CALIBRATION RAMPS FOR REFLECTANCE-BASED NITROGEN MANAGEMENT IN COTTON

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Background

Water and nitrogen are the first and second constraints to cotton production in the arid southwestern U.S, respectively (Morrow and Krieg, 1990). Subsurface drip irrigation (SDI) area in cotton land is relatively small at present in West Texas but is expanding at a rapid rate. Efficiency of water application to cotton in SDI systems approaches 100 % (Bordovsky, 2001). However, N management research for cotton in SDI has not kept up with the water management research. The main problem we address in this proposal is low N use efficiency in cotton systems, typically < 50 % (Chua et al., 2003). Improving N fertilizer use efficiency would allow lower rates of N fertilizer to be used by producers without hurting lint yields. The reduced costs of improving efficiency of inputs such as fertilizer would help keep cotton farmers competitive in the world market place. Additionally, residual nitrate can be leached to groundwater and impact water quality. The environment of the West Texas and Oklahoma Regions is thereby protected when N fertilizer use efficiency is improved.

Our previous research in West Texas has demonstrated the potential of canopy level spectral reflectance to assess need for in-season N in irrigated cotton (Bronson et al., 2003; Bronson et al., 2005). Reduced N fertilizer applications and reduced residual soil NO_3^--N resulted from using in-season sensing of cotton N status (Chua et al. 2003, Yabaji et al., 2009). However, calibration of remote sensing indices such as NDVI to need for N fertilizer is difficult. Typically well-fertilized plots or strips are used to reference NDVI data or chlorophyll meter data in the crop area of interest in corn and other crops (Varvel et al., 1997; Hussain et al., 2000). However, in cotton over-fertilization often results in rank growth and reduced lint yields. Recently, Oklahoma State University has developed a crop reflectance calibration procedure of using multiple N rate calibration plots, or a ramp approach for wheat and corn (Raun et al., 2006). We tested this approach in irrigated cotton in West Texas. In this project calibration N fertilizer ramps will be applied to farmers' fields. Our aim is to use the calibration ramp approach to determining optimum in-season N fertilizer rates in irrigated cotton. Unlike in wheat and corn, optimum N rate in cotton will probably not correspond with maximum NDVI and biomass. We will estimate nonlinear functions of N rate on (lint yield and NDVI) from the ramp data. To determine economically optimum N rates, N fertilizer price/lint price ratios will need to be part of the analysis. Including leaf N and biomass data should further elucidate the N rate vs. (lint yield, NDVI) functions.

Objectives

1. Establish N fertilizer calibration ramps in farmers and researcher's irrigated cotton fields for calibrating need of in-season N fertilizer.

2. Determine economically optimum N fertilizer rates from nonlinear functions of N rate vs. lint yield and NDVI for varying prices of N fertilizer and lint.

Methods

Soil sampling for extractable NO_3-N from 0 to 36 inches was done in February and March of 2008 in each cooperating producer's field. The N fertilizer calibration ramps were established near planting in May 2008 on multiple producer fields. These included furrow, center-pivot, and subsurface drip irrigated fields (Table 1). For the pivots and drip systems we tried to locate some fields where the producer does not inject N fertilizer with the irrigation water. In most cases, however, N fertilizer in drip and pivots is injected, but we still tested the utility of the N ramp approach "on top" of the farmers N fertigation program.

Nitrogen ramps were applied in researchers and farmer's fields in 13.5 ft wide by 320 ft long strips by computer-controlled liquid (32-0-0) applicators. Nitrogen fertilizer rates varied sequentially from 170 lb N/ac to 0 lb N/ac and back to 170 lb N/ac in 10 lb N/ac steps. Duplicate (end-to-end) ramps were applied in each field.

Spring soil samples from 0-24 inches were taken at appropriate density from each field and analyzed from extractable NO_3. GreenSeeker and CropCircle spectroradiometers were used to make measurements of canopy reflectance at 39 inches above the plants at early bloom (7 August) and mid bloom (22 August) in all ramps. Leaf samples for N analysis and biomass samples were taken at mid bloom in August. Lint yield was measured by a John Deere stripper fitted with an AgriPlan yield monitors at all sites.

Table 1. Nitrogen calibration ramp descriptions: soil type, variety, and irrigation type.

Ramp no.	Farmer	Soil Type	Variety	Irrigation
3	Casey Jones	Estacado clay loam	FM9180	Center-pivot
4	Casey Jones	Estacado clay loam	FM9180	Subsurface drip
5	Casey Jones	Amarillo fine sandy loam&Acuff loam	FM9180	Center-pivot
6	Casey Jones	Olton clay loam	FM9180	Center-pivot
7	Casey Jones	Amarillo fine sandy loam&Midessa fsl	FM9058	Furrow
8	Casey Jones	Amarillo fine sandy loam	FM9058	Furrow
9	Steve Jones	Estacado clay loam	FM9180	Center-pivot
10	Walter VerKamp	Pullman clay loam	FM989	Subsurface drip
11	Walter VerKamp	Pullman clay loam	FM9063	Subsurface drip
12	Walter VerKamp	Pullman clay loam	MG3538	Furrow
13	Walter VerKamp	Pullman clay loam	FM9180	Subsurface drip

Results

We successfully applied 11 N calibration ramps (each with two replicates) on several farms in Lubbock County Texas, in 2008. These included furrow, center-pivot and drip irrigated fields. Cotton in the ramps in Mr. VerKamp's fields our large and green, due to adequate irrigation and N fertilization. Mr. Casey Jones' fields on the other hand were not watered as much as Mr. Verkamps' fields, and did not receive any N fertilizer (Table 1). The Jones' plant height was much shorter than the plants in Mr. VerKamps' fields and the lint yields followed the same pattern (Table 2). Lint yields on Mr. VerKamps' fields were very high, with the exception of ramp 12, which was furrow-irrigated. Soil type may have been another important factor in controlling yields. The Pullman soils have higher organic matter, CEC, and water holding capacity than Estacado or Amarillo soils. Soil test nitrate-N (0-24 in) averaged 58, and 54 lb NO_3-N/ac in the Jones, and VerKamps' fields, respectively. Soil test P (Mehlich-3) averaged 30, and 101 ppm P in the Jones, and VerKamps' fields, respectively.

Significant regression relationships between NDVI in July and August and N fertilizer rate were observed in only two ramps in Mr. Jones fields, ramps 3 (pivot) and 4 (drip) (Fig. 1). These two ramps also had significant relationships between lint yield and N rate (Fig. 2 and 3). Few ramps with significant N rate effects were not surprising considering the high level of pre-plant soil profile NO_3 at the sites (Table 1). Among all ramp plots, lint yield did not respond to N fertilizer (Fig. 4). Leaf N was weakly related to NDVI in ramps 3 and 4 only (Fig. 5)

Significant regressions were observed for July NDVI and lint yield as well as August NDVI and lint yield across all ramps (Fig. 6a and b). Good relationships between NDVI and yield are a foundation of Oklahoma State Universities' N fertilizer recommendation algorithms based on in-season NDVI.

We plan to calculate economically optimum N rate for the ramps in 2008, and we plan to repeat this study with the same locations of the ramps in 2009.

Table 2. Nitrogen calibration ramp: pre-plant soil nitrate, farmer nitrogen management, and average lint yields.

Ramp no.	Farmer	Soil NO_3-N (0-24 in)	Pre-plant N applied	In-season N fertigations	Average Lint yield
		----------------------- lb N/ac		------------------------	lb/ac
3	Casey Jones	68	0	0	1088
4	Casey Jones	68	0	0	873
5	Casey Jones	50	0	0	-
6	Casey Jones	92	0	0	1364
7	Casey Jones	58	0	0	943
8	Casey Jones	60	0	0	554
9	Steve Jones	82	21	0	1483
10	Walter VerKamp	55	22	145	2313
11	Walter VerKamp	55	30	165	1946
12	Walter VerKamp	74	30	165	1048
13	Walter VerKamp	30	30	165	1259

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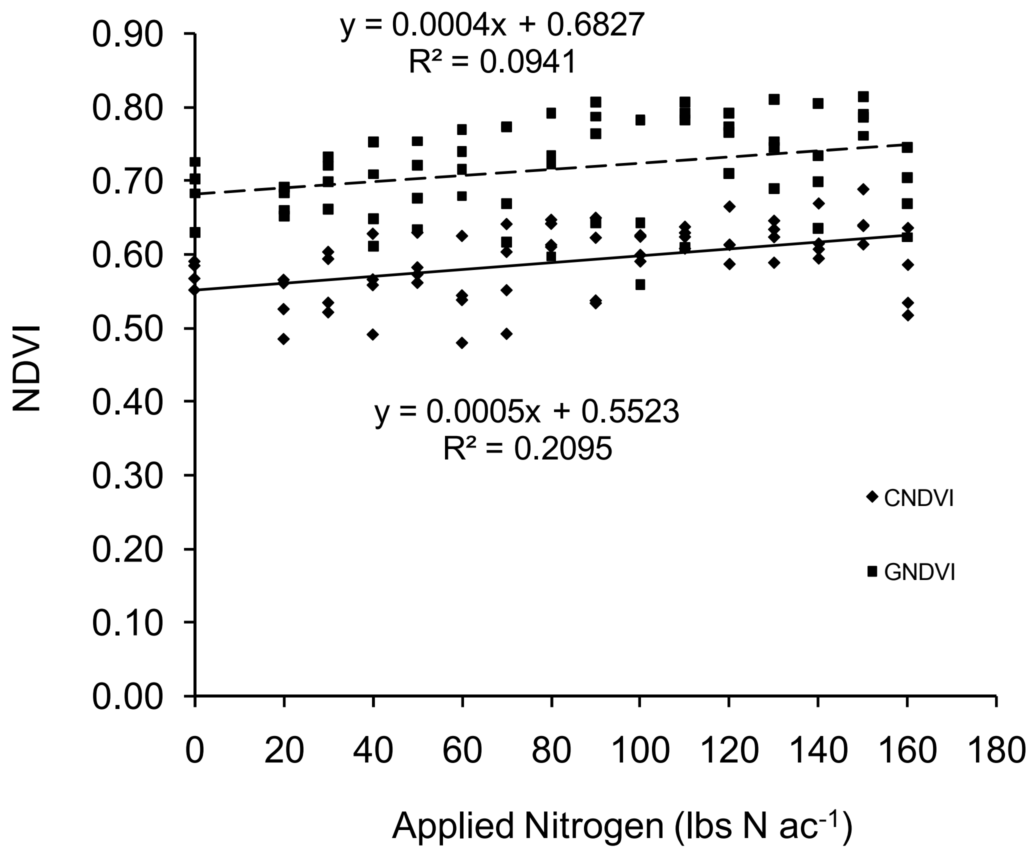

Fig. 1. Normalized difference vegetative index vs. Nitrogen fertilizer rate at mid bloom, ramps 3 and 4, Lubbock county, TX, 2008.

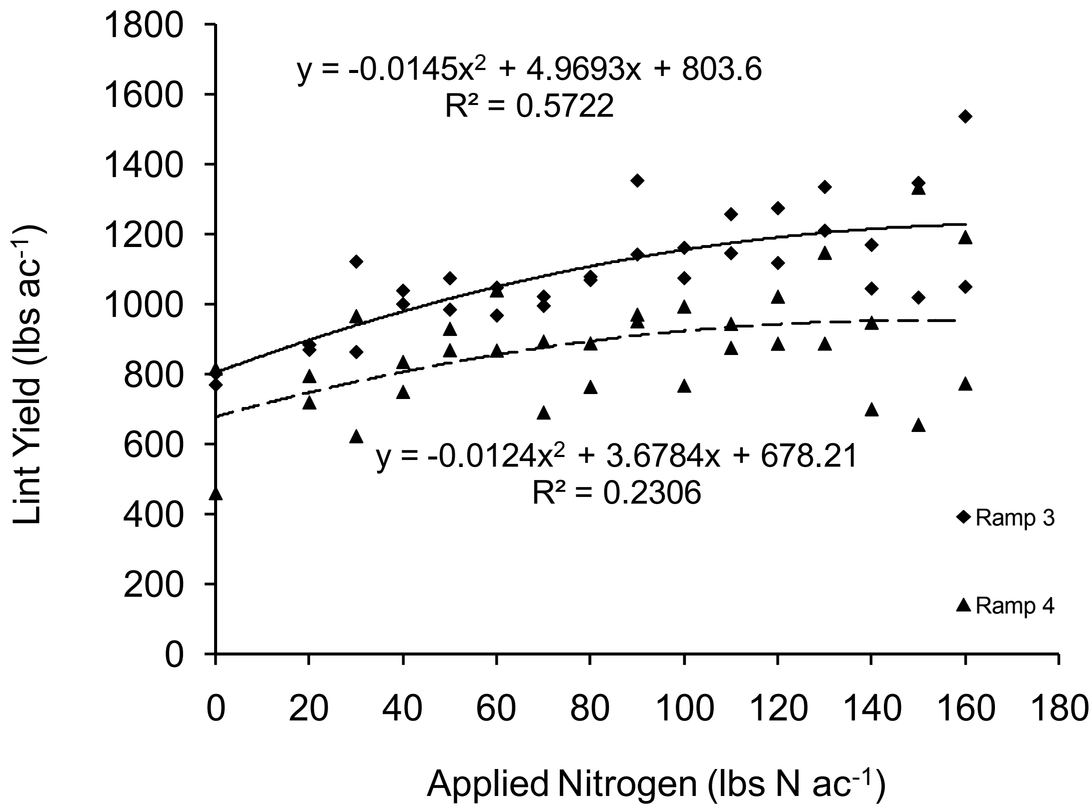

Fig. 2. Lint yield vs. Nitrogen fertilizer rate at mid bloom, ramps 3 and 4, Lubbock county, TX, 2008.

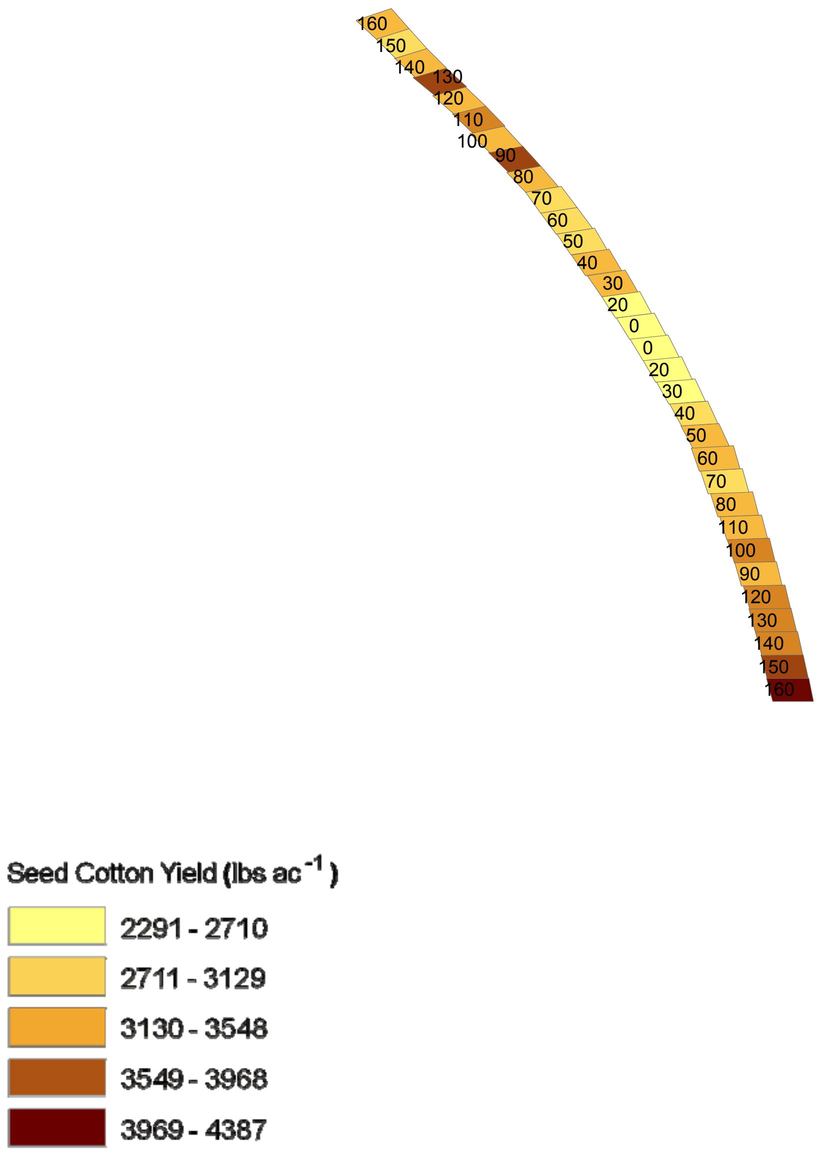

Fig. 3. Lint yield in each ramp plot, ramps 3, Lubbock county, TX, 2008.

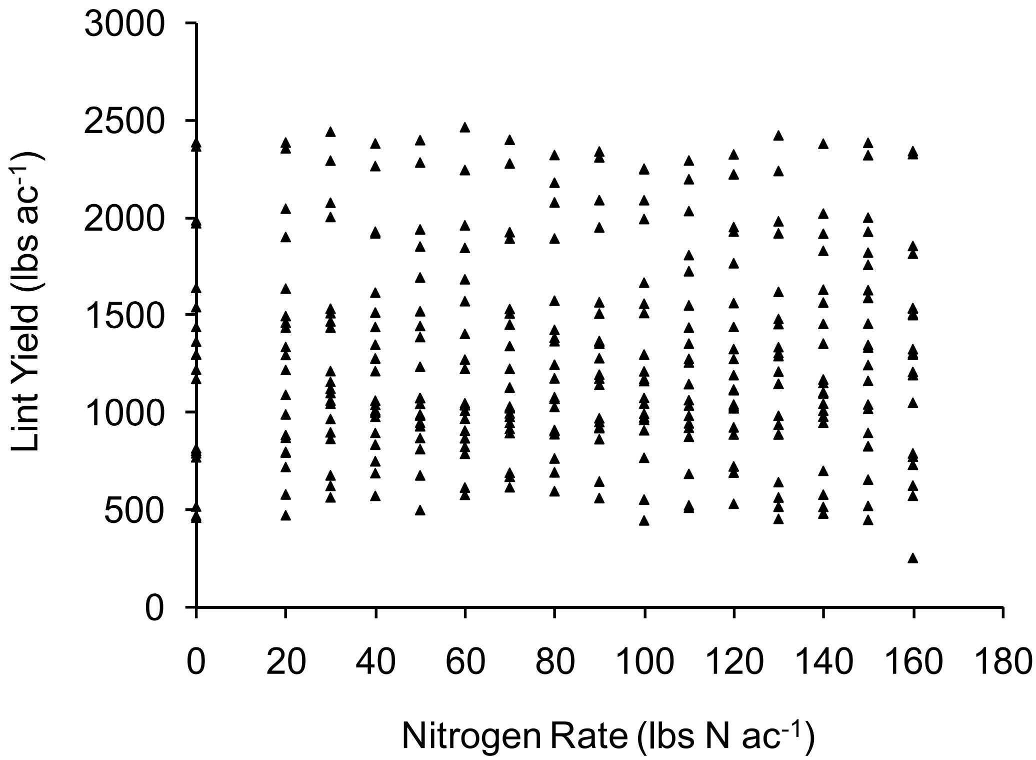

Fig. 4. Lint yield vs. Nitrogen fertilizer rate at mid bloom, 11 ramps, Lubbock County, TX, 2008.

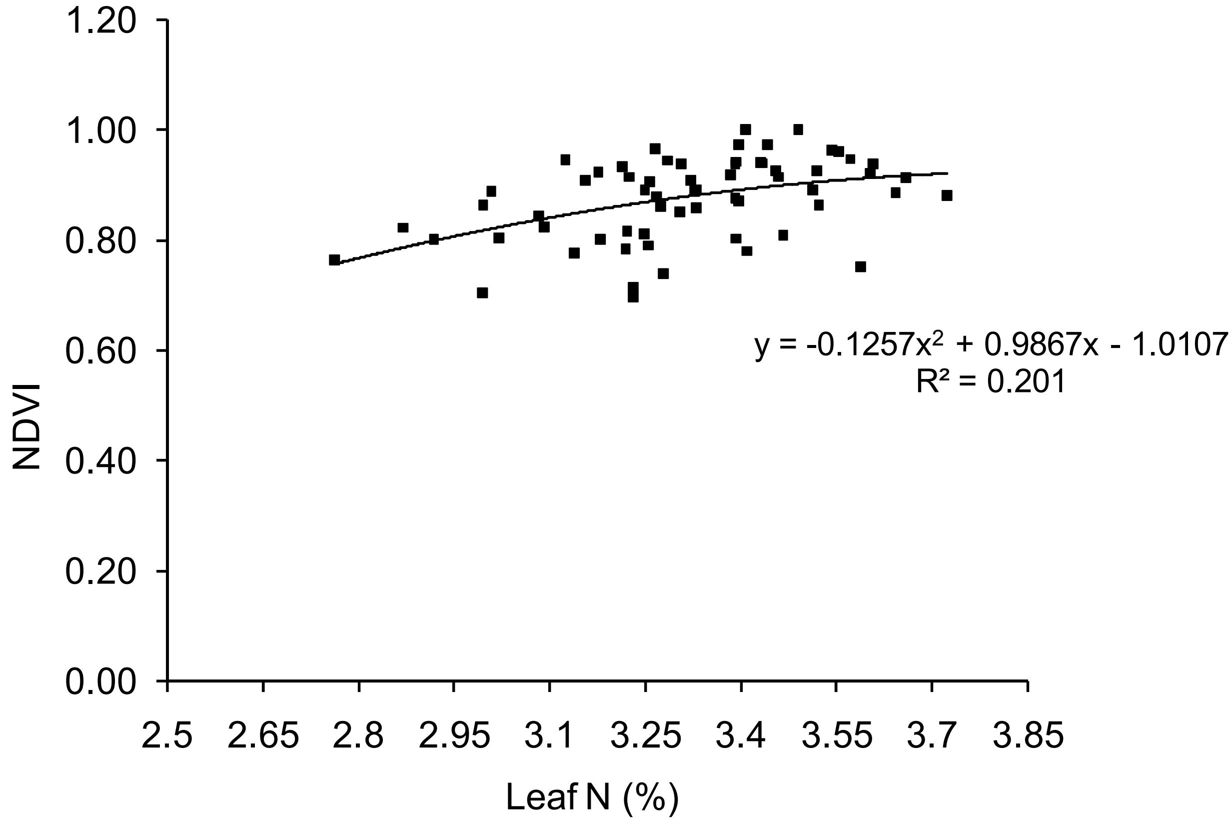

Fig. 5. Normalized differnence vegetative index (CropCircle) vs. leaf N at mid bloom, ramps 3 and 4, Lubbock County, TX, 2008.

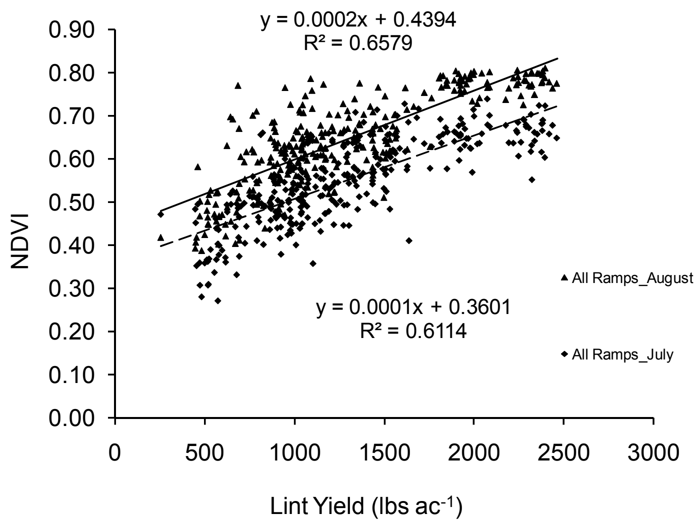

Fig. 6a. Normalized difference vegetative index (CropCircle) vs. lint yield at early (July) mid bloom (August) for 11 ramps, Lubbock county, TX, 2008.

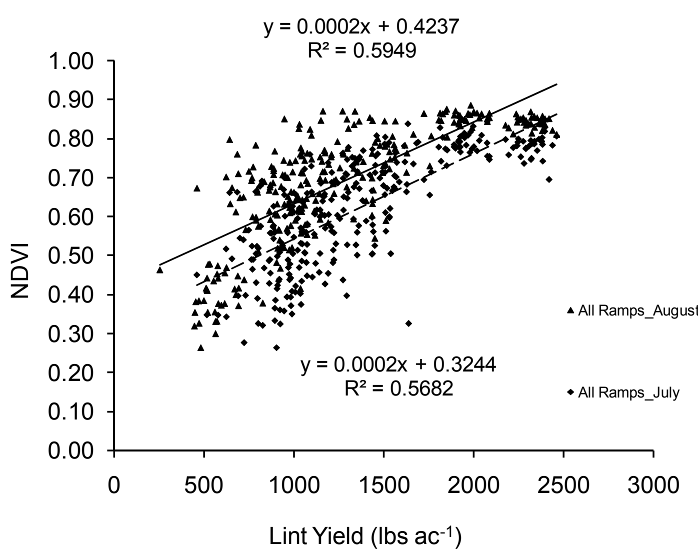

Fig. 6b. Normalized difference vegetative index (GreenSeeker) vs. lint yield at early (July) mid bloom (August) for 11 ramps, Lubbock county, TX, 2008.