass, table 3. However, control was strongly influenced by method of application. This trend was especially evident in the late season rating of grass weeds. PPI application resulted in significantly less control of both fall panicum and large crabgrass than either PRE or OL applications, table 5. Substituted urea herbicides, which include diuron, are known to lose activity when incorporated into soil because of excessive soil-herbicide binding. Early season control of pitted morningglory was acceptable with all methods of application; however, late season control was poor regardless of application method. Acceptable early season prickly sida control was obtained with PRE and OL but not with the PPI application. Late season control was poor with all methods.

Noncultivated yields from this combination were significantly less than what was obtained with pendimethalin + fluometuron, table 4. In all years, cultivation enhanced yield. Again, this reflects incomplete control of the weed spectrum. Pendimethalin + diuron was the only combination in this study where the means of application affected the 3-year-average noncultivated yield. In 2 of the 3 years (and with the combined average), yield from PPI application was significantly less than from OL application, which was consistently superior.

Pendimethalin + Norflurazon (Prowl 4EC + Zorial 80WP)

This combination provided excellent season-long control of redroot pigweed, fall panicum, and large crabgrass regardless of method of application, table 3. PRE application provided excellent full season control of prickly sida. This combination produced significantly greater early season crop injury than any other combination tested except pendimethalin + perfluridone. Injury was significantly greatest with PRE application; however, by the late rating, no injury was detectable regardless of means of application.

Average noncultivated seed cotton yield for the 3-year period was 2,130 pounds per acre, table 4. This is significantly lower than yields obtained with pendimethalin + fluometuron. In all years, cultivation enhanced yields approximately 100-300 pounds per acre, which reflects incomplete control of the weed spectrum. In no year could a significant difference in yield be attributed to method of application, nor could any trends be identified.

Pendimethalin + Perfluidone (Prowl 4EC + Destun 50WP)⁴

This combination provided excellent full season control of redroot pigweed, fall panicum, and large crabgrass, regardless of method of application, table 3. As evidenced by the late ratings, this combination had no appreciable activity on pitted morningglory or prickly sida. All methods of application resulted in "moderate" (29 percent) crop injury. Injury was significantly greater with OL application.

Average yields with and without cultivation were 1,410 and 1,210 pounds per acre, respectively, table 4. These yields, which were the lowest observed in the study (except the noncultivated check), reflect injury from which the crop never fully recovered. Cultivation enhanced weed control in all years. Averaged across all years, method of application had no effect on yield.

⁴Destun was removed from the market in 1980 due in part to excessive crop injury.

SUMMARY

Excellent control of each of these weed species, except fall panicum, was attained only with herbicide mixtures. Of the combinations evaluated, pendimethalin + fluometuron was the most effective. Only this combination provided excellent full season control of both pitted morningglory and prickly sida. Pendimethalin + norflurazon was statistically equal to pendimethalin + fluometuron in terms of prickly sida control; however, this combination had no appreciable activity on pitted morningglory. All combinations except pendimethalin + cyanazine provided excellent control of redroot pigweed. However, the addition of cyanazine to pendimethalin provided no greater control than pendimethalin alone. Excellent control of large crabgrass was achieved with pendimethalin + fluometuron or norflurazon regardless of method of application, and with pendimethalin + cyanazine or diuron depending on method of application. The 3-year-average noncultivated yields from pendimethalin + fluometuron and norflurazon were comparable to the cultural weed-free checks, indicating the superiority of these two combinations.

For pendimethalin alone and most pendimethalin combinations, the method of application had no bearing on weed control or crop injury. For a few combinations, notably pendimethalin + fluometuron for control of prickly sida and pendimethalin + diuron for control of fall panicum and large crabgrass, the method of application comprised the difference between acceptable and nonacceptable control. In these cases, an overlay invariably gave the best control. Results demonstrate that in most cases pendimethalin alone or combined with other herbicides, applied as a single PPI or PRE treatment, gave control comparable to separate applications.