2015 Annual Progress Report
for the
Agriculture Demonstration of Practices and Technologies (ADOPT) Program

Project Title: Optimal Seeding Rate with Plant Growth Regulators (PGRs) and Fungicides for Spring Wheat

Project Number: 201403041

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Project Location(s): The project is conducted at the AAFC Scott Research Farm. Legal land description: NE 17 39 20 W3

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Objectives and Rationale

Project objectives

The objective of this demonstration was to provide information on the yield benefits associated with increasing seeding rate in spring wheat accompanied by plant growth regulators to reduce risk of crop lodging and fungicides to reduce risk of leaf and head disease.

Project Rationale

Farmers may see a benefit of increasing spring wheat seeding rate above the recommended rates when targeting higher grain yields. A more dense plant stand allows the crop to compete better with weeds. Higher seed rates reduce tillering meaning that a higher proportion of heads reach flowering stage at the same time, which could be beneficial in timing of fusarium head blight control. This in turn could enhance both yield and quality of the crop. However, increased seeding rates may also create an environment that is more conducive to disease as higher seeding rates tend to induce increased lodging of wheat. Lodging risk may be reduced with the use of plant growth regulators (PGRs).

Previous demonstrations conducted by Agri-ARM sites has shown that wheat yields can be increased by increasing seeding rates; however, there is a point when the benefits of an increased plant population do not outweigh the costs of additional seed. As seeding rate is increased, there is a point above which lodging becomes more severe and also reduced the benefit of the higher seeding rate. Local demonstrations from retailers in 2013 have shown PGRs to considerable reduce lodging and increased yields of spring wheat. This project will demonstrate to local producers the potential yield and grain quality benefits that can be achieved by increasing plant populations in combination with application of PGRs and fungicides.

Methodology and Results

This demonstration was conducted at the AAFC Scott Research Farm in 2015. The demonstration was a 2 x 2 x 4 (PGR, fungicides and seeding rate, respectively) factorial in a randomized complete block design with four replicates. Plots were seeded at 100, 200, 300 or 400 seeds/m^2. A PGR (Manipulator™) was either applied to plots at Zadoks growth stage 31 or left "untreated". A fungicide (Caramba) was either applied to plots at 50 % anthesis or left "untreated". A lodging susceptible spring wheat variety, (Shaw VB) was direct seeded using an R-Tech plot drill in 10 inch row spacing and at a depth of 3-4cm (See Table 1 for complete treatment list). Fertilizer was applied at seeding according to soil test recommendations. Weeds were controlled using a pre-seed burndown and registered in-crop herbicides and fungicide was applied according to the treatments (See Appendix, Table A.1 for complete details of field maintenance activities).

Table 1. Detailed treatment list for the "*Optimal Seeding Rate with Plant Growth Regulators (PGRs) and Fungicides for Spring Wheat*" at Scott, Saskatchewan, 2015.

Treatment #	Seeding Rate (seeds/m^2)	PGR	Fungicide
1	100	No	No
2	200	No	No
3	300	No	No
4	400	No	No
5	100	Yes	No
6	200	Yes	No
7	300	Yes	No
8	400	Yes	No
9	100	No	Yes
10	200	No	Yes
11	300	No	Yes
12	400	No	Yes
13	100	Yes	Yes
14	200	Yes	Yes
15	300	Yes	Yes
16	400	Yes	Yes

Plant densities were assessed when there were visible rows to determine plant emergence among treatments. These were assessed by counting two 1 m rows in the front and back of the plot for a total of four rows per plot. The average of the four rows was converted to plants per m^{-2} based on 10 inch row spacing. This was done to determine how the different seeding rates achieved recommended plant density. Due to the dry spell at the onset of the growing season, no lodging and disease conditions were encountered, so lodging and % FDK will not be reported in the results. Grain yields were determined after plots were mechanically harvested, cleaned and corrected to 14.5 % seed moisture. Test weights were determined using the Canadian Grain Commission protocols and percent protein was determined at the Scott Research Farm laboratory. Seed samples were sent to Intertek for % FDK and grade determination.

Statistical Analysis

An analysis of variance (ANOVA) was conducted on all response variables using the PROC MIXED in SAS 9.3. Seeding rate, PGR and fungicide were all considered fixed effect factors and replicates were considered a random effect factor. The assumptions of ANOVA (equal variance and normally distributed) were tested using Levene's test, and Shapiro-Wilks. The data fitted to the ANOVA assumptions. The data was normally distributed; therefore no data transformation was necessary. Treatment means were separated according to Tukey's Honestly Significant Difference (HSD) and were considered significant at $P \leq 0.05$. Weather data was collected from the Scott Environment Canada weather station (Table 2).

Weather Conditions

In 2015, the early growing season was very dry with only 4.1 mm and 19.4 mm accumulated precipitation during the month of May and June, respectively. July received 36 % less rainfall compared to the long-term average. However, August received 39 % more moisture compared to the long-term average. The mean monthly temperatures were comparable to previous years (Table 2).

Table 2. Mean monthly temperature, precipitation and growing degree day accumulated from May to September 2015 at Scott, SK

Year	May	June	July	August	September	Average /Total
			Temperature (°C)			
2015	9.3	16.1	18.1	16.8	10.9	14.24
Long-term[z]	10.8	15.3	17.1	16.5	10.4	14.0
			Precipitation (mm)			
2015	4.1	19.4	46.4	74.5	49.6	194.0
Long-term[z]	36.3	61.8	72.1	45.7	36.0	215.9
			Growing Degree Days			
2015	140.3	332	405.1	365.8	179.8	1423.0
Long-term[z]	178.3	307.5	375.1	356.5	162.0	1379.4

[z]Long-term average (1981-2010)

Table 3. Seeding rate (SR), plant growth regulator (PGR) and fungicide (FUNG) effects on selected response variables in spring wheat at Scott in the 2015 growing season. Means were separated using a Tukey's HSD test and were considered significant at P ≤ 0.05.

	Plant Density	**Days to Maturity**	**Height (cm)**	**Yield (kg/ha)**	**Bushel weight (kg/hL)**	**TKW (g/1000s)**	**Protein (%)**
Effects	--*P values*--						
Seeding Rate (SR)	*<.0001*	*<.0001*	*0.0163*	*0.0484*	*0.0254*	0.0624	*0.0028*
Plant Growth Regulator (PGR)	-	0.0621	*<.0001*	0.7954	*<.0001*	*0.0001*	*<.0001*
Fungicide (FUNG)	-	*0.0268*	0.1664	*<.0001*	*<.0001*	0.3157	*<.0001*
SR x PGR	-	0.0725	0.6221	0.3906	0.256	0.2583	0.5564
SR x FUNG	-	0.1827	0.9749	0.9941	0.2878	*0.0213*	*0.0028*
PGR x FUNG	-	0.8983	0.2442	0.4007	0.5361	0.3642	0.8325
SR x PGR x FUNG	-	0.7713	0.9548	0.7732	0.2415	0.3075	0.8607

Results

Generally, protein was significantly affected by seeding rate, PGR and fungicides and their effects were negative. Protein content had an inverse relationship to yield, due to the dilution effects of additional yield. Higher yields typically result in lower protein contents, because when yield increases it dilutes the available N and depletes the seed N required for protein synthesis (Campbell et al. 1977; Clark et al. 1990). There was generally no significant interaction between any of the response variable, except seeding rate x fungicide on TKW (P = 0.0213) and protein (P <.0001). A seeding rate of 100 seeds/m^2 resulted in the best protein levels but it was only significantly different with that of seeding rate of 300 seeds/m^2.

Effects of seeding rate on all response variables

Significant effects of seeding rates were found for all measured variables except for thousand kernel weight (P = 0.0624) (Table 3). The trend in plant density was anticipated; the highest seeding rate of 400 seeds/m^2 had the highest plant population (209 plants/m^2) and the lowest seeding rate of 100 seeds/m^2 recorded the lowest plant population (63 plants/m^2) (Table 4). Days to maturity (DTM) decreased with increased seeding rate, with the lowest seeding rate of 100 seeds/m^2 resulting in a later maturity date (99 days). In contrast, the highest seeding rates of 400 seeds/m^2 matured early (91 days) (Table 4). The probable explanation for the delay in maturity with lower seeding rate is that, at low plant population, the wheat plants tend to develop more tillers with uneven maturity leading to an overall delayed maturity (Geleta et al. 2002). Yield tended to increase as the seeding rate reached 300 seed/m^2, but then slightly decreased once the seeding rate exceeded 300 seed/m^2 (Table 4). Therefore, seeding rate should be considered as a factor in obtaining higher grain yield with good end-use quality.

Increasing the seeding rate from 300 seed/m^2 to 400 seed/m^2 did not result in a significant increase in the measured response variables except for plant density (Table 4). This may be because high seeding rates increase early dry matter accumulation and weed competitiveness, but may have negligible or negative impacts on grain yield due to increased inter-plant competition (Park et al., 2003). It was determined through a regression analysis that, to obtain the maximum yield of 2894.6 kg/ha the best seeding rate was 271 seed/m^2 (data not shown). The trend in this study corroborates that of May et al. (2009) who found that increasing seeding rate (150, 250, 350 and 450 grains m^{-2}) increased the plant density and spike density, but reduced the number of grains per panicle and the number of panicles per plant; the 1000-grain weight was not affected by the seeding rate. These results highlight the theory of Grafius (1972), which suggests that plants compete for fixed resources during their development and that yield is the result of a balance among yield components. However, protein % as expected followed an inverse trend to yield.

The trend in bushel weight can be explained by the fact that, in crops with a lower density, a greater number of secondary tillers is created, which produce small grains with less weight and lower quality. These results agree with those of Geleta et al. (2002), and may have been caused by the presence of additional secondary tillers that delayed maturity and reduced kernel uniformity at lower seeding rates. The later tillers produce smaller grains which result in low grain volume weight (bushel weight).

The non-significant effects of seeding rate on TKW in this study agrees with that of Lloveras et al. (2004) and Otteson et al. (2007), who established that kernel weight was significantly affected by environment and variety, but not by seeding rate.

Table 4. Main effect means for seeding rate and fungicide effects on spring wheat at Scott in the 2015 growing season.

Seeding Rate (seeds/m^2)	**Plant Density (Plants/m^2)**	**Days to Maturity**	**Height (cm)**	**Yield (kg/ha)**	**Bushel weight (kg/hL)**	**TKW (g/1000s)**	**Protein (%)**
100	63^d	99^a	73^a	2536^b	80.0^b	35.8^a	14.4^a
200	114^c	94^b	72^{ab}	2799^{ab}	80.3^{ab}	34.8^a	14.2^{ab}
300	164^b	91^c	72^{ab}	2916^a	80.4^{ab}	35.1^a	14.1^b
400	209^a	91^c	69^b	2675^{ab}	80.5^a	34.8^a	14.2^{ab}
Fungicide effects							
Fungicide	-	94^a	72^a	2950^a	80.9^a	35.0^a	14.0^b
No Fungicide	-	93^b	71^a	2513^b	79.6^b	35.3^a	14.4^a

Effects of fungicides on all response variables

Significant effects of fungicide were found for all measured variable except for height (P = 0.1664) and TKW (P = 0.3157) (Table 3). The effect of fungicide on thousand kernel weight was not significant in this study; however, there was an increment of 0.9 % between the treated and untreated treatments. Olesen et al. (2000) reported that kernel weight increased (8 % averaged over two years) with fungicide application, but the magnitude of the fungicide effect varied considerably between the two years. Again, Ruske et al. (2003) found greater increases in kernel weight with the use of the strobilurin azoxystrobin plus a triazole than with the triazole alone.

Bushel weight increased significantly with the application of a triazole (Caramba) (Table 4). Olesen et al. (2000) found similar results in which test weights tended to be higher in all varieties when fungicides were applied, though differences were not always significant (Kelley, 2001). Similarly, Ruske et al. (2003) found that when azoxystrobin was added to a triazole fungicide there was an increase test weight of wheat. This is likely attributed to delayed senescence of the flag leaf to result in a prolonged grain filling period and thus increasing bushel weight and yield. This corresponds with our results (Table 4), in which yield and bushel weight were significantly increased with the application of Caramba.

Despite the yield increase, there was a significant decrease in protein with fungicide application in this study. This could also be attributed to the inverse relationship between yield and protein, as higher yields typically result in lower protein content because greater proportion of available seed N is used for seed production rather than protein synthesis. An alternative theory could also be linked to application timing or the prevalence of disease. Brinkman (2012) found that protein levels were slightly decreased by application of fungicide at mid anthesis. However, there are varied views on the effects of fungicide application on grain protein. For example, Dimmock and Gooding (2002) suggest in a review of literature that the effect of fungicides on grain protein is partially dependent on which disease is being controlled: protein concentrations are rarely decreased when the main pathogen is either leaf rust or powdery mildew, while reductions in grain protein are more common when septoria is the main pathogen. The different protein trend among diseases is not absolute, as some studies in their review indicated an interaction with variety.

Effects of PGR on all response variables

Significant effects of PGR were found for all measured variable except for days to maturity (P = 0.062) and grain yield (P = 0.7954) (Table 3). As expected, the PGR treatment was significantly shorter (67 cm) than the 'no PGR' treatment (77 cm), a 13 % reduction in height with the application of PGR (Fig. 1). This is due to the effects of the PGR in inhibiting the production of gibberellins, the primary plant hormones responsible for cell elongation. Therefore, these growth-retardant effects are primarily seen in reduced plant height due to reduced inter-nodal length. This reduction in height may have played an important role in the increase of the grain yield in wheat, via the alteration of dry matter partitioning into the spikes. Results of several field experiments also showed that in winter wheat the number of spikes per unit area generally increases when treated with PGR (CCC) (Karchi, 1969; Knapp and Harms, 1988). Shekoofa and Emam (2008) found similar results in which PGR treatments reduced plant height in maize (*Zea mays* L.).

In this study, however, PGR did not significantly affect wheat yield despite a small increase in yield of the PGR treatment relative to the 'no PGR' treatment (Fig. 2). The relatively small grain yield advantage with PGR application may be because, under water stress conditions, PGR increases grain yield by extending water availability during critical stages like grain filling (Kasele et al., 1994). Water availability is increased using PGR, because PGR reduces the size of the plants, which in turn reduces water consumption especially when applied at early vegetative stages (Kasele et al., 1994).

As stated, from this study, yield was not significantly affected by PGR; however, a general trend noted an increase in yield with PGR applications compared to the untreated check (Fig. 2). Application of PGR did significantly affect seed thousand kernel weight, bushel weight, and protein negatively (Figs. 2 and 3), with TKW and Bushel weight positively correlated (Fig. 3).

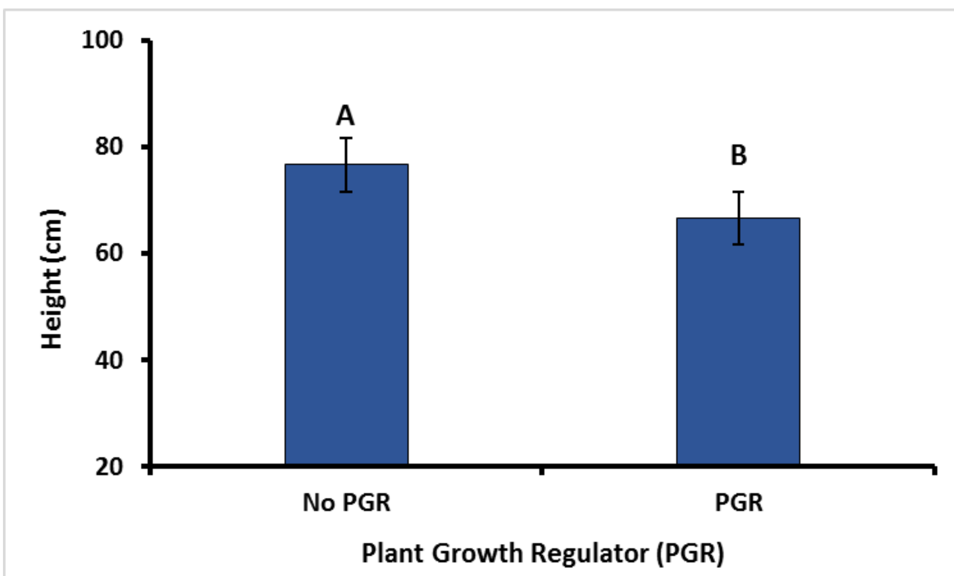

Figure 1: Effects of PGR on plant height (cm) in wheat for the 2015 growing season at Scott, SK. Vertical bars followed by the same letters are not significantly different according to Tukey's Honestly Significant Difference (HSD) ($P > 0.05$).

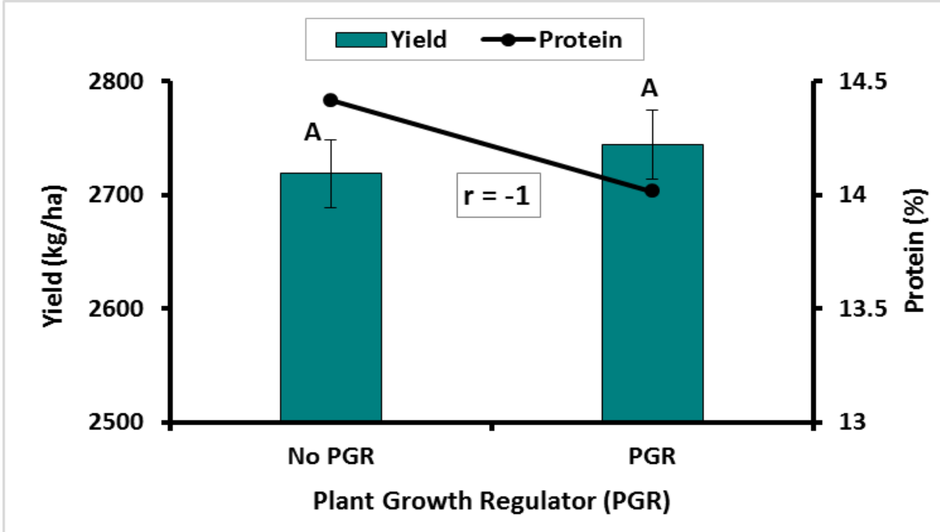

Figure 2: Relationship between wheat grain yield (*columns*) (kg/ha) and protein(*line*) (%) with the application of PGR for the 2015 growing season at Scott, SK. Vertical bars followed by the same letters are not significantly different according to Tukey's Honestly Significant Difference (HSD) (P > 0.05).

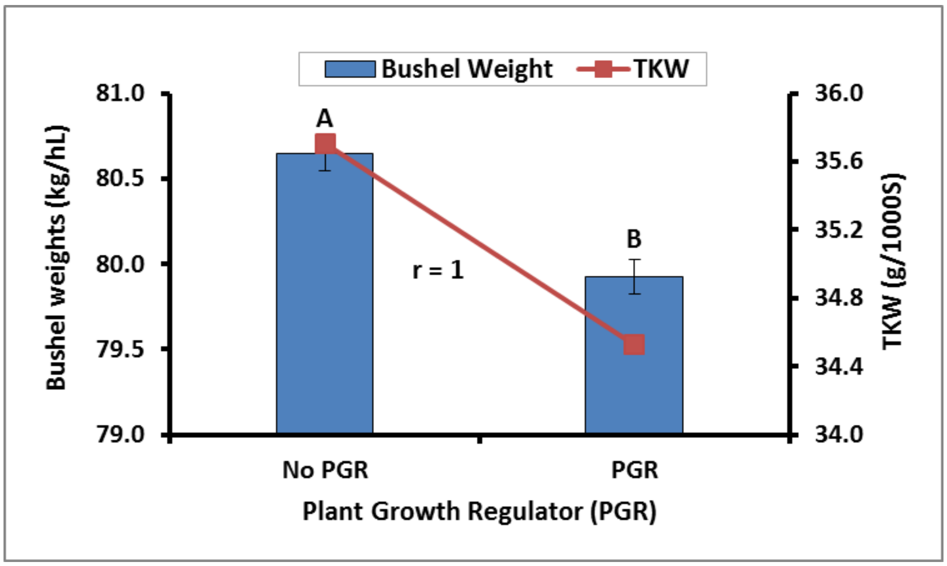

Figure 3: Relationship between bushel weight (*columns*) (kg/hL) and TKW (*line*) (g/1000s) with the application of PGR for the 2015 growing season at Scott, SK. Vertical bars followed by the same letters are not significantly different according to Tukey's Honestly Significant Difference (HSD) (P > 0.05).

Conclusions and Recommendations

Overall, there was a significant effect of seeding rate on yield and most of the quality parameters, with maximum yield of 2894.6 kg/ha obtained at a seeding rate of 271 seed/m^2. There was no yield advantage of seeding above 300 seed/m^2 so farmers may target between 200-300 seed/m^2 to get an appreciable yield and acceptable quality. Fungicide effect was significant on most of the response variables with a negative effect on protein. PGR application served its intended purpose of height reduction but as no lodging occurred, we could not see its actual effects on crop stand-ability. PGR did not increase yield, but it did have a negative effect on the measured yield quality parameters (protein, TKW and bushel weights). Therefore, the benefits associated with PGR application in terms yield and yield quality may not outweigh the cost of application, especially in drier years. The interaction of all the main effect factors over multiple years need to be investigated further before any synergistic effects can be deduced. In a drier season such as 2015, application of fungicides should be decided based on disease pressure and its projected impacts on yield. PGR application effects from this study needs further probing to ascertain the trend; however, if seeding rate is on the high side and a wetter year is forecast, it may be worth an investment to apply PGR.

Supporting Information

Acknowledgements

We would like to thank the Ministry of Agriculture for the funding support on this project. We would like to acknowledge Herb Schell and our summer staff for their technical assistance with project development and implementation for the 2015 growing season. This report will be distributed through WARC's website and included in WARC's annual report.

Appendices

Appendix A – Agronomic information for the demonstration

Abstract

Abstract/Summary

There may be a yield benefit for farmers with increased seeding rate of spring wheat above the recommended rates due to better competition with weeds with dense plant stand. Higher seed rates will also reduce tillering making higher proportion of heads to reach flowering stage at the same time, which could be beneficial in timing of fusarium head blight control. This in turn could enhance both yield and quality of the crop. However, increased seeding rates may create a favorable environment for disease development due to increased lodging, though lodging can be reduced with the use of plant growth regulators (PGRs) and diseases can be controlled with fungicide application.

Therefore, to be able to determine, if there is any synergistic effects of seeding rate, fungicide and PGR, a 2 x 2 x 4 factorial experiment in a randomized complete block design was set up to determine the effects all three factors on wheat yield and quality. Overall, there was a significant effect of seeding rate on yield and most of the yield quality, with maximum yield of 2894.6 kg/ha obtained at a seeding rate of 271 seed/m^2. Fungicide effect was evident on most of the response variables with a negative effect on protein. PGR application served its intended purpose of height reduction, but because no lodging occurred, we could not see its actual effects on crop stand-ability. PGR did not adversely affect yield but yield quality parameters (protein, TKW and bushel weights) were negatively impacted. Therefore, the benefits associated with PGR application in terms yield and yield quality may not outweigh the cost of application, especially in drier years. The interaction of all the main effect factors over multiple years need to be investigated further before any synergistic effects can be deduced. From the study, there was no yield advantage of seeding above 300 seed/m^2 so farmers may target between 200-300 seed/m^2 to get an appreciable yield and acceptable quality. In a drier season such as 2015, application of fungicides should be decided based on disease pressure and its projected impacts on yield. PGR application effects from this study needs further probing to ascertain the trend; however, if seeding rate is on the high side and a wetter year is forecast, it will be worth an investment. Results from this demonstration will be distributed through WARC's website and included in WARC's annual report.

Appendix A
Agronomic information for 2015 demonstration

Table A.1. Selected agronomic information for the "*Optimal Seeding Rate with Plant Growth Regulators (PGRs) and Fungicides for Spring Wheat*" at Scott, Saskatchewan, 2015.

Seeding Information	2015
Seeder	R-Tech Drill, 10 inch row spacing, knife openers
Seeding Date	May 12, 2015
Cultivar	Hard Red Spring Wheat – Shaw VB
Seeding Rate	Based on treatments
Stubble Type	Canola
Fertilizer applied	MAP (48.1 lb/ac) and AS (41.7 lb/ac)- side band Urea (187.7 lb/ac)-mid-row band (*based on soil test recommendation)
Plot Maintenance Information	
Pre-plant herbicide	Roundup ¾ L/ac + Pardner 0.4 L/ac (May 8, 2015)
In-crop herbicide	Buctril M 0.4 L/ac + Axial 0.48 L/ac (June 10, 2015)
Fungicide application	Caramba applied at recommended rate based on treatment list
Desiccation	Glyphosate @ 1L/ac (August 20, 2015)
Emergence Counts	June 01, 2015
Harvest Date	September 01, 2015

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