PEANUT YIELD RESPONSE TO FOLIAR APPLIED PHOSPHORUS

By

JASON WADE LAWLES

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PEANUT (*Arachis hypogaea)* YIELD RESPONSE TO FOLIAR APPLIED PHOSPHORUS

Abstract

Two experimental sites were established in irrigated, conventionally farmed peanut producing areas of Caddo County, OK in 2002. The objective of this study was to evaluate the effects of foliar applied phosphorus on peanut yields. Because the total amounts of P in grain are relatively small compared to N (1:10), correcting plant deficiencies by foliar application is more plausible for this and other nutrients. Limited work is available documenting the application of foliar P at early stages of growth in wheat, corn, and other legume crops like peanuts that are known to have demand for P. Foliar P was applied at rates of 3 kg ha^{-1} and 6 kg ha^{-1} as potassium phosphate (KH_2PO_4) at pegging. At Hydro in 2002, foliar applied P at 3 kg P ha^{-1} resulted in significantly increased yields when compared to the check Also, foliar applied N at a rate of 15 kg N ha^{-1} resulted in significant increases in yield when compared to the check. At Eakly in 2002, there was a trend for preplant P to increase yields. Both preplant P and foliar applied P resulted in increased yields at Colony in 2003. It was important to find that similar to results at Hydro in 2002, the foliar applied P treatment with no preplant P at 3 kg P ha^{-1} produced greater yields than the preplant P

treatment at 30 kg P ha^{-1}. Foliar applied K increased peanut yields at Colony. At Eakly in 2003, there was a trend for increased peanut yields from preplant P (no foliar N or P) when compared to the check. Limited differences were noted for all other foliar N and P treatments when compared to the check and or check combinations. With no preplant P, foliar P at 3 kg ha^{-1} had phosphorus use efficiencies in excess of 35%, and that represents a significant improvement over preplant soil applications.

Introduction

Nitrogen use efficiencies for cereal crop production in the world today average 33%, while phosphorus use efficiencies seldom exceed 15%. Total P taken up in wheat grain ranges from about 9 to 14 kg ha^{-1} at yield levels ranging between 2 and 3 Mg ha^{-1}, with concentrations of 0.42% P. In corn, 20 to 50 kg P ha^{-1} is taken up the grain at yield levels between 8 and 15 Mg ha^{-1}, and a concentration of 0.31% P.

Because the total amounts of P in grain are relatively small compared to N (1:10), correcting plant deficiencies by foliar application is a more viable option for this and other nutrients. Limited work is available documenting the application of foliar P at early stages of growth in wheat, corn, and other legume crops like peanuts that are known to have higher demand for P. Recent work has shown that foliar applications after anthesis of 5 to 10 kg KH_2PO_4 ha^{-1} (1.1 to 2.2 kg P ha^{-1}) can increase wheat grain yields by up to 1 Mg ha^{-1} (Benbella and Paulsen.1998). The increases have been attributed to a slowed senescence, or stay-green, but that may have been due to P response.

In general P deficient soils require preplant broadcast-incorporated rates of 10 to 20 kg P/ha to correct the deficiency in either wheat or corn. At a P use efficiency (PUE) of 15%, this addition results in only 1.5 to 3.0 kg P taken up in the grain. Although the literature does not provide information on relative efficiencies (soil applied versus foliar applied P), because it circumvents soil chemical reactions that greatly reduce pant availability, foliar applied P should be expected to be much higher. We believe that small amounts required to correct deficiencies can be easily introduced to the plant by a foliar P application. This approach has been overlooked for decades because it was assumed that the amounts of fertilizer P required by the crop were too great to be satisfied by a single foliar application. That assumption was easily accepted when P fertilizers were first used because soil deficiencies tended to be greater than today and solution fertilizers were uncommon.

Conventional P-soil test correlation utilizes knowledge that soil deficiencies may be represented as a percentage of the maximum yield when there is no P deficiency (Mitscherlich-Sufficiency Concept). Consequently, soil test calibrations identify rates of fertilizer-P required to correct the plant deficiency for a season. Depending on the relative annual input and removal, this practice may either increase or decrease long-term available soil-P. Appropriate for soil-applied P, as rates do not need to be adjusted for yield level. However, rates of foliar P need to address uptake deficiencies of the plant, which are influenced both by potential yield (biomass) and available soil-P. Our research has shown that potential yield can be reliably predicted, midseason, for each

$1m^2$, and that yield is known to vary over very short distances. (Solie el al., 1999 and Raun et al., 2001a). A result of our mid-season estimates of potential grain yield is that nutrient needs (N, P, K, and all other essential elements) to be applied in direct relation to the potential yield since removal for each specific element by the crop can be predicted.

Prediction of Potential Yield

All of the following work has been developed for wheat, unlike peanuts, requires substantial amounts of preplant and in-season N. However, based on current work showing increased peanut yields from in-season application of foliar N, we believe that this work is applicable for various nutrients required by peanuts, based on a projected yield (mid-season), using canopy reflectance as an indirect measure.

In the past three years, several indices have been developed such that temporal and spatial variability does not impair the ability to detect differences, and that employ plant reflectance readings in the red and near infrared bands (Raun et al. 2001a; In-Season-Estimated-Yield (INSEY), Lukina et al. 2001). Reflectance (ratio of incident and reflected light) is used in the normalized difference vegetative index (NDVI) calculation to minimize error with cloud cover, shadows and sun angle. The reflectance-based NDVI equation is;

NDVI = [(NIRref/NIRinc)-(Redref/Redinc)] / [(NIRref/NIRinc) + (Redref/Redinc)]

NIRref and Redref = magnitude of reflected light;

NIRinc and Redinc = magnitude of the incident light.

Unlike models that rely on inputs such a soil tests and growing degree days alone to predict plant biomass and growth, optical sensing uses the plant as the indicator of overall health and vigor. NDVI provides an accurate estimate of plant biomass (Lukina et al., 2001). Therefore optical sensor measurements (NDVI) taken at a specific date, can integrate production and time, resulting in an estimate of rate of growth. This rate of growth has in turn been correlated with final winter wheat grain yield over 24 sites, and four years (Lukina, 2001b). Integrated information from planting to any point mid or late-season within the growth cycle of plants is critical concerning final yield potential.

The OSU approach operates under the premise that optical measurements should be taken every 1m^2 due to inherent variability in most soils, which affects yield potential on that area (Solie el al., 1999). Thus, yield potential depends on the interaction between 1m^2 conditions and the environment (Lukina et al., 2001). Previous work has shown that adjacent 1 m^2 areas will not always have the same yield potential (within the same field in a single year), and individual 1 m^2 areas having a high yield potential one year may not necessarily have a high yield potential in subsequent years.

OSU's most recent work has focused on refining in-season nutrient additions based on the likelihood of obtaining a response (Johnson et al.,2003). The response index (RI) can be obtained for any nutrient, simply by creating within each field, a representative area where the nutrient of interest is not limiting, and right adjacent to that location, an additional area where the nutrient in question is limiting and/or where this nutrient has not been applied. Our work has shown that the response index is highly dependent upon the environmental conditions that influenced growth up to the time where mid-season measurements are taken (Johnson et al.,2003). It is therefore obvious that RI can change drastically for the same field from one year to the next.

Mid-season Algorithm for General Plant Nutrition

Patents developed at OSU (Stone et al., 2001, and Raun et al., 2001b), mid season N needs can be predicted using in-season estimates of yield (INSEY). The in-season estimate of yield with out any additional nutrients (YPo) is then multiplied by the response index to obtain the yield potential if N fertilizer is applied (YPn). The N fertilizer that should be applied is determined by subtracting estimated grain N uptake at YPo from estimated N uptake at YPn divided by a theoretical efficiency factor of 0.60 to determine mid-season foliar N rates. This efficiency can change depending on the production system and method of application.

The INSEY index that has been used to predict yield (NDVI/(days from planting where growing degree days are > 0 or YPo) can also be applied to estimate removal of any element at harvest, based on known concentrations of different elements in the cereal grain at harvest. Predicted element uptake in cereal grain is estimated by multiplying the potential grain yield (INSEY) times known concentrations of element in the grain of that crop. Mid-season estimates of dry biomass can be obtained using NDVI. This is in turn multiplied times known concentrations of the element in the plant to obtain total plant uptake of the element.

Although not considered in the approach for nitrogen, x-element mid-season uptake needs to be expressed as a percent of the total x-element accumulation, or percentage of the total growing days included in the cycle.

Peanuts are one of the leading agriculture crops of the world for the production of oil and plant protein (Woodroof, 1966). Burkhart and Collins (1942) showed that a peanut absorbs nutrients through the pegs and roots. It has been shown that by adding nutrient sources based on soil testing, yields of peanuts can be increased (Woodroof.1966, Reddy and Tanner 1980). Earlier trials indicated that a greater yield response might be obtained from phosphorus than from either nitrogen or potassium. Walker (1984) found that the addition of foliar applied nitrogen to peanuts increased yields; however nodulation decreased with additional nitrogen. The overall yield and quality of peanut was increased with the addition of nitrogen fertilizer.

The results of a ten-year study at the Georgia Costal Plain Experiment Station in which peanuts were grown after crops that received moderate fertilization showed little effect from adding 23 kg ha^{-1} of P_2O_5 on peanut yields. For many years the recommended placement of fertilizer was in a band below and to the side of the seed. (Batten and Cummings,. 1945; Futral, 1952). Burrell, (1942) showed that an alternative way to applying fertilizer was to broadcast and mix with the soil to reduce the direct contact with the peanut seed thus, reducing seed injury.

For a soil test to be effective, the extracting solution P concentration should indicate whether or not a site will be responsive to fertilizer containing that element. The critical concentration for the deficient and non- responsive soils may vary somewhat with the soil type and the crop being grown. The Mehlich III method for P and K extraction is used extensively through Oklahoma. Walker el al. (1974.) evaluated regions of Alabama where there was no response to soil P of 22 mg g^{-1}. Soil test P levels that are adequate for peanuts are often lower than those required for most other crops (Cope et al. 1984) Gascho et al. (1988) reported that the Mehlich III P extractant method extracted one and a half times more P than did the Mehlich 1 method. This indicated that the critical levels would need to be 17-25 mg g^{-1} (Cox, 1994).

Materials and Methods

The experimental sites were selected in irrigated conventionally farmed peanut producing areas of Caddo County, OK (Latitude 35.455N Longitude -98.550W). Two locations were initiated in the spring of 2002 on private farms at Eakly, and Hydro, OK to evaluate the effects of foliar applied P. The Eakly site was also used in 2003 and a farm near Colony, OK was substituted for the Hydro site. Soil chemical characteristics are reported in Table. 2. At the Hydro farm, (Eufaula loamy fine sand, sandy, siliceous, thermic, Psammentic Paleustalfs), the variety TAMSPAN 90 was planted on May 6, 2002 At the Eakly farm, (Noble fine sandy loam, mixed, thermic, Udic Ustochrepts), the variety TAMRUN 98 was planted on May 6, 2002. For the 2003 season at Eakly, (Noble fine sandy loam, mixed, thermic, Udic Ustochrepts), the variety TAMSPAN 90 was planted on May 3, 2003. At the Colony site (Devol coarse-loamy, mixed, thermic Udic Haplustalfs), the variety TAMRUN 98 was planted on May 14, 2003.

Treatment structure for the entire experiment is reported in Table 1. At each location, a randomized complete block design was employed with four replications. Each plot consisted of four 91 cm rows, 610 cm long. The two inside rows were harvested for yield. Each variety was planted at the rate of 90 to 110 kg/ha. Application of foliar applied nutrients was applied pegging growth stage. Peggs are intercalary meristems located adjacent to basal ovules, once the ovoules are fertilized with pollen then pegging commences. Preplant P was applied and incorporated as 0-46-0, foliar P was a applied as 22% solution of KH_2PO_4 , foliar N was applied as 28-0-0 (UAN) with a 50% dilution with water. Foliar K rate can a KH_2PO_4 , treatment 15 received K applied as $KHCO_3$ to distinguish any effect of foliar K applied with the foliar P treatments. Weed control consisted of Prowl 3.3EC (pendimethalin) at a rate of 134 g a.i./ha and Pursuit 2L (imazethapyr) at a rate of 12 g a.i./ha and midseason application of Cadre (imazapyc) at a rate of 0.29 l/ha at all locations.

At the Eakly site 34, 1m^2 plots, and 24, 1m^2 plots at the Colony site were sensed using GreenSeeker optical sensor throughout the growing season. Each plot consisted of two rows (91cm wide by 182 cm long) and each row was sensed holding the GreenSeeker 60 to 90 cm above the crop canopy. NDVI values were then calculated then averaged between the two rows. The plots were sensed every two weeks until early maturity and yield prediction using a modified INSEY equation will be evaluated.

Harvested rows were dug with a mechanical inverter. The plants were then allowed to air-dry until leaves and stems were dry enough to thrash. The pods were then removed from the vines in the field by a regular plot thresher. Pods were placed in burlap bags and dried to 12-14% moisture then weighed. Yield was then calculated on a kg ha^{-1} basis. Subsamples of pods were selected from each treatment for determination of grade and chemical composition of kernels. The percent sound kernels (SMK), sound mature splits (SS), hulls according to United States Department of Agriculture Inspection Service.

The P analysis for this experiment was carried out by grinding the nuts as fine as possible without turning the material into paste. The sample was then digested with 5ml HNO_3 at 125°C for 4 hours, which was then analyzed using a high resolution inductively coupled plasma spectrophotometer (Thermo-Jarrell Ash IRIS ICP). Check plot samples were spiked with 6.476 mg P kg^{-1} processed peanut material since no peanut standard reference material (SRM) is currently available. The method recovered 98.7% of the spiked phosphorus. Total nitrogen valued was determined using a Leco CN-2000 carbon and nitrogen analyzer. The method for sample preparation and analysis was conducted according to the Leco CN-2000 Instruction Manual.

Results

2002 Crop Year

At Hydro in 2002, foliar applied P at 3 kg P ha^{-1} resulted in significantly increased yields when compared to the check (3 vs 1, Table 4). It was noteworthy to see that foliar applied P at only 3 kg P ha^{-1} resulted in the same yields as 30 kg P ha^{-1} applied preplant. This resulted in 50% phosphorus use efficiency (PUE). Also, foliar applied N at a rate of 15 kg N ha^{-1} resulted in significant increases in yield when compared to the check (13 vs 1). Because a response to applied P and N (independent of one another) as foliar sources was noted, we expected the combined foliar N and P treatment to result in even greater yields (11 vs 13 and 1).

At Eakly in 2002, there was a trend for preplant P to increase yields. However, when comparing response to the absolute check (all treatments versus 1), limited differences in peanut yield and/or N and P uptake were observed. No response to foliar applied K was noted at either Hydro or Eakly in 2002 (15 versus 2, Table 4).

2003 Crop Year

Peanut yield and N and P uptake results are reported for Colony and Eakly in Table 5. Both preplant P and foliar applied P resulted in increased yields at Colony in 2003. It was important to find that similar to the results at Hydro in 2002, the foliar applied P treatment with no preplant P at 3 kg P ha^{-1}

produced greater yields than the preplant P treatment at 30 kg P ha^{-1}. This is a significant improvement in both efficiency and yield at what was not expected to be a P responsive site (see Table 3, soil test levels). However, this result was somewhat speculative, noting that no response was seen at the higher foliar P rate of 6 kg P ha^{-1} (4 vs 3 and 1). Similar to the Hydro site, foliar applied N without preplant P resulted in increased peanut yields, N and P uptake when compared to the check (treatments 13, and 14 versus 1). It is not understood why the lack of synergistic effects were observed when applying both N and P since N and P alone resulted in increased yields. Foliar applied K increased peanut yields at Colony (15 versus 2).

At Eakly in 2003, there was a trend for increased peanut yields from preplant P (no foliar N or P) when compared to the check (15 versus 1, confounded K effect). Limited differences were noted for all other foliar N and P treatments when compared to the check and or check combinations. Also, a trend for increased yields from foliar applied K (treatment 15 versus 2) was observed at this location.

Peanut grades and the components of the grade were evaluated at each site during both years. Although not shown there was not any significant difference in the grade or the component of the grade due to treatment.

Prediction of Yield Potential

Although NDVI alone showed some promise for predicting yields from mid season sensor measurements (planted in May and sensed in July and August) it may well be that earlier readings were required (Figures 1-4) This is evidenced in the narrow range of NDVI readings with corresponding differences in yield that were quite large. July sensor readings were characterized by 100% within row canopy cover and earlier readings would have resulted in increased variability subsequently enhancing the ability in detecting differences in plant biomass. NDVI values tended to increase with advancing stage of growth at all four sites (Figures 5-8).

Conclusions

Soil tests that indicate a low P index in routine random soil samples will identify those sites where the addition of pre plant P can increase yield. At each location where the initial soil sample indicated there was a P deficiency, preplant P was able to correct the deficiency. However, mid season foliar application of 3 kg ha^{-1} P in addition to 15 kg ha^{-1} N increased yields at two of the four locations. The addition of foliar N alone did not always produce a significant increase in yield. At the Hydro site in 2002 foliar P at 3 kg P ha^{-1} produced the same yields as 30 kg P ha^{-1} resulting in greater P use efficiency. At Colony in 2003, there was also response to foliar P at the 3 kg P ha^{-1} rate. However response to foliar applied N applied alone only occurred at the Hydro site in 2002. At both the Hydro and Colony sites where a response to P was observed 3 kg P ha^{-1} was able to maintain and or increase yields with greater than 50% PUE. Possible solutions to detecting a response may be the application of a non-P limiting strip in the field to detect if any additional P is needed. Our ability to predict yield using a modified INSEY equation showed some promise, however this data suggests that earlier sensing dates should be evaluated. By sensing earlier within row canopy cover will be reduced thus allowing for differences in plant biomass to be detected. Foliar applied P at rates of 3 kg P ha^{-1}. had phosphorus use efficiencies (PUE) in excess of 35% at all locations, which is much higher than PUE from preplant applications.

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Table 1. Treatment structure implemented during crop years 2002 and 2003

Treatment	Pre-Plant P Rate+	Foliar P#	Foliar N##	Foliar K
	----------kg ha^{-1}----------			
1	0	0	0	0
2	30	0	0	0
3	0	3	0	3.6
4	0	6	0	7.2
5	30	3	0	3.6
6	30	6	0	7.2
7	30	3	15	3.6
8	30	3	30	3.6
9	30	6	15	7.2
10	30	6	30	7.2
11	0	3	15	3.6
12	0	3	30	3.6
13	0	0	15	0
14	0	0	30	0
15	30	0	0	3.6 Ŧ

\+ Pre plant P applied as 0-46-0
\# Foliar P applied as 22% solution of KH_2PO_4
\## Foliar N applied as 28-0-0 solution with 50% dilution with water
Ŧ Foliar K applied as $KHCO_3$, other foliar K rates from carrier KH_2PO_4

Table 2. Surface soil (0-15 cm) and chemical characteristics prior to experiment initiation at Eakly, Hydro and Colony, OK.

Location	NH_4-N	NO_3-N	P	K	pH
	mg kg^{-1}				
Eakly	14.35	8.86	9.34	282	5.67
Hydro	15.78	3.89	6.49	222	6.23
Colony	15.87	11.16	28.23	225	5.70

NH_4-N and NO_3-N – 2 M KCL extract; P and K – Mehlich-3 extraction; pH – 1:1 soil:deionized water

Table 3. Planting, fertilizer, and harvest dates at Eakly, Hydro and Colony, OK, experiment sites. 2002-03.

Location	Application Pre-Plant P	Planting	Foliar Application	Harvest
Eakly 2002	April 25	May 6	August 8	October 16
Hydro 2002	April 25	May 6	August 8	October 16
Eakly 2003	April 23	May 3	July 25	October 3
Colony 2003	April 23	May 14	August 15	October 20

Table 4. Peanut yield means, N uptake, and P uptake as a function of pre-plant P, foliar P, foliar N and foliar K, 2002 crop year.

				Hydro				Eakly			
Trt	PP	FP	FN	Grain Yield	N uptake	P uptake	PUE	Grain Yield	N uptake	P uptake	PUE
				------------- $kg\ ha^{-1}$	-------------	-------------	%	------------- $kg\ ha^{-1}$	-------------	-------------	%
1	0	0	0	1017	54	4.5		5001	183	19.7	
2	30	0	0	1530	81	6.5	6.6	4687	173	18.1	0
3	0	3	0	1797	95	7.5	100	5082	185	20.7	35
4	0	6	0	1702	92	7.4	48	4879	183	18.7	0
5	30	3	0	1033	55	5.5	3.0	4826	186	20.0	0
6	30	6	0	1316	69	5.7	3.3	4789	184	19.0	0
7	30	3	15	1506	79	6.3	5.4	5429	216	22.6	3.4
8	30	3	30	1387	72	6.0	4.5	5229	205	20.8	2.5
9	30	6	15	1486	76	6.2	4.7	5498	211	21.9	3.3
10	30	6	30	1219	63	5.3	2.2	5345	201	20.8	2.5
11	0	3	15	1338	70	6.0	50	5201	193	21.9	73
12	0	3	30	1442	75	6.3	60	4982	194	19.2	0
13	0	0	15	1728	91	7.4		4846	176	19.1	
14	0	0	30	1607	83	6.6		5022	185	20.5	
15	3.6 Foliar K			1511	80	6.8	7.6	4664	179	18.6	0
SED				267	14.3	2.3	26	236	10.0	2.6	36
Contrast											
Pre plant P				*	*	ns	ns	**	**	ns	ns
6vs9				ns	ns	ns	*	*	*	**	*
2vs5				ns	**	ns	ns	**	ns	ns	ns
1vs13				*	*	ns		ns	ns	ns	
1vs3				*	**	*	*	ns	ns	ns	ns

Trt- treatment
PP- preplant P
FP- foliar P
FN- foliar N
* Significant at the 0.05 probability level
** Significant at the 0.10 probability level
ns- not significant
SED- Standard error of the difference between two equally replicated means
PUE- phosphorus use efficiency determined by subtracting grain p uptake in the check (no P applied) from the P treated plot, divided by the rate of P applied.

Table 5. Peanut yield means, N uptake, and P uptake as a function of pre-plant P, foliar P, foliar N and foliar K, 2003 crop year.

Trt	PP	FP	FN	Colony Grain Yield	Colony N uptake	Colony P uptake	Colony PUE	Eakly Grain Yield	Eakly N uptake	Eakly P uptake	Eakly PUE
				------------kg ha^{-1}------------			%	------------kg ha^{-1}---------			%
1	0	0	0	2553	123	9.0		4087	187	16.2	
2	30	0	0	2954	140	10.6	5.3	3892	185	16.2	0
3	0	3	0	3426	160	11.3	100	4140	183	18.0	73
4	0	6	0	2793	141	9.9	15	4061	194	13.7	0
5	30	3	0	3191	161	11.3	6.9	4438	211	18.6	7.2
6	30	6	0	3811	180	13.4	12	4695	228	19.8	10
7	30	3	15	3136	155	11.0	6.0	4137	197	16.9	2.1
8	30	3	30	3373	167	11.7	8.2	4514	214	18.4	6.6
9	30	6	15	2994	149	11.3	6.4	4448	213	18.4	6.1
10	30	6	30	3601	159	12.5	9.8	4280	194	17.6	3.8
11	0	3	15	3357	139	10.2	40	4333	204	17.9	56
12	0	3	30	3785	175	12.7	100	3914	181	16.2	0
13	0	0	15	3475	188	12.6		3850	186	17.1	
14	0	0	30	3626	184	12.5		4088	198	16.6	
15	3.6 Foliar K			3516	167	13.4	14.6	4587	213	19.3	10
SED				407	36	2.2	35	263	27	3.1	41
Contrast											
Pre plant P				*	**	ns	**	**	ns	ns	ns
6vs9				**	ns	ns	ns	ns	ns	**	ns
2vs5				ns	ns	ns	ns	**	ns	ns	**
1vs13				**	ns	**		ns	**	ns	
1vs3				**	ns	ns	*	ns	ns	ns	ns

Trt- treatment
PP- preplant P
FP- foliar P
FN- foliar N
* Significant at the 0.05 probability level
**S ignificant at the 0.10 probability level
ns- not significant
SED- Standard error of the difference between two equally replicated means
PUE- phosphorus use efficiency determined by subtracting grain p uptake in the check (no P applied) from the P treated plot, divided by the rate of P applied.

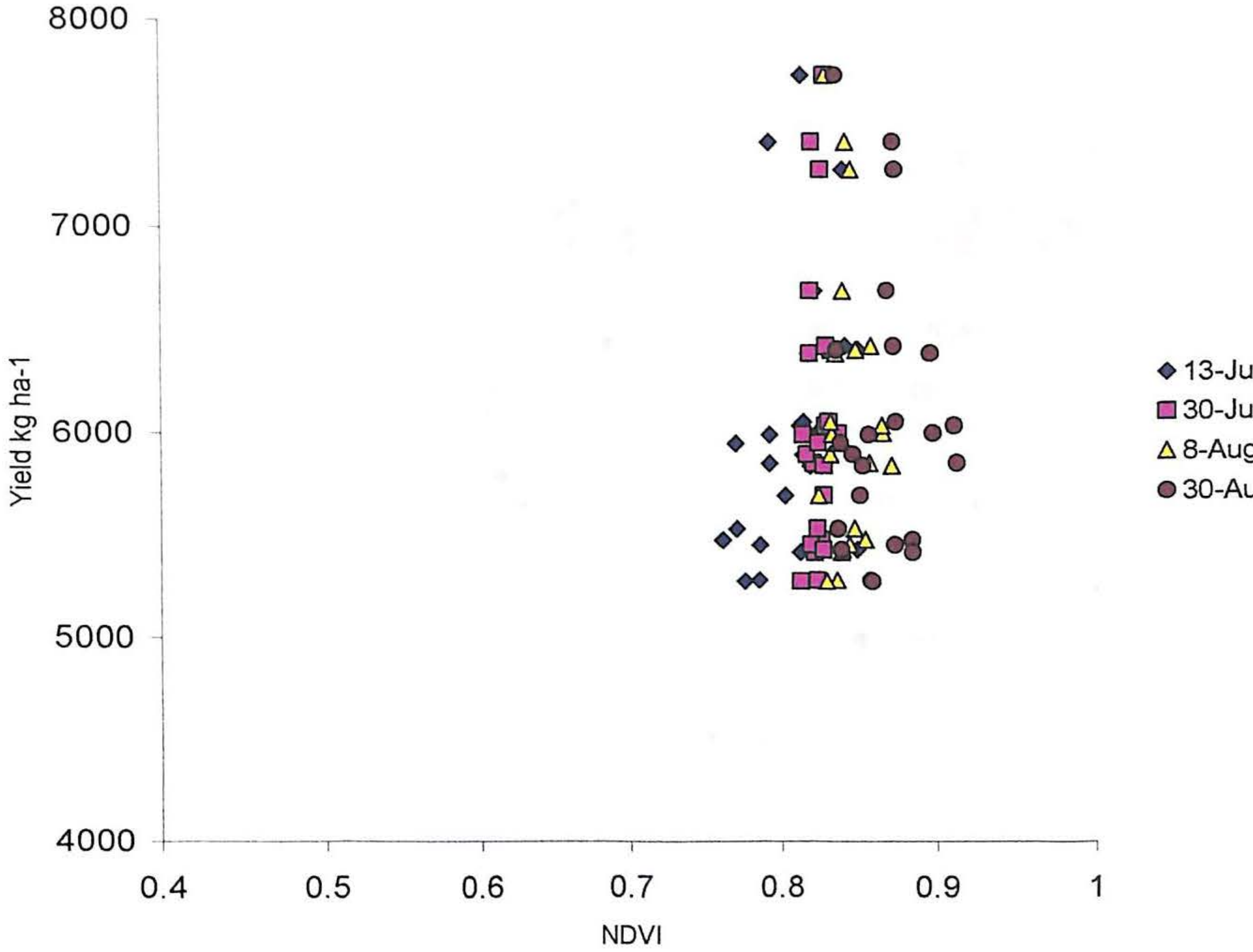

Figure 1. Relationship between mid season NDVI readings and grain yield at the Eakly location 2002 for four sensing dates.

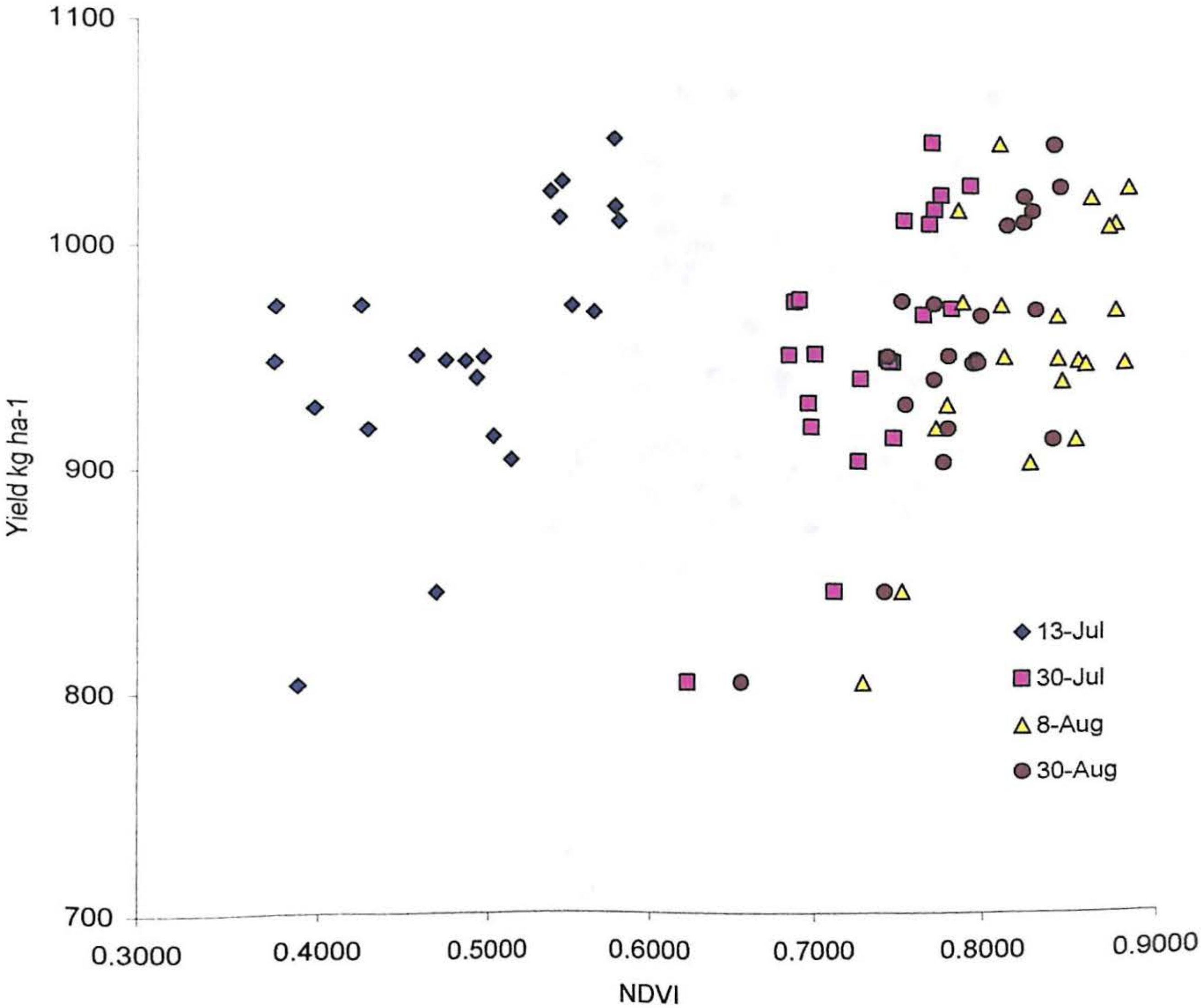

Figure 2. Relationship between mid season NDVI readings and grain yield at Hydro, 2002, at four sensing dates.

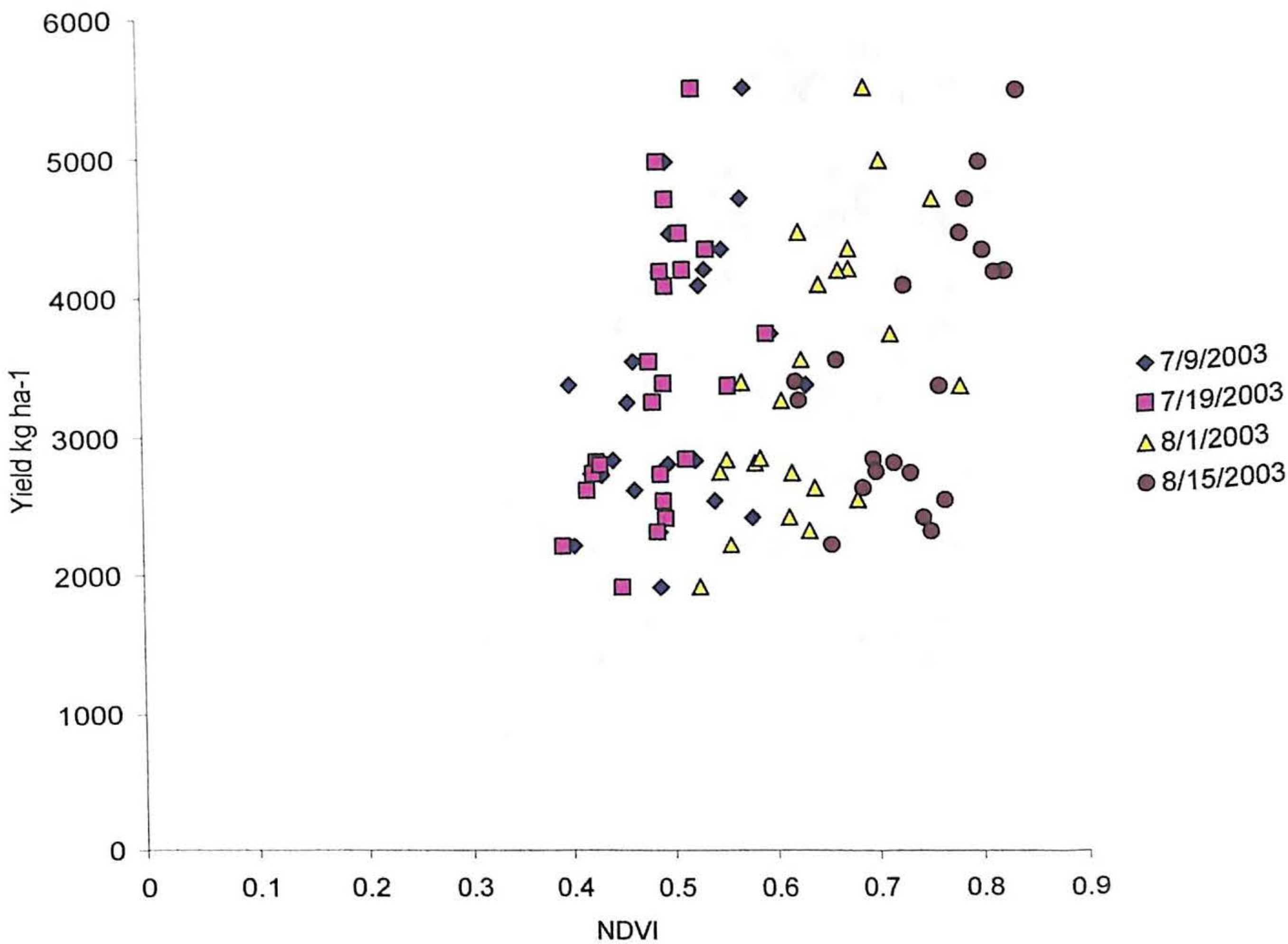

Figure 3. Relationship between mid season NDVI readings and grain yield at, Colony, 2003, at four sensing dates.

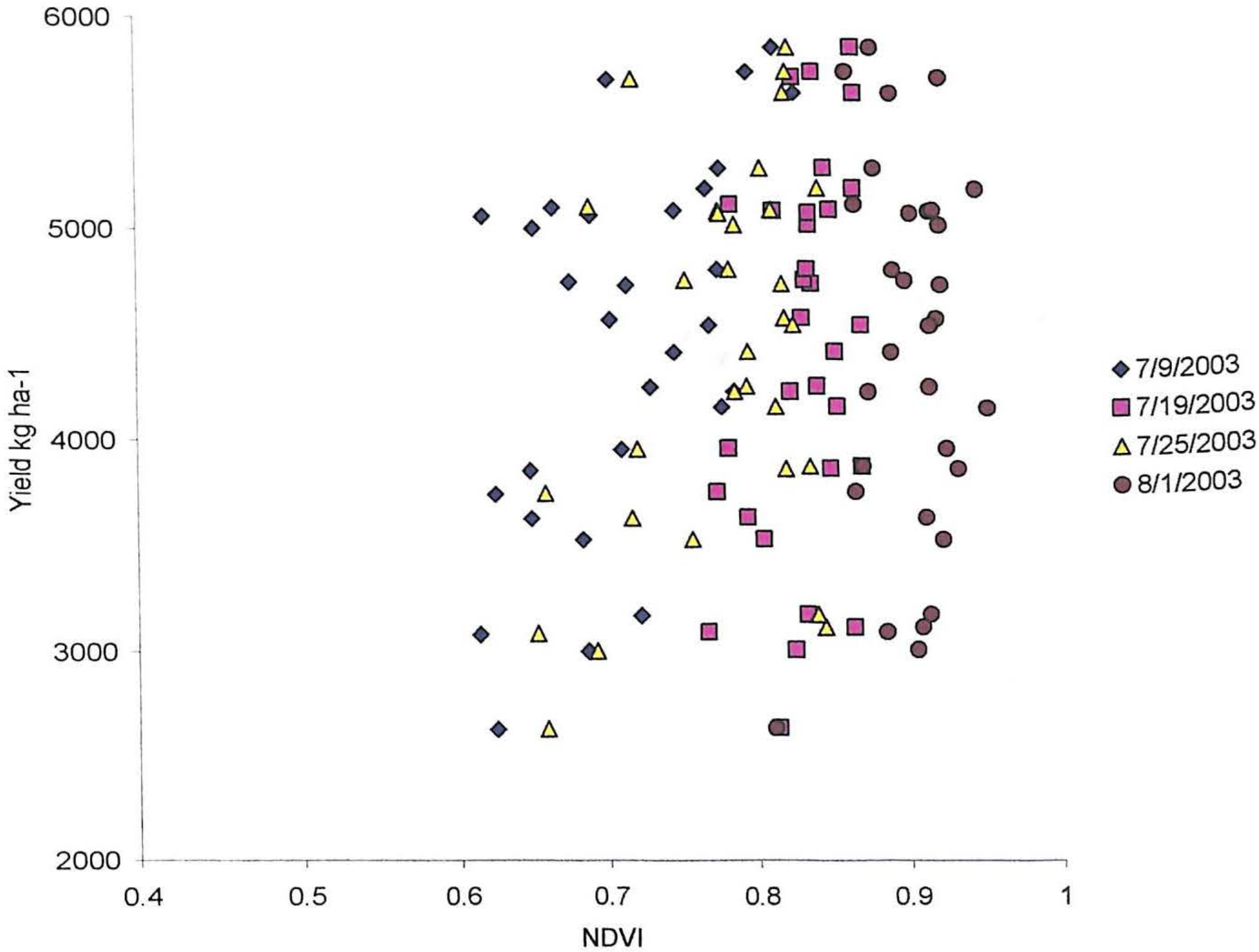

Figure 4. Relationship between mid season NDVI readings and grain yield at, Eakly, 2003, at four sensing dates.

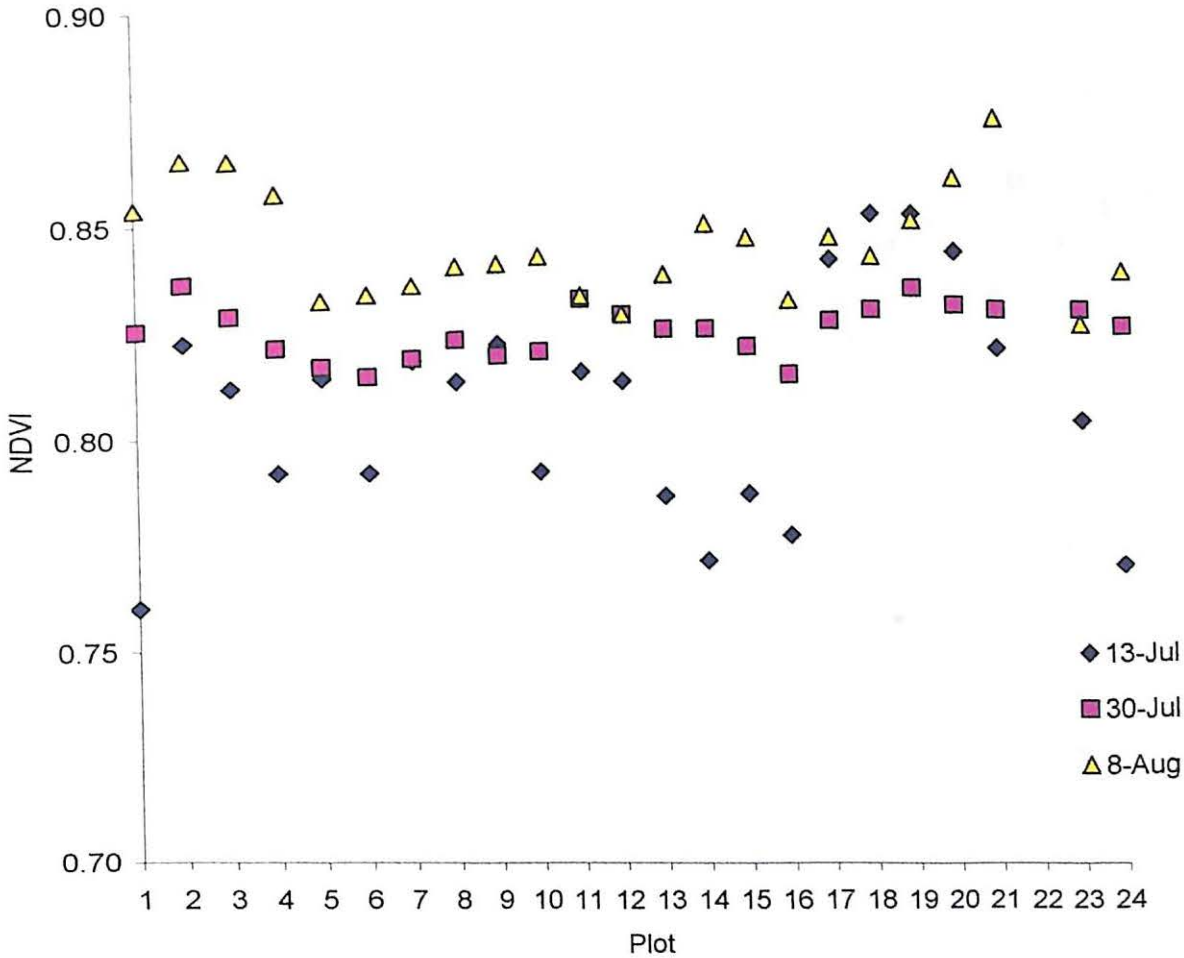

Figure 5. Mid-season NDVI readings as a function of time, Eakly, 2002.

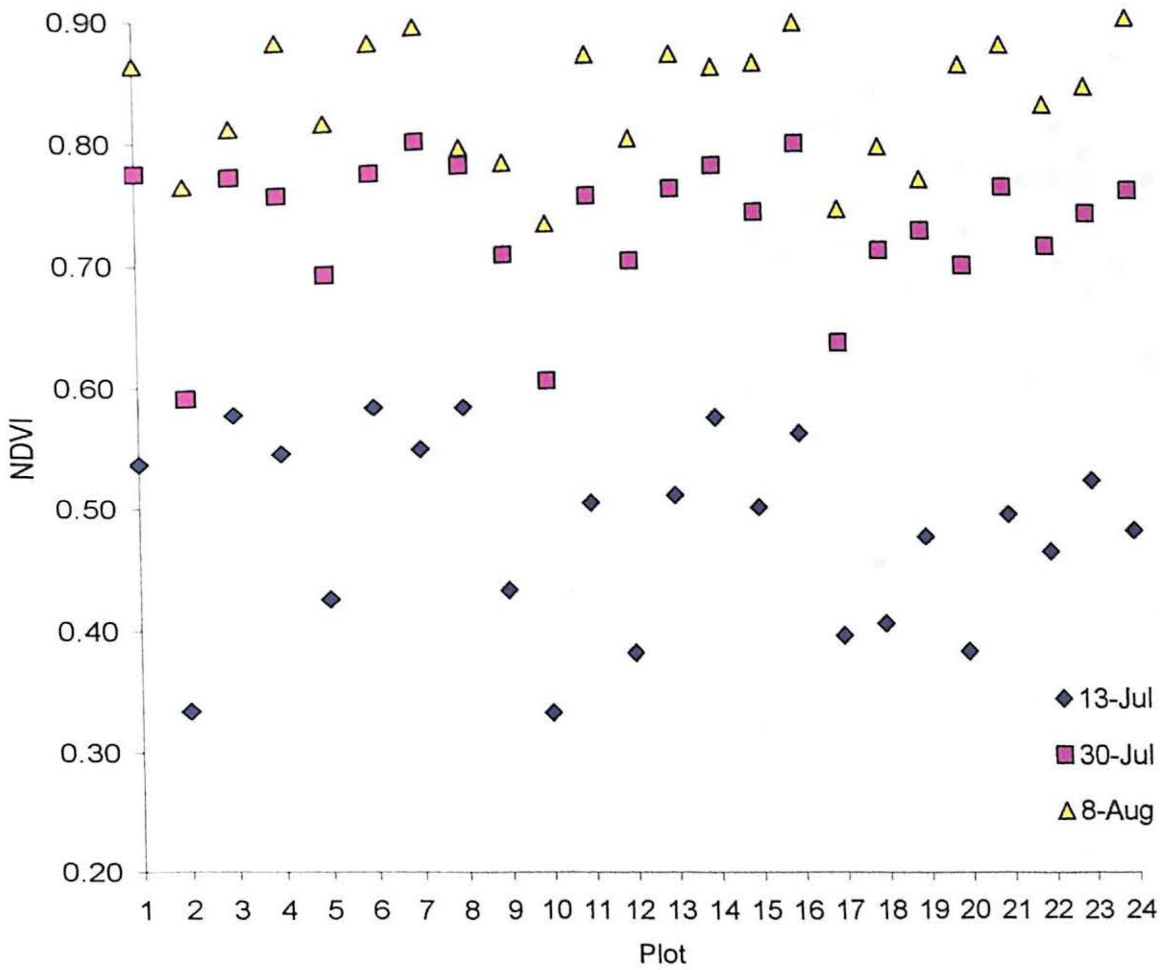

Figure 6. Mid-season NDVI readings as a function of time, Hydro, 2002.

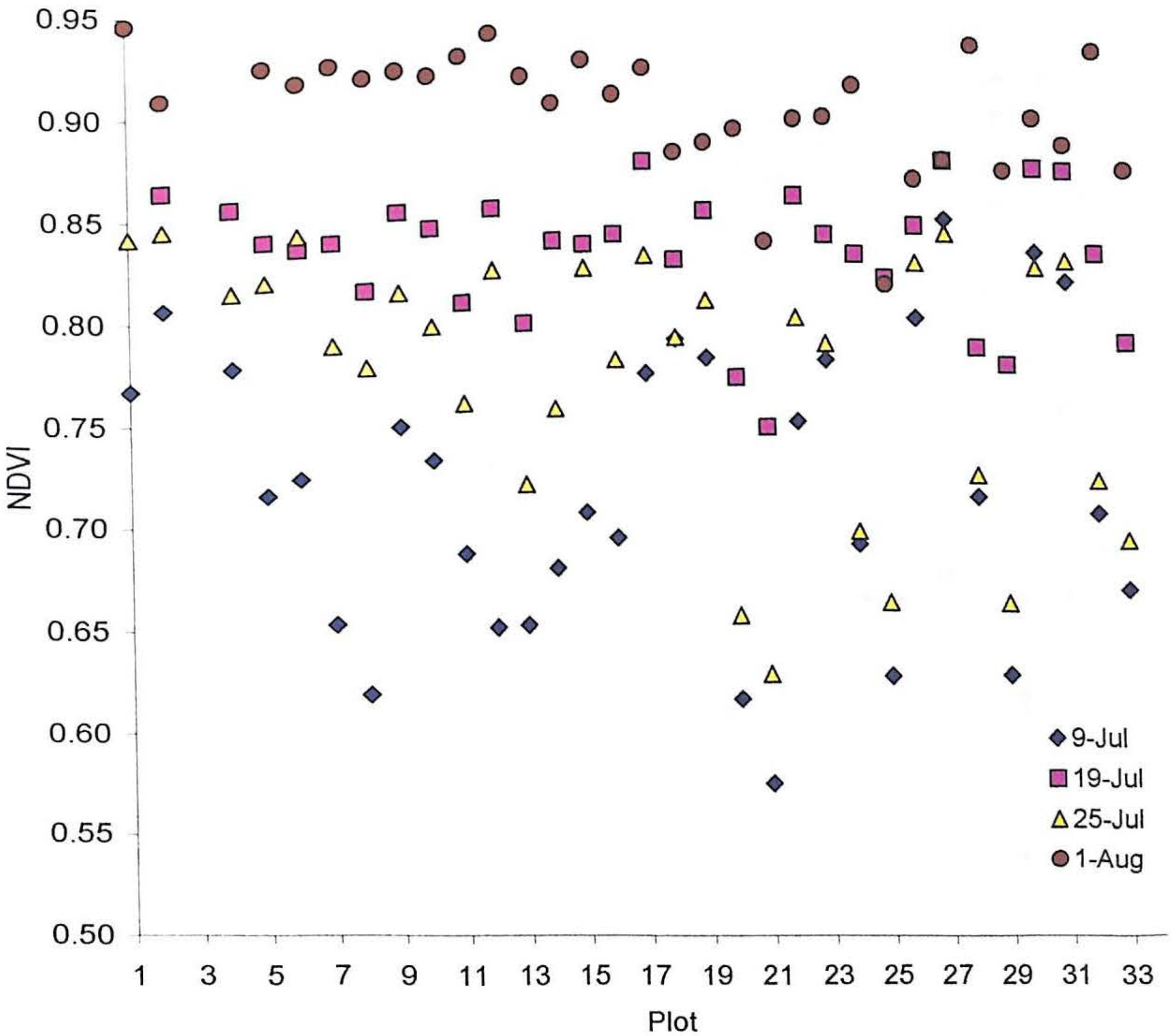

Figure 7. Mid-season NDVI readings as a function of time, Eakly, 2003.

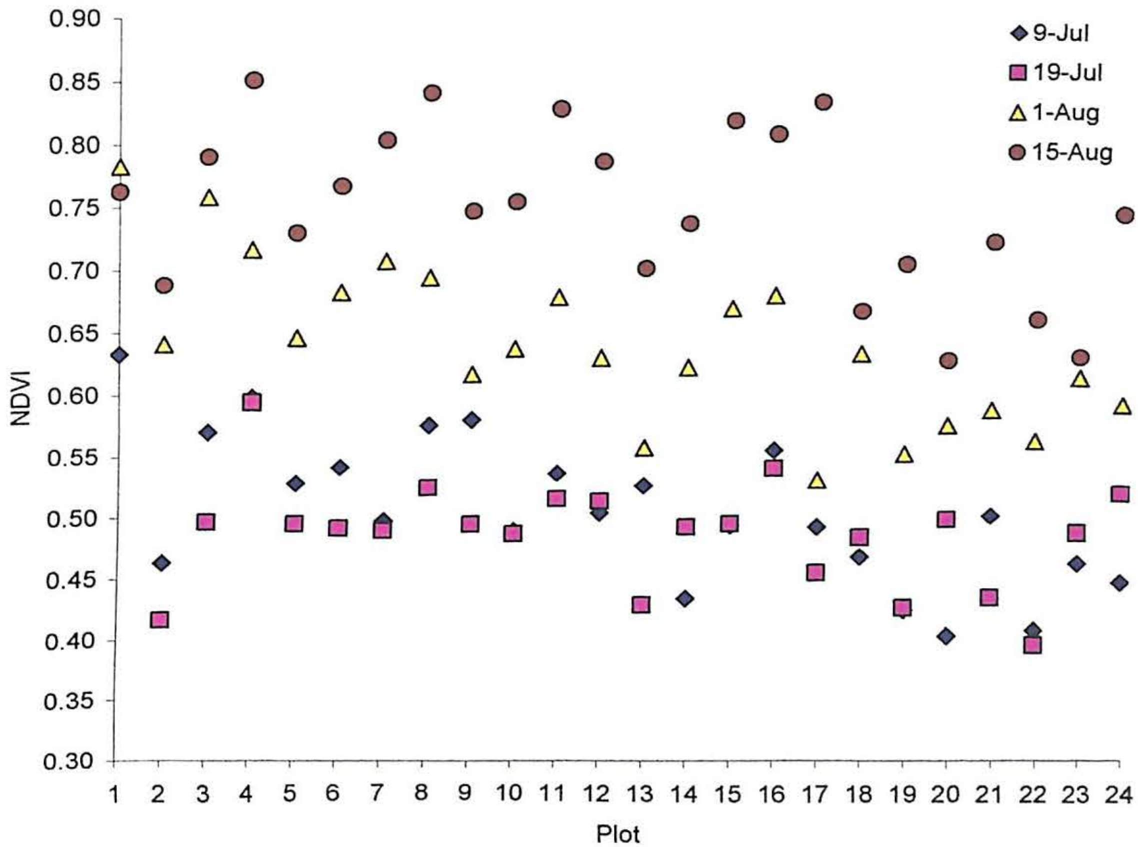

Figure 8. Mid-season NDVI readings as a function of time, Colony, 2003.

VITA #1

Jason Wade Lawles

Candidate for the Degree of

Master of Science

Thesis: PEANUT YIELD RESPONSE TO FOLIAR APPLIED PHOSPHORUS

Major Field: Plant and Soil Sciences

Biographical:

Personal Data: Born in Clinton, Oklahoma, on August 7, 1978.

Education: Graduated from Hydro High School, Hydro, Oklahoma in May 1997; attended Redlands Community College, El Reno, Oklahoma from August 1997 to December 1998; received Bachelors of Science degree in Plant and Soil Sciences from Oklahoma State University, Stillwater, Oklahoma in May 2002. Completed the requirements for the Master of Science degree with a major in Plant and Soil Science at Oklahoma State University in May 2004.

Experience: employed by Oklahoma State University, Department of Plant and Soil Sciences as lab technician for Soil, Water, Forages Analytical Lab, Soil Fertility Project 1999-2001; employed by United State Department of Agriculture Natural Resources Conservation Services 2001-2002; employed by Oklahoma State University Department of Plant and Soil Sciences as a graduate research assistant 2002-2004.

Professional Memberships: American Society of Agronomy, Soil Science Society of America, and Crop Science Society of America.