

Milestone ^{TM*} (Azafenidin): A New Pre-Emergent Herbicide for Citrus

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*registration pending

Introduction

Weed control in citrus usually consists of a winter-applied pre-emergent material and several applications of post-emergent materials throughout the spring and summer. Some weeds, such as common groundsel, *Senecio vulgaris* L., in the winter and prostrate spurge, *Euphorbia maculata* L., in the summer have shown tolerance to some pre-emergent materials. In addition, flax-leaved fleabane, *Conyza bonariensis* (L.) Cronq., has become a problem because some standard pre-emergent programs are ineffective and it is difficult to control with most post-emergent materials. Milestone 80 DF TM (Azafenidin) is a new pre-emergent herbicide developed by E. I. duPont de Nemours & Company, Inc. In two trials, Azafenidin (Milestone) was tested in two young citrus orchards to evaluate weed control spectrum, longevity and safety to young citrus.

Materials And Methods

Ivanhoe Site

The Ivanhoe site consisted of three-year-old citrus trees, planted in loam soil, recently grafted over to Late Powell Navel. Azafenidin was applied at 8, 12, and 16 oz ai/A. Norflurazon (Solicam DF) and Thiazopyr (Visor 2E) were the grower standards in this trial and applied at 64 oz ai and 64 fl. oz /A, respectively. Glyphosate (Roundup Ultra 4 SL) was added to each treatment at 1.0 lb. ai/A. Treatments were administered with a CO₂ backpack sprayer attached to a hand-held flat boom, housing six nozzles 20 inches apart. Treatments were mixed to volume and applied at 30 GPA and 30 psi. Each plot was 20 ft wide (1 swath on each side of a tree) and 40 ft. long. The trial was set up in a randomized complete block design, with four (4) replications. The application was made on January 16, 1999 and incorporated three days later with over 0.4 inches of rain.

At the time of application, several weed species were present, including: coastal fiddleneck, *Amsinckia intermedia* Fisch. & Mey; common mallow, *Malva neglecta* Wallr.; shepherdspurge, *Capsella bursa-pastoris* (L.) Medic.; annual bluegrass, *Poa annua* L.; red-stem filaree, *Erodium cicutarium* (L.) L'Her. Ex Ait.; and flax-leaved fleabane, *Conyza bonariensis* (L.) Cronq. Post-emergent weed control was evaluated at 14 and 27 DAA (DAA= Days after Application), and then all plots were over-sprayed with Glyphosate in preparation of pre-emergent weed emergence data. Pre-emergent weed control was evaluated at 65, 95, and 120 DAA by noting species present and recording the number of each weed in each plot.

Elderwood Site

This trial was conducted in a four-year-old citrus orchard, (c.v. Thompson Improved), planted in clay loam soil. Azafenidin was applied at 8, 12 and 16 oz ai/A. For comparison, Simizine (Princep 90 WP) and Diuron (Karmex 80 DF) were applied as a tank-mixture at 25.6 + 25.6 oz ai/A and Thiazopyr was applied at 64 fl. oz/A. Treatments were applied with a CO₂ backpack sprayer attached to hand-held flat boom, housing six nozzles 20 inches apart. Treatments were mixed to volume and applied at 30 GPA and 30 psi. Each plot was 20 ft wide (1 swath on each side of a tree) and 28 ft. long. The trial was set up in a randomized complete block design, with four replications. The application was made on January 20, 1999, and incorporated two hours later with over 0.8 inches of rain.

At the time of application no emerged weeds were present. Weed control was evaluated at approximately 118, 160, and 191 DAA, by noting species present and recording the number of each weed in each plot. Plots were over sprayed with Glyphosate at 118 and 161 DAA to clean up the plots and reset untreated areas.

Results

Ivanhoe Site

Post-Emergent Weed Control

At 27 DAA, all rates of Azafenidin + Glyphosate showed 100% control of all weeds evaluated except for flaxleaved fleabane (98 to 100% control) (Table 1). These levels of control by Azafenidin were observed as early as 20 DAA. Glyphosate tank-mixed with non post-emergent herbicides, Norflurazon and Thiazopyr gave 100% control of fiddleneck, 98 to 100% control of annual bluegrass, 68 to 70% control of fleabane, 38 to 50% control of shepherdspurse, and less than 20% control of common mallow and red-stem filaree (Thiazopyr + Glyphosate showed 50% control of filaree) at 27 DAA.

Table 1: Post-Emergent Control (% Control) at 27 DAA.

Treatment	Shepherdspurse	Annual Bluegrass	Red-Stem Filaree	Common Mallow	Flax-leaved Fleabane
Azafenidin - 8 oz ai/A	100	100	100	100	98
Azafenidin - 12 oz ai/A	100	100	100	100	98
Azafenidin - 16 oz ai/A	100	100	100	100	99
Norflurazon - 64 oz ai/A	38	98	20	18	70
Thiazopyr - 64 fl. oz/A	50	100	50	18	68

Pre-Emergent Weed Control

By 95 DAA, the untreated averaged 213 fleabane and 28 mallow plants per plot (Table 2). Azafenidin applied at 8, 12, and 16 oz ai/A had 60, 59, and 12 fleabane per plot, respectively. The Norflurazon and Thiazopyr treatments averaged 21.3 and 18.6 fleabane plants per plot,

respectively. No treatment of Azafenidin , Norflurazon, or Thiazopyr showed any mallow emergence at 95 DAA. The untreated also had 14 annual sowthistle, *Sonchus oleraceus* L., and 5 common chickweed, *Stellaria media* (L.) Vill., plants per plot. The 8 oz ai/A rate of Azafenidin had 3.8 sowthistle per plot, while all other treatments showed no annual sowthistle emergence. The lower two rates of Azafenidin had 1 to 2 chickweed per plot, while the highest rate of Azafenidin and Norflurazon had no chickweed emergence. The 8 oz ai/A rate of Azafenidin also showed 12 panicle willowweed, *Epilobium paniculatum* Nutt. Ex T. & G., plants per plot. Small populations (less than 0.5) were found in the 12 oz ai/A rate and Norflurazon plots. No panicle willowweed was found in the 16 oz ai/A rate of Azafenidin. The untreated was also void of panicle willowweed because of competition with other weeds. For comparison, the Thiazopyr treatment averaged 14.6 willowweed plants per plot. Summer annual weed emergence was observed at 95 DAA with 132 tumble pigweed, *Amaranthus albus* L., plants found per plot in the untreated (Table 2). All Azafenidin treatments showed no pigweed emergence except the lowest rate (1.3 pants per plot). Norflurazon averaged 26 pigweed plants per plot at 95 DAA, while no pigweed was observed in the Thiazopyr plots.

At 120 DAA, the untreated averaged 175 fleabane plants per plot (Table 3). Azafenidin applied at 8 and 12 oz ai/A had 141 and 115 fleabane per plot, while the 16 oz ai/A rate had 40 per plot. For comparison, Norflurazon and Thiazopyr had 33 and 21.6 fleabane plants per plot, respectively. The untreated also showed high pressure of mallow and sowthistle (63 per plot each). All treatments showed no mallow emergence, except Thiazopyr (1.6). The lowest Azafenidin rate, Norflurazon, and Thiazopyr showed sowthistle populations at 6.3, 1.8, and 1.6 plants per plot, respectively. The 12 to 16 oz ai/A rates of Azafenidin showed no sowthistle emergence. The untreated had 25 prostrate knotweed, *Polygonum aviculare* L., plants per plot at 120 DAA. The lower two rates of Azafenidin had some knotweed emergence (2.8 and 1.3 plants per plot), while the highest rate and Norflurazon showed no knotweed emergence. Azafenidin applied at 8, 12, and 16 oz ai/A had 7.8, 2.5 and 0.5 willowweed per plot, while Norflurazon averaged 1.3 per plot (Table 4). Thiazopyr continued to show weakness against willowweed with 15 plants emerged per plot.

Summer annuals emerged at 120 DAA included tumble pigweed and annual grasses (predominately junglerice, *Echinochloa colona* (L.) Link). The untreated averaged 200 pigweed and 34 grass plants per plot. Azafenidin applied at 8, 12, and 16 oz ai/A had 18, 3, and 0.8 pigweed plants per plot, respectively, while Norflurazon had 26 and Thiazopyr averaged 12. No grass had emerged in any treated plot by 120 DAA (Table 4). A total weed count at 120 DAA revealed that the untreated plots averaged 581 plants per plot. Azafenidin applied at 8, 12, and 16 oz ai/A had 185, 126, and 41 plants per plot, respectively, corresponding to 69, 79, and 93% control when compared to the untreated (Table 5). For comparison, Norflurazon and Thiazopyr averaged 64 and 59 plants per plot, respectively, corresponding to 89 and 90% weed reduction.

Table 2: Average Number of Weeds Plants per Plot at 95 DAA.

Treatment	Flax-leaved Fleabane	Tumble Pigweed	Common Mallow	Prostrate Knotweed	Annual Sowthistle	Common Chickweed	Panicle Willowweed
Untreated	213	132	28	25	14	5	0
Azafenidin - 8 oz ai/A	60	1.3	0	3	3.8	1.5	13
Azafenidin - 12 oz ai/A	59	0	0	1.3	0	1.3	0.3
Azafenidin - 16 oz ai/A	12	0	0	0	0	0	0
Norflurazon - 64 oz ai/A	21	26.3	0	0	0	0	0.5
Thiazopyr - 64 fl. oz/A	19	0	0		0		14.5

Table 3: Average Number of Weeds Plants per Plot at 120 DAA.

Treatment	Flaxleaved Fleabane	Tumble Pigweed	Annual Sowthistle	Common Mallow
Untreated	175	200	63	63
Azafenidin - 8 oz ai/A	141	18	6.3	0
Azafenidin - 12 oz ai/A	115	2.5	0	0
Azafenidin - 16 oz ai/A	40	0.8	0	0
Norflurazon - 64 oz ai/A	33	26.3	1.8	0
Thiazopyr - 64 fl. oz/A	22	12	1	1.6

Table 4: Average Number of Weeds Plants per Plot at 120 DAA.

Treatment	Panicle Willowweed	Prostrate Knotweed	Junglerice	Common Lambsquarters	California Burclover	Prostrate Spurge
Untreated	0	25	34	18	5	0
Azafenidin - 8 oz ai/A	7.8	2.8	0	0.5	4.8	5
Azafenidin - 12 oz ai/A	2.5	1.3	0	0	0.5	5
Azafenidin - 16 oz ai/A	0.5	0	0	0	0	0
Norflurazon - 64 oz ai/A	1.3	0	0	0.5	2	0
Thiazopyr - 64 fl. oz/A	15		0			0

Table 5: Average Number of Weeds Plants per Plot at 120 DAA.

Treatment	All Weed Species
Untreated	581
Azafenidin - 8 oz ai/A	185
Azafenidin - 12 oz ai/A	126
Azafenidin - 16 oz ai/A	41
Norflurazon - 64 oz ai/A	64
Thiazopyr - 64 fl. oz/A	59

Elderwood Site

Because the Elderwood site did not have a high pressure of winter annuals, the results discussion will focus on summer annual weed control. Summer annuals started to emerge by 118 DAA (Table 6). The untreated plots averaged 19 puncturevine, *Tribulus terrestris* L.; 2.3 witchgrass, *Panicum capillare* L.; 5.5 tumble pigweed, *Amaranthus albus* L.; 25 lovegrass, *Eragrostis cilianensis* (All.) E. Mosher; and 6 prostrate spotted spurge, *Euphorbia maculata* L, plants per plot. Puncturevine was the only summer annual observed in Azafenidin treatments at 118 DAA, though in low populations. Azafenidin applied at 8 oz ai/A had 0.3 puncturevine per plot, while the 12 and 16 oz ai/A rates showed no puncturevine. Simizine + Diuron had 9 puncturevine, 12 witchgrass, 2 tumble pigweed, and 3 lovegrass plants per plot. Thiazopyr showed little or no summer annuals except 2 pigweed per plot and a low population of prostrate spurge (less than one plant per plot).

By 161 DAA, the untreated showed 20 lovegrass and 40 junglerice plants per plot. Azafenidin applied at 8, 12, and 16 oz ai/A showed 7, 2, and 5 lovegrass per plot, respectively, and 10, 6, and 2 junglerice (Table 7). Simizine + Diuron averaged 3.0 lovegrass and 16 junglerice per plot, while Thiazopyr had no grass emerged at 161 DAA. The untreated also showed 15 to 16 pigweed and puncturevine per plot. Azafenidin applied at 8, 12, and 16 oz ai/A had 2, 0.3, and 0 pigweed and 2.5, 2.8, and 0.3 puncturevine per plot, respectively (Table 7). Simizine + Diuron showed no new pigweed emergence and an average of 11 puncturevine plants per plot. Thiazopyr had less than 1 plant per plot of either puncturevine or pigweed.

At 190 DAA, the grass population in the untreated averaged 10 lovegrass, 18 junglerice, and 11 feather fingergrass, *Chloris virgata* Swartz, plants per plot. Emergence in the untreated and Simizine + Diuron plots was hindered because of the residue of previous weeds through the season blocked sunlight to the soil. Azafenidin applied at 8, 12, and 16 showed 18, 9, and 6 junglerice per plot, respectively and 7, 5, and 5 lovegrass, with little or no fingergrass (Table 8). Simizine + Diuron averaged 13, 4.3, and 0.8 junglerice, lovegrass, and fingergrass, respectively per plot. Thiazopyr showed little grass emergence at 190 DAA with 1.5, 0.5 and 0 junglerice, lovegrass, and fingergrass per plot.

Broadleaf weeds present in the untreated at 190 DAA included an average of 13 pigweed and 9 puncturevine per plot. Azafenidin applied at 8, 12, and 16 oz ai/A showed 6, 2, and 0.5 pigweed per plot, respectively; and 4, 4, and 0.8 puncturevine per plot. Simizine + Diuron averaged 4 pigweed and 14 puncturevine per plot, while Thiazopyr had 8 pigweed and 4 puncturevine per plot at 190 DAA (Table 8).

Table 6: Average Number of Weed Plants per Plot at 118 DAA.

	Little Lovegrass	Puncturevine	Witchgrass	Prostrate Spurge	Tumble Pigweed
Untreated	25	19	2.3	6	5.5
Azafenidin - 8 oz ai/A	0	0.3	0.6	0.1	0
Azafenidin - 12 oz ai/A	0	0	0	0	0
Azafenidin - 16 oz ai/A	0	0	0.3	0	0
Simizine + Diuron (25.6 + 25.6 oz ai/A)	2.5	8.8	12	0	2.3
Thiazopyr (Visor) - 16 oz ai/A	0	0.3	0.3	0.8	2.5

Table 7: Average Number of Weed Plants per Plot at 161 DAA.

Treatment	Little Lovegrass	Junglerice	Tumble Pigweed	Puncturevine
Untreated	20	41.3	15.3	16.3
Azafenidin - 8 oz ai/A	7.3	10	2	2.5
Azafenidin - 12 oz ai/A	2.3	5.5	0.3	2.8
Azafenidin - 16 oz ai/A	5.3	2	0	0.3
Simizine + Diuron (25.6 + 25.6 oz ai/A)	3	15.5	0	10.8
Thiazopyr (Visor) - 16 oz ai/A	0	0	0.3	0.8

Table 8: Average Number of Weed Plants per Plot at 190 DAA.

Treatment	Junglerice	Little Lovegrass	Feather Fingergrass	Tumble Pigweed
Untreated	17.5	10	11	12.8
Azafenidin - 8 oz ai/A	17.5	7.3	0.3	5.6
Azafenidin - 12 oz ai/A	8.8	5	0	2.3
Azafenidin - 16 oz ai/A	5.5	5	0	0.5
Simizine + Diuron (25.6 + 25.6 oz ai/A)	12.5	4.3	0.8	4.1
Thiazopyr (Visor) - 16 oz ai/A	1.5	0.5	0	8.3

Conclusions

Azafenidin provided excellent post-emergent activity (>98% control) at 27 DAA against all weeds tested at the Ivanhoe site when tank-mixed with Glyphosate. Azafenidin tank-mixed with Glyphosate (1 lb ai/A) showed a significant increase in post emergent control on common mallow, red-stem filaree, flaxleaved fleabane, and shepherdspurge when compared with Glyphosate tank-mixed with pre-emergent standards of Norflurazon or Thiazopyr.

Azafenidin applied at 8 to 16 oz ai/A showed excellent pre-emergent weed control on a broad spectrum of weeds. At the Ivanhoe site, all rates of Azafenidin showed nearly 100% control of the following weeds: common mallow, annual sowthistle, tumble pigweed, junglerice, and common lambsquarters, *Chenopodium album* L., at 120 DAA. The 16 oz ai/A of

Azafenidin rate showed nearly 100% control of California burclover, *Medicago polymorpha* L.; panicle willowweed and prostrate spurge. By 120 DAA, the 8 oz ai/A rate of Azafenidin did show weakness on panicle willowweed, California burclover, common chickweed and spurge. The lower two rates (8 and 12 oz ai/A) of Azafenidin showed 75% reduction of fleabane at 95 DAA, however, by 120 DAA, fleabane control broke for both rates. The 16 oz ai/A rate of Azafenidin showed fleabane control comparable to Norflurazon and Thiazopyr at 120 DAA. At the Elderwood site, all rates of Azafenidin showed excellent control of the following summer annuals at 118 DAA: lovegrass, puncturevine, witchgrass, tumble pigweed, and prostrate spurge.

Azafenidin gave long-term weed control. At the Elderwood site, all rates of Azafenidin gave excellent control of all summer annual weeds that had emerged in the untreated at 118 DAA. By 161 DAA, Azafenidin gave adequate grass control and excellent broad-leaf control. By 190 DAA, Azafenidin applied at 16 oz ai/A was still showing excellent pigweed and puncturevine control at the Elderwood site. Azafenidin showed significantly longer weed control than the grower standard of Simazine + Diuron. When compared to Norflurazon and Thiazopyr, Azafenidin tended to give longer control of broadleaves such as puncturevine and pigweed, but control broke down sooner on grass species such as junglerice and lovegrass.

Azafenidin was safe to citrus trees. No phytotoxicity was observed on the citrus trees in either trial at any evaluation date.