Weed Control in No-Tillage Zucchini Squash Production

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Abstract

A field study was conducted over two growing seasons (2000 and 2001) to determine the effect of preemergence (PRE) herbicides or combinations of PRE herbicides on control of smooth crabgrass and redroot pigweed in no-tillage 'Independence II' zucchini squash production. In 2000, clomazone + imazamox, clomazone + ethalfuralin, and dimethenamid resulted in sufficient weed control along with little crop injury/growth reduction and high squash yields. In 2001, the above mentioned herbicides except dimethenamid had the greatest potential for no-tillage squash production, as these treatments resulted in the best overall weed control while providing little crop injury/growth reduction and high squash yields. The clomazone and no-herbicide treatments tended to produce high early-season yields over both years; however, weed emergence and competition increased in these treatments over the production season, and tended to cause a yield decrease. Data collected over the 2000 and 2001 growing seasons indicate that clomazone + imazamox and clomazone + ethalfuralin resulted in the best overall weed control without having a detrimental influence on 'Independence II' squash yields in a no-tillage production system. In addition, these two herbicide combinations caused minimal or no effects on zucchini squash stand, squash growth, yield or maturity.

INTRODUCTION

Vegetable growers are interested in growing vegetables utilizing no-tillage as many have observed the benefits to agronomic crops with this production system. There has been a 300% increase in conservation tillage acreage in the Midwestern U.S. during the last decade (Conservation Tillage Information Center, 1999). Reduced tillage practices are an effective and inexpensive means of reducing soil erosion (Blevins et al., 1983), and provide several other benefits including increasing soil organic matter and increasing water-holding capacity of soils (Johnson and Hoyt, 1999). Research has shown that plants grown under no-tillage conditions have more water available and tend to grow with less stress (Blevins et al., 1971; Lal, 1976). No-tillage, in conjunction with the use of winter cover crops, can become an important part of vegetable production by reducing soil erosion problems, especially during the winter months as most soils during this time of year do not have vegetative cover and are easily eroded with winter rainfall or high winds.

Research has indicated that squash grown in no-tillage yielded similarly to those grown in conventional tillage (Knavel and Herron, 1986; NeSmith et al., 1994; Walters and Kindhart, 2002). However, weeds become the major problem in this type of production system, as between row tillage is used in conventional production to reduce weed populations that preemergence (PRE) herbicides fail to control. During harvest, laborers cannot find fruit as easily on squash plants that are shaded by weeds compared to those growing under weed-free conditions and this contributes to yield loss due to decreased harvest efficiency. A major limitation to implementation of no-tillage in vegetable production is weed management. Improved weed management practices need to be developed before no-tillage systems in vegetable production can be adopted.

Few herbicides are labeled for squash production (Foster et al., 2000, 2001) and most do not provide season-long weed control. The objective of this study was to evaluate various PRE herbicides or combinations of PRE herbicides to control smooth crabgrass [*Digitaria ischaemum* (Schreb. Ex Schweig) Schreb. Ex Muhl.] and redroot pigweed (*Amaranthus rebroflexus* L.) in no-tillage 'Independence II' zucchini squash production.

MATERIALS AND METHODS

This experiment was conducted during the 2000 and 2001 growing seasons at Rendleman's Orchard in Alto Pass, Ill. The soil type was an Alford silty clay loam soil, which is a fine-silty, mixed, mesic typic Hapludalf (Miles, 1979). Winter wheat (*Triticum aestivum* L.) was established during October of 1999 and 2000 at a broadcast seeding rate of 135 kg/ha. Wheat was mowed to a height of 6 to 10 cm in late March and then killed with a postemergence application of paraquat (0.15 kg ai/ha). The experiment was set up as a randomized complete block design with 10 treatments using three replications.

2000 Evaluation. Ten treatments were evaluated: 1) no herbicide, 2) clomazone 3ME (0.28 kg ai/ha), 3) clomazone 3ME (0.28 kg ai/ha) + sulfentrazone (0.28 kg ai/ha), 4) clomazone 3ME (0.28 kg ai/ha) + ethalfuralin (1.68 kg ai/ha), 5) clomazone 3ME (0.28 kg ai/ha) + imazamox (0.04 kg ai/ha), 6) ethalfuralin (1.68 kg ai/ha), 7) napropamide (2.24 kg ai/ha), 8) dimethenamid (2.24 kg ai/ha), 9) halosulfuron (0.03 kg ai/ha), and 10) imazamox (0.04 kg ai/ha). Treatments were sprayed on 27 April and received approximately 12.5 mm of rain later that day. 'Independence II' zucchini transplants were planted 29 April and harvest began on 31 May and ended 23 June, with a total of 12 harvests.

2001 Evaluation. Ten treatments were evaluated: 1) no herbicide, 2) clomazone 3ME (0.28 kg ai/ha), 3) clomazone 3ME (0.21 kg ai/ha) + ethalfuralin (0.67 kg ai/ha), 4) clomazone 3ME (0.28 kg ai/ha) + ethalfuralin (0.90 kg ai/ha), 5) clomazone 3ME (0.28 kg ai/ha) + imazamox (0.04 kg ai/ha), 6) clomazone 3ME (0.28 kg ai/ha) + flumioxazin (0.07 kg ai/ha), 7) ethalfuralin (1.68 kg ai/ha), 8) napropamide (1.40 kg ai/ha), 9) dimethenamid (2.24 kg ai/ha), 10) imazamox (0.04 kg ai/ha). Treatments were sprayed on 1 May and received approximately 6.3 mm of rain on 6 May, 12.5 mm rain on 11 May, and approximately 87.5 mm inches between 17 May and 21 May. 'Independence II' zucchini transplants were planted 3 May and harvest began on 31 May and ended 2 July, with a total of 15 harvests.

Plots were 3 m long with in-row spacings of 0.6 m allowing 5 plants per row. Three rows were planted per plot allowing 15 plants per plot. Center-to-center row spacing was 0.9 m with a 1.5 m alley between plots. No supplemental irrigation was provided. Standard cultural practices for squash production in Illinois were used (Foster et al., 2000; Foster et al., 2001). Before planting, 224 $kg \cdot ha^{-1}$ of 13-13-13 was applied, and plots were side-dressed 3 weeks after planting with 112 $kg \cdot ha^{-1}$ of 15.5-0-0 (Calcium Nitrate). Recommended pest control was used which consisted of spraying a tank mixture of esfenvalerate or carbaryl (alternating) and chlorothalonil once a week for the duration of the test (Foster et al., 2000, 2001). Honeybee (*Apis mellifera* L.) hives were placed in close proximity of plots to ensure adequate pollination and fruit set.

Harvest frequency was every 2 to 4 days and fruit at each harvest were graded into marketable (3.8 – 6.3 cm diameter), oversize (>6.4 cm diameter), and cull (unmarketable - misshapen, off-color, or decaying fruit). Yields are reported as the number of 9 kg boxes per acre, which is the standard packaging unit for the industry.

Squash plant injury and growth reduction were rated from 0 (none) to 100 (severe injury or growth reduction) at 28 and 56 days after transplanting (DAT). Smooth crabgrass and redroot pigweed control was rated from 0 (no control) to 100 (complete control) at the same intervals as crop injury/growth reduction. Weed counts per 1 m^2 area were determined in the no herbicide treatment.

Data were subjected to analysis of variance procedures appropriate for a randomized complete block experimental design. Fisher's protected least significant difference (LSD) tests were used to separate differences among means at $P \leq 0.05$.

RESULTS AND DISCUSSION

2000 Evaluation

Although 'Independence II' plants were transplanted into herbicide-treated soil, plant stands were not affected by any of the treatments evaluated (data not shown). However, the napropamide, clomazone + sulfentrazone, and halosulfuron treatments resulted in significant ($P \leq 0.05$) crop injury and growth reduction throughout the production season compared to the other treatments evaluated (Table 1). The rates of dimethenamid and imazamox used resulted in excessive crop injury and growth reduction for the first half of the growing season at 28 DAT (Table 1). Clomazone was the only treatment evaluated in which no observable crop injury and growth reduction was noted. Clomazone often causes bleaching of zucchini squash foliage (Grey et al., 2000), but none was observed on plants that were treated with this herbicide.

Season-long redroot pigweed control (>90 %) was achieved in most treatments with the exception of ethalfuralin, clomazone, and the no herbicide treatments (Table 2). Most treatments also provided season-long smooth crabgrass control (>90 %) with the exception of halosulfuron, imazamox, and no herbicide treatments. Five treatments provided adequate control of redroot pigweed and smooth crabgrass throughout the season: clomazone + sulfentrazone, clomazone + ethalfuralin, clomazone + imazamox, dimethenamid, and napropamide (Table 2). Although adequate weed control was provided by the clomazone + sulfentrazone and napropamide treatments, excessive squash crop injury and growth reduction occurred with these treatments. At the end of the season, redroot pigweed and smooth crabgrass plant counts averaged 233 and 189/m^2, respectively, in the no-herbicide treatment.

'Independence II' yields were influenced by herbicide treatment. For early-season yields (first four harvests), the clomazone, no herbicide, clomazone + ethalfuralin, and dimethenamid treatments provided high yields (Table 3). However, weed emergence and competition became excessive in the no-herbicide treatment as the season progressed which tended to reduce total season yields compared to the clomazone, clomazone + ethalfuralin, clomazone + imazamox, and dimethenamid treatments. Treatments that resulted in yields that were equal or lower to the yields obtained in the no-herbicide treatment due to crop injury and growth reduction included clomazone + sulfentrazone, imazamox, napropamide, and halosulfuron.

The 2000 evaluation indicated that clomazone + imazamox, the clomazone + ethalfuralin, and dimethenamid have potential for no-tillage squash production, as these treatments resulted in the best overall weed control along with providing little crop injury/growth reduction and high squash yields.

2001 Evaluation

Since several treatments resulted in severe crop injury and yield reduction in 2000, these treatments were discarded for 2001 including clomazone + sulfentrazone and halosulfuron. The rate of napropamide was reduced to 1.40 kg ai/ha as the 2.24 kg ai/ha rate caused extensive crop injury and yield reduction during 2000.

Only the clomazone + flumioxazin treatment reduced 'Independence II' plant stands (data not shown). The clomazone + flumioxazin treatment resulted in significant ($P \leq 0.05$) crop injury and growth reduction throughout the production season compared to the other treatments evaluated (Table 1). Other treatments such as the napropamide, dimethenamid, and imazamox treatments at 28 DAT resulted in minor but acceptable levels of crop injury and growth reduction; but most treatments besides the clomazone + flumioxazin treatment resulted in little or no crop injury and growth reduction (Table 1).

Redroot pigweed control was less than what was achieved during the 2000 season (Table 2). Only the clomazone + flumioxazin provided excellent control (> 90%) throughout the growing season. No other treatment provided adequate control of redroot pigweed throughout the growing season (Table 2). The lower rate of napropamide evaluated in 2001 resulted in less squash injury and growth reduction (Table 1), but did not adequately control redroot pigweed (Table 2). All treatments evaluated except the no-herbicide treatment provided excellent season-long control of smooth crabgrass (Table 2). At the end of the season, redroot pigweed and smooth crabgrass plant counts averaged 256 and 122/m^2, respectively, in the no-herbicide treatment.

Again, 'Independence II' yields were influenced by herbicide treatment. Weed emergence occurred slower in 2001 compared to 2000 (data not presented), which allowed the clomazone and no-herbicide treatment to have high early-season yields (Table 3). The clomazone + flumioxazin, ethalfuralin, napropamide, dimethenamid, and imazamox treatments had low early season yields (Table 3), which probably resulted from these herbicides causing some crop injury and growth reduction (Table 1). The treatments that tended to perform the best for total-season yields included clomazone, clomazone + imazamox, no herbicide, and the two clomazone + ethalfuralin rates evaluated (Table 3).

The 2001 evaluation indicated that clomazone + imazamox and the two clomazone + ethalfuralin rates evaluated showed potential for no-tillage squash production, as these treatments resulted in the best overall weed control along with providing little crop injury/growth reduction and high squash yields.

CONCLUSIONS

Before no-tillage production systems will be widely adapted in squash or any other vegetable crop, adequate weed control systems must be developed. This study indicated the clomazone and no-herbicide treatments tended to produce high early-season zucchini squash yields over both years; however, as weed pressures increased in these treatments throughout the production season, yields decreased. Data collected over the 2000 and 2001 growing seasons indicate that the clomazone + imazamox and clomazone + ethalfuralin treatments resulted in the best overall weed control without having a detrimental influence on zucchini squash yields in a no-tillage production system. The rates utilized for these two herbicide combinations caused minimal or no effects on zucchini squash stand, growth, yield or maturity.

Due to the limited number of herbicides and inadequate weed control of those that are currently available for use in summer squash, registration of additional herbicides or the development of alternative methods of weed control is needed to allow the implementation of no-tillage squash production.

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Tables

Table 1. Ratings of crop injury (CI) and growth reduction (GR) of 'Independence II' zucchini squash at 28 and 56 days after transplanting (DAT) as influenced by various preemergence herbicide treatments during spring 2000 and 2001 at Alto Pass, IL.[1]

	2000				2001			
	28 DAT		56 DAT		28 DAT		56 DAT	
Treatment (kg ai/ha)	CI	GR	CI	GR	CI	GR	CI	GR
Clomazone (0.28)	0	0	0	0	3	3	0	0
Clomazone (0.21) +Ethalfuralin (0.67)	-	-	-	-	2	2	2	2
Clomazone (0.28) +Ethalfuralin (0.90)	-	-	-	-	4	4	2	2
Clomazone (0.37) +Ethalfuralin (1.68)	5	5	0	0	-	-	-	-
Clomazone (0.28) +Flumioxazin (0.07)	-	-	-	-	82	82	63	53
Clomazone (0.28) + Imazamox (0.04)	8	8	0	0	5	5	0	0
Clomazone (0.28) +Sulfentrazone (0.28)	53	53	23	18	-	-	-	-
Dimethenamid (2.24)	23	23	6	6	11	11	5	5
Ethalfuralin (1.68)	8	8	3	3	2	2	3	3
Halosulfuron (0.03)	85	85	65	65	-	-		- -
Imazamox (0.04)	15	15	5	5	10	10	5	5
Napropamide (1.40)	-	-	-	-	9	9	3	3
Napropamide (2.24)	50	50	18	18	-	-	-	-
No Herbicide	0	0	0	0	0	0	0	0
LSD ($P \leq 0.05$)	16	16	16	16	7	7	7	4

[1]CI is crop injury and GR is growth reduction to zucchini squash. Zucchini squash injury and growth reduction was rated from 0 (none) to 100 (severe injury or growth reduction).

Table 2. Ratings of smooth crabgrass (SMCG) and redroot pigweed (RRPW) control in no tillage 'Independence II' zucchini squash at 28 and 56 days after transplanting (DAT) as influenced by various preemergence herbicide treatments during Spring 2000 and 2001 atAlto Pass, IL.[1]

	2000				2001			
	28 DAT		56 DAT		28 DAT		56 DAT	
Treatment (kg ai/ha)	SMCG	RRPW	SMCG	RRPW	SMCG	RRPW	SMCG	RRPW
Clomazone (.28)	97	60	97	83	96	50	96	27
Clomazone (0.21) +Ethalfuralin (0.67)	-	-	-	-	99	47	97	90
Clomazone (0.28) +Ethalfuralin (0.90)	-	-	-	-	99	67	93	87
Clomazone (0.37) +Ethalfuralin (1.68)	97	94	97	95	-	-	-	-
Clomazone (0.28) +Flumioxazin (0.07)	-	-	-	-	99	99	99	94
Clomazone (0.28) + Imazamox (0.04)	95	96	97	99	99	73	96	83
Clomazone (0.28) +Sulfentrazone (0.28)	97	97	97	99	-	-	-	-
Dimethenamid (2.24)	95	95	93	94	99	30	96	65
Ethalfuralin (1.68)	95	85	93	85	96	75	98	87
Halosulfuron (0.03)	80	99	48	99	-	-	-	-
Imazamox (0.04)	63	97	86	99	99	67	96	60
Napropamide (1.40)	-	-	-	-	99	67	98	68
Napropamide (2.24)	99	99	99	97	-	-	-	-
No Herbicide	0	0	0	0	0	0	0	0
LSD ($P \leq 0.05$)	20	27	15	7	2	31	4	22

[1]Smooth crabgrass and redroot pigweed control was rated from 0 (no control) to 100 (complete control).

Table 3. 'Independence II' zucchini squash yield (number of 9 kg boxes/ha) as influenced by various preemergence herbicide treatments during spring 2000 and 2001 at Alto Pass, IL.[1]

	2000				2001			
	Early		Total		Early		Total	
Treatment (kg ai/ha)	Mark	Total	Mark	Total	Mark	Total	Mark	Total
Clomazone (0.28)	232	240	558	716	230	231	958	1098
Clomazone (0.21) +Ethalfuralin (0.67)	-	-	-	-	126	129	948	992
Clomazone (0.28) +Ethalfuralin (0.90)	-	-	-	-	167	167	832	874
Clomazone (0.37) +Ethalfuralin (1.68)	215	247	591	674	-	-	-	-
Clomazone (0.28) +Flumioxazin (0.07)	-	-	-	-	26	26	525	598
Clomazone (0.28) + Imazamox (0.04)	196	196	555	681	180	182	867	876
Clomazone (0.28) +Sulfentrazone (0.28)	147	157	494	598	-	-	-	-
Dimethenamid (2.24)	205	210	609	713	128	131	694	739
Ethalfuralin (1.68)	187	203	530	623	138	142	732	769
Halosulfuron (0.03)	10	10	27	55	-	-	-	-
Imazamox (0.04)	152	166	472	582	145	145	764	802
Napropamide (1.40)	-	-	-	-	104	109	702	842
Napropamide (2.24)	125	125	390	467	-	-	-	-
No Herbicide	214	221	501	607	190	190	857	860
LSD ($P \leq 0.05$)	70	83	75	134	62	60	214	235

[1]Early is the sum of the first four harvests (2000) or first five harvests (2001). Total is the sum of all harvests (12 for 2000 and 15 for 2001). Mark is marketable yields and Total is total yields, which is the sum of marketable, oversize, and cull fruit.