

**ECONOMIC ANALYSIS OF SPATIALLY VARIABLE APPLICATION OF COTTON
DEFOLIANT**

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Introduction

New technologies and precision agriculture tools have opened the doors to many useful field applications for California producers. Remote sensing allows a new way of looking at field variability and GPS tools provide the means of addressing field variability with variable rate applications. Useful practices developed over the past five years for cotton include variable rate applications of soil amendments, fertilizer, seeding rates, and plant growth regulators. Each of these practices has been shown to be economically viable. Combining these practices over a farm scale enterprise greatly enhances the agronomic and economic potential of this technology.

In addition to increased profitability, spatially variable pesticide (SVP) applications offers great promise to agriculture in reducing environmental externalities associated with pesticide applications. Specifically, SVP applications allow for precise application of pesticides to specific areas at the specific rate required for the area. California research with variable rate nitrogen and soil amendment applications have been shown to be agronomical and cost effective practices (Horney et al. 2005, Roberts et al. 2002, Taylor et al. 2002). Variable rate application of plant growth regulators and harvest aids can decrease cost inputs from 20 to 40% for each application (Bethel et al. 2003, Fridgen 2003, and Fridgen et al. 2003).

Preliminary work with cotton defoliant has indicated potential success with this cultural application (Fridgen 2002). More recent work in Louisiana and Texas support the use of spatially variable applications of cotton defoliant. Spatially variable defoliation applications have been shown to reduce chemical input cost by 10 to 40% without significantly impacting, crop maturity, lint yield or quality (Bagwell, 2005; Maas and Brightbill, 2005). However, cotton does not defoliate equally with similar treatments across the US Cotton Belt (Supak et al. 2001). Additionally, previous research in California on cotton defoliation was performed on vigorously growing cotton managed to develop as uniform plant canopy as possible.

The aim of the underlying research was to evaluate different chemical treatments on uniform cotton. Management was directed to minimize the canopy variability to reduce the plant variable in separating differences in chemical efficacy. The application of different amounts of chemical defoliant on variable cotton canopies (i.e. plant heights, boll loads, vigor indexes, percent open bolls) raised new questions to the current research methodologies. Therefore, the initial questions were framed in perspective of this limited knowledge. The working hypothesis was that canopy variations were caused by different stress levels associated with soil related field variability. Following this line of reasoning, it was hypothesized that more vigorous plants would take higher concentrations of chemical treatments than less vigorous, stressed plants. It was also hypothesized that similar plant canopies would respond to different chemical treatments equally. The basis of evaluation was plant defoliation, leaf desiccation, and HVI fiber grades.

In this paper we provide analysis to determine the economic viability of the variable rate application process relative to standard uniform applications. Additional experiments are being conducted this crop year. Data from those experiments will be added to this analysis to provide additional observations regarding potential economic benefits associated with variable rate chemical application.

Field Trial

The trial was conducted in a 155 acre field (MK 30-4) managed by AzCal Farms, Stratford, CA. This field was selected because of its range of variability. The field was planted on April 17, 2005 with Phytogen 72, Acala cotton. The field received normal management including pest monitoring, nitrogen fertilizer and furrow irrigation. Following field and treatment selections, treatment plots were laid out as shown in Figure 1.

The treatments were determined based on the two most popular chemical defoliant combinations used in this area. The grower standard of Def/Prep (2 pts Def + 2 pts Prep) was applied as a Standard (uniform) application or as the Variable Rate application with rates of Def/Prep 1.5+1.5, low; 2 +2, med.; and 2.5+2.5, high. The other treatments used a combination of Ginstar plus Prep. The Standard (uniform) rate of 6 oz + 2 pts., Ginstar and Prep respectively and for the Variable Rates, 4.5 oz + 1.5 pt; med., 6 oz + 2 pts; and high, 7.5 oz + 2.5 pts.

Rates were applied by adjusting the volume output from a known concentration. The treatments were applied on September 21st, using a commercial ground rig with a 60 foot boom. The uniform treatments were applied at the medium rate for both materials. The Variable Rates were applied as prescribed by the modified application map indicating specific rates (Figure 2). The second (cleanup) application of sodium chlorate plus paraquat was made 9 days after the initial treatment on September 30th. This application used the same “application” map as the first treatments which allowed the maintenance of true uniform and variable rate treatments.

The variable rates applied on this date were: Low; 0 + 0, Med; 2 gal +10 oz., and High; 2.5 gal. + 12.5 oz. of sodium chlorate and paraquat, respectively. InTime provided aerial images of field MK 30-4 prior to defoliation and weekly during the field evaluations. Treatment evaluations for percent defoliation, leaf desiccation, and percent open bolls were made 7 and 14 days after the initial treatments. The last evaluations were within 2 days of harvest. Hyperspectral canopy measurements and whole plant samples for the same post-application periods were collected for comparison with the InTime flights of 4-band optical and thermal instruments.

The treatment combinations allowed the comparison of two major defoliation treatments applied as a uniform (Std) or a variable rate (VR) application. Each of the four main treatments was replicated three times across the field. Individual plots were 180 feet by one half mile.

Harvest was performed by Bill Son Harvesting on October 13th using 3 4-row John Deere spindle harvesters. A module was harvested from the center of each main plot. Module bale grades and HVI results were collected and analyzed for statistical differences. The number of bales from the test modules ranged from 8 – 15 bales. Much of the HVI parameters are averaged for the module. In the instances where individual bale data was available that information was used in the statistical analysis. All other data was done from the module averages. The average lint yield for MK 30-4 was 1373 lbs/a (2.77 bales/acre) with a field average gin turnout of 0.3267.

Field Trail Results

The pre-treatment evaluations are presented in Table 1. Overall field conditions (average of multiple sites) show the field average height of 44 inches with normal node development and at 4 Nodes Above Cracked Boll (NACB), ready to defoliate (Roberts et al. 2001). Table 1 also shows a summary of field locations as assigned numerical values from the InTime and as applied maps (Figures 1 and 2). Figures 3 – 5, show simple correlations between the map values and plant heights from the GPS sampling sites. There was excellent correlation between the applied map for rates of defoliant applied and average plant height and NACB (Figures 4 and 5).

The second application of sodium chlorate plus paraquat was applied using the as applied map. The low vigor area did not require additional defoliant. This resulted in the following applications on the 155 acre field: 35 % (54 acres) was not treated with additional defoliants, 38% (59 acres) received the standard Medium rate and 27 % (42 acres) received the higher rate of sodium chlorate plus paraquat.

There was no significant difference between the defoliation treatments and percent defoliation, desiccation and percent open bolls (Table 2). Visual evaluations of defoliation and desiccation ratings at 7 and 14 DAT are presented in Figures 6 and 7. Also, illustrated in the figures is the percent change from the two evaluations. There was greater change (increased desiccation) between the sampling dates for the Def/Prep treatments of both Standard

and Variable Rate applications compared to the GinStar/Prep treatments. However, with no significant difference between treatment response from either method, under the conditions of this field trail both treatment combinations produced similar final results.

The module HVI analysis is presented in Table 3. There were significant differences in bale values for Leaf Grade, Rd, B+ and Trash grade. These were the variables having individual bale values. The other fiber HVI values were of “module averages” and were not significantly different (data not presented). The HVI variable showing significant differences are show in Figure 8 (a – d). Further analysis of this data will be performed to evaluate material and application method interaction. These parameters are important determinants of final bale grades

HVI bale grades for color and leaf are illustrated in Figures 9 and 10, respectively. Color grades are reported in 4 categories. The variable rate treatments show higher percentages for bale grades 11-1 compared to the standard applied treatments for both defoliant. The same trend is evident for the HVI leaf grades with higher bale numbers receiving grade 11 over grade 21.

Economic Analysis

In the economic analysis we compared the cost of standard (uniform) applications to the cost of image-based variable rate applications. The cost of imaged-based variable rate applications includes imagery and prescription generating costs. Imagery costs were \$1.50/acre. Prescriptions and related variable rate applications based on remote images resulted in an application cost of \$9 per acre. The cost for the standard applications was \$7.00/acre.

The chemicals applied in this experiment correspond to the most commonly applied combinations for the area. Treatments included application of DEF (\$4.90/pt), PREP (\$3.68/pt), Ginstar (\$1.28/oz), sodium chlorate (\$1.84/gallon) and Paraquat (\$0.29/oz).

The focus of the analysis is the cost differences between different applications and combinations of use of chemical materials. There were two types of applications. The first application includes two types of treatments; treatment A: application of Def and Prep, and treatment B: application of Ginstar and Prep. The second cleanup application of sodium chlorate and Paraquat was applied on all test plots, where appropriate the prescription for variable rate applications was followed. Variable rate with medium application had the same chemical use as the standard application. The variable rate procedure required obtaining images of the plots and developing prescriptions for the variable rate applications that resulted in a increased cost of \$5.5 per acre over the standard application.

Results indicate that between the different treatments, treatment B with cleanup was less costly than treatment A with cleanup (Table 4). For the standard application the cost of treatment A exceeds treatment B by \$2.12 per acre. For the variable rate low range application the treatment cost differ by \$1.59 per acre (25 % less than the standard application cost). Under the variable rate high range application, treatment A was \$2.65 per acre more expensive than treatment B (25% more than the standard application cost).

On a weighted average cost per acre basis variable rate treatment A is \$4.39 per acre greater than treatment B (Table 5). Both variable rate treatments exceed their standard application cost on a weighted average cost basis (treatment A, + \$4.45 per acre and treatment B, + \$2.18 per acre). The percentage costs of each treatment relative to the standard application cost are presented in Table 6.

In this analysis we are limited in assigning economic significance to differences in costs associated with the alternative application scenarios. No value is attached to any benefits associated with decreased chemical release into the environment from variable rate applications. When considering the amounts of chemical used in the different treatments three significant effects are observed. First, both variable rate applications result in less total chemical release than the standard application protocol (Table 7). Second, variable rate treatment B requires significantly less amounts of total chemical use than standard and/or variable rate treatment A (39% and 28% respectively). Third, the variable rate application in treatment B provides a 34% decrease in chemical use from the standard application (Figure 11).

If a measurable economic value were assignable to reduced chemical use the value of the variable rate application technology would be enhanced. However the value of any environmental benefit from reduced chemical use is not presently returned to the producer. Hence the profitability of individual production enterprises is not enhanced.

In this experiment share for the prescriptions for variable rate applications were: 27% low, 41% med, and 32% high for the treatment A and 43% low, 36% med, and 21% high for the treatment B. By varying the prescription percentages for low, medium and high application rates it is possible to determine a breakeven point for the variable rate applications relative to the cost of standard for each treatment. For the VR treatment A, rates of 54% low, 40% med, and 6% high, result in a cost per acre of \$37.73 versus \$37.74 for the standard application. For the VR treatment B the rates of 57% low, 37% med, and 6% high result in a \$35.55 per acre cost relative to the \$35.62 per acre for the standard application (Table 8). Accordingly, for the VR application to be cost effective relative to standard application, more than half of the area needs to be in low rate application and only small shares of the application to be at the high rate. However, as illustrated in Figure 12, the decrease in overall chemical use in a breakeven application is enhanced relative to the standard application.

Conclusions

The two defoliant materials performed well as standard broadcast applications or as variable rate applications. The variable rate applied treatments performed as well as the standard broadcast applications. There were no significant differences in field pre-harvest preparation for the different defoliation treatments. Fiber properties were not influenced by pre-harvest application of either variable rate or standard applications of the defoliant treatments used for this trial.

HVI data indicated an increase in the percent bales having a final grade of 11 over 21 for the variable rate treatments. If this result is consistently observed the increased value could be added to the economic evaluation of variable rate applications. The price premium observed for the 2005 season was 200 points (\$0.02/lb). However in this analysis the value of alternative defoliant application protocols are judged against their relative costs.

The results from this experiment indicate that the variable rate defoliant applications do not generate cost savings compared to the standard applications. The results from this field trial are consistent with those reported by Bagwell for similar experiments in Louisiana in 2005. Among the alternative treatments the GinStar/Prep combination results in a lower weighted average cost per acre than the Def/Prep combination. The overall chemical use attributable to the variable rate applications is lower than the standard rate application. Among treatments, the Ginstar/Prep variable rate combination resulted in significantly less chemical application per acre than either the standard rate application or the Def/Prep applications.

The results of this experiment will be compared to those obtained in field trials during the current crop year. Multiple observations should improve our understanding of the economics of variable rate application of chemical defoliants in California cotton production. The additional information provided by the follow-up trials will also provide another observation to compare the effects of variable rate defoliant applications across production regions.

The experimental results do provide additional evidence regarding the ability of variable rate application technology to reduce the overall amount of chemical use required in various stages of cotton production. At present any environmental benefits resulting from reduced chemical use are not assigned an economic value.

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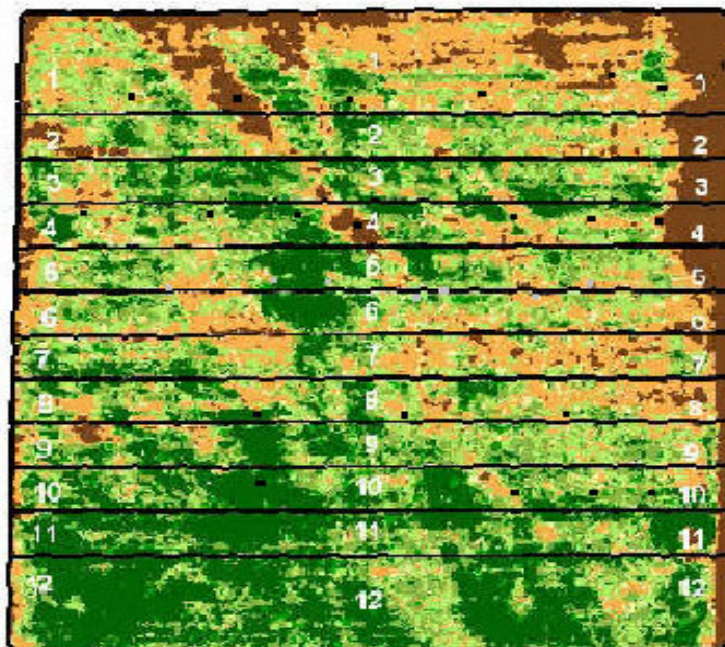


Figure 1. InTime map of MK 30-4, Acala cotton (Phy 72) showing defoliation plots overlaid on the map. Field variation is divided into seven categories with the dark green representing the most vigorous and the tan the least. Plots were 180 ft by one half mile.

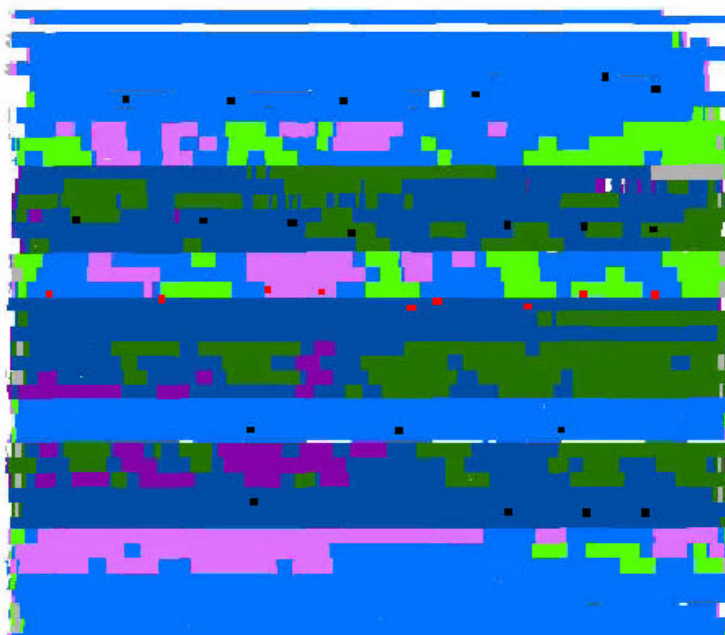


Figure 2. Application map of MK 30-4, 2005. Light blue is the Def/Prep treatments and the dark bands are the three replicates of the Ginstar/Prep applications. Solid strips are the Standard Uniform applications and multiple colors are the Variable Rate applications. The colors are coded for rates and apply to both treatment materials. Green – low rate, Blue – medium and Magenta - high rates. Standard uniform treatments received the medium rates for both materials.

Table 1. PreTreatment Field Conditions (September 17, 2005)

Field values (average) for:				
	<u>Plt. Ht.*</u>	<u># Nodes</u>	<u>NACB**</u>	
	38.8	23.8	3.6	
	46.3	23.7	4.4	
	44.7	23.7	4.0	
	<u>45.0</u>	<u>25.0</u>	<u>7.3</u>	
Average:	43.7	24.0	4.1	
Range	(30-57)	(21-26)	(2-7)	
InTime Map (1-7 values, Fig. 1)				
	<u>Plt. Ht.</u>	<u># Nodes</u>	<u>NACB</u>	<u>H/R</u>
1	30.3	23.0	2.0	1.3
2	47.3	24.3	4.0	1.9
3	-	-	-	-
4	44.3	24.0	4.4	1.8
5	39.3	23.3	2.8	1.7
6	44.0	24.0	4.7	1.8
7	57.3	25.7	7.0	2.2
Applied Map (1-3 Values, Fig. 2)				
1	30.3	23.0	2.0	1.3
2	43.4	23.9	3.9	1.8
3	57.3	25.7	7.0	2.2

* Plant height (inches), ** NACB: Nodes Above Cracked Boll

Table 2. Statistical Results of Field Observations MK 30-4, 2005 CA

Treat.	Variables					
	Defoliation		Desiccation		% Open Bolls	
	<u>7 DAT</u>	<u>14 DAT</u>	<u>7 DAT</u>	<u>14 DAT</u>	<u>7 DAT</u>	<u>14 DAT</u>
	NS	NS	NS	NS	NS	NS

Table 3. Statistical Results of HVI Bale Grades MK 30-4, 2005 CA

	<u>Leaf Grade</u>	<u>Rd</u>	<u>HVI Variables</u>	<u>Trash</u>
p value:	0.001	0.0001	<u>B+</u> 0.0001	0.0001

Figure 3.

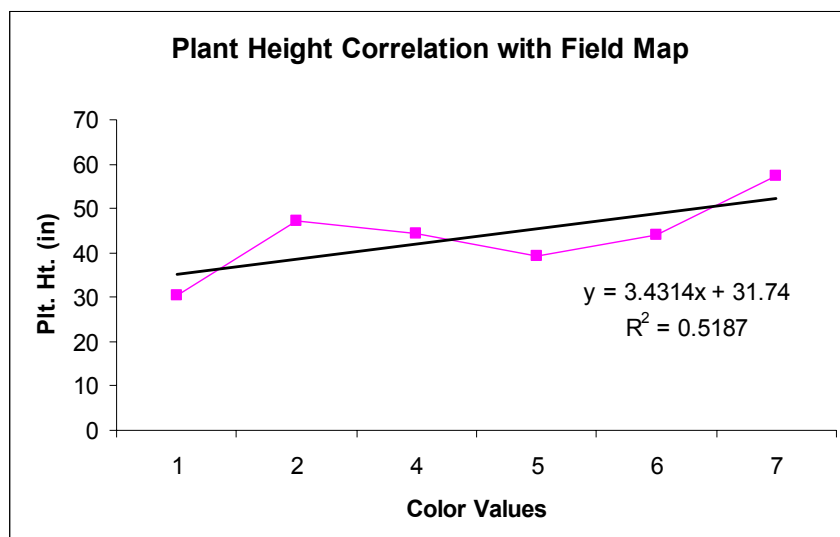


Figure 4.

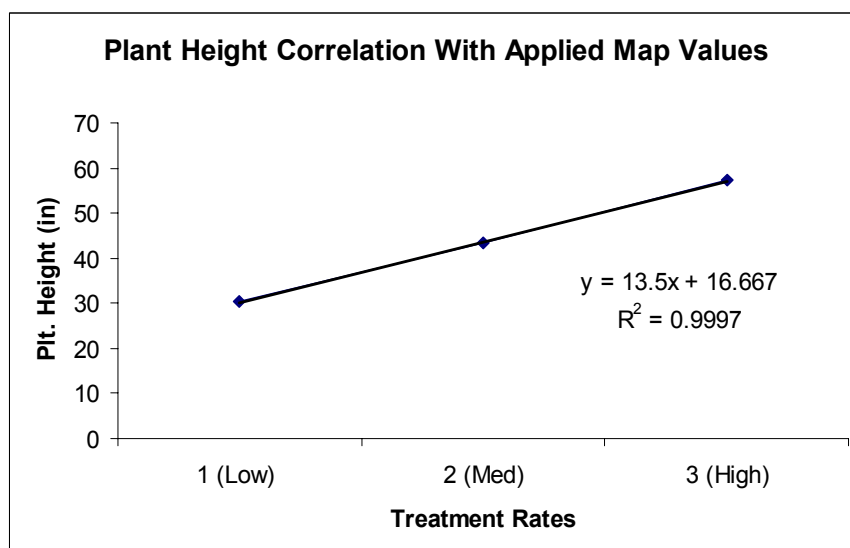


Figure 5.

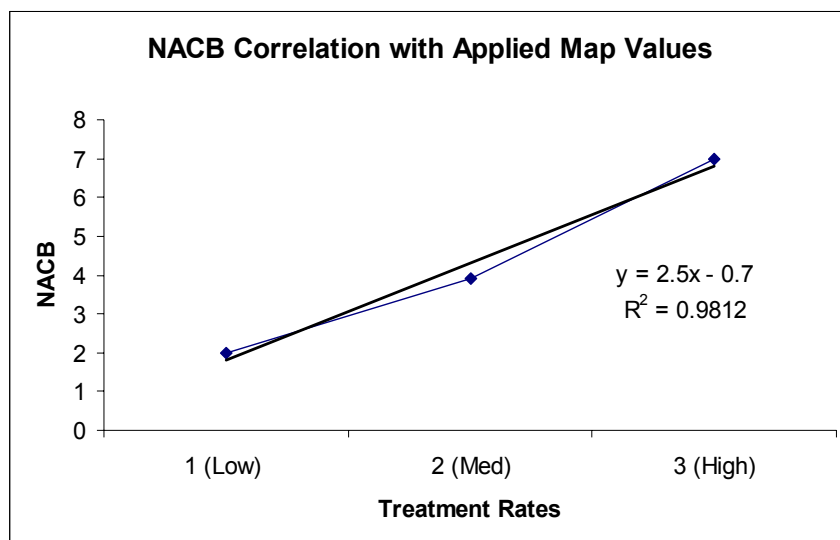


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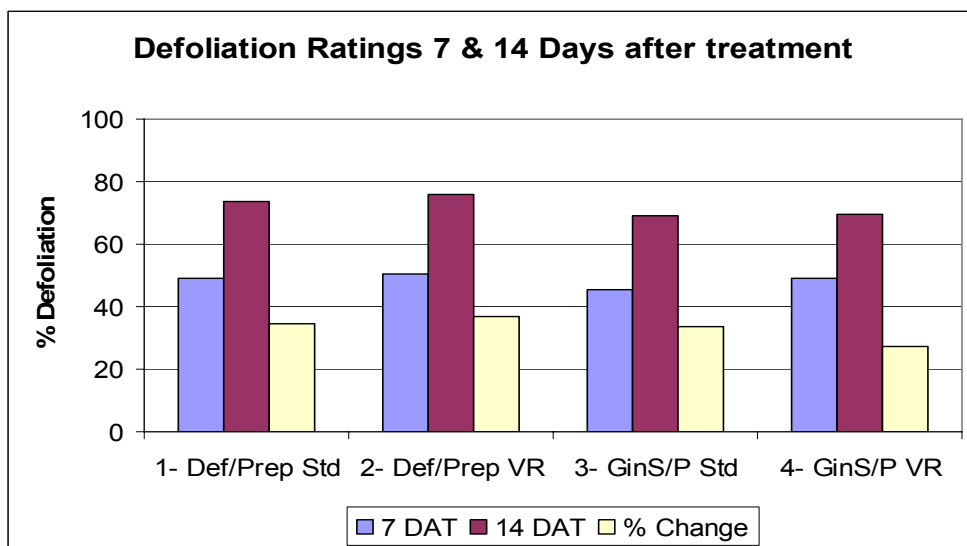


Figure 7.

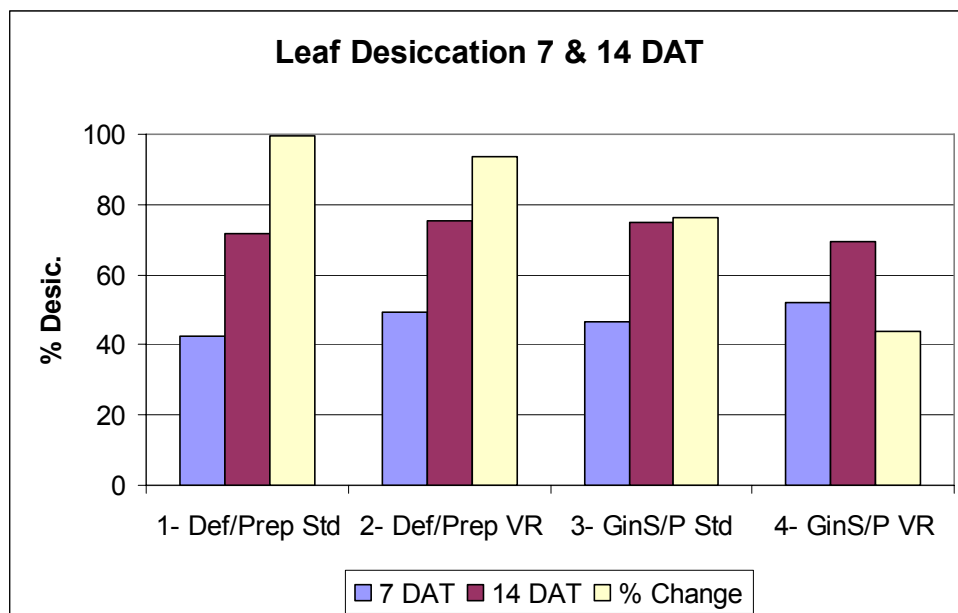
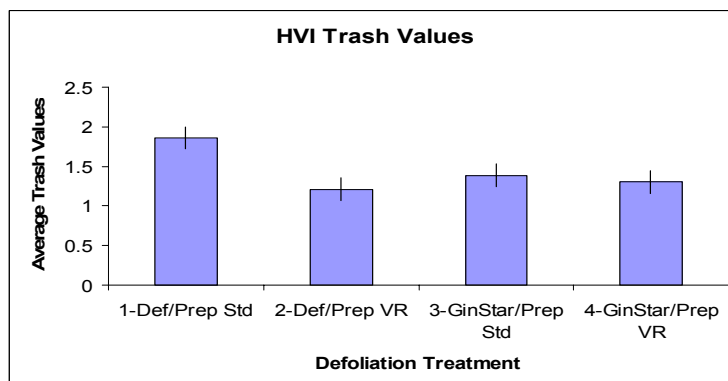
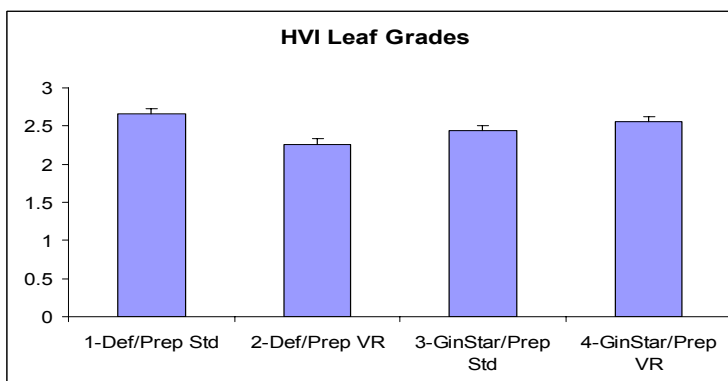


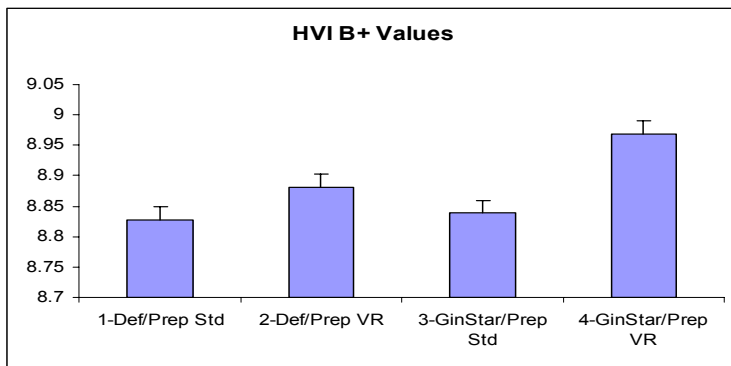
Figure 8.



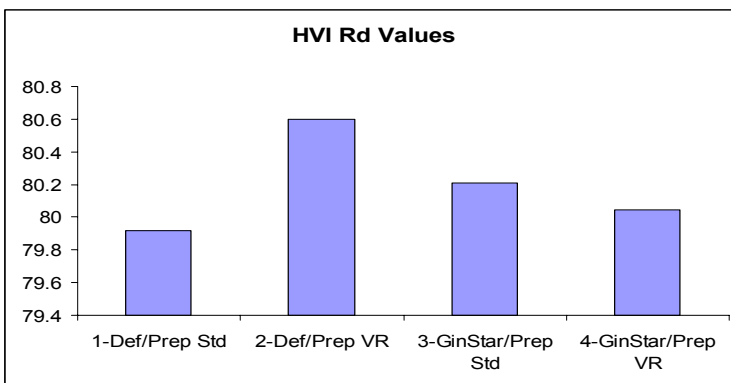
a.



b.



c.



d.

Figure 9.

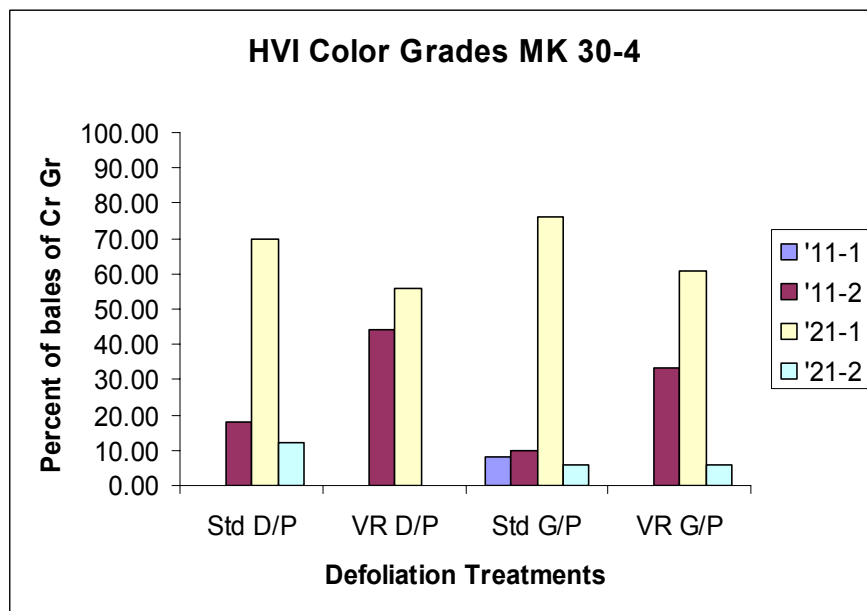


Figure10.

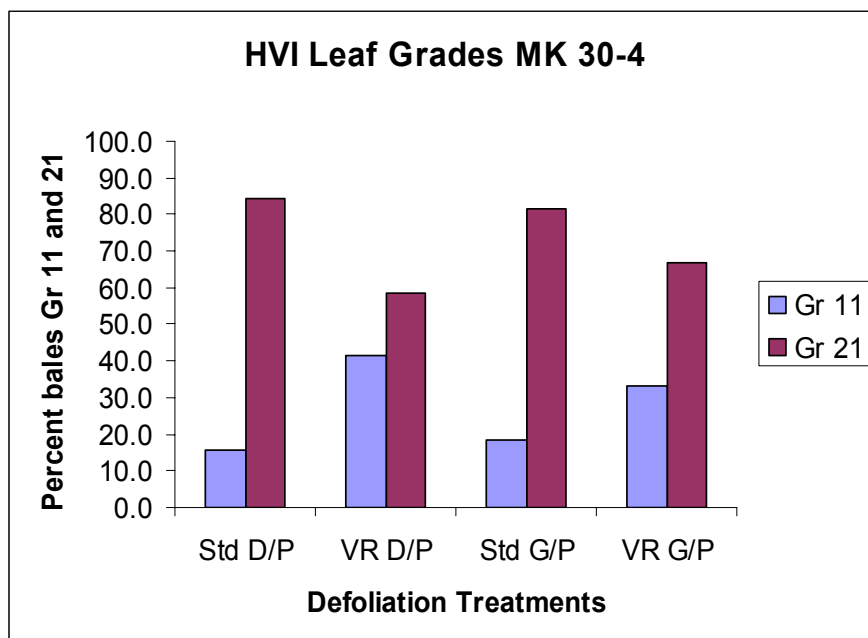


Table 4. Average Cost for Each Treatment

Application	Costs (\$/acre)	Application	Costs (\$/acre)
Treatment A + Cleanup:		Treatment B + Cleanup:	
Standard	37.74	Standard	35.62
Variable rate		Variable rate	
Low	32.37	Low	30.78
Med	43.24	Med	41.12
High	49.18	High	46.53
Differences from Standard:		Differences from Standard:	
Variable rate		Variable rate	
Low	-5.37	Low	-4.84
Med	5.50	Med	5.50
High	11.44	High	10.91
Differences between A and B:			
Standard	2.12		
Variable rate			
Low	1.59		
Med	2.12		
High	2.65		

Table 5. Weighted Average Cost of Different Treatments

Application	Acres	Costs (\$/acre)	Total cost	Share in VR
Treatment A with Cleanup: Standard	58.2	37.74	2196.47	
Treatment A with Cleanup: VR	31			100.00%
Treatment A with Cleanup: VR Low	8.4	32.37	271.91	27.10%
Treatment A with Cleanup: VR Med	12.7	43.24	549.15	40.97%
Treatment A with Cleanup: VR High	9.9	49.18	486.83	31.94%
<i>Treatment A with Cleanup: Weighted average of VR</i>		<i>42.19</i>	<i>1307.89</i>	
Treatment B with Cleanup: Standard	32.5	35.62	1157.65	
Treatment B with Cleanup: VR	30.7			100.00%
Treatment B with Cleanup: VR Low	13.2	30.78	406.30	43.00%
Treatment B with Cleanup: VR Med	11.1	41.12	456.43	36.16%
Treatment B with Cleanup: VR High	6.4	46.53	297.76	20.85%
<i>Treatment B with Cleanup: Weighted average of VR</i>		<i>37.80</i>	<i>1160.49</i>	
Total Acres	152.4			

Table 6. Percent Cost Difference among the Treatments

Application	% Cost over Standard	
	All Costs	Chemical and Application
Treatment A + Cleanup:		
Standard	100.00%	100.00%
Variable rate		
Low	85.77%	81.80%
Med	114.57%	110.60%
High	130.30%	126.32%
Treatment B + Cleanup:		
Standard	100.00%	100.00%
Variable rate		
Low	86.41%	82.20%
Med	115.44%	111.23%
High	130.61%	126.40%

Note: For the standard application, all costs and costs for the chemical and application are the same.
Differences in above column are cost of imagery.

Table 7. Amounts of Chemical Used for Each Treatment with Increasing Acreage

Treatment A		Def chemical use (gal/acre)	Prep chemical use (gal/acre)	Sodium chemical use (gal/acre)	Paraq chemical use (gal/acre)	Total chemical use (gal/acre)
<i>Treatment A with Cleanup: Standard</i>		0.25	0.25	2	0.08	2.58
Treatment A with Cleanup: VR	100.00%					
Treatment A with Cleanup: VR Low	27.10%	0.19	0.19	0.00	0.00	0.38
Treatment A with Cleanup: VR Med	40.97%	0.25	0.25	2.00	0.08	2.58
Treatment A with Cleanup: VR High	31.94%	0.31	0.31	2.50	0.10	3.22
<i>Treatment A with Cleanup: Weighted average of VR</i>		0.25	0.25	1.62	0.06	2.19
Treatment B		Gin chemical use (gal/acre)	Prep chemical use (gal/acre)	Sodium chemical use (gal/acre)	Paraq chemical use (gal/acre)	Total chemical use (gal/acre)
<i>Treatment B with Cleanup: Standard</i>		0.05	0.25	2.00	0.08	2.38
Treatment B with Cleanup: VR	100.00%					
Treatment B with Cleanup: VR Low	43.00%	0.04	0.19	0.00	0.00	0.22
Treatment B with Cleanup: VR Med	36.16%	0.05	0.25	2.00	0.08	2.38
Treatment B with Cleanup: VR High	20.85%	0.06	0.31	2.50	0.10	2.97
<i>Treatment B with Cleanup: Weighted average of VR</i>		0.04	0.24	1.24	0.05	1.57

Table 8. Summary Cost and Chemical Usage for Experiment and Breakeven Use Rates

Application	Costs (\$/acre)	Chemical use (gal/acre)
Experiment rate for the VR: VR A; 27%L,41%M,32%H; VR B; 43%L,36%M,21%H		
Treatment A with Cleanup: Standard	37.74	2.58
Treatment A with Cleanup: Weighted average of VR	42.19	2.19
Treatment B with Cleanup: Standard	35.62	2.38
Treatment B with Cleanup: Weighted average of VR	37.80	1.57
Breakeven rate for the VR: VR A; 54%L,40%M,6%H; VR B; 57%L,37%M,6%H		
Treatment A with Cleanup: Standard	37.74	2.58
Treatment A with Cleanup: Weighted average of New VR	37.73	1.43
Treatment B with Cleanup: Standard	35.62	2.38
Treatment B with Cleanup: Weighted average of New VR	35.55	1.18

Figure 11. Cost and Chemical Usage with Different Treatments of the Experiment
VR A: 27%L, 41%M, 32%H; VR B: 43%L, 36%M, 21%H

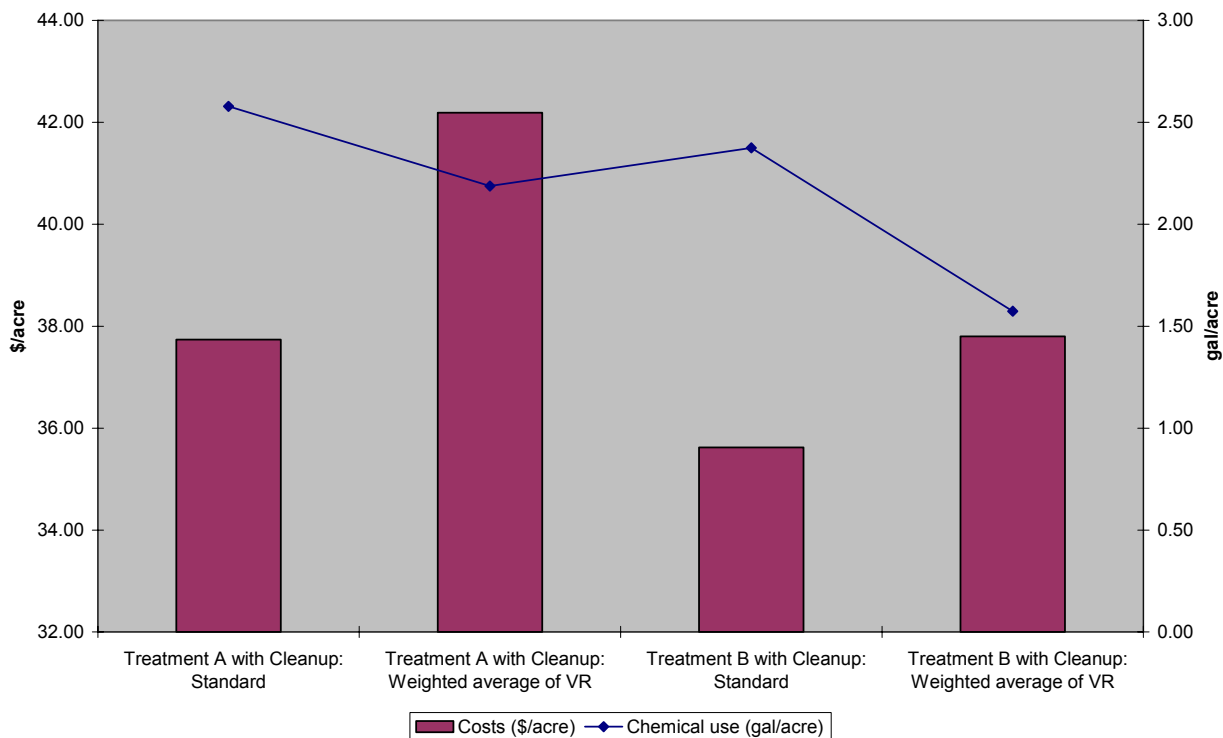


Figure 12. Cost and Chemical Usage with Breakeve Rate for the VR Applications
VR A: 54%L,40%M,6%H; VR B: 57%L,37%M,6%H

