International Research Journal of Agricultural Science and Soil Science (ISSN: 2251-0044) Vol. 2(4) pp. 142-148, April 2012
Available online http://www.interesjournals.org/IRJAS

Full Length Research Paper

Response of winter wheat (*Triticum aestivum* L.) to glyphosate tankmixes

Lynette R. Brown, Nader Soltani*, Christy Shropshire and Peter H. Sikkema

University of Guelph, Ridgetown Campus, 120 Main Street E., Ridgetown, Ontario, Canada

Accepted 27 February, 2012

Two sets of experiments were conducted over a four-year period (2006-2009) to evaluate the tolerance of winter wheat to fall applications of 2 week preplant (WPP), 1 WPP, 1 day preplant (DPP) and preemergence (PRE) glyphosate tankmixes in combination with commonly used burndown herbicides (amitrole, dicamba/diflufenzopyr, chlorimuron-ethyl, dicamba, 2,4-D amine and 2,4-D ester). Glyphosate plus 2,4-D amine, 2,4-D ester or amitrole tankmixes applied 2 and 1 WPP, 1 DPP and PRE caused minimal wheat injury and no yield decrease. Glyphosate plus dicamba applied 1 DPP and PRE caused 3.6 and 6.4% injury shortly after emergence, however, this injury was transient and did not affect final yield. Glyphosate plus dicamba/diflufenzopyr applied 1 DPP and PRE caused less than 5% injury in Exeter and up to 27% in Ridgetown which resulted in a yield loss of 1.1 t ha^{-1} at 1 DPP. The glyphosate plus chlorimuron-ethyl tankmix caused the most injury at all four application timings. Injury with this tankmix was evident 2 weeks after emergence and by July of the following year was as high as 54%. This tankmix caused a decrease in height of 4 to 7 cm and a yield loss of 0.7-3.1 t ha^{-1}.

Keywords: 2,4-D amine, 2,4-D ester, amitrole, chlorimuron-ethyl, dicamba, dicamba/diflufenzopyr, glyphosate, winter wheat

INTRODUCTION

When it comes to seeding winter wheat, there are many advantages to using no-till. Not only does no-till reduce soil erosion, minimize soil compaction, conserve soil moisture, reduce fuel, equipment and labour costs, it also decreases the amount of time required for seedbed preparation and seeding in the limited fall harvesting and seeding period in Ontario. However, one of the disadvantages of a no-till system is that there is a tendency for weed shifts to occur (Coffman and Frank, 1991; Kapusta and Krausz, 1993; Moyer et al., 1994; Triplett and Lytle, 1972) and the presence of established weeds at the time of seeding. Since winter wheat is seeded in the fall, good establishment before vernalization is essential. Established winter annual, biennial and perennial weeds such as wild carrot (*Daucus carota* L.), common chickweed (*Stellaria media* L.), henbit (*Lamium amplexicaule* L.) shepherd's-purse (*Capsella bursa-pastoris* L.), hedge bindweed (*Convolvulus sepium* L.), dandelion (*Taraxacum officinale* Weber), common milkweed (*Asclepias syriaca* L.), yellow nutsedge (*Cyperus esculentus* L.), plantain (*Plantago major* L.), quack grass (*Agropyron repens* L.), perennial sow thistle (*Sonchus arvensis* L.) and Canada thistle (*Cirsium arvense* L.) can all compete with an emerging winter wheat crop for light, moisture and nutrients.

With the increase of no-till practices, there has also been an increase in the use of glyphosate for weed control (Moyer et al., 1994). Glyphosate is a non-selective herbicide commonly used as a burndown in no-till crops (corn and soybean) in order to control emerged annual, biennial and perennial weeds prior to seeding. It can be very effective on its own, however, when tankmixed with other herbicides it can increase the spectrum of weeds controlled, provide residual weed control and reduce the selection intensity for glyphosate resistant biotypes (Shaner, 2000; VanGessel et al., 2001).

Potential tankmix partners with glyphosate include commonly used burndown herbicides such as amitrole, dicamba/diflufenzopyr, dicamba, 2, 4-D and chlorimuron-ethyl which have activity on specific winter annual, biennial and perennial weeds. Amitrole can effectively

*Corresponding Author E-mail: nsoltani@ridgetownc.uoguelph.ca

Table 1. Soil characteristics of sites at Exeter and Ridgetown, ON from 2007 to 2009[a]

Location	Year	Experiment	Sand (%)	Silt (%)	Clay (%)	OM (%)	pH	CEC
Exeter	2007	1	31	38	31	4.4	7.9	35
Ridgetown	2007	1	45	29	26	4.9	7.0	11
Exeter	2008	1	39	37	24	4.3	7.9	38
Ridgetown	2008	1	54	27	19	5.6	6.4	18
Exeter	2009	1	28	38	34	4.1	7.9	36
Ridgetown	2009	1	40	35	25	7.1	6.6	23
Ridgetown	2007	2	45	29	26	4.9	7.0	11
Exeter	2008	2	39	37	24	4.3	7.9	38
Ridgetown	2008	2	54	27	19	5.6	6.4	18
Exeter	2009	2	28	38	34	4.1	7.9	36
Ridgetown	2009	2	40	35	25	7.1	6.6	23

[a]Abbreviations; OM, organic matter; CEC, Cation Exchange Capacity

control quackgrass, dandelion, plantain and Canada thistle (OMAFRA, 2010). Hodgson (1970) reported that amitrole was effective at limiting regrowth of Canada thistle which had only 29% survival 11 months after treatment at the bud stage. Dicamba/diflufenzopyr, dicamba and 2, 4-D effectively control broadleaf weeds including Canada thistle, common chickweed, field bindweed and perennial sow thistle (OMAFRA, 2010; Swan, 1982). Franssen and Kells (2007) reported that dicamba/diflufenzopyr provided 83% control of established populations of common dandelion in no-till corn. Other research has also shown that glyphosate in combination with 2, 4-D or dicamba provided additive or synergistic field bindweed control (Flint and Barrrett, 1989). Chlorimuron-ethyl controls common milkweed, wild carrot, nutsedge and perennial sow thistle (OMAFRA, 2010).

There is little research on injury to the winter wheat crop from glyphosate tankmixed with amitrole, dicamba/diflufenzopyr, dicamba, 2, 4-D and chlorimuron-ethyl. Injury to winter wheat has been shown when glyphosate plus dicamba/diflufenzopyr and glyphosate plus chlorimuron-ethyl were applied immediately before planting (Soltani et al., 2009). However, there is very little research on the effect of increasing the time interval between application of these tankmixes and winter wheat seeding. It would be of great benefit to the winter wheat industry if the level of crop injury with tankmixes of glyphosate plus amitrole, dicamba/diflufenzopyr and chlorimuron ethyl could be decreased by increasing the time interval between herbicide application and seeding date. Therefore, the objective of this study was to examine the tolerance of winter wheat to tankmixes of glyphosate with amitrole, dicamba/diflufenzopyr, chlorimuron-ethyl, dicamba, 2,4-D amine or 2,4-D ester applied 2 week preplant (WPP), 1 WPP, 1 day preplant (DPP) and preemergence (PRE).

MATERIALS AND METHODS

Two sets of experiments (eleven field trials in total) were conducted at the Huron Research Station near Exeter, ON and at the University of Guelph Ridgetown Campus, Ridgetown, ON. The experiments were seeded in the fall of 2006, 2007 and 2008 and harvested in 2007, 2008 and 2009. The soil characteristics for each field trial are presented in Table 1.

The experiments were established as an RCBD with four replications. Each experiment consisted of 13 herbicide treatments. Experiment 1 included a preemergence (PRE) application of glyphosate (1800 g a.i. ha^{-1}) plus glyphosate (1800 g a.i. ha^{-1}) applied in combination with amitrole (1155 g a.i. ha^{-1}), dicamba/diflufenzopyr (200 g a.i. ha^{-1}) plus a non-ionic surfactant (0.25% v/v) plus 28% UAN (1.25% v/v) or chlorimuron-ethyl (9 g a.i. ha^{-1}) plus a non- ionic surfactant (0.25% v/v) applied 2 WPP, 1 WPP, 1 DPP and PRE. Experiment 2 included a PRE application of glyphosate (1800 g a.i. ha^{-1}) plus glyphosate (1800 g a.i. ha^{-1}) applied in combination with dicamba (300 g a.i. ha^{-1}), 2,4-D amine (700 g a.i. ha^{-1}) and 2,4-D ester (700 g a.i. ha^{-1}) applied 2 WPP, 1 WPP, 1 DPP and PRE. Pioneer 25R47 was seeded in the fall at both locations at a rate of approximately 150 kg ha^{-1} in rows that were 17.5 or 19 cm apart in plots that were 2 m wide by 8 or 10 m long depending on location. Herbicide treatments were applied with a CO_2-pressurized backpack sprayer equipped with 120-02 ultra low drift nozzles (Hypro, New Brighton, MN) calibrated to deliver 200 L ha^{-1} at 207 or 241 kPa. All plots were maintained weed-free with a cover spray of bromoxynil plus MCPA (1:1 ratio) at 560 g ai ha^{-1} applied early in the spring.

For both experiments, crop injury was rated visually 2 and 4 weeks after emergence (WAE) in the fall and at

Table 2. Winter wheat injury 2 and 4 WAE as a function of tankmix partner and application timing[a]

Treatment	Timing	2 WAE E2007/8	2 WAE E2009	2 WAE R	4 WAE E	4 WAE R2007
		%				
Glyphosate alone	PRE	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
Gly + amitrole	2 WPP	0.4 b	0.0 a	0.0 a	0.3 ab	0.0 a
Gly + amitrole	1 WPP	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
Gly + amitrole	1 DPP	0.2 ab	0.0 a	0.0 a	0.6 abc	0.0 a
Gly + amitrole	PRE	0.8 b	0.0 a	0.0 a	1.0 bc	0.0 a
Gly + dicamba/diflufenzopyr[b]	2 WPP	0.5 b	0.0 a	0.0 a	0.3 ab	0.0 a
Gly + dicamba/diflufenzopyr	1 WPP	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
Gly + dicamba/diflufenzopyr	1 DPP	1.9 bc	2.4 c	1.3 bc	1.6 bcd	2.9 bc
Gly + dicamba/diflufenzopyr	PRE	4.6 cd	0.8 b	0.3 ab	2.6 cd	1.7 b
Gly + chlorimuron-ethyl[c]	2 WPP	0.6 b	0.0 a	0.7 abc	1.7 bcd	5.4 d
Gly + chlorimuron-ethyl	1 WPP	1.1 bc	0.0 a	0.7 abc	1.4 bcd	4.3 cd
Gly + chlorimuron-ethyl	1 DPP	4.3 cd	0.0 a	1.5 c	4.2 d	3.9 cd
Gly + chlorimuron-ethyl	PRE	6.6 d	0.0 a	0.7 abc	5.0 d	4.2 cd
SE		0.3	0.1	0.1	0.3	0.4
Contrasts[d]						
amitrole vs d/d		NS	*	NS	NS	*
amitrole vs chlorimuron-ethyl		*	NS	*	*	*
d/d vs chlorimuron-ethyl		NS	*	*	*	*

[a]Abbreviations: d/d, dicamba/diflufenzopyr; DPP, days preplant; E, Exeter location; Gly, glyphosate; PRE, preemergence; R, Ridgetown location; WAE, weeks after emergence; WPP, weeks preplant.
[b] Included non-ionic surfactant (0.25% v/v) and 28% UAN (1.25% v/v).
[c] Included non-ionic surfactant (0.2% v/v).
[d] All treatments included glyphosate.
* Denotes significance at P<0.05.
a-d Means followed by the same letter within a column are not significantly different according to Fisher's Protected LSD at P<0.05.

the beginning of May, June and July of the following year. Crop injury was rated using a scale of 0% (no injury) to 100% (complete death). Wheat height was measured before harvest from 10 randomly selected plants per plot. Yield was measured at crop maturity by harvesting the middle 1.5 m of each plot with a plot combine. Yields were adjusted to 14.5% moisture.

All data were subjected to analysis of variance using the PROC MIXED procedure of SAS (software Ver. 9.1, SAS Institute, Inc., Cary, NC) with contrasts comparing tankmix partners. In Experiment 1, in order to meet the assumptions of variance analyses, injury 2 WAE was square root transformed. Injury 4 WAE as well as the June and July injury for Exeter and Ridgetown was log and square-root transformed, respectively. The May injury for Exeter and Ridgetown (2007) was square-root transformed, and Ridgetown (2009) was log transformed. Data were converted back to original scale for presentation of results. Ratings were missing for Ridgetown 2008 (injury 4 WAE) and Ridgetown 2009 (injury 2 and 4 WAE) due to snow cover. The random effects of environment (year) and their interaction with the herbicide treatments were significant for all of the variables analyzed. Consequently, data for some parameters are reported by environment or environment (year). Means were separated using Fisher's protected LSD at P=0.05.

In Experiment 2, in order to meet the assumptions of variance analyses, injury 4 WAE and the Exeter data for the May injury was log transformed. The June and July injury for Exeter was square root transformed. Data were converted back to original scale for presentation of results. Ratings were missing for Ridgetown 2008 (injury 4 WAE) and Ridgetown 2009 (injury 2 and 4 WAE) due to

Table 3. Winter wheat injury in May, June and July as a function of tankmix partner and application timing[a]

Treatment	Timing	May				June			July		
		E	R2007	R2008	R2009	E	R2007	R2008/9	E	R2007	R2008/9
		%									
Glyphosate alone	PRE	0 a	0 a	0 a	0 a	0 a	0 a	0 a	0 a	0 a	0 a
Gly + amitrole	2 WPP	1 a	0 a	0 a	0 a	1 a	0 a	0 a	1 ab	0 a	0 a
Gly + amitrole	1 WPP	1 a	0 a	0 a	0 a	1 a	0 a	0 a	2 b	0 a	0 a
Gly + amitrole	1 DPP	1 a	0 a	0 a	0 a	0 a	0 a	0 a	1 ab	0 a	0 a
Gly + amitrole	PRE	3 a	0 a	0 a	0 a	1 a	0 a	0 a	1 ab	0 a	0 a
Gly + dicamba/diflufenzopyr[b]	2 WPP	2 a	0 a	0 a	0 a	1 a	0 a	0 a	3 b	0 a	0 a
Gly + dicamba/diflufenzopyr	1 WPP	1 a	0 a	0 a	0 a	0 a	0 a	0 a	2 b	0 a	0 a
Gly + dicamba/diflufenzopyr	1 DPP	4 a	22 b	5 b	2 b	1 a	17 c	10 c	2 b	13 b	3 bc
Gly + dicamba/diflufenzopyr	PRE	5 a	20 b	5 b	0 a	2 a	27 cd	2 b	2 b	21 b	1 b
Gly + chlorimuron-ethyl[c]	2 WPP	14 b	46 c	9 c	7 c	12 bc	50 e	14 cd	9 c	46 c	7 cd
Gly + chlorimuron-ethyl	1 WPP	12 b	40 c	11 cd	10 c	8 b	43 de	22 d	10 c	44 c	12 d
Gly + chlorimuron-ethyl	1 DPP	17 bc	42 c	14 de	23 d	16 bc	15 b	34 e	14 c	45 c	22 e
Gly + chlorimuron-ethyl	PRE	27 c	40 c	15 e	2 b	25 c	50 e	14 cd	20 c	54 c	7 cd
SE		1	3	1	1	1	4	1	1	4	1
Contrasts[d]											
amitrole vs d/d		NS	*	*	*	NS	*	*	NS	*	NS
amitrole vs chlorimuron-ethyl		*	*	*	*	*	*	*	*	*	*
d/d vs chlorimuron-ethyl		*	*	*	*	*	*	*	*	*	*

[a] Abbreviations: d/d, dicamba/diflufenzopyr; DPP, days preplant; E, Exeter location; Gly, glyphosate; PRE, preemergence; R, Ridgetown location; WAE, weeks after emergence; WPP, weeks preplant.
[b] Included non-ionic surfactant (0.25% v/v) and 28% UAN (1.25% v/v).
[c] Included non-ionic surfactant (0.2% v/v).
[d] All treatments included glyphosate.
* Denotes significance at P<0.05.
a-e Means followed by the same letter within a column are not significantly different according to Fisher's Protected LSD at P<0.05.

snow cover. The random effects of environment and their interaction with the herbicide treatments were significant for injury at 2 WAE, May, June and July. However, Ridgetown injury data was all zero and could not be combined with Exeter data. The one exception to this was injury 4 WAE which includes both Exeter and Ridgetown data. Environment by treatment interactions were not significant for height and yield data, and all five environments were combined for analysis. With the exception of injury 2 WAE (Exeter), the fixed effect "treatment" was non-significant and therefore the data presented do not include means separations. For injury 2 WAE (Exeter), means were separated using Fisher's protected LSD at P=0.05.

RESULTS AND DISCUSSION

Experiment 1

At 2 WAE, the addition of amitrole to glyphosate resulted in injury to winter wheat at Exeter 2007/2008 when it was applied 2 WPP and PRE (Table 2). At 4 WAE, the addition of amitrole to

Table 4. Winter wheat height and yield as a function of tankmix partner and application timing[a]

		Height		Yield	
Treatment	**Timing**	**E**	**R**	**E**	**R**
		_____ cm _____		____ t ha^{-1} ____	
Glyphosate alone	PRE	81 a	81 a	6.6 ab	6.8 a
Gly + amitrole	2 WPP	81 a	80 ab	6.5 ab	6.6 a
Gly + amitrole	1 WPP	80 ab	80 ab	6.5 ab	6.5 ab
Gly + amitrole	1 DPP	81 a	79 ab	6.8 a	6.3 ab
Gly + amitrole	PRE	80 ab	80 ab	6.5 ab	6.3 ab
Gly + dicamba/diflufenzopyr[b]	2 WPP	80 ab	79 ab	6.5 ab	6.4 ab
Gly + dicamba/diflufenzopyr	1 WPP	81 a	78 ab	6.6 ab	6.4 ab
Gly + dicamba/diflufenzopyr	1 DPP	82 a	77 b	6.4 ab	5.7 b
Gly + dicamba/diflufenzopyr	PRE	82 a	78 ab	6.4 ab	6.1 ab
Gly + chlorimuron-ethyl[c]	2 WPP	76 c	72 c	5.4 c	4.5 cd
Gly + chlorimuron-ethyl	1 WPP	76 c	71 c	5.9 bc	4.5 cd
Gly + chlorimuron-ethyl	1 DPP	77 bc	70 c	5.3 cd	3.7 d
Gly + chlorimuron-ethyl	PRE	74 c	72 c	4.7 d	4.6 c
SE		1	1	0.1	0.1
Contrasts[d]					
amitrole vs d/d		NS	*	NS	NS
amitrole vs chlorimuron-ethyl		*	*	*	*
d/d vs chlorimuron-ethyl		*	*	*	*

[a] Abbreviations: d/d, dicamba/diflufenzopyr; DPP, days preplant; E, Exeter location; Gly, glyphosate; PRE, preemergence; R, Ridgetown location; WAE, weeks after emergence; WPP, weeks preplant.
[b] Included non-ionic surfactant (0.25% v/v) and 28% UAN (1.25% v/v).
[c] Included non-ionic surfactant (0.2% v/v).
[d] All treatments included glyphosate.
* Denotes significance at $P<0.05$.
a-d Means followed by the same letter within a column are not significantly different according to Fisher's Protected LSD at $P<0.05$.

glyphosate resulted in injury to winter wheat at Exeter when it was applied PRE (Table 2). This injury observed 2 and 4 WAE was transient with no significant injury observed at the beginning of May, June and July of the following growing season (Table 3). Furthermore, the addition of amitrole to glyphosate did not affect winter wheat height or yield (Table 4). The addition of dicamba/diflufenzopyr to glyphosate applied 2 WPP, 1 WPP, 1 DPP and PRE resulted in injury to winter wheat depending on application timing and injury rating date (Table 2 and 3). Generally, the level of injury observed increased as the time interval between herbicide application and winter wheat seeding decreased. For example, at Ridgetown 2007 there were 0, 0, 17 and 27% injury at the beginning of June with the 2 WPP, 1 WPP, 1 DPP and PRE applications, respectively (Table 3). The addition of dicamba/diflufenzopyr did not adversely affect winter wheat height or yield at Exeter but there was a decrease in height and yield with the 1 DPP applications at Ridgetown (Table 4). The addition of chlorimuron-ethyl to glyphosate applied 2 WPP, 1 WPP, 1 DPP and PRE resulted in injury to winter wheat (Table 2 and 3). Injury symptoms from this tankmix resulted in delay in plant growth and maturation and a decrease in winter wheat height. Generally, the level of injury observed increased as the time interval between herbicide application and winter wheat seeding decreased but this observation was not always consistent. For example, at Ridgetown 2008 at the beginning of May there was 9, 11, 14 and 15% injury with the 2 WPP, 1 WPP, 1 DPP and PRE applications, respectively (Table 3). Soltani et al. (2009) also found 2 to 18% injury when glyphosate plus chlorimuron-ethyl was applied PP and PRE. The addition of chlorimuron-ethyl to glyphosate resulted in a decrease in winter wheat height of 5 to 7 cm at Exeter and 9 to 11 cm at Ridgetown. Soltani et al (2009) also reported a height reduction of 11% in winter wheat when chlorimuron-ethyl was added to glyphosate. The addition of chlorimuron-ethyl to glyphosate resulted in a decrease in winter wheat yield of 0.7 to 1.9 t ha^{-1} at Exeter and 2.2 to 3.1 t ha^{-1} at Ridgetown.

Based on the orthogonal contrasts completed, glyphosate plus dicamba/diflufenzopyr resulted in greater crop injury than glyphosate plus amitrole for 8 of the 15

Table 5. Winter wheat injury, height and yield as a function of tankmix partner and application timing

Treatment	Timing	Injury 2 WAE	4 WAE	May	June	July	Height[b]	Yield[b]
		%					cm	t ha^{-1}
Glyphosate alone	PRE	0 a	0	0	0	0	80	6.9
Gly + dicamba	2 WPP	0.6 a	0.3	0.9	1.2	1.1	81	6.8
Gly + dicamba	1 WPP	2.1 ab	0.4	0.8	1.0	1.2	81	6.8
Gly + dicamba	1 DPP	3.6 bc	0.6	1.1	0.6	2.4	81	7.0
Gly + dicamba	PRE	6.4 c	0.6	1.6	1.2	1.2	81	6.7
Gly + 2,4-D amine	2 WPP	0 a	0.1	1.1	1.8	1.2	80	6.9
Gly + 2,4-D amine	1 WPP	0 a	0.3	1.9	0.5	1.4	80	6.8
Gly + 2,4-D amine	1 DPP	0 a	0.3	3.1	4.2	2.3	80	6.7
Gly + 2,4-D amine	PRE	0 a	0.3	4.2	5.7	6.0	80	6.4
Gly + 2,4-D ester	2 WPP	0 a	0.1	3.6	2.9	1.2	80	6.9
Gly + 2,4-D ester	1 WPP	0 a	0.2	1.0	1.4	2.1	81	6.7
Gly + 2,4-D ester	1 DPP	0 a	0.0	2.3	3.3	4.3	81	6.8
Gly + 2,4-D ester	PRE	0 a	0.0	2.1	4.2	3.8	79	6.5
SE		0.2	0.1	0.9	0.5	0.4	0.4	0.1
Contrast[c]								
dicamba vs 2,4-D amine		*	NS	NS	NS	NS	NS	NS
dicamba vs 2,4-D ester		*	*	NS	NS	NS	NS	NS
2,4-D amine vs 2,4-D ester		NS	NS	NS	NS	NS	NS	NS

[a] Abbreviations: DPP, days preplant; Gly, glyphosate; PRE, preemergence; WAE, weeks after emergence; WPP, weeks preplant.
[b] Exeter and Ridgetown data combined.
[c] All treatments included glyphosate.
a-c Means followed by the same letter within a column are not significantly different according to Fisher's Protected LSD at P<0.05.

contrasts (Table 2 and 3). The tankmix of glyphosate plus dicamba/diflufenzopyr resulted in shorter wheat at the Ridgetown location but there was no difference in wheat yield when comparing glyphosate plus amitrole compared to glyphosate plus dicamba/diflufenzopyr (Table 4). Also, based on the orthogonal contrasts completed, glyphosate plus chlorimuron-ethyl consistently caused greater injury and a greater decrease in winter wheat height and yield than either glyphosate plus amitrole or glyphosate plus dicamba/diflufenzopyr (Tables 2, 3 and 4). These results are consistent with Soltani et al. (2009) who reported a yield decrease of 26 and 15% with glyphosate plus chlorimuron-ethyl and glyphosate plus dicamba/diflufenzopyr, respectively.

Experiment 2

At 2 WAE, the addition of dicamba to glyphosate resulted in injury to winter wheat of 0.6, 2.1, 3.5 and 6.4% when the tankmix was applied 2 WPP, 1 WPP, 1DPP and PRE, respectively (Table 5). This injury was transient with no significant injury observed 4 WAE and at the beginning of May, June and July of the following growing season (Table 5).The addition of dicamba to glyphosate did not result in a decrease in height or yield. The addition of 2,4-D amine or ester to glyphosate and applied 2 WPP, 1 WPP, 1DPP and PRE resulted in no injury to winter wheat and no decrease in height or yield (Table 5). Generally, based on orthogonal contrast there was no difference between the addition of dicamba, 2,4-D amine or 2,4-D ester to glyphosate in respect to winter wheat injury, height or yield with the exception of crop injury 2 WAE. At 2 WAE, the addition of dicamba to glyphosate caused greater crop injury

(Table 5). These results are similar to those found by Ogg and Young (1991) who reported that glyphosate plus 2,4-D applied 31 to 1 D prior to seeding did not affect wheat yields.

This study concludes that glyphosate plus amitrole, dicamba, 2,4-D amine or 2,4-D ester can safely be applied 2 WPP, 1 WPP, 1DPP and PRE to seeding wheat. Injury from these tankmixes at the application timings evaluated caused minimal injury and did not affect final yield. Similarly, glyphosate plus dicamba/diflufenzopyr can safely be applied 2 WPP and 1 WPP. However, at 1 DPP and PRE, significant injury was observed and there was a decrease in height and yield in some environments at some locations. Glyphosate plus dicamba/diflufenzopyr applied PRE caused as much as 27% injury (Ridgetown), but did not result in a height decrease or yield loss at either location. These conflicting results indicate a location effect and caution should be used when applying glyphosate plus dicamba/diflufenzopyr 1 DPP or PRE. The glyphosate plus chlorimuron-ethyl applications caused unacceptable injury to the winter wheat. This tankmix should not be considered when looking for herbicide options to increase the spectrum of weeds controlled with glyphosate prior to seeding winter wheat.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Todd Cowan for his expertise and technical assistance in these studies. Funding for this project was provided, in part, by the Grain Farmers of Ontario (GFO).

REFERENCES

Coffman CB, Frank JR (1991). Weed-crop responses to weed management systems in conservation tillage corn (Zea mays). Weed Technol. 5, 76-81.

Flint JL, Barrett M (1989). Effects of glyphosate combinations with 2,4-D or dicamba on field bindweed (Convolvulus arvensis). Weed Sci. 37, 22-18.

Franssen AS, Kells JJ (2007). Common dandelion (Taraxacum officinale) control with postemergence herbicides in no-tillage glufosinate-resistant corn. Weed Technol. 21, 14-17.

Hodgson JM (1970). The response of Canada thistle ecotypes to 2,4-D, amitrole and intensive cultivation. Weed Sci. 18, 253-255.

Kapusta G, Krausz RF (1993). Weed control and yield are equal in conventional, reduced-, and no-tillage soybean (Glycine max) after 11 years. Weed Technol. 7, 443-451.

Moyer JR, Roman ES, Lindwall WW, Blackshaw RE (1994). Weed management in conservation tillage systems for wheat production in North and South America. Crop Prot. 13, 243-259.

Ogg AG Jr., Young FL (1991). Effects of preplant treatment interval and tillages on herbicide toxicity to winter wheat (Triticum aestivum). Weed Technol. 5, 291-296.

(OMAFRA) Ontario Ministry of Agriculture, Food and Rural Affairs (2010). Guide to Weed Control. Publication 75, Toronto, ON, 355 pp.

Shaner DL (2000). The impact of glyphosate-tolerant crops on the use of other herbicides and on resistance management. Pest Manag. Sci. 56, 320-326.

Soltani N, Shropshire C, Sikkema PH (2009). Sensitivity of winter wheat to preplant and preemergence glyphosate tankmixes. Crop Prot. 28, 449-152.

Swan DG (1982). Long-term field bindweed (Convolvulus arvensis) control in two cropping systems. Weed Sci. 30, 476-480.

Triplett GB Jr, Lytle GD (1972). Control and ecology of weeds in continuous corn grown without tillage. Weed Sci. 20, 453-457.

VanGessel MJ, Ayeni AO, Majek BA (2001). Glyphosate in full-season no-till glyphsoate-resistant soybean: role of preplant applications and residual herbicides. Weed Tech. 15, 714-724.