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Yearly Report

Project Title:

Impact of 2,4-D drift on Non 2,4-D-Tolerant Soybeans

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Auxin type herbicides (eg. dicamba, 2,4-D) have been an integral component of major cropping systems in North America for the last 50 years. With the recent launching of Enlist E3 soybean in the U.S., in-season application of 2,4-D to soybean fields is expected to significantly increase. This will enable use of Enlist One and Enlist Duo herbicides thus broadening farmers' flexibility in controlling tough-to-control broadleaf and grass weeds including glyphosate-resistant biotypes. Despite the availability of new Enlist herbicides with low volatility, their potential off-target movement still represents a major threat to non 2,4-D tolerant soybean as well as other broadleaf crops. Furthermore, the negative impact of 2,4-D drift on non-2,4-D tolerant crops may vary with the rate of the herbicide, crop type and/or growth stage at time of drift occurrence Since the majority of soybeans are not tolerant to 2,4-D, it is important to understand the potential impact of 2,4-D drift on non 2,4-D tolerant soybean. Therefore, a field study was initiated in 2019 (and will be repeated in 2020) to measure the impact of 2,4-D micro-rates on four non 2,4-D tolerant soybeans (Dicamba-Tolerant, Roundup Ready, Liberty-Link and Conventional soybean).

Study Procedure

A field trial was conducted in 2019 at Haskell Ag Lab, Concord, NE. The study was laid out in a randomized complete block design with eight replications and a split-split-plot arrangement. The main plot treatments consisted of three application times [second trifoliate (V2); beginning of flowering (R1); and full flowering (R2)]; the sub plot treatments consisted of six micro rates of 2,4-D (1/5; 1/10; 1/50; 1/100; 1/500; and 1/1000 of the label recommended rate (32 oz/A) and a check with no herbicide applied; and the sub-sub plot treatments consisted of four soybean types (Dicamba-Tolerant, Roundup Ready, Liberty-Link, and Conventional). The first application time (V2) simulates early-season 2,4-D drift, and the remaining application times (R1 and R2)

simulate late-season 2,4-D drift when planting in neighboring fields is delayed. Several factors can lead to delay in planting (e.g. logistics, weather). To assess the impact of potential 2,4-D drift, visual injury ratings (VIR) on a scale of 0 (no injury) to 100% (complete injury) and plant height (PLHT; inches) measurements were collected at 7, 14 and 21 days after treatment (DAT). In addition, soybean yields were also collected. All data were analyzed in R-statistical software by regressing VIR, PLHT and soybean yield over 2,4-D micro rates.

Results:

Note: The results of the 2,4-D effects are primarily discussed. However, to make the text a bit more interesting, in several instances the comparisons between dicamba and 2,4-D were made.

Soybean Injury

Based on the first year of data, soybean injuries increased with increase in 2,4-D micro rates regardless of application time and soybean type. Furthermore, highest injuries were observed when 2,4-D was applied at beginning of flowering (R1) versus second trifoliate (V2) and full flowering (R2) stages regardless of soybean type (Figure 1). Across all soybean types, the 2,4-D applications at the V2 stage has resulted in similar at 14 and 21 DAT (Figure 1). For example, the 1/10 of the label recommended dose of 2,4-D (3.2 oz A^{-1}) was required to cause 5-20% injury to all soybean types at 14 and 21 DAT. All soybean types were more sensitive to 2,4-D at R1 and R2 stages (Tables 1 and 2) suggests that soybean is more sensitive at reproductive than vegetative stages.

It is interesting to note that the same rate (1/10) of dicamba, caused significantly higher (60-80%) visual injury of sensitive soybeans., suggesting that dicamba herbicide has potential to cause 3-4X more visual injury of sensitive soybeans than 2,4-D.

Soybean Height

Impact of 2,4-D micro-rates on soybean height was clear with similar trends observed across all soybean types both at 14 and 21 DAT (Figure 2). In general, soybean height increased with delay in application time. The 2,4-D application at the second trifoliate stage (V2) had greater impact on soybean height than the beginning of flowering (R1) and full flowering (R2) stages (Figure 2). Soybean height at the latter stage, R2, was the least impacted by 2,4-D than other application timings. Despite the impact of 2,4-D on plant height, soybean continued to grow. For example, when 2,4-D was applied at V2, all soybean types grew 4-5 inches from 7 to 14 and 14 to 21DAT (data not shown). About 1/10 of the label recommended dose of 2,4-D (3.2 oz A^{-1}) was required to reduce plant height by 5-20% across all soybean types and application timings both at 14 and 21 DAT (Tables 3 and 4).

Soybean Yield

Data analysis based on only 1 year of data revealed that soybean yield was significantly impacted by 2,4-D micro-rates regardless of soybean type and application timing. It is worth noting, however, that differences between application timings were not clear except in LLSB (Table 5). Unsprayed (control) plots with DTSB, RRSB, LLSB and CONVSB yielded approximately 67, 72, 66 and 68 bu/A, respectively. However, when the same soybeans were sprayed at the V2 stage with 1/10 of the label recommended dose of 2,4-D (3.2 oz/A), the yields

were reduced (6-15 bush) to 61, 57, 51 and 54 bu/A, respectively. Furthermore, when the same 1/10 rate was applied at R1 stage the DTSB, RRSB, LLSB and CONVSB yielded 54, 55, 52 and 51 bu/A, respectively. When the highest dose of 2,4-D (6.4 oz/A) was sprayed at the V2, R1 and R2 stages, however, DTSB yielded 53, 52 and 50 bu/A, RRSB yielded 43, 51 and 53 bu/A, LLSB yielded 45, 45 and 53 bu/A, and CONVSB yielded 43, 44 and 44 bu/A, respectively. In general, soybean yield was mostly affected by 2,4-D when sprayed at the R1 stage except LLSB. It could be argued, therefore, that soybean seems to be more sensitive to potential 2,4-D drift at reproductive stages.

Soybean Yield Loss

In general, yield losses increased with dose of 2,4-D regardless of soybean type (Figure 3). Yield losses ranged from 0 to 28, 0 to 52, 7 to 36.3 and 5.4 to 38.7% when the dose of 2,4-D sprayed at the V2 stage on DTSB, RRSB, LLSB and CONVSB, respectively, was increased from 0.032 (1/100) to 6.4 oz/A (1/5). When DTSB, RRSB, LLSB and CONVSB were sprayed at the R1 stage with 2,4-D dose ranging from 0.032 (1/100) to 6.4 (1/5) oz/A, yield losses increased from 0 to 20.1, 0 to 17, 4.6 to 35.2 and 0 to 35.4%, respectively. The risk of yield loss was less than or equal to that at V2 and R1 when 2,4-D was applied at the R2 stage regardless of soybean type (Figure 3). Increasing the dose of 2,4-D sprayed at the R2 stage on DTSB, RRSB, LLSB and CONVSB from 0.032 to 6.4 oz/A increased yield losses from 0 to 15.5, 1.2 to 21.1, 0 to 17 and 4.7 to 20%, respectively. Based on ED value estimates (Table 6), the reproductive stages (R1 and R2) were more sensitive to 2,4-D than V2 regardless of soybean type. With the exception of LLSB, all other soybeans ED value estimates at R1 were consistently less than those at R2 and V2 (Table 6). This suggests that soybean sensitivity to 2,4-D seems to vary with growth stage

and that R1is more sensitive to yield loss due to 2,4-D than R2 and V2 stages. The latter, on the other hand, seems to be the stage at which soybean is the least sensitive to 2,4-D. Furthermore, this study clearly shows that all soybean types are sensitive to 2,4-D but sensitivity seems to vary depending on the type of soybean.

Summary, Conclusions and Implications

Results from this study clearly showed that all soybean types (DTSB, RRSB, LLSB and CONVSB) were sensitive to micro-rates of 2,4-D but the degree of sensitivity varied depending on growth stage at time of herbicide application as well as soybean type. The V2 stage was the least, while the R1 was the most sensitive to 2,4-D.

Increase in visual injury and reduction in both plant height and grain yield clearly delayed canopy closure especially when earlier application timings were targeted (data not shown). This delay in canopy closure and reduction in plant height were a result, in part, of a more stunted and epinastic growth following 2,4-D application especially in younger plants. Potential implications of this includes reduced crop competitiveness against weeds. It is also worth noting, however, that flowering and maturity were delayed (data not shown) which could potentially pushback harvesting as well as planting of subsequent crops in double crop soybean systems. Delaying harvesting, on the other hand, could subject soybean to early frost damage. Therefore, it is important to prevent potential 2,4-D drift onto non-2,4-D tolerant soybean.

On the end of this report, lets compared results from 2,4-D to Dicamba. The largest impact of 2,4-D was during the reproductive growth stages, which is similar to the impact of dicamba. However, dicamba had much more negative impact than 2,4-D. For example, 1/10 of dicamba rate caused 60-80% visual injury of sensitive soybeans while the same rate of 2,4-D

causing only 5-20% injury. Furthermore, the same dicamba rate (1/10) reduced soybean yields by 45-65 bushels (as mush as 90%) compared to 10-20 bushels (as much as 35%) with 2,4-D. It is clear that dicamba has potential to cause significantly higher (likely 3X) visual injury and yield loss of sensitive soybeans than 2,4-D.

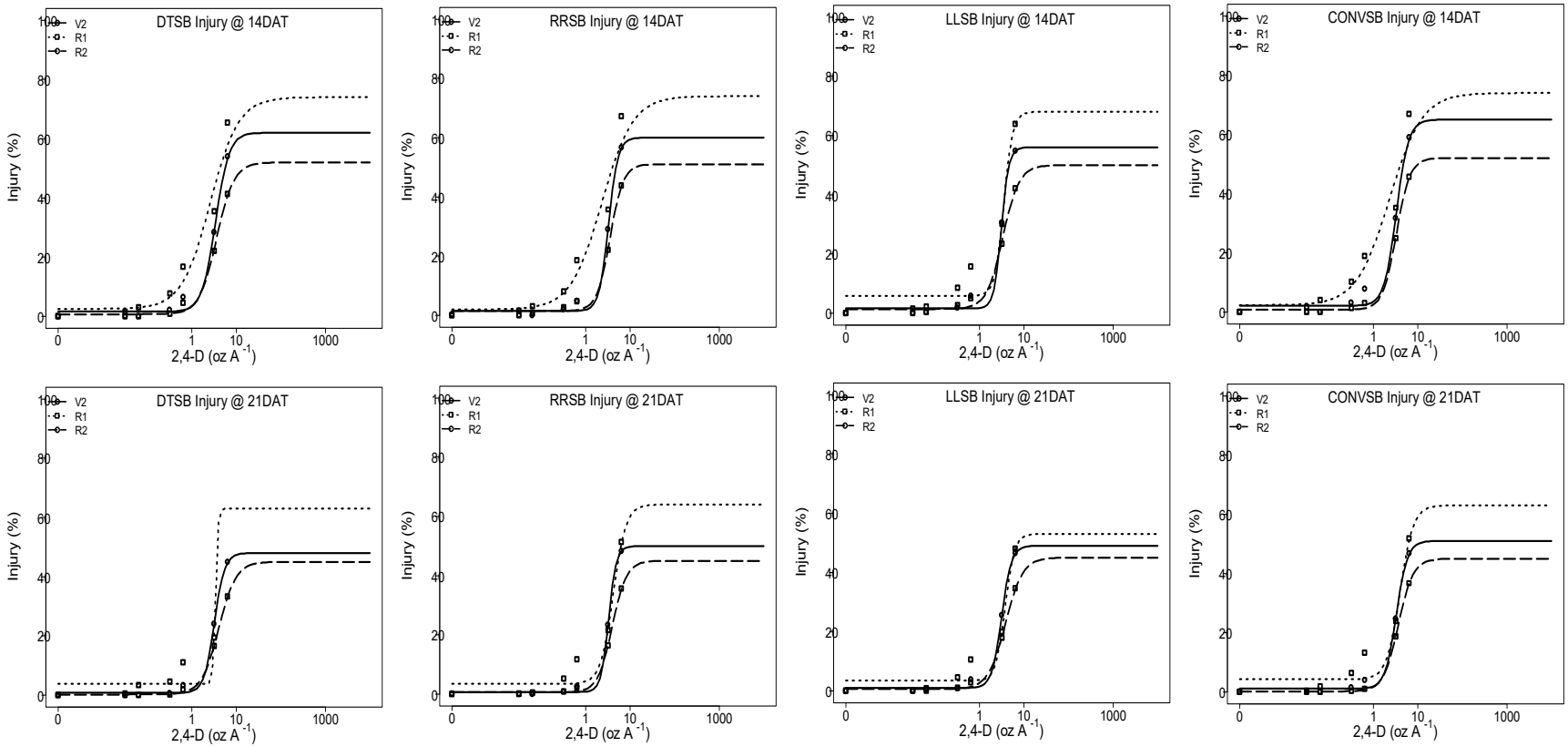

Figure 1. Dicamba-tolerant (DTSB), Roundup-Ready (RRSB), Liberty-Link (LLSB) and conventional (CONVSB) soybean injury caused by micro-rates of 2,4-D at 14 and 21 days after treatment (DAT) at second trifoliate (V2), beginning of flowering (R1) and full flowering (R2) stages.

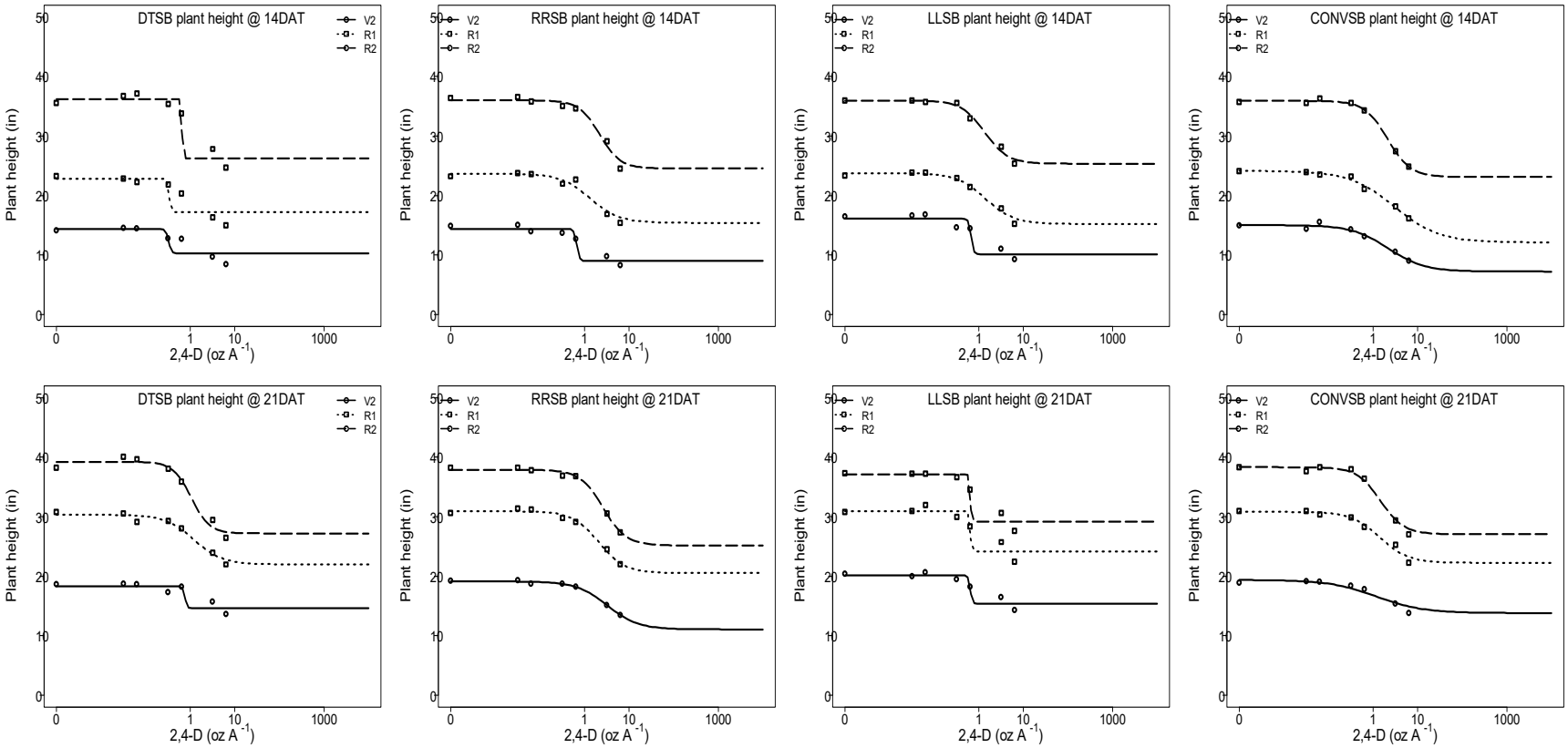

Figure 2. Dicamba-tolerant (DTSB), Roundup-Ready (RRSB), Liberty-Link (LLSB) and conventional (CONVSB) soybean plant height as impacted by micro-rates of 2,4-D at 14 and 21 days after treatment (DAT) at second trifoliate (V2), beginning of flowering (R1) and full flowering (R2) stages.

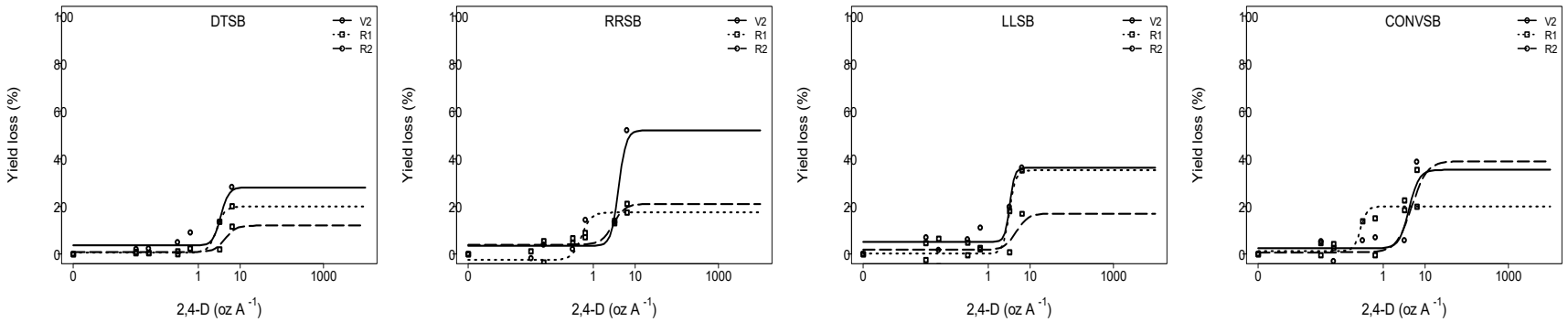

Figure 3. Dicamba-Tolerant (DTSB), Roundup-Ready (RRSB), Liberty-Link (LLSB) and Conventional soybean yield loss as impacted by micro-rates of 2,4-D at second trifoliate (V2), beginning of flowering (R1) and full flowering (R2) stages.

Table 1. Dose of 2,4-D that resulted in 5, 10 and 20% injury in Dicamba-Tolerant, Roundup-Ready, Liberty-Link and Conventional soybeans 14 DAT at three growth stages

Soybean type	App/stage	ED_5 (SE)	ED_{10} (SE)	ED_{20} (SE)
		---------- 2,4-D in oz A^{-1} ----------		
Dicamba-Tolerant	V2	1.21 (0.14)	1.58 (0.14)	2.10 (0.13)
	R1	0.29 (0.13)	0.51 (0.18)	0.93 (0.24)
	R2	0.97 (0.32)	1.35 (0.35)	1.95 (0.35)
Roundup Ready	V2	1.60 (0.10)	1.92 (0.09)	2.34 (0.07)
	R1	0.21 (0.07)	0.39 (0.11)	0.76 (0.16)
	R2	1.31 (0.14)	1.69 (0.14)	2.22 (0.13)
Liberty-Link	V2	1.77 (0.26)	2.04 (0.23)	2.39 (0.18)
	R1	1.80 (0.25)	2.14 (0.22)	2.57 (0.17)
	R2	0.97 (0.22)	1.33 (0.23)	1.87 (0.23)
Conventional	V2	1.30 (0.17)	1.65 (0.17)	2.13 (0.15)
	R1	0.19 (0.07)	0.35 (0.11)	0.71 (0.17)
	R2	1.18 (0.13)	1.53 (0.13)	2.03 (0.13)

Table 2. Dose of 2,4-D that resulted in 5, 10 and 20% injury in Dicamba-Tolerant, Roundup-Ready, Liberty-Link and Conventional soybeans 21 DAT at three growth stages

Soybean type	App/stage	ED_5 (SE)	ED_{10} (SE)	ED_{20} (SE)
		---------- 2,4-D in oz A^{-1} ----------		
Dicamba-Tolerant	V2	1.47 (0.15)	1.79 (0.14)	2.22 (0.12)
	R1	2.81 (1.57)	2.96 (1.06)	3.12 (0.53)
	R2	1.09 (0.29)	1.52 (0.31)	2.18 (0.31)
Roundup Ready	V2	1.84 (0.11)	2.14 (0.10)	2.51 (0.07)
	R1	1.58 (0.23)	2.03 (0.22)	2.65 (0.21)
	R2	1.34 (0.14)	1.76 (0.14)	2.38 (0.14)
Liberty-Link	V2	1.50 (0.16)	1.81 (0.15)	2.22 (0.12)
	R1	1.86 (0.19)	2.22 (0.18)	2.70 (0.15)
	R2	1.04 (0.18)	1.45 (0.19)	2.07 (0.19)
Conventional	V2	1.40 (0.15)	1.74 (0.15)	2.20 (0.13)
	R1	1.44 (0.28)	1.86 (0.28)	2.46 (0.26)
	R2	1.18 (0.13)	1.57 (0.14)	2.14 (0.14)

Table 3. Dose of 2,4-D that resulted in 5, 10 and 20% reduction in plant height in Dicamba-Tolerant, Roundup-Ready, Liberty-Link and Conventional soybeans 14 DAT at three growth stages

Soybean type	App/stage	ED_5 (SE)	ED_{10} (SE)	ED_{20} (SE)
		---------- 2,4-D in oz A^{-1} ----------		
Dicamba-Tolerant	V2	0.26 (0.01)	0.28 (0.01)	0.29 (0.01)
	R1	0.30 (0.01)	0.31 (0.01)	0.32 (0.02)
	R2	0.60 (0.01)	0.62 (0.01)	0.64 (0.01)
Roundup Ready	V2	0.55 (0.01)	0.58 (0.01)	0.61 (0.01)
	R1	0.14 (0.03)	0.25 (0.06)	0.46 (0.12)
	R2	0.45 (0.08)	0.67 (0.12)	1.04 (0.19)
Liberty-Link	V2	0.56 (0.02)	059 (0.02)	0.62 (0.02)
	R1	0.15 (0.05)	0.27 (0.09)	0.49 (0.17)
	R2	0.23 (0.07)	0.36 (0.11)	0.58 (0.18)
Conventional	V2	0.55 (0.02)	0.57 (0.02)	0.61 (0.02)
	R1	0.30 (0.02)	0.31 (0.02)	0.32 (0.02)
	R2	0.26 (0.08)	0.41 (0.12)	0.67 (0.20)

Table 4. Dose of 2,4-D that resulted in 5, 10 and 20% reduction in plant height in Dicamba-Tolerant, Roundup-Ready, Liberty-Link and Conventional soybeans 21 DAT at three growth stages

Soybean type	App/stage	ED_5 (SE)	ED_{10} (SE)	ED_{20} (SE)
		---------- 2,4-D in oz A^{-1} ----------		
Dicamba-Tolerant	V2	0.65 (0.18)	0.67 (0.19)	0.70 (0.20)
	R1	0.13 (0.04)	0.23 (0.08)	0.43 (0.15)
	R2	0.32 (0.13)	0.45 (0.18)	0.67 (0.26)
Roundup Ready	V2	0.30 (0.18)	0.56 (0.27)	1.07 (0.55)
	R1	0.28 (0.16)	0.47 (0.26)	0.81 (0.46)
	R2	0.45 (0.21)	0.71 (0.33)	1.15 (0.54)
Liberty-Link	V2	0.56 (0.01)	0.58 (0.01)	0.60 (0.01)
	R1	0.59 (0.01)	0.60 (0.01)	0.62 (0.01)
	R2	0.60 (0.01)	0.61 (0.01)	0.62 (0.01)
Conventional	V2	0.03 (0.01)	0.08 (0.03)	0.22 (0.09)
	R1	0.16 (0.04)	0.28 (0.07)	0.51 (0.13)
	R2	0.24 (0.08)	0.39 (0.12)	0.63 (0.21)

Table. 5. Dicamba-Tolerant, Roundup-Ready, Liberty-Link and Conventional soybean yield as influenced by 2,4-D micro-rates at three growth stages

Soybean type	App/stage	2,4-D (32 Oz/A)						
		0	1/1000	1/500	1/100	1/50	1/10	1/5
Dicamba-tolerant	V2	68 (2)	69 (3)	70 (4)	66 (3)	64 (3)	61 (4)	53 (2)
	R1	67 (2)	67 (3)	66 (3)	65(1)	64 (3)	55 (2)	52 (2)
	R2	65 (1)	66 (5)	64 (2)	66 (4)	63 (3)	60 (2)	50 (3)
Roundup Ready	V2	67 (1)	64 (2)	65 (2)	64 (1)	63 (1)	57 (3)	43 (1)
	R1	73 (2)	68 (1)	66 (1)	59 (2)	56 (1)	55 (1)	51 (1)
	R2	75 (1)	68 (2)	67 (2)	61 (2)	59 (1)	57 (2)	53 (1)
Liberty-Link	V2	67 (1)	61 (1)	61 (1)	53 (1)	55 (1)	51 (2)	45 (1)
	R1	66 (1)	64 (1)	64 (1)	61 (1)	60 (3)	52 (1)	45 (2)
	R2	65 (1)	63 (1)	61 (1)	60 (1)	59 (1)	54 (1)	53 (1)
Conventional	V2	67 (1)	60 (1)	58 (1)	57 (2)	54 (1)	54 (3)	43 (1)
	R1	72 (2)	65 (1)	57 (1)	54 (2)	55 (1)	51 (2)	44 (1)
	R2	66 (1)	60 (1)	61 (1)	60 (1)	55 (1)	49 (2)	44 (1)

Table 6. Dose of 2,4-D that resulted in 5, 10 and 20% yield loss in Dicamba-Tolerant, Roundup-Ready, Liberty-Link and Conventional soybeans at three growth stages

Soybean type	App/stage	ED_5 (SE)	ED_{10} (SE)	ED_{20} (SE)
		---------- 2,4-D in oz A^{-1} ----------		
Dicamba-Tolerant	V2	1.80 (0.21)	2.12 (0.25)	2.54 (0.30)
	R1	1.37 (0.17)	1.62 (0.20)	1.96 (0.24)
	R2	1.83 (0.41)	2.28 (0.52)	2.89 (0.66)
Roundup Ready	V2	2.20 (0.27)	2.57 (0.31)	3.03 (0.37)
	R1	0.24 (0.08)	0.29 (0.10)	0.364 (0.13)
	R2	1.15 (0.51)	1.47 (0.65)	1.91 (0.85)
Liberty-Link	V2	2.19 (0.19)	2.42 (0.21)	2.69 (0.23)
	R1	1.89 (0.15)	2.16 (0.18)	2.49 (0.20)
	R2	1.76 (0.42)	2.25 (0.54)	2.95 (0.71)
Conventional	V2	1.86 (0.31)	2.28 (0.38)	2.84 (0.47)
	R1	0.17 (0.05)	0.19 (0.05)	0.22 (0.06)
	R2	1.40 (0.29)	1.91 (0.40)	268 (0.57)