USE OF OPTICAL SENSORS TO EVALUATE DICAMBA INJURY TO COTTON

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Abstract

A technique was evaluated to assess dicamba herbicide damage to cotton using normalized difference vegetation index on plots treated with a continuously diluting logarithmic sprayer application of dicamba. Four applications were made from early squaring to cut out, and geo-referenced NDVI readings were taken. Plots were replicated three times and two study locations in southwest Oklahoma were used. Plots were harvested with a commercial picker equipped with a yield monitor. Dicamba injury to the cotton resulted in reduced yield in all treatments, the magnitude of the loss depended on growth stage at the time of application and concentration of dicamba. Yield reduction at the full rate of dicamba ranged from 22 to 98 percent. Correlation between yield and NDVI measured with sensors varied. In general, the correlation was greater for plots with early dicamba application when sensing was completed within 15 to 50 days of injury.

Introduction

Drift of hormone herbicides has historically resulted in damage to cotton and with the possible introduction of transgenic dicamba resistant cotton, there is more potential for accidental application or drift of dicamba to cotton without the resistance gene. The affect of dicamba on cotton growth and yield has been well documented with simulated drift studies (Hamilton and Arle, 1979; Hurst, 1982; Marple et al., 2007; Marple et al., 2008). The basis for simulated drift studies is that the effects of drift are typically uneven across a field or region, with areas closer to the intended application being affected at a greater extent. If crop injury occurs, it would be desirable to assess the impact of this injury on final yield for all areas in the affected area. Hickman et al. (1991) concluded that moderate to severe herbicide injury could be detected through remote sensing. In this study, vegetative indices such as NDVI and reflectance data were related to herbicide dosage and moderate to severe visual rating. However, visual ratings of dicamba injury may not be well correlated with yield (Marple et al. 2007). On the other hand, reflectance data and vegetative indices for some growth stages are correlated with lint yield (Vellidis et al., 2004; Yang et al., 2001; Zhao et al., 2006).

The objectives of this project were

1. To determine cotton injury from dicamba based on growth stage and application rate.
2. To evaluate active optical sensors for assessing injury.

Materials and Methods

Cotton variety Deltapine 164 B2RF was planted on May 14, 2008 and Phytogen 375 WRF was planted on May 19, 2009. Plots were on a Tillman/Hollister clay loam on the OSU Southwest Research and Extension Center. Row spacing was 40 inches. In 2008, plots were randomized strips four rows wide by 440 feet long, replicated three times. Spray applications were made on June 18, July 2, July 23, August 9, and August 27. The growth stages for applications were first square, first bloom, mid bloom, full bloom, and cutout. In 2009 plots were randomized strips four rows wide by 400 feet long, replicated four times. Spray applications were made on June 18, July 6, July 23, August 4, and August 26. The growth stages for applications were 4-5 leaf, first square, first bloom, mid bloom, and cutout.

Spray applications were made with a constantly diluting logarithmic broadcast sprayer that was calibrated to deliver half rates at 40 foot intervals. The initial rate of dicamba was 0.25 lb active ingredient per acre or 8 ounces of product per acre. At a distance of 400 feet, the dicamba application rate was 0.1% of initial rate or 0.00025 lb ac^{-1}. This procedure allowed evaluation of the complete rate range from full rate of dicamba recommended for vegetation control in other crops to less than 1/1000 of this rate at each application stage of the cotton.

Normalized difference vegetative index (NDVI) was collected with GreenSeeker® sensors five times throughout the season in 2008 and four times in 2009. Sensor data collection was scheduled around spray application and irrigation schedules. Data were recorded five times per second with an average distance of 1.5 feet between points in 2008 and once per second in 2009 for an average spacing of 5 feet. Geographic location was also recorded for each sensor reading. These data were transformed to local coordinates to determine the location of each sensor reading relative the end of the plot.

Plots were harvested with John Deere 9965 cotton picker equipped with an Ag Leader® yield monitor. Data were recorded once per second and with an average distance of 5.4 feet between points. All plots were harvested in the same direction and seed cotton weights were measured for each plot. The yield monitor data were exported from SMS software in ASCII format for further analysis. Total estimated seed cotton mass was determined from the mass flow data in the yield monitor export file. The actual seed cotton mass for each plot was measured with a boll buggy weigh system. The estimated seed cotton mass measured by the yield monitor was adjusted to match the mass measured by the boll buggy by correcting the seed yield at each point by the appropriate percent for the plot. Local coordinates were calculated from the geographical coordinates in Excel and the dicamba concentration for each point was determined based on distance from the beginning of the plot.

Yield was regressed as a function of dicamba concentration (conc) to fit a sigmoidal function (equation 1) using the PROC NLIN procedure in SAS®. The yield plateau of the sigmoid function is α. Predicted yield from the equation was divided by α to obtain a relative yield.

$$yield = \delta + \left(\frac{\alpha - \delta}{1 + \left(\frac{conc}{\gamma} \right)^{\beta}} \right) \qquad \text{Eq. 1}$$

yield is seed cotton yield in lbs/ac
α, δ, γ, and β are regression coefficients
conc is dicamba concentration in percent relative to the initial mix.

Since NDVI and yield monitor data were collected at different times and scales, the NDVI data within ± 5 feet of a yield point along each transect were averaged to correlate with yield at that point. Since the average spacing of yield monitor data was 5.4 feet, some NDVI values were used for multiple yield monitor points. This correlation was used to assess NDVI as a predictor of yield reduction due to herbicide injury.

Results and Discussion

All treatments impacted cotton yield through crop injury. However, the yield reduction was dependent upon dicamba concentration and growth stage at application. Table 1 shows the relative yield reduction for three concentrations of dicamba applied at the six growth stages over two years. These data were determined from the sigmoid regression. In general the yield loss in 2008 was greater than that in 2009. Application at first square caused significant injury, but the plant was able to partially recover and yield was reduced by about a third at 100 percent concentration in both years. However, during first and mid bloom, the full rate of dicamba caused large yield reductions in both years. The 10 percent concentration caused a 30-50% yield loss in 2008, but only a 10-15 percent yield reduction in 2009. Injury occurring during cutout had less affect on yield.

Table 1. Estimated yield reduction at three concentrations of dicamba for the growth stages at application.

	% Yield Reduction at Conc.					
	100%		10%		1%	
	2008	2009	2008	2009	2008	2009
4-5 Leaf	--	62	--	2	--	0
1st Square	35	37	7	7	0	2
1st Bloom	87	91	28	10	6	0
Mid Bloom	98	61	52	15	9	2
Full Bloom	44	--	20	--	6	--
Cutout	22	10	5	0	1	0

Seed cotton yield in 2008 as a function of dicamba concentration applied at first square is shown in Figure 1 for the three replicated plots individually. While the yield plateau values at concentrations below 1 percent were different, the general trend at concentrations above 10 percent was similar. In general, the sigmoidal equation fit the data with the exception of plot 303 where regression failed to converge. The sigmoidal equation may not have been the best choice for some treatments, but it was used for consistency and the ability to compare coefficients across treatments. The seed cotton yield from 2008 as a function of dicamba concentration applied at mid bloom is shown in Figure 2 for the three replicated plots individually. Data from the first two reps were nearly identical whereas the third rep had a slightly greater plateau yield. Yield data from the other treatments are not shown, but observations between reps were similar to treatments 1 and 3. The r^2 values for treatment 5, dicamba applied at cutout, were the lowest.

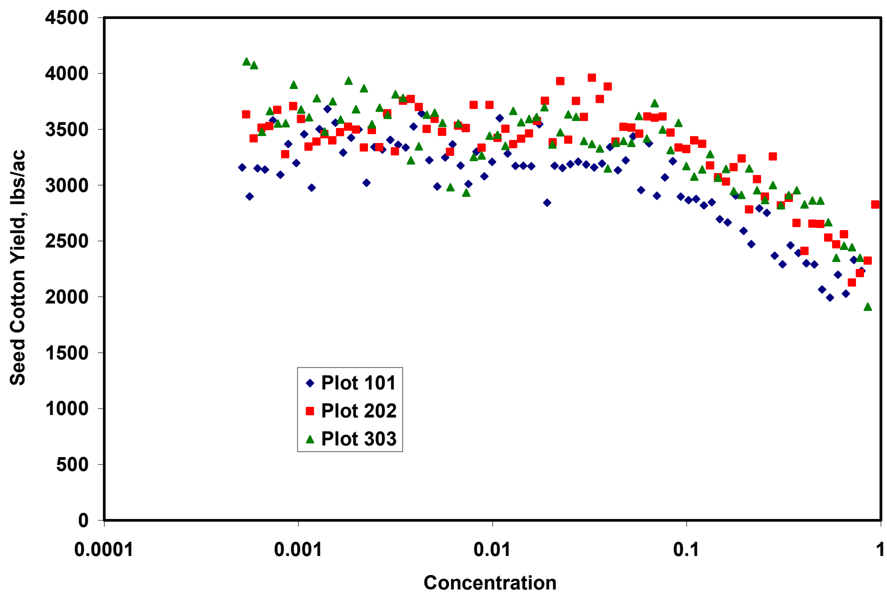

Figure 1. 2008 seed cotton yield as a function of dicamba concentration for application at first square.

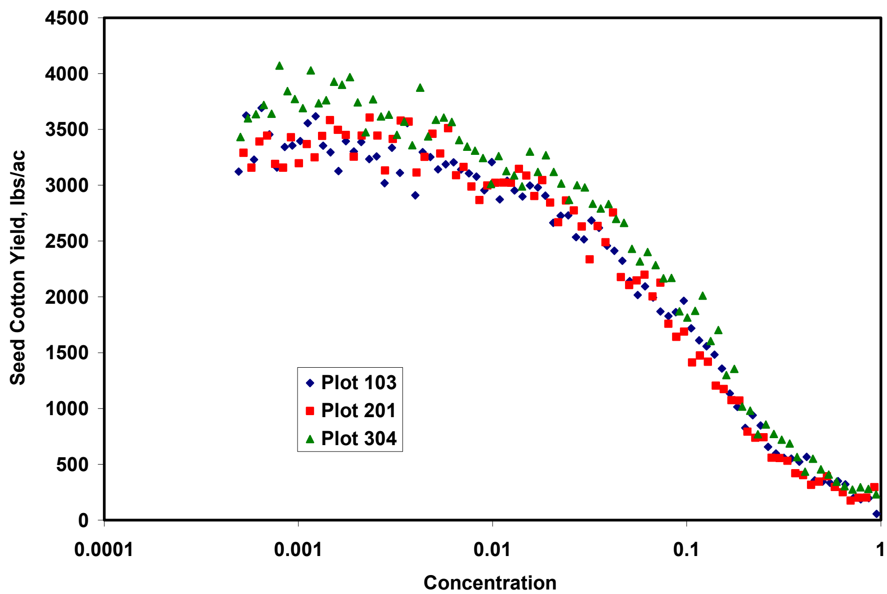

Figure 2. 2008 seed cotton yield as a function of dicamba concentration for application at mid bloom.

Active light sensors were used in an attempt to quantify herbicide injury. Figure 3 shows NDVI data measured 21 days after application as a function of dicamba concentration. These data are for two reps of the first treatment where dicamba was applied at first square. Data for one rep for this treatment was incomplete and was not included in any analysis. The NDVI decreases with increasing concentration at concentrations greater than about 5 percent, whereas is appears independent at lower concentrations. The correlation between NDVI and seed cotton yield for these two reps was approximately 0.80.

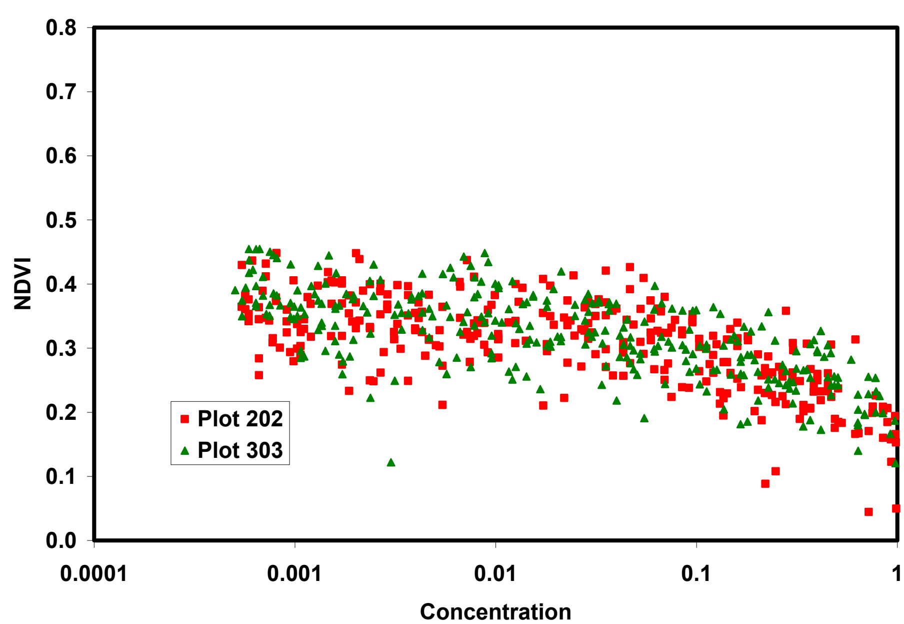

Figure 3. 2008 NDVI measured 21 days after application as a function of dicamba concentration for application at first square. Data for the first rep was incomplete and not used in the analysis

Figure 4 shows NDVI data for the first bloom application. Similar to Figure 3, these data were collected 22 days after application. These data shows a higher plateau value than Figure 3 because it is later in the season. However, NDVI is affected at lower concentrations of dicamba than the first square application. The NDVI decreases with increasing concentration at rates above 1 percent. The correlation between NDVI shown in Figure 4 and seed cotton yield exceeded 0.90. Figure 5 shows NDVI as a function of dicamba concentration for the mid bloom application. Consistent with Figures 3 and 4, these data were taken 22 days after application. Even though the data were collected about three weeks after the data in Figure 4, the plateau NDVIs are similar. The NDVI decreases with increasing concentration at levels greater than 10 percent. However the magnitude of the slope is not large. The average correlation between seed cotton yield and NDVI for the three reps shown in figure 5 is less than 0.60. Even though the mid bloom application had the greatest effect on yield, the correlation between NDVI and yield for this treatment was not high.

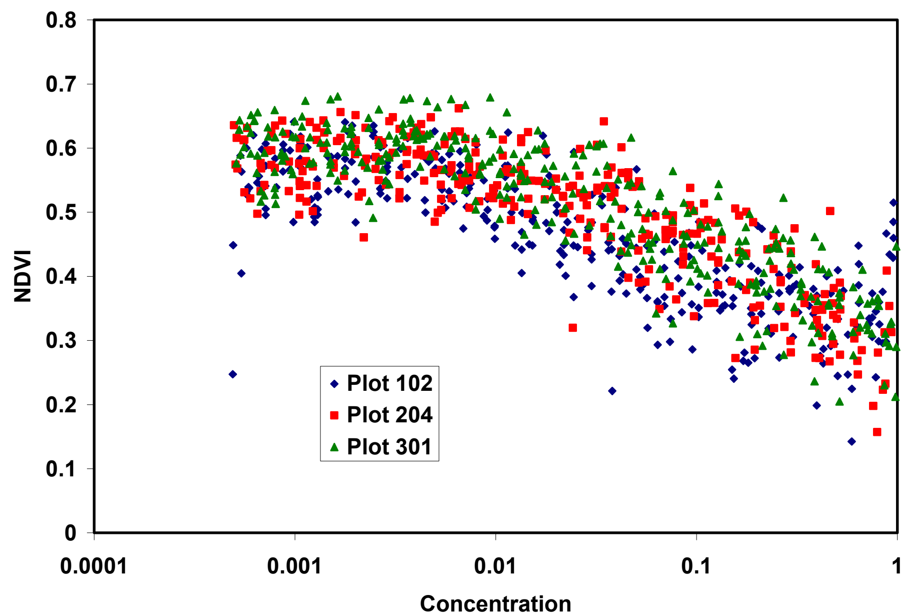

Figure 4. 2008 NDVI measured 22 days after application as a function of dicamba concentration for application at first bloom.

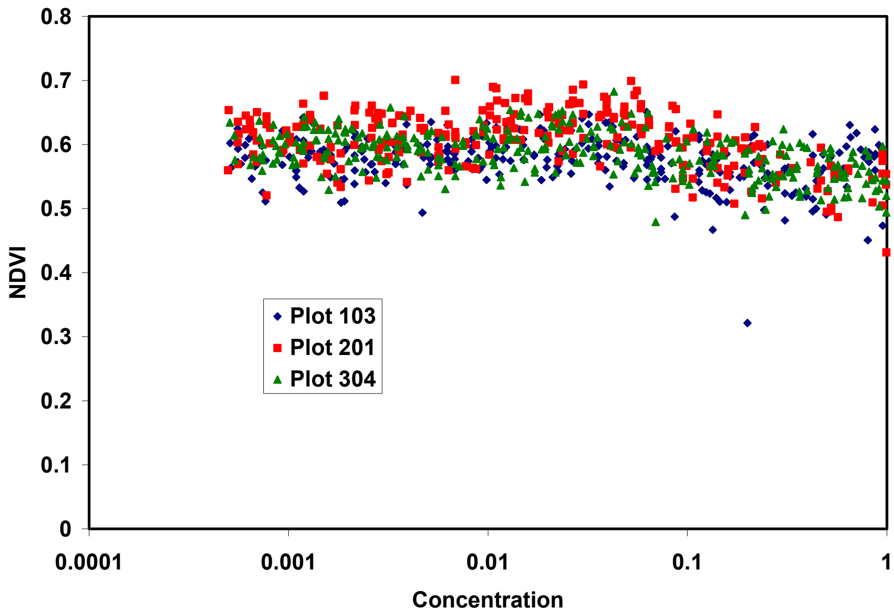

Figure 5. 2008 NDVI measured 22 days after application as a function of dicamba concentration for application at mid bloom.

Correlation between NDVI readings and yield was dependent on growth stage when injury occurred and time between injury and sensing. The outlined plot in Figure 6 shows crop discoloration at mid bloom resulting from a dicamba application at 1st bloom. This discoloration was also evident in the NDVI readings.

Figure 6. Injury from first bloom application shown at mid bloom. The four rows to the left were treated at first square and the rows on the right were untreated.

In general, correlation was better at early growth stages (1st square to 1st bloom) when sensing was completed within 15 to 50 days after injury (Figure 7). The apparent outliers from 2009 are reps 3 and 4. These reps were stacked behind the first two reps and may have been affected by irrigation. Regardless, the correlations are lower and more varied once 60 days from injury have passed. As the crop matured to mid bloom and later, there was less time after injury for sensing (Figure 8). Correlation between NDVI and yield continually decreased from the time of crop injury. Data from 2009 are less consistent than 2008 data.

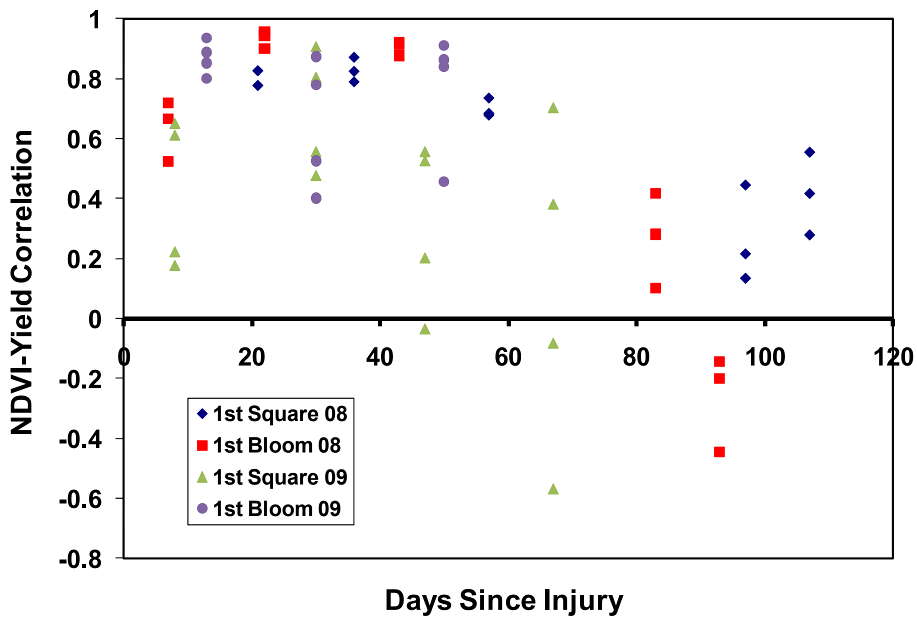

Figure 7. Correlation between NDVI readings and yield as a function of days since injury occurred for two early growth stages when injury occurred.

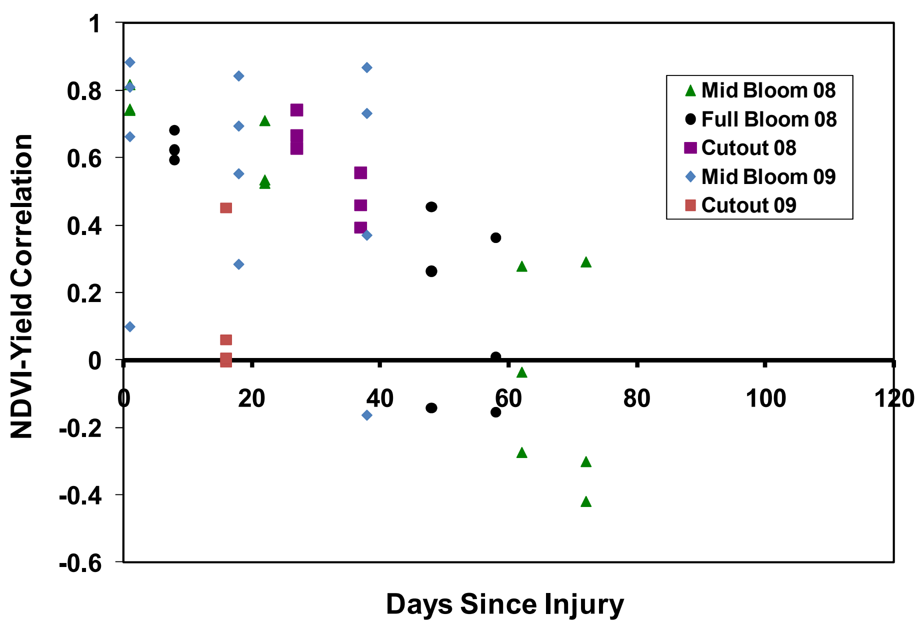

Figure 8. Correlation between NDVI readings and yield as a function of days since injury occurred for three later growth stages when injury occurred.

Though the correlation values shown in Figures 7 and 8 show some promise for estimating potential yield reduction due to dicamba application, the predictive capability of these data has not been sufficiently explored. To fully assess the injury with optical sensors or remotely sensed images, NDVI must be capable of predicting yield.

Summary

Yield reduction from dicamba injury was dependent on growth stage and rate. Cotton tended to 'grow out' of early season damage and was less susceptible to late season injury. Mid season application caused the most severe injury. Measuring NDVI showed some promise for assessing the effect of dicamba injury on cotton yield when it occurs at first bloom and earlier. Furthermore there was a longer time window for detecting early season injury. Though NDVI correlated with yield for early application of dicamba, the predicative capability may be limited. Future efforts will focus on improving the predictive capability of NDVI for dicamba injury in cotton.

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