HERBICIDE TOLERANCE TRAIT IN SOYBEAN: FLEXIBILITY OR COMPLEXITY

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Summary

1. The herbicide treatment used with herbicide traits is more important than trait and respective herbicide(s) applied with the trait.
2. Herbicide traits are opportunities for improved control of troublesome weeds when the herbicide treatment fails to provide control or deliver multiple effective herbicides.
3. Use both effective PRE and timely POST applications to manage weeds, regardless of the herbicide or herbicide trait.

Introduction

Weeds continue to concern sugarbeet producers (Soltani et al. 2018). Sugarbeet is a poor competitor with weeds from emergence to canopy closure (Cattanach et al. 1991). Sugarbeet cotyledons are small, lack vigor, and take roughly two months to shade ground between rows, thus providing ample time for weeds to establish and compete. Limited weed control options and herbicide resistance places sugarbeet at a disadvantage compared to other row crops (Soltani et al. 2018). A strategy to aid weed control in sugarbeet is to maximize weed management in the crop sequence with sugarbeet. Crop rotations introduces growth cycle diversification thus changing inputs including pesticides (Liebman and Dyck 1993) and changing weed spectrum and pressure resulting in increased crop yield (Peterson and Varvel 1989). Crop sequences across the region and cooperatives (Southern Minnesota Beet Sugar Cooperative, Minn-Dak Farmers' Cooperative, and American Crystal Sugar Company) all include soybean. Soybean producers in the United States, particularly in the Midwest, list waterhemp as one of their most troublesome weeds to control (Soltani et al. 2009). Waterhemp growth characteristics, including extended emergence patterns, cause waterhemp escapes since waterhemp may germinate, emerge, and produce seed after the producer has completed his / her weed control program.

Herbicide tolerant trait technologies, including Xtend and Liberty Link, have created POST herbicide options creating effective option for control of late germinating waterhemp in soybean, thus reducing seed in the soil seed bank while improving herbicide diversification throughout crop sequence with sugarbeet. The objective of this experiment was to evaluate herbicide treatments and trait technologies in soybean by considering waterhemp and common lambsquarters control, crop rotation flexibility, herbicide diversity, and cost. Our hypotheses is a weed management plan delivering multiple effective herbicides for lambsquarters and waterhemp control will improve overall control. Second, effective weed control can be achieved with multiple herbicide trait technologies thus providing opportunity for improved profitability. The question for producers is selecting a herbicide trait technology the first or last step in finalizing the weed management plan in soybean.

Materials and Methods

An experiment was conducted near Moorhead, MN in 2019. The experimental area was prepared for planting using a Kongskilde s-tine field cultivator on May 9, 2019. ND Stutsman conventional, AG0934 Roundup Ready2, S150097 LibertyLink, and AG07X9 Roundup Ready 2 Xtend soybean were planted in 22-inch rows at 160,000 seeds per acre on May 30 with a John Deere 1700XP 6-row planter. Herbicide trait technologies represent some of the many traits available to MN and ND producers in soybean (Table 1).

Experimental design was randomized complete block with four replications for each trial. Treatment arrangement was a two-factor factorial; factors being herbicide treatment and herbicide trait technology. PRE, EPOST, and POST herbicides were applied immediately after planting on May 31, June 19, and July 1, respectively. Herbicide treatment was a soil residual herbicide applied as single herbicide, a mixture, or PRE, and a soil residual herbicide EPOST followed by the herbicide conforming to the herbicide trait (i.e. Liberty applied to LibertyLink soybean) (Table 2). FlexStar was applied POST over conventional soybean. All herbicide treatments were applied with a bicycle sprayer in 17 gpa spray solution through 8002 XR flat fan nozzles pressurized with CO_2 at 40 psi to the center four rows of six row plots 30 feet in length. Environmental conditions at application are indicated in Table 3.

Table 1. Soybean herbicide-resistance traits and herbicides that can be used in combination with resistant traits. A checkmark indicates that soybean herbicide trait packages have resistance to various herbicide products.[a]

Soybean Herbicide Trait	Glyphosate	Glufosinate	2,4-D Choline[b]	Dicamba[c]	HPPD Inhibitors[d]
Conventional	✓				
Glyphosate Tolerant (GT)	✓				
Roundup Ready[e]	✓				
Roundup Ready 2 Yield[e]	✓				
Roundup Ready 2 Yield Xtend[e]	✓			✓	
Roundup Ready 2 Yield Xtendflex[e]	✓	✓		✓	
LibertyLink (LL)		✓			
LLGT27d	✓	✓			✓
Enlist	✓		✓		
Enlist E3	✓	✓	✓		
GT27	✓				✓

[a] Always consult herbicide labels for application requirements.
[b] Only approved 2,4-D choline formulations (Enlist Duo, Enlist One) are permitted for over-the top applications to Enlist and Enlist E3 soybeans.
[c] Only approved dicamba formulations (Engenia, FeXapan, Tavium, XtendiMax) are permitted for over-the-top application to Xtend and XtendFlex soybeans.
[d] GT27 and LLGT27 are resistant to isoxaflutole pre-emergence. No HPPD-inhibiting herbicide is approved for use in soybeans in the U.S. as of January 2020.
[e] Always consult herbicide label to determine if glyphosate formulation is approved for RR soybeans.
[f] Not approved for commercial production in the U.S. as of January 2020.

Table 2. Herbicide treatment in soybean

Herbicide treatment	Timing
Valor / Trait	PRE / POST
Valor[a] + Zidua / Trait	PRE / POST
Valor + Zidua / chloroacetamide[b] / Trait	PRE / EPOST /POST
Valor + Zidua + metribuzin / chloroacetamide / Trait	PRE / EPOST /POST

[a]Valor or Engenia, depending on seed trait
[b]Dual Magnum, Outlook, or Warrant depending on seed trait

Table 3. Application Information – Moorhead, MN 2019

Date	May 31	June 19	July 1
Time of Day	2:30 PM	1:00 PM	11:00 AM
Air Temperature (F)	79	76	77
Relative Humidity (%)	30	44	57
Wind Velocity (mph)	8	2	4
Wind Direction	N	SE	N
Soil Temp. (F at 6”)	65	66	70
Soil Moisture	Fair	Good	Good
Cloud Cover (%)	0	90	50
Next Rainfall	June 8	June 20	July 3
Soybean Stage	PRE	1 Trifoliolate	2 Trifoliolate
Common lambsquarters	0 in	3 in	9 in
Redroot Pigweed	0 in	2 in	9 in
Waterhemp	0 in	2 in	9 in

Soybean injury and common lambsquarters and waterhemp control described in this report were evaluated on June 26, July 15, and 25, 2019. All soybean injury and weed control evaluations were a visual estimate of percent fresh weight reduction in the four treated rows compared to the adjacent untreated strip. Data were analyzed with the ANOVA procedure of ARM, version 2019.4, software package.

Results

Visible soybean injury from herbicide treatments was negligible 26 DAP (days after planting) but increased to 40% when Liberty followed Fierce MTZ and Outlook 30 DAT (days after treatment) (70 DAP) (Tables 4-7). Soybean injury increased when either Zidua, metribuzin or a chloroacetamide herbicide was combined with Valor or Engenia. Soybean injury may have been exacerbated by Iron Deficiency Chlorosis (IDC) which increased soybean injury especially from Valor or Valor plus Zidua (Fierce) plus a chloroacetamide herbicide or Valor, Fierce, and metribuzin combined with the chloroacetamide herbicide. Soybean injury generally was not influenced by Flexstar, PowerMax, or Liberty applied with their respective herbicide trait technology POST.

Table 4. Soybean injury and common lambsquarters and waterhemp control in response to herbicide treatment in conventional soybean, Moorhead MN, 2019.

		Growth Reduction		Lambsquarters	Waterhemp
Herbicide Treatment	**Rate**	**26 DAP[a]**	**30 DAT[b]**	**38 DAT[c]**	**38 DAT**
	oz/A	%	%	%	%
Valor / Flexstar	2.5 / 12	3	3 c	45	98
Fierce / Flexstar	3 /12	0	16 b	68	99
Fierce + Dual Magnum / Flexstar	3 / 16 / 12	8	29 ab	45	99
Fierce MTZ + Dual Magnum / Flexstar	16 / 16 / 12	3	35 a	65	99
P-Value		0.3076	0.0011	0.2409	0.5896

[a]Growth reduction 26 days after planting (DAP).
[b]Growth reduction 30 days after treatment (DAT) or 70 DAP.
[c]Control 38 DAT or 78 DAP.

Table 5. Soybean injury and common lambsquarters and waterhemp control in response to herbicide treatment in Xtend soybean, Moorhead MN, 2019.

		Growth Reduction		Lambsquarters	Waterhemp
Herbicide Treatment	**Rate**	**26 DAP[a]**	**30 DAT[b]**	**38 DAT[c]**	**38 DAT**
	oz/A	%	%	%	%
Engenia / PowerMax	12.8 / 32	0	9 b	97	68
Engenia + Zidua / PowerMax	12.8 + 2.1 / 32	3	15 b	99	73
Engenia + Zidua / Warrant / PowerMax	12.8 + 2.1 / 40 / 32	0	31 a	99	83
Engenia + Zidua + Metribuzin / Warant / PowerMax	12.8 + 2.1+ 5 / 40 / 32	3	33 a	99	85
P-Value		0.4363	0.0355	0.4363	0.0623

[a]Growth reduction 26 days after planting (DAP).
[b]Growth reduction 30 days after treatment (DAT) or 70 DAP.
[c]Control 38 DAT or 78 DAP.

Common lambsquarters and waterhemp control was influenced by both herbicide treatment and herbicide with its respective herbicide tolerant trait (Tables 4-7). Some POST herbicide treatment and seed trait options provided over 95% lambsquarters and / or waterhemp control regardless of soil applied herbicides regardless of soil residual herbicide. For example, waterhemp control from FlexStar POST applied with conventional soybean, lambsquarters control from PowerMax POST applied with Xtend soybean and common lambsquarters and waterhemp control from Liberty POST applied with LibertyLink soybean provided 95% or greater control regardless of the soil residual herbicides.

Some soil applied herbicides mixtures improved lambsquarters or waterhemp control. For example, Fierce, Fierce plus metribuzin (Fierce MTZ), or Fierce MTZ and Dual Magnum EPOST fb PowerMax POST with RR2 soybean controlled greater than 95% lambsquarters compared to Valor PRE followed by PowerMax POST alone. Likewise, Fierce or Fierce MTZ and Dual Magnum EPOST followed by PowerMax POST provided greater than 95% waterhemp control compared to Valor or Fierce fb PowerMax POST with RR2 soybean.

Table 6. Soybean injury and common lambsquarters and waterhemp control in response to herbicide treatment in LibertyLink soybean, Moorhead MN, 2019.

		Growth Reduction		Lambsquarters	Waterhemp
Herbicide Treatment	**Rate**	**26 DAP[a]**	**30 DAT[b]**	**38 DAT[c]**	**38 DAT**
	oz/A	%	%	%	%
Valor / Liberty	2.5 / 32	0	21 b	95	92 b
Fierce / Liberty	3 /32	3	26 b	96	98 a
Fierce + Outlook / Liberty	3 / 10 / 22	0	37 a	95	99 a
Fierce MTZ + Outlook / Liberty	16 / 10 / 32	0	40 a	95	99 a
P-Value		0.4363	0.0354	0.9838	0.0495

[a]Growth reduction 26 days after planting (DAP).
[b]Growth reduction 30 days after treatment (DAT) and 70 DAP.
[c]Control 38 DAT or 78 DAP.

Table 7. Soybean injury and common lambsquarters and waterhemp control in response to herbicide treatment in Roundup Ready soybean, Moorhead MN, 2019.

		Growth Reduction		Lambsquarters	Waterhemp
Herbicide treatment	**Rate**	**26 DAP[a]**	**30 DAT[b]**	**38 DAT[c]**	**38 DAT**
	oz/A	%	%	%	%
Valor / PowerMax	2.5 / 32	0	13 b	88	69 b
Fierce / PowerMax	3 /32	0	28 a	99	86 a
Fierce + Dual Magnum / PowerMax	3 / 16 / 32	0	36 a	98	97 a
Fierce MTZ + Dual Magnum / PowerMax	16 / 16 / 32	5	37 a	97	96 a
P-Value		0.4363	0.0003	0.4326	0.0020

[a]Growth reduction 26 days after planting (DAP).
[b]Growth reduction 30 days after treatment (DAT) and 70 DAP.
[c]Control 38 DAT or 78 DAP.

Some herbicide and seed trait combinations did not provide 95% lambsquarters and waterhemp control. For example, Valor, Fierce, Fierce followed by (fb) Dual Magnum or Fierce MTZ fb Dual Magnum EPOST and followed by Flexstar POST failed to provide acceptable lambsquarters control. Likewise, Engenia (dicamba) substituted for Valor and followed by PowerMax POST failed to provide acceptable waterhemp control.

Table 8. Soybean injury and common lambsquarters and waterhemp control in response to Valor at 2.5 oz/A or Engenia at 12.8 fl oz/A PRE across herbicide traits in soybean, Moorhead MN, 2019.

		Growth Reduction		Lambsquarters	Waterhemp
Herbicide Trait	**Herbicide**	**26 DAP[a]**	**30 DAT[b]**	**38 DAT[c]**	**38 DAT**
		%	%	%	%
Conventional	Valor	3	8 b	45 b	98 a
Xtend	Engenia	0	9 b	97 a	68 b
LibertyLink	Valor	0	21 a	95 a	92 ab
Roundup Ready	Valor	0	13 b	88 a	79 ab
Average		1	13	81	84
P-Value		0.4363	0.0003	0.0008	0.0312

[a]Growth reduction 26 days after planting (DAP).
[b]Growth reduction 30 days after treatment (DAT) and 70 DAP.
[c]Control 38 DAT or 78 DAP.

Table 9. Soybean injury and common lambsquarters and waterhemp control in response to Fierce at 3 oz/A or Engenia plus Zidua SC at 12.8 fl oz + 2.1 oz/A PRE across herbicide traits in soybean, Moorhead MN, 2019[a].

		Growth Reduction		Lambsquarters	Waterhemp
Herbicide Trait	**Herbicide**	**26 DAP[a]**	**30 DAT[b]**	**38 DAT[c]**	**38 DAT**
		%	%	%	%
Conventional	Fierce	0	16	68 b	99 a
Xtend	Engenia + Zidua SC	3	15	99 a	73 b
LibertyLink	Fierce	3	26	96 a	98 a
Roundup Ready	Fierce	0	28	99 a	86 ab
Average		2	21	91	89
P-Value		0.4363	0.0759	0.0166	0.0223

[a]Growth reduction 26 days after planting (DAP).
[b]Growth reduction 30 days after treatment (DAT) and 70 DAP.
[c]Control 38 DAT or 78 DAP.

Soybean injury and common lambsquarters and waterhemp data was analyzed by herbicide treatment across herbicide trait technologies (Tables 8-11). Once again, soybean injury 26 DAP was negligible but increased and ranged from 8 to 39%, depending on herbicide treatment and herbicide trait 30 DAT / 78 DAP. Soybean injury tended to increase when Zidua, a chloroacetamide herbicide or metribuzin was combined with Valor (Figure 1).

Common lambsquarters and waterhemp control was dependent on herbicide treatment, herbicide trait, and respective POST herbicide (Tables 8-11). For example, lambsquarters and waterhemp control averaged across POST herbicides following Valor PRE provided 81% and 84% control, respectively (Figure 1) which is less than desirable.

Table 10. Soybean injury and common lambsquarters and waterhemp control in response PRE followed by EPOST treatments across herbicide traits in soybean, Moorhead MN, 2019[a].

		Growth Reduction		Lambsquarters	Waterhemp
Herbicide Trait	**Herbicide**	**26 DAP[a]**	**30 DAT[b]**	**38 DAT[c]**	**38 DAT**
		%	%	%	%
Conventional	Fierce / Dual Magnum	8	29	45 b	99 a
Xtend	Engenia + Zidual SC / Warrant	0	25	99 a	83 b
LibertyLink	Fierce / Outlook	0	31	95 a	99 a
Roundup Ready	Fierce / Dual Magnum	0	29	98 a	97 a
Average		2	29	84	95
P-Value		0.1298	0.8085	0.0001	0.0066

[a]Growth reduction 26 days after planting (DAP).
[b]Growth reduction 30 days after treatment (DAT) and 70 DAP.
[c]Control 38 DAT or 78 DAP.

Table 11. Soybean injury and common lambsquarters and waterhemp control in response PRE followed by EPOST and POST treatments across herbicide traits in soybean, Moorhead MN, 2019[a].

		Growth Reduction		Lambsquarters	Waterhemp
Herbicide Trait	**Herbicide**	**26 DAP[a]**	**30 DAT[b]**	**38 DAT[c]**	**38 DAT**
		%	%	%	%
Conventional	Fierce MTZ / Dual Magnum	3	35	65 b	99
Xtend	Engenia + Zidual SC + metribuzin / Warrant	3	29	99 a	85
LibertyLink	Fierce MTZ / Outlook	0	39	95 a	99
Roundup Ready	Fierce MTZ / Dual Magnum	5	39	97 a	96
Average		4	36	89	95
P-Value		0.6915	0.2477	0.0011	0.0515

[a]Growth reduction 26 days after planting (DAP).
[b]Growth reduction 30 days after treatment (DAT) and 70 DAP.

However, embedded within these averages, Valor fb Flexstar with conventional soybean provided 98% waterhemp control and Engenia fb PowerMax with Xtend soybean provided 97% common lambsquarters control and highlighting the need to review specific herbicide and trait combinations. We observed the same outcome when lambsquarters and waterhemp control was averaged across POST herbicides following more complex treatments. We believe lambsquarters and waterhemp control, in general, improved with more complex herbicide treatments since the number of effective herbicides in the treatment increased.

Effective herbicides were determined by considering weed control scores assigned to herbicides using the 2020 ND Weed Control Guide (Table 12). Herbicide treatment must provide 'good' or 'excellent' control for treatment to be considered an effective herbicide. Value in table is cumulative score for herbicides representing the treatment. In general, mixtures or sequential treatments increased the number of effective herbicides. Target should be a herbicide treatment delivering two or three effective herbicides. We believe greater than three effective herbicides is excessive but might be required for broad spectrum control.

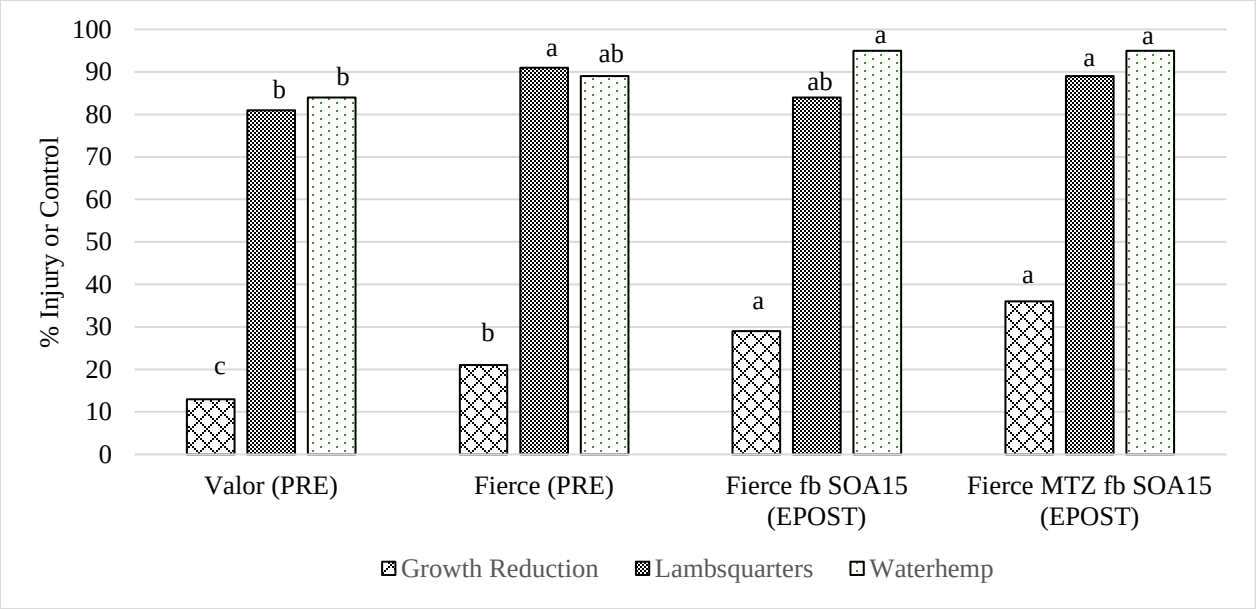

Figure 1. Soybean injury and common lambsquarters and waterhemp control in response to herbicide treatment averaged across herbicide trait, Moorhead MN, 2019.

Table 12. Effective sites of action against common lambsquarters or waterhemp.[a]

Herbicide Treatment	Flexstar		Roundup		LibertyLink		Xtend[b]		Avg.
	LQ[a]	WH	LQ	WH	LQ	WH	LQ	WH	
Valor	1	2	2	1	2	2	2	1	1.6
Fierce (Valor + Zidua)	1	3	2	2	2	3	2	2	2.1
Fierce / chloroacetamide	1	4	2	3	2	4	2	3	2.6
Fierce MTZ / chloroacetamide	1	5	2	4	2	5	2	4	3.1

[a]Abbreviation: LQ= common lambsquarters; WH= waterhemp; Avg = average.
[b]Includes glyphosate or dicamba.

We were interested in profitability plotted against performance metrics. Profitability was calculated by subtracting cost of the herbicide treatment and soybean seed plus trait technology fee from an estimate of revenue. Revenue was estimated simply as the average soybean yield in Cass county by $8.35 soybean per bushel. No application cost estimates were included since we applied herbicides using our owned equipment.

Performance metrics considered were less than 30% soybean injury (1 point), greater than 95% lambsquarters (1 point) and waterhemp control (1 point) and treatments containing at least two (1 point) or three (2 point) effective herbicides against lambsquarters or waterhemp.

The data suggests greater cost (less profitability) with treatments delivering more effective herbicides or treatments providing broad spectrum weed control. However, a more detail review of the analysis reveals that profitability is not as simple as selecting the cheapest trait. Profitability is a function of understanding your most important weed control needs for a field and matching it up against herbicide treatments and possible crop rotation restrictions that one may have depending on your crop sequence.

In my opinion, the take home message of this experiment is that while the new herbicide resistant traits provide opportunities for improved waterhemp or lambsquarters management, the herbicide system used with these traits is more important than the individual trait or their respective herbicide. This experiment emphasizes the importance of using both effective PRE and timely POST applications to manage waterhemp and / or lambsquarters, regardless of the herbicide or trait.

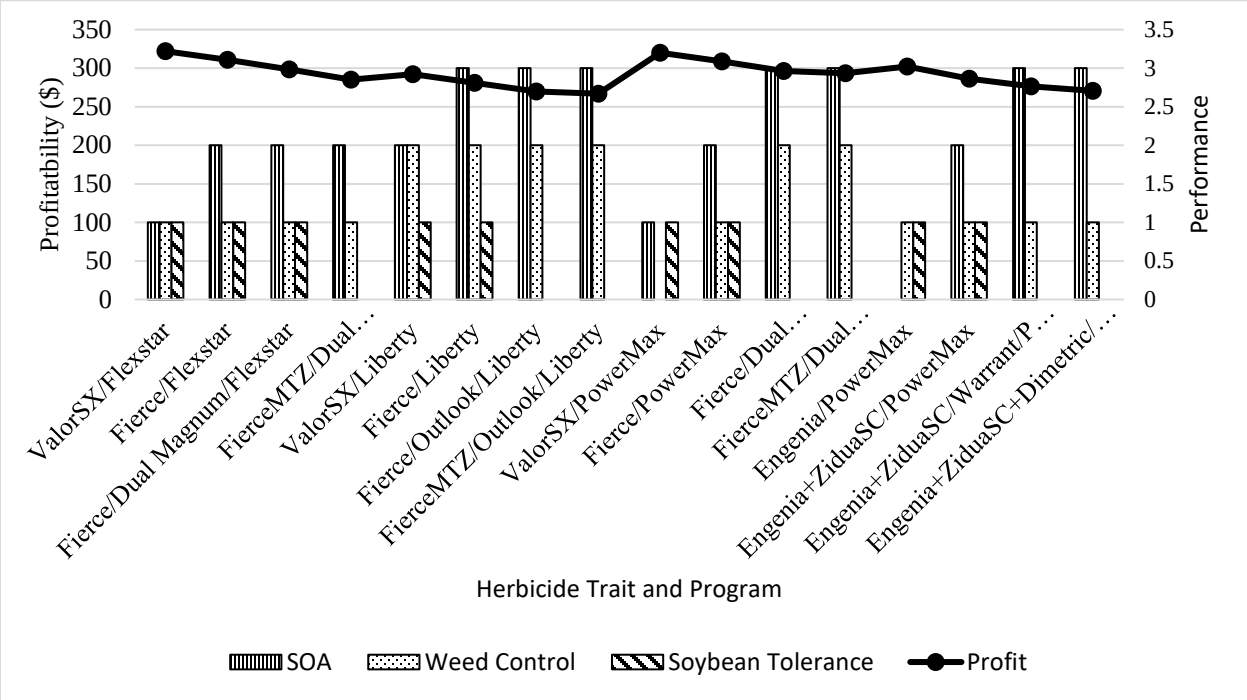

Figure 2. Herbicide treatment and trait performance plotted against profit (revenue minus herbicide treatment and trait cost)

Conclusions

Herbicide treatments (mixtures or PRE fb POST combinations) provided greater than 95% lambsquarters and waterhemp control. Herbicide mixtures usually provide multiple effective sites of action. Herbicide traits use strategically solve field specific weed control challenges. Finally, profitability is more complex than simply plotting the cost of herbicide treatment and herbicide trait.

References

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