Evaluation of New and Existing Desiccants in Lentil

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Abstract

Globally, herbicide resistance has become a major challenge for many producers. In western Canada, many lentil (*Lens culinaris* L.) producers have great difficulty controlling Group 2 resistant biotypes. Two of these problematic weeds, wild mustard (*Sinapis arvensis L.*) and kochia (*Kochia scoparia*), are particularly challenging for lentil growers and can cause extensive yield loss when not adequately controlled. Desiccation is primarily used to dry down lentil for harvest ease and efficiency but can also be used as a late season control for actively growing weeds. The objective of this project is to evaluate the response of wild mustard and kochia to different herbicides, tank mixed with two different rates of glyphosate (450 g a.e. ha^{-1} and 900 g a.e. ha^{-1}) at Saskatoon and Scott, Saskatchewan over a 2 year period. Desiccation occurred when the lentil seed moisture content was approximately 30%. Preliminary results are under investigation. Evaluation of seed and plant moisture of the treated plots is ongoing, along with an evaluation of the effects of the treatments on viability and vigour of affected weed seeds.

Introduction

Despite the fact that lentil (*Lens culinaris* Medik) is a relatively new crop to Saskatchewan, first introduced in 1969, it has become widely grown, particularly in the brown soil zone (Slinkard *et al.* 1990). Saskatchewan is the world's leading exporter of lentil and the centre of Canada's pulse industry, with nearly the country's entire lentil production produced in province (Saskatchewan Pulse Growers 2013). Due to the popularity of lentil crops within the province, there has been much research centred on increasing yields, weed management, disease resistance and reduced lodging (Sarker and Erskine 2006). Weed management in lentil crops is the most important factor in maintaining high yields at harvest (Erman *et al.* 2004). Yield losses due to weeds are approximately 14-100% in pulse crops (Swanton *et al.* 1993). Consequently, chemical research is centred on herbicides that can control the problematic weeds in lentil as it is a poor competitor with weeds. One of the innovations emanating from this research was the first imidazolinone (IMI) tolerant lentil variety from the University of Saskatchewan's Crop Development Centre (Chant 2004). IMI tolerance was bred into the crop, which allowed imazamox (Solo®) which was generally recommended, imazethapyr (Pursuit®), later on, a mixture of both herbicides as (Odyssey®), which are group 2 herbicides, to be sprayed in-crop for weed control without harming the lentil crop (Johnson 2006). While this innovation was good news to lentil producers within Saskatchewan and elsewhere, the development of weed resistance to Group 2 herbicides is becoming problematic for producers. Group 2 resistance is the most common form of resistance within weeds with 132 different weeds worldwide in 2013 (Heap, 2012). Apart from just Group 2 resistant cases, there are growing numbers of new resistance cases in many of the other commonly used herbicides on the market such as those in Groups 1, 4, and 9. This increasing trend of resistance has led to further development of tank mix products with two or more modes of action, improved weed management through herbicide rotations, and integrated weed management strategies (IWM).

Importance of Research

Herbicide resistance has become a major challenge for many producers globally. In Western Canada many lentil producers have great difficulty controlling Group 2 resistant biotypes. In Canada, there are 20 different Group 2 resistant weeds due to their relatively simple chemistry (Heap 2012). Two of these problematic weeds, wild mustard (*Sinapis arvensis L.*) and kochia (*Kochia scoparia*), are particularly challenging for lentil growers and can cause extensive yield loss when not adequately controlled. To reduce the pressure of these weeds and other Group 2 resistant biotypes in lentil crops, new herbicide options need to be considered. Desiccants are used by lentil growers to dry down lentil crops for harvest and to control established weed. The use of desiccants, particularly glyphosate, has been shown to reduce weed seed germination the following year in many weed species (Bennett and Shaw 2009). Many producers have begun to tank-mix herbicides to use as desiccants for enhanced weed control and dry-down of crop biomass in recent years. These mixtures of herbicides, which are used as, desiccants, may have different effects on the germination of the next generation of weeds as they work in different ways and varying speeds. For producers looking to reduce the number, or control Group 2 resistant weeds in their fields, or any producer looking to decrease the amount of viable seed or competitive weed seed in the seed bank, the use of these herbicides may be prove to be desirable. As this may be partially accomplished through the use of desiccants, it is important to determine which desiccants or mixtures of desiccant will have the best level of weed control as well as possibly reducing the seed bank population of problem weeds in the following years.

The premise behind this research for including glyphosate as a tank-mix partner with the other herbicides was the glyphosate maximum residual limit (MRL) trade issue in Europe for lentil crops. Previous limits for the glyphosate MRL was 0.1. ppm. As glyphosate is a common harvest aid in lentil, this limit was of concern to Canadian lentil producers as the MRL was considered low in Canada. Research at the University of Saskatchewan, is now being conducted to examine the effects of different herbicide tank-mix partners with glyphosate to understand how they affect the MRL levels in lentil seeds. With Group 2 resistant weeds increasingly becoming problematic for Canadian lentil producers, this research is intended to discover the efficacy of certain desiccants in lentil that can control these problem weeds. The results could then be compared to those studying the MRL limits to determine which combinations of herbicides would work best for controlling Group 2 resistant wild mustard and kochia, while ensuring that the MRL in lentil was under European regulations. The objective of this research is to evaluate the efficacy of desiccants on Exceed™ canola as a pseudo-weed for Group 2 resistant wild mustard and Group 2 resistant kochia within lentil. Results will provide lentil growers with the best herbicide options to control wild mustard and kochia in their fields as well as which tank mix option will best reduce weed seed viability of the developing seedlings the following year.

Materials and Methods

The trial was conducted at two locations (Saskatoon and Scott) Saskatchewan in the 2012 and 2013 seasons and are planned again for the 2014 season.

Plot sizes in Kernen and Scott were 2.25 by 6 meters and 2 by 5 meters, respectively, in 2012 and 2013. The soil type at Kernen was a silt loam with a pH value and organic matter content or 7.5 and 4.5% in 2012 and 2013. In Scott the soil type was a silty loam with pH and organic matter content of 5.3 and 2.6% respectively in 2013.

The experiment was set up as a one-way randomized complete block design (RCBD) with four replications. The plots in each block were seeded with CDC Maxim lentil, Exceed™ canola, and group 2 resistant kochia before being randomly assigned one of the 18 treatments for a total of 72 plots with boarder plots at the start and end of each replication. This trial was repeated twice at Kernen (2012 and 2013) and once at Scott (2013). The trial will be repeated again at both Scott and Kernen in 2014.

The experimental treatments consist of five herbicides alone and tank mixed with two different glyphosate rates for a total of eighteen treatments, including the untreated control. These treatments consist of three group 14 herbicides (flumioxazin, saflufenacil, and pyraflufen-ethyl), 1 group 10 (glufosinate), 1 group 22 (diquat), and one group 9 (glyphosate). The treatments and rates are listed in Table 1. The treatments were foliar applied when lentil moisture was approximately 30% as that is the recommended timing according to the Saskatchewan Ministry of Agriculture (Saskatchewan Ministry of Agriculture, 2014). The herbicide rates were determined by their label rates taken from the Saskatchewan Crop Protection Guide (Saskatchewan Ministry of Agriculture, 2014) with the glyphosate rates at full and half the registered rates, which 900g a.e. h^{-1} and 450g a.e. h^{-1} respectively.

Table 1: Herbicide treatments and rates in the evaluation trial at Kernen and Scott, Saskatchewan (2012, 2013).

Herbicide	Treatment	rate (g a.i./a.e. ha^{-1})
Untreated	1	0
Glyphosate	2	450
Glyphosate	3	900
Pyraflufen-ethyl	4	20
Pyraflufen-ethyl + Glyphosate	5	20 + 450
Pyraflufen-ethyl + Glyphosate	6	20 + 900
Glufosinate	7	600
Glufosinate + Glyphosate	8	600 + 450
Glufosinate + Glyphosate	9	600 + 900
Flumioxazin	10	210
Flumioxazin + Glyphosate	11	210 + 450
Flumioxazin + Glyphosate	12	210 + 900

Saflufenacil	13	36
Saflufenacil + Glyphosate	14	50 + 450
Saflufenacil +Glyphosate	15	50 + 900
Diquat	16	415
Diquat +Glyphosate	17	415 + 450
Diquat +Glyphosate	18	415 + 900

At Kernen, the experiment was established on land that had been chemical fallow the year prior, with maintenance tillage prior to the current two site years in order to control early season weeds. Site preparation included a pre-seed tillage application to control emerged weeds and a pre-seed application of glyphosate at a 900 g a.e./ha^{-1}. Lentil seed was inoculated with Liquid Nodulator® prior to seeding at a 2.76ml/kg rate. Seeding occurred on May 17, 2012 and May 12, 2013 with a small plot drill set to achieve a target density of 130 lentil plants per m^2 or 47 kg/ha^{-1}. Weed seeding took place the following day with both weeds being seeded to achieve a target plant density of 30 plants per m^2. The Exceed® canola was cross-seeded using the same seeder as the lentil, while the kochia was broadcasted on with a Valmar granular applicator. Plots were then rolled to ensure proper crop and weed emergence. Seeding depth was approximately 3cm for lentil and 2cm for the canola, with the kochia surface applied.

Herbicide treatments (Table 1) were applied when lentil seed moisture content was approximately 30% which is when the lower most pods are brown and rattle when shaken. To determine an approximate moisture samples from the boarder plots were collected and analyzed. Data collection consisted of several observations. Visual dry-down ratings were conducted at 3, 7, 14, and 21 (if needed) days after application (DAA) on a 0-100 scale with 0=no control and 100=full control. 14 day moisture ratings, lentil and weed yields, combined seed and straw moisture content, thousand seed weight and dockage data were also collected. Thousand seed weight and 14 day moisture contents have yet to be completely analyzed and included in this report.

Analyses of the data were conducted in SAS, using the Mixed Procedure, with the experimental design being conducted as a randomized complete block design (RCBD). Proc Univariate and Levene's test were used to test for the assumptions of variance and type III statistics were used to investigate the fixed effects. The herbicide treatments were considered as the fixed effects while the site year and replications were analyzed as random effects. Comparisons of treatments were done using the LSD method, with letter grouping, with a significance level of 0.05by PDMIX800 macro in SAS (Saxton, 1998).

Preliminary Results

Results were analyzed by site year as there no bases of consistency evaluate by location. For example lentil yield was not significantly affected by site year at Kernen, while the Exceed yield was significantly affected between the 2012 and 2013 seasons. Kochia yields and the combined seed and straw moisture contents consistently show significant to very strongly significant treatment effects. Exceed yields tended not to be significantly affected by treatments with the exception of Kernen 2013, while lentil yields were not affected at all.

Table 2: P-values derived from analysis of variance showing fixed factors combinations at Saskatoon and Scott, Saskatchewan in 2012 and 2013.

Site-year	Kochia Yield	Mustard Yield	Lentil Yield	Kochia TSW	Mustard TSW	Straw M	Seed M
	P values						
Kernen 2012	<.0001***	0.4149	0.4106	TBD	TBD	<.0001***	<.000.1***
Kernen 2013	0.4077	0.0260*	0.9632	TBD	TBD	0.0015**	0.0004**
Scott 2013	0.0220*	0.4794	0.3801	TBD	TBD	<.0001***	<.0001***

*, **,*** , significant at the 0.05, 0.01, and 0.001 probability levels, respectively.
TBD – To be determined

Yield

There was a significant difference in kochia yields at Kernen in 2012. Pyraflufen, saflufenacil alone, saflufenacil with a half rate of glyphosate, and a half rate of glyphosate alone did not differ significantly from the untreated check (Table 3). The three treatments of glufosinate provide the greatest reduction in kochia yields 376.75 kg ha^{-1} (no tank-mix), 373 kg ha^{-1} (with half rate), 601.5 kg ha^{-1} (with full rate). Both flumioxazin and diquat tank-mixes with full rates of glyphosate were significantly different from the untreated checks. Non-significant data was not included in Table 3 (Exceed yield 2012, kochia yield 2013, and lentil yields from all three site years).

At Kernen in 2013, the opposite results were observed. At this site, kochia yield response was unaffected while the Exceed canola response showed significant differences. Only glufosinate with a full rate of glyphosate was significantly different from the untreated check, though the other two glufosinate treatments were not significantly different from the glufosinate with full glyphosate treatments. Again, all three glufosinate treatments provided the greatest reduction in yields while the reminding treatments were not significantly different from the untreated check.

In 2013 at the Scott site, the same trend was observed wherein the three glufosinate treatments provided the greatest reduction in in kochia yield. Glyphosate at a half rate alone and with saflufenacil pyraflufen, and diquat, glyphosate at a full rate with flumioxazin, and pyraflufen alone were all not significantly different from the untreated check.

Table 3 Kochia and Exceed canola yield with various herbicide combinations at Saskatoon and Scott, Saskatchewan in 2012 and 2013.

Herbicide	Treatment	Rate	Yield Kernen 2012	 Kernen 2013	 Scott 2013
		g a.i./a.e. ha^{-1}	Kg ha^{-1}		
			Kochia	Mustard	Kochia
Untreated	1	0	1325.75 A	1099.26 ABCD	75.5 A
Glyphosate	2	450	1106.25 AB	1242.97 A	73.5 AB
Glyphosate	3	900	862.5 ABCD	1109.63 ABCD	49.25 BCDE
Pyraflufen-ethyl	4	20	1091.75 ABC	1012.22 ABCD	52.75 ABCDE
Pyraflufen-ethyl + Glyphosate	5	20+450	1017.5 ABC	985.56 ABCDE	62.5 ABCD
Pyraflufen-ethyl + Glyphosate	6	20+900	921.75 ABC	1152.22 ABC	49 BCDE
Glufosinate	7	600	376.75D	819.63 CDE	35.25 E
Glufosinate + Glyphosate	8	600+450	373 D	799.26 DE	33 E
Glufosinate + Glyphosate	9	600+900	601.5 CD	642.97 E	38 DE
Flumioxazin	10	210	1046.25 ABC	1249.63 A	56.25 ABCDE
Flumioxazin + Glyphosate	11	210+450	1020 ABC	1199.26 AB	44.25 CDE
Flumioxazin + Glyphosate	12	210+900	783.25BCD	1231.48 A	68.25 ABC
Saflufenacil	13	36	1094 ABC	988.89 ABCD	47.5 CDE
Saflufenacil + Glyphosate	14	50+450	1180.75 AB	1128.52 ABCD	60.75 ABCD
Saflufenacil +Glyphosate	15	50+900	912 ABC	1029.26 ABCD	49.25 BCDE
Diquat	16	415	891.5 ABC	855.93 BCDE	39.75 DE
Diquat +Glyphosate	17	415+450	889.5 ABC	850.37 CDE	57.5 ABCDE
Diquat +Glyphosate	18	415+900	719.25 BCD	974.45 ABCDE	39 DE

Straw Moisture

Harvest straw moisture was significantly affected by herbicide treatments at Kernen in 2012 (Table 2 and 4). Treatments containing pyraflufen and diquat were not significantly different from the untreated check. Glyphosate alone at the full rate and flumioxazin with a full rate of glyphosate provided the best dry down on the lentil and weeds (Table 4). Glufosinate with half and full glyphosate rate and saflufenacil with a full glyphosate rate also provided superior dry down compared to the other treatments Furthermore, contrasts of tank-mixes with half rates of glyphosate against glyphosate alone at a half rate showed no significant difference, while contrasts of the full rates tank-mixed against full rates of glyphosate showed significant differences. This may suggest that by increasing the rate of glyphosate available to be taken in by targeted plants more of it can move throughout the plant before its translocation is impeded by the contact herbicides.

Harvest straw moisture also was significantly affected by some herbicide treatments at Kernen in 2013. Flumioxazin, saflufenacil, diquat, pyraflufen and glufosinate alone and flumioxazin and glufosinate with half rates of glyphosate were not significantly different from the untreated check

(Table 2 and 4). The remaining treatments (other than pyraflufen with a half rate of glyphosate), such as saflufenacil and glufosinate with full rates of glyphosate and glyphosate alone provided greater dry down of the crop and weeds. Contrasts of half and full rates of glyphosate alone against tank-mixes both showed no significant differences.

Harvest straw moisture was significantly affected by treatments at Scott in 2013 (Table 2 and 4). Pyraflufen and flumioxazin were not significantly different from the untreated check. At this site saflufenacil alone and combined with a full rate or glyphosate provided the greatest dry-down but were not significantly different from a full rate of glyphosate, diquat, glufosinate, pyraflufen with full glyphosate rates, and diquat alone. Furthermore, results showed a similar trend to that of Kernen in 2012 with contrasts of tank-mixes of the other herbicides with half rates of glyphosate against glyphosate alone at a half rate showed no significant difference, while contrasts of the full rates of glyphosate tank-mixed with the other herbicides against full rates of glyphosate showed significant differences.

Table 4 Combined harvest straw moisture content at Saskatoon and Scott, Saskatchewan in 2012 and 2013

				Harvest straw moisture	
Herbicide	Treatment	Rate	Kernen 2012	Kernen 2013	Scott 2013
		g a.i./a.e. ha^{-1}		% Moisture	
Untreated	1	0	46.28 A	39.40 AB	40.62 A
Glyphosate	2	450	37.23 CDE	33.95 BCDE	19.45 CD
Glyphosate	3	900	23.16 J	28.08 E	12.45 EFG
Pyraflufen-ethyl	4	20	43.99AB	39.93 AB	35.62 AB
Pyraflufen-ethyl + Glyphosate	5	20+450	38.18 CDE	34.78 BCD	18.27 CDE
Pyraflufen-ethyl + Glyphosate	6	20+900	32.38FGH	33.68 BCDE	14.87 DEFG
Glufosinate	7	600	32.34 FGH	36.39 ABC	18.35 CDE
Glufosinate + Glyphosate	8	600+450	29.80 HI	36.22 ABC	17.32 CDE
Glufosinate + Glyphosate	9	600+900	30.77 GHI	30.49 CDE	16.15 CDEFG
Flumioxazin	10	210	40.62 BC	40.00 AB	36.02 AB
Flumioxazin + Glyphosate	11	210+450	35.25 EFG	36.49 ABC	20.32 CD
Flumioxazin + Glyphosate	12	210+900	27.33 IJ	30.41 CDE	34.05 B
Saflufenacil	13	36	41.49 BC	41.73 A	10.85 G
Saflufenacil + Glyphosate	14	50+450	35.67DEF	34.11 BCDE	21.6 C
Saflufenacil + Glyphosate	15	50+900	30.11 HI	28.54 DE	11.05 FG
Diquat	16	415	41.83 ABC	37.87 AB	16.6 CDEFG
Diquat + Glyphosate	17	415+450	39.52 BCDE	34.37 BCDE	17.05 CDEF
Diquat + Glyphosate	18	415+900	40.41 BCD	34.61 BCDE	16.1 CDEFG

Combined Seed Moisture

Combined seed moisture was the at harvest seed moisture content of all three plant species. The moisture content was significantly affected by treatments at Kernen in 2012 (Table 2 and 5). Pyraflufen, saflufenacil, and flumioxazin alone were not significantly different from the untreated check. Glufosinate alone and with both rates of glyphosate and flumioxazin provided the best reduction of seed moisture. Contrasts showed that neither half nor full rates of glyphosate tank-mixed with the other herbicides were significantly different from the contact herbicides without glyphosate as a tank-mix partner.

Kernen 2013 seed moisture contents showed a similar trend to Kernen 2012 where all three treatments of glufosinate provided the best reduction in seed moisture, but were not significantly different from saflufenacil, diquat with a half rate of glyphosate, pyraflufen mixed with a full rate of glyphosate, or a full rate of glyphosate applied on its own. Flumioxazin and saflufenacil alone were not significantly different from the untreated check. Contrasts of half and full rates of glyphosate alone against tank-mixes both showed no significant differences from the other herbicides when they were applied without glyphosate.

Harvest straw moisture was significantly affected by treatments at Scott in 2013 (Table 2 and 5). Flumioxazin was not significantly different from the untreated check. At this site pyraflufen alone, flumioxazin alone and at a half rate and glyphosate at a half rate were not significantly different and had greater seed moistures compared to the remaining treatments. Results showed a similar trend to that of Kernen in 2012 and 2013 with contrasts of half and full rates of glyphosate alone against tank-mixes both rates with the other herbicides showing no significant differences

Table 5 Combined harvest seed moisture content at Saskatoon and Scott, Saskatchewan in 2012 and 2013

				Combined seed moisture	
Herbicide	Treatment	Rate	Kernen 2012	Kernen 2013	Scott 2013
		g a.i./a.e. ha^{-1}		% Moisture	
Untreated	1	0	34.38 A	17.05 A	5.08 A
Glyphosate	2	450	23.09 CDEF	12.69 BCDE	3.43 BC
Glyphosate	3	900	19.66 EF	10.29 DEF	2.73 CDEF
Pyraflufen-ethyl	4	20	30.96 AB	13.36 BCD	3.28 BCDE
Pyraflufen-ethyl + Glyphosate	5	20+450	26.54 BCDE	11.83 CDE	2.80 CDEF
Pyraflufen-ethyl + Glyphosate	6	20+900	20.69 DEF	11.64 CDE	2.55 CDEF
Glufosinate	7	600	11.34 G	9.84 DEF	2.25 F
Glufosinate + Glyphosate	8	600+450	11.97 G	9.22 EF	2.45 DEF
Glufosinate + Glyphosate	9	600+900	11.84 G	7.89 F	2.58 CDEF
Flumioxazin	10	210	28.09 ABC	15.68 AB	4.13 AB
Flumioxazin + Glyphosate	11	210+450	27.34 BCD	12.15 BCDE	2.83 CDEF
Flumioxazin + Glyphosate	12	210+900	17.70 FG	11.16 DEF	3.40 BCD
Saflufenacil	13	36	28.14 ABC	15.09 ABC	2.68 CDEF
Saflufenacil + Glyphosate	14	50+450	24.29 BCDEF	12.62 BCDE	2.68 CDEF
Saflufenacil +Glyphosate	15	50+900	23.43 CDEF	9.97 DEF	2.35 EF
Diquat	16	415	26.29 BCDE	12.90 BCD	2.65 CDEF
Diquat +Glyphosate	17	415+450	24.62 BCDE	10.23 DEF	2.93 CDEF
Diquat +Glyphosate	18	415+900	21.74 CDEF	13.23 BCD	2.68 CDEF

Discussion

Using herbicides to control weeds at the preharvest stage is not the optimal timing. Each crop was a different period of weed control will help to maximize a crops yield by minimizing the negative effects of crop-weed competition. In imi-tolerant lentil, the critical period of weed control (CPWC) is at the five to six node stage (Fedoruk 2011). This means that the yield benefits on the lentil of controlling the weeds after this staging diminish as the crop is able to outcompete and suppress new weed seedlings that may germinate. At the pre-harvest stage concern over lentil yield in respect to weed control should not be a priority. Depending on the situation, a grower should be primarily concerned with maximizing the quality and the harvest efficiency of the lentil crop through desiccation use or harvest aids. If a situation arises where certain weed species have escaped prior control efforts then management of these populations may need to be primary concern in order to maintain an efficient harvest and help to manage the problem weed populations for future seasons.

This experiment consisted of two different types of herbicides, systemic and contact. Glyphosate, a systemic herbicide, is the slower acting herbicide as it has to be transported through a treated plants phloem and xylem in order to fully hinder a plants amino acid synthesis (Baumann, Dotray, and Prostko 2008). Contact herbicides like saflufenacil, diquat, glufosinate, flumioxazin, and pyraflufen have little or no movement within the plant and are often faster acting (Baumann, Dotray, and Prostko 2008). It has been suggested that contact herbicides provide faster acting results than systemic herbicides than that the faster acting contacts may impede the glyphosates ability to move throughout the plant.

Lentil yield was not negatively impacted by any of the treatments in this experiment. The control of the two weed species in this experiment was not significant for each species every year, though, when significance was shown, certain herbicides tended to have greater effects on final weed yields and seed moistures. Also, an expected general trend was found when tank-mixing glyphosate with the other herbicides, which was more control over yields and moisture contents than the contact herbicides had alone.

Weed control and the effectiveness of the herbicides tended to increase with the addiction of glyphosate at the half and full rates (450 and 900 g a.e. /h^{-1}). Glufosinate tended to provide the greatest and most consistent control of kochia, though the addition of glyphosate tank-mixes did not significantly reduce yields compared to glufosinate alone. Other herbicides such as diquat and saflufenacil tended to do slightly better than flumioxazin and pyraflufen with the general trend of glyphosate tank-mixes increasing the effectiveness at reducing kochia yield. With respect to glyphosate tank-mixed with the other herbicides on the Exceed, only at Kernen in 2013 had significant differences with respect to treatments, with glufosinate and glyphosate at a full rate providing the best control reduction in yield. Also, diquat tended to provide the next best control on the Exceed in 2013 at Kernen though tank-mixes of glyphosate were not significantly different from one another.

Straw moisture at all three site years had significant differences between the treatments and trend appears with full rates of glyphosate tank-mixed with providing the greatest benefit compared to a full rate of glyphosate alone. Glufosinate treatments tended to do well in all three site years along with a full rate of glyphosate applied without any contact herbicide partner. The application of glyphosate alone, at a full rate, providing the best control suggests that the addiction of the other herbicides tend to impede the glyphosates ability to move throughout the plant. Increases of glyphosate rates may ensure that more of the systemic herbicide can enter the plant to provide a greater dry-down of the entire plants before its movement is impeded by the effects of the contact herbicides on the plants. The treatments of just a full rate of glyphosate tended to have lower moisture levels than the contact herbicides mixed with full glyphosate rates. This trend seems to be supported by other research that suggests as glyphosate needs to move throughout the plant over time, faster acting contact herbicides can shut down plant functions which effectively provide a barrier to the translocation of glyphosate to other parts of the plant.

The combined seed moisture of all three plant species also showed significant differences between treatments. Similarly to straw moisture, glufosinate treatments provided the best and most consistent reduction of seed moisture across all three site years. Interestingly, pyraflufen with a full rate of glyphosate provided greater reduction in combined seed moisture content compared to the reductions of straw moisture and weed yields.

When trying to manage herbicide resistant weeds or any weed biotype, the goal is to continually reduce the weed population to a manageable threshold that will not have too great of an impact on crop yields. When targeting problem weeds at the desiccation timing, such as group 2 resistant kochia and wild mustard, reducing the amount of seeds that will be introduced into the seed bank will help future control of these problem weeds. Glufosinate provided the greatest reduction of weed yields, most notably kochia, in the field. It also did well on other aspects of desiccation such as reducing straw moisture that would be beneficial to growers combining at harvest. While tank mixtures of glyphosate did not always provide significantly greater control statistically, it is important to note that biologically, applying more than one mode of action greatly reduces the chances of weeds developing herbicide resistance. Also, managing resistance through tank-mixes insures that even if weeds are resistant to one herbicide, they and still be controlled by the other mode of action. With respect to kochia, which is also becoming increasing resistant to glyphosate, tank-mixes of glyphosate with other modes of action at any herbicide timing is important so growers will be able to rely on glyphosates benefits to the farmer such as its non-selective nature and relatively inexpensive cost.

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