RELATIONSHIP OF N AND P TISSUE CONCENTRATION AND YIELD OF WINTER WHEAT AS INFLUENCED BY FERTILIZATION

By

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This thesis is dedicated to my late grandfather, W. O. Zangger and my parents, who taught me how to express happiness when it seemed there was not a lot to be happy about.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Soil testing is the primary tool for use in determining the fertilizer for cultivated crops. This diagnostic tool has provided the farmer and the researcher with the means to accurately obtain optimum yields for the crop in question. Due to the fluctuation in the nutritional needs of the crop during the growing season, an accurate method to determine the nutritional status of the plant is desirable. Tissue analysis can be used to supplement soil testing when fertilizer recommendations fail to meet the nutrient demands of established crops.

Tissue analysis, developed for wheat in Arizona, accurately determines the N status in the plant during the growing season. Only limited success with tissue analysis has been achieved in Oklahoma due to variable environmental conditions that exist year to year. The role of tissue analysis for wheat should be one that simply complements the existing soil testing procedures.

Maximum production from the absolute minimum economic investment could be enhanced by the combined use of soil testing and tissue testing procedures.

CHAPTER II

RELATIONSHIP OF N AND P TISSUE CONCENTRATION AND YIELD OF WINTER WHEAT AS INFLUENCED BY FERTILIZATION

Abstract

Winter wheat (Triticum aestivum L.) was sampled at selected stages of growth from N and P fertility experiments at two locations in 1981 and four locations in 1982. Specific growth stages were determined using Feekes scale. Plants were separated into roots, crowns and leaves at each growth stage, dried, ground and analyzed for NO3-N and PO4-P. Both crown and leaf NO3-N at growth stages four and five were significantly correlated with yield in 1981 at the Stillwater location, (R = .90, .91, .86, .84), respectively. At stage five crown PO4-P indicated limited correlation with yield, (R = .64). This same location in 1982 demonstrated no significant correlation with yield for either NO3-N or PO4-P concentration in the roots, crowns or leaves at any of the four growth stages sampled. Two other locations in 1982 did however demonstrate positive correlation with yield for crown and leaf PO4-P, (Lahoma, stage four, R = .51, .62, Haskell, stage five, R =.62, .59), respectively.

Climatic differences between years significantly affected the concentration of NO3-N and PO4-P found at the different stages of growth.

Stepwise regression that included the tissue analysis variables,

soil test results (pre-plant) and fertilizer applications was used to develop prediction equations for yield. These models increased the R^2 values over and above any independent variable from the tissue test. Data obtained at the Magruder location from the crop years of 1980-81 and 1981-82, were eliminated from the discussion due to sub sampling error.

CHAPTER III

LITERATURE REVIEW

Plant analysis has been used successfully to diagnose the nutritional needs of several crops. Plant tissue analysis will indicate a nutrient deficiency before visual symptoms appear, and often early enough to apply nutrients before yields are reduced (3, 15). Nitrate-N in plant tissue has been used to indicate the N status of various plants (e.g., cotton, sugar beet, lettuce, spinach and ryegrass) (8, 9, 10,17). Wheat NO3-N is also a good indicator of the N status at specific stages of growth (1, 3, 6, 13, 16).

Concentration of nutrients vary with the stage of growth of the plant and the plant part sampled (4, 7). Therefore critical levels should be established for a specific stage of growth and a specified plant part. Small grain crops are accumulators of NO3-N (4). This accumulation is a function of the amount of fertilizer applied and the time of sampling (11). Soil phosphorus deficiency has demonstrated induced NO3-N build up in the plant (2). Stress moisture conditions have also caused NO3-N concentrations to increase in wheat (18). Manganese and Mo deficiencies have also caused an accumulation of NO3-N in small grains (18). Since concentration increases with increasing N fertility, the diagnostic capabilities of a tissue test seem desirable.

Plant samples taken at Feekes 2-4 (early to mid-tillering) are the most useful in determining whether an adequate amount of P fertilizer has been applied. Plant samples taken after Feekes 6 (jointing) are not useful in diagnosing P nutrition, because of possible dilution effects (14). In Arizona, differentiation between P treatments was obtained early in the sampling season, but the value of the test for phosphate diagnosis was limited (6).

The objectives of this study were: 1) To determine the ideal plant part and optimum stage of growth for use in detecting critical levels of NO_3-N and PO_4-P, and 2) To determine the relationship of N and P tissue concentration and yield of winter wheat.

CHAPTER IV

MATERIALS AND METHODS

Winter wheat (*Triticum aestivum* L.) was sampled at selected stages of growth from two locations in 1981 and four locations in 1982. Plots were arranged in a randomized block design with four replications at each location. Specific growth stages were determined using Feekes scale as translated by Croy (5). The first tissue samples were taken in early March at the four to five leaf stage, Feekes stage four. Subsequent sampling took place precisely at Feekes growth stages five, seven and ten, (Pseudo stem strongly errect, second node of the stem formed, boot stage), respectively. A summary of experimental locations is presented in Table I. Following collection, plants were separated into roots, crowns and leaves, dried at 65-70C, ground to pass a 20-mesh screen, and analyzed for NO3-N using a specific ion electrode and PO4-P determined by the method of Murphy and Riley (12). Crowns were identified as the portion of the plant two centimeters above the roots at stages four and five. Crown samples at stages seven and ten consisted of the five centimeter portion of the stem above the roots. Roots were washed in deionized water before being dried and ground.

Fertilizers were applied prior to planting and consisted of ammonium nitrate, concentrated superphosphate and muriate of potash as the N, P and K sources respectively. A summary of the fertilization and seeding data at each location is presented in Table II and III. Wheat was seeded in 25 cm rows between late September and early October both years at all locations.

A composite sample of 30 plants selected at random outside of the center 3 x 15 m strip used for yield, were collected from each plot. The length of the interval between sampling was not consistent due to the effect of environmental conditions on the plants at the various locations. Grain yields were obtained by harvesting a 3 x 15 m strip out of 6 x 15 m plots using a self-propelled combine.

TABLE I

EXPERIMENTAL LOCATIONS AND SOIL TEST INDEXES

Location	Year	Soil Type	pH	@ Avg. soil NO3-N $kg \cdot ha^{-1}$	@ Avg. soil P $kg \cdot ha^{-1}$	@ Avg. soil K $kg \cdot ha^{-1}$
Stillwater	1981	Kirkland silt loam (Pachic Paleustolls)	5.1	21.0	81.0	412
Stillwater	1982	Kirkland silt loam (Pachic Paleustolls)	5.6	18.5	60.0	394
Lahoma*	1982	Grant silt loam (Udic Argiustolls)	5.5	14.5	162.0	857
Haskell	1982	Taloka silt loam (Mollic Albaqualfs)	4.9	1.25	29.0	152

* Soil samples taken 10/28/80. No samples taken in the Fall of 1981

@ averaged over treatments

TABLE II

FERTILIZATION AND SEEDING DATES, WHEAT VARIETIES AND SEEDING RATES

Location	Year	Date Fertilized	Variety	Seeding Rate kg/ha	Seeding Date
Stillwater	1981	10/20/80	TAM 101	67	10/28/80
Stillwater	1982	9/18/81	TAM 101	80	9/22/81
Lahoma	1982	10/20/81	TAM 101	78	10/23/81
Haskell	1982	10/27/82	TAM 101	101	10/30/81

TABLE III

FERTILIZER SOURCES AND RATES USED IN WINTER WHEAT EXPERIMENTS AT STILLWATER, 1981 AND 1982 AND HASKELL AND LAHOMA, 1982.

Stillwater 1981 & 1982			Lahoma 1982			Haskell 1982		
(pre-plant)								
N	P	K	N	P	K	N	P	K
kg/ha								
0	29	18	0	20	28	112	0	0
45	29	18	22	20	28	168	0	0
90	29	18	45	20	28	112	0	55
*134	29	18	67	20	28	112	20	55
90	0	18	90	20	28	112	39	55
90	15	18	112	20	28	168	59	55
90	44	18	67	0	28	*168	59	55
0	0	0	67	10	28			
			67	29	28			
			67	39	28			
			112	39	28			
			67	29	0			
			0	0	0			

* N - Split

N as Ammonium nitrate
P as Concentrated superphosphate
K as Muriate of potash

CHAPTER V

RESULTS AND DISCUSSION

Leaf, Crown and Root Relationships

Nitrate-N relationship in roots, crowns and leaves averaged over treatments with advancing stage of growth is illustrated in Figure 1. Leaf and crown NO3-N showed a parallel relationship with time. A relatively constant decrease in NO3-N with time was shown in the crowns and leaves. Root NO3-N changed very little with time regardless of location. No significant differences were observed between NO3-N in the crowns and leaves at stages four and five. Leaf and crown NO3-N demonstrated positive correlation. All correlation coefficients for this relationship were above 0.70. This suggests the possibility of using the above ground portion of the plant instead of separating the crowns and leaves into independent fractions. This is highly conceivable since the potential for further fertilization exists at or before stages four and five. This would also enhance the ease of sampling for future tissue tests.

Phosphate-P in roots, crowns and leaves averaged over treatments with time is shown in Figure 2. Crown and leaf PO4-P values were similar at stage four and also at stage five. Crown PO4-P decreased significantly after stage five. Leaf PO4-P remained relatively constant at all locations. Results at Haskell were an exception to the preceeding relationship. Root PO4-P changed little with time. The whole plant excluding the roots appears to be a suitable parameter for PO4-P tissue testing of wheat at stages four and five.

Treatment Effects

Nitrate-N in wheat crowns during growth from the different N rates at two locations is presented in Figure 3. Yield and NO3-N in crowns differed significantly between treatments at growth stages four and five. Higher rates of N fertilization (Lahoma 1982, 112 $kg \cdot ha^{-1}$, Stillwater 1982, 134 $kg \cdot ha^{-1}$) demonstrated a reduction in yield. At these rates, an increased concentration of NO3-N was found in both the crowns and leaves. These plots demonstrated increased vegetative growth, wider leaves and superior height.

Phosphate-P in crowns during the growth of wheat is illustrated for the different rates of P fertilizer in Figure 4. Limited significance was obtained between crown PO4-P values at stages four and five. No significance was observed beyond stage five. Limited significance can partially be explained by the high P sufficiency levels found at both locations listed.

Environmental Differences

Data was obtained two years at the Stillwater location, therefore providing an opportunity to observe possible climatic effects. Stress moisture conditions existed throughout the sampling season in 1981. An extremely cool spring along with ample moisture conditions during the sampling months was exhibited in 1982. Monthly rainfall data is displayed in Table VI for all locations. Nitrate-N and PO4-P in the crowns and leaves averaged over treatments is illustrated in Figures 5 and 6. Significant differences were recorded for NO3-N and PO4-P in the crowns and leaves at stages four, five and seven between 1981 and 1982. Nitrate-N and PO4-P were much higher for the dry year sampled in 1981. High NO3-N and PO4-P levels observed in 1981 were apparently due to the stress moisture conditions during the sampling months. Abundant moisture present in 1982 could have caused $NO3^-$ to be either leached or metabolized into protein thus utilizing abailable phosphate anions; resulting in decreased levels for both.

Regression Analysis

Simple linear regression was used to determine the correlation coefficients of individual tissue analysis variables for predicting yield. With few exceptions, root tissue analysis for NO3-N and PO4-P demonstrated little significance in predicting yield at any stage of growth. Tissue analysis for NO3-N and PO4-P in the leaves and crowns at stages seven and ten, also indicated limited significance in the prediction of yield. Highest correlation coefficients were recorded at the Stillwater location in 1981 for NO3-N in the crowns and leaves at stages four and five. At this same location in the following year, no positive correlation was found with yield at any stage for NO3-N or PO4-P in the crowns, roots or leaves. Highest R values were obtained for NO3-N and PO4-P in the crowns and leaves at stages four and five (Table IV).

Quadratic regression was used to determine critical values for NO3-N and PO4-P in the crowns and leaves at stages four and five. Root data was not correlated with yield at any growth stage. Critical values in this text are defined as the point at which an increase in concentration no longer increases yield. Critical levels were determined by obtaining the value on the quadratic curve where the slope was equal to zero. These values are provided in Table V. Only four critical levels could be established with any certainty and are indicated as such with an asterisk. These critical values were as follows; NO3-N, stage 4, 3827 ug/g; NO3-N, stage 5, 2059 ug/g; PO4-P, stage 4, 3400 ug/g; PO4-P, stage 5, 2458 ug/g.

Stepwise regression that used tissue analysis variables at stages four and five, soil test results (pre-plant) and fertilizer applications, was employed to develop prediction equations for yield. These equations are listed in Table VII. Results obtained in 1981 at the Stillwater location included several tissue analysis variables, while the equations listed for this same location in 1982 exhibited none. This observation manifests the need to obtain viable alternatives for such a tissue test highly susceptible to error. Prediction of yield (R^2) was increased using soil test, fertilizer applications and tissue analysis above any R^2 value obtained for individual tissue analysis variables in simple linear regression. Tissue testing must be combined with treatment applications and or soil test variables in a multiple linear regression equation to obtain both increased and consistent accuracy in prediction equations for yield.

Simple linear regression was used to correlate NO3-N with PO4-P at the four different growth stages sampled. The relationship varied at each location for both crown PO4-P vs crown NO3-N and leaf PO4-P vs leaf NO3-N. Ratios were also established for the three plant parts for concentration of PO_4-P and NO_3-N. No consistent patterns could be established at any stage of growth.

TABLE IV

CORRELATION COEFFICIENTS (R) OF NO3-N AND PO4-P IN CROWNS AND LEAVES WITH YIELD

Location	Year	Part	Growth Stage			
			4		5	
			NO3-N	PO4-P	NO3-N	PO4-P
Stillwater	1981	Crowns	0.90	0.53	0.86	0.64
Stillwater	1981	Leaves	0.91	0.22	0.84	0.44
Stillwater	1982	Crowns	0.10	0.20	0.49	0.19
Stillwater	1982	Leaves	0.32	0.33	0.42	0.47
Lahoma	1982	Crowns	0.29	0.51	0.17	0.43
Lahoma	1982	Leaves	0.31	0.62	0.20	0.46
Haskell	1982	Crowns	0.36	0.34	0.28	0.36
Haskell	1982	Leaves	0.38	0.44	0.55	0.33

TABLE V

CRITICAL NO3-N AND PO4-P LEVELS IN LEAVES OF WINTER WHEAT

Location	Year	Growth Stage 4 (ug/g) NO3-N	Growth Stage 4 (ug/g) PO4-P	Growth Stage 5 (ug/g) NO3-N	Growth Stage 5 (ug/g) PO4-P
Stillwater	1981	3827*	2296	2059*	2196
Stillwater	1982	914	674	1279	673
Lahoma	1982	1719	$\geq$ 3400*	5058	$\geq$ 2458*
Haskell	1982	3580	1890	5330	690

* Values reported had an $R^2 \geq 0.50$ in quadratic regression

TABLE VI

PRECIPITATION QUANTITIES (mm) AT EXPERIMENTAL LOCATIONS AND THE DEPARTURE OF PRECIPITATION FROM NORMAL

Location	Year	Month												Total	Departure from normal rainfall
		J	F	M	A	M	J	J	A	S	O	N	D		
Stillwater	1980	45	15	73	136	166	209	1	88	36	43*	10*	41*	864	- 47
Stillwater	1981	2*	27*	57*	23*	162*	122*	141	83	66*	104*	89*	5*	907	- 90
Stillwater	1982	65*	61*	30*	63*	371*	111*	50							
Lahoma	1981	5	11	59	32	122	170	64	36	100	107*	66*	5*	777	- 64
Lahoma	1982	18*	48*	58*	66*	235*	80*	83							
Haskell	1981	22	37	59	67	169	76	57	101	43	222*	57*	10*	919	+144
Haskell	1982	101*	25*	32*	45*	225*	156*	83							

* Months wheat was in the field

TABLE VII

STEPWISE REGRESSION EQUATIONS TO PREDICT YIELD OF WINTER WHEAT

Location	Year	Growth Stage	Equation	R^2
Stillwater	1981	4	Yld = 419 + .91 (NO3-NL) + .29 (PO4-PC) −.00012 $(NO3-NL)^2$	0.89
Stillwater	1981	5	Yld = 888 + .36 (PO4-PC) + 10.6 (N APPLIED)	0.87
Stillwater	1982	4	Yld = 1402 + 31 (NO3-NS)	0.25
Stillwater	1982	5	Yld = 1339 + 15.4 (NO3-NS) + 4.8 (N APPLIED)	0.55
Lahoma	1982	4	Yld = 638 + 1.4 (PO4-PL) −.00004$(NO3-NC)^2$ −.0003$(PO4-PL)^2$ −21 (NO3-NS) + 3.6(P-S)	0.64
Lahoma	1982	5	Yld = 1596 + 30.3 (P APPLIED) −17.2 (NO3-NS)	0.60
Haskell*	1982	4	Yld = 1099 −.000023$(NO3-NL)^2$ + 8.4(N APPLIED)	0.75
Haskell*	1982	5	Yld = 3824 − 22 (N APPLIED)	0.98

* different treatments sampled for stages 4 and 5 as environmental conditions distorted homogeneity

PL: phosphorus leaves; NC: nitrogen crowns; NS: nitrogen soil; P-S: phosphorus soil; NL: nitrogen leaves; PC: phosphorus crowns;

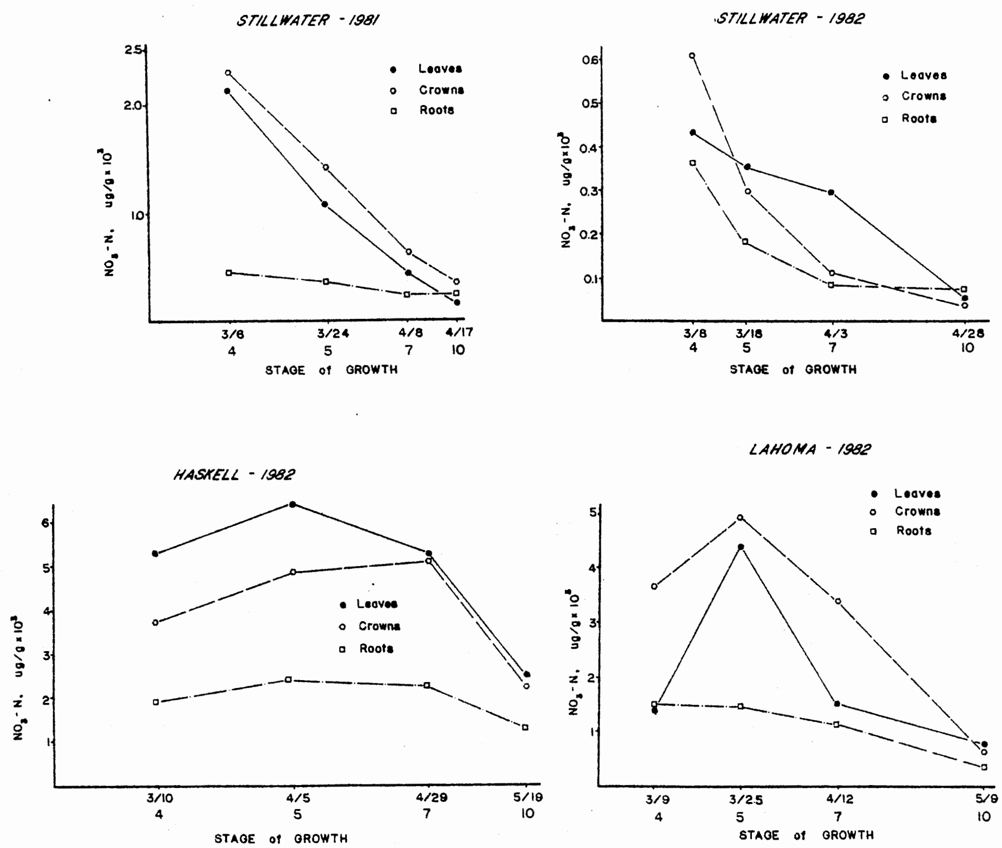

Figure 1. Nitrate-N in Leaves, Crowns and Roots of Winter Wheat, Stillwater 1981 and 1982 and Haskell and Lahoma, 1982.

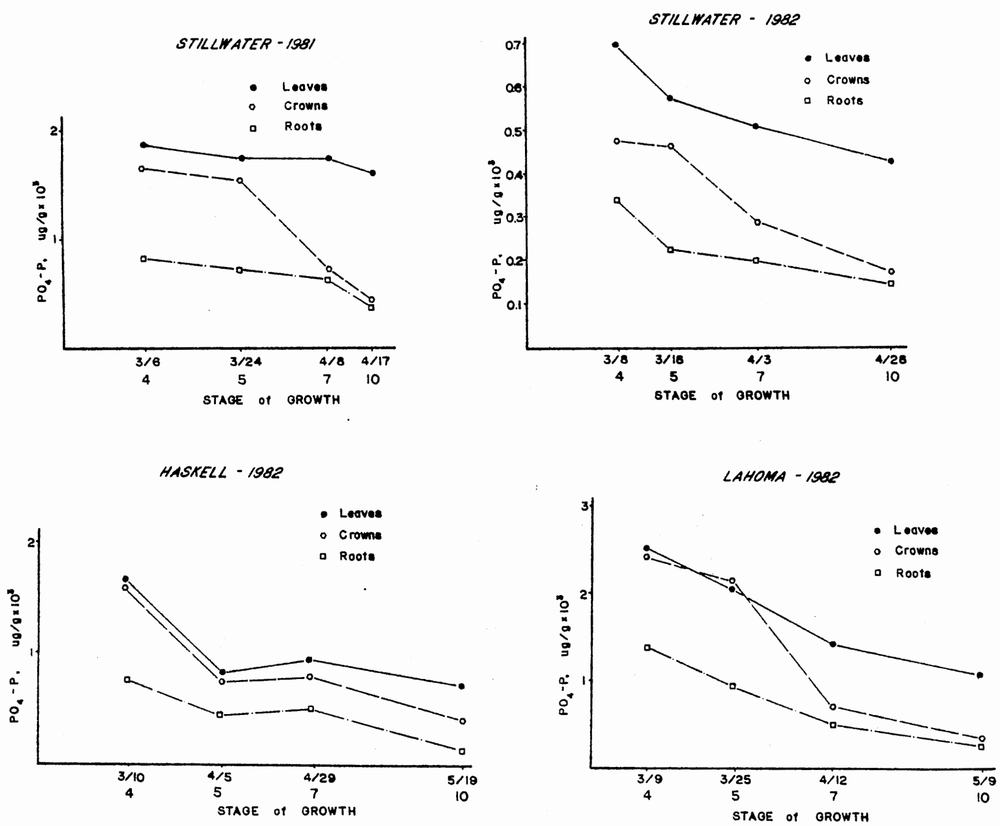

Figure 2. Phosphate-P in Leaves, Crowns and Roots of Winter Wheat, Stillwater 1981 and 1982 and Haskell and Lahoma, 1982.

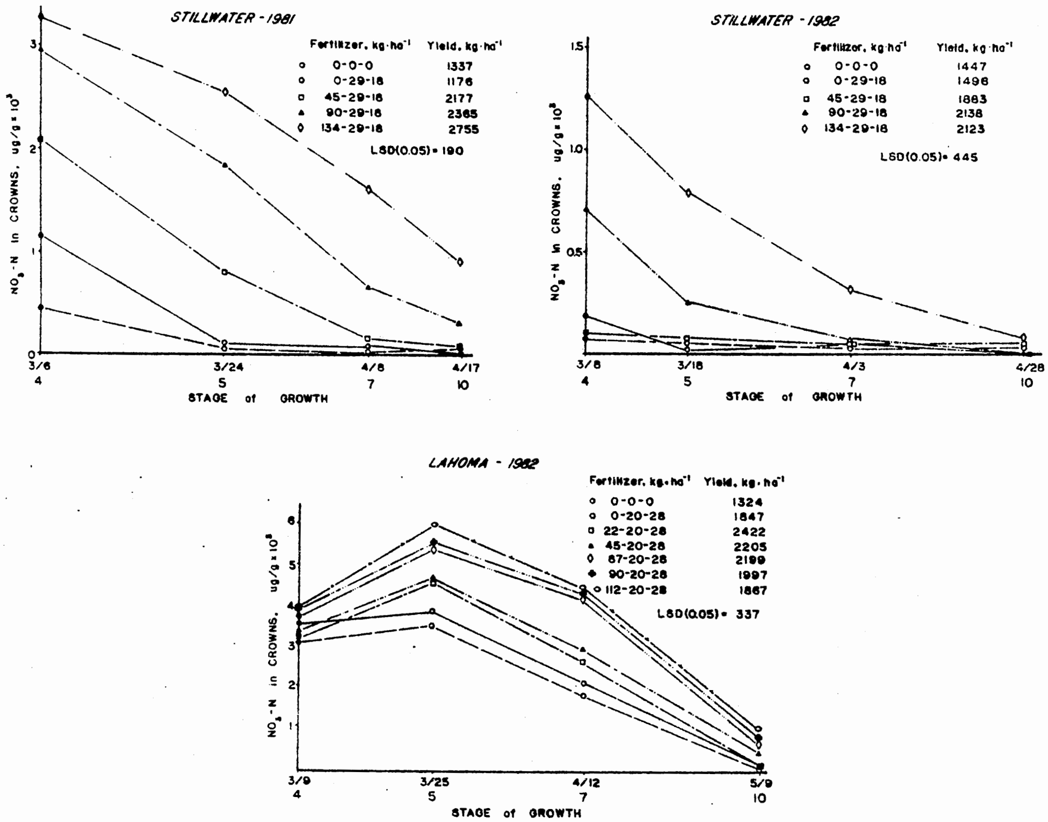

Figure 3. Effect of N Fertilization on NO3-N in Crowns of Winter Wheat with Varying Stages of Growth, Stillwater 1981 and 1982, and Lahoma 1982.

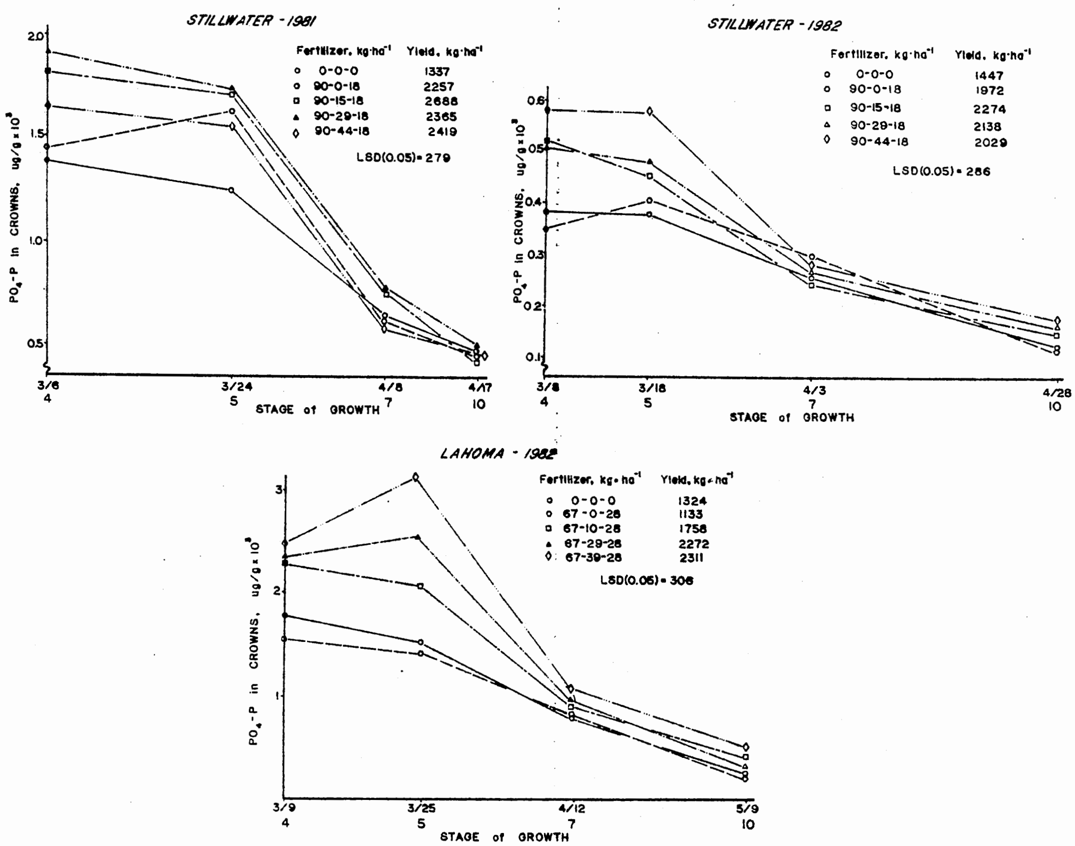

Figure 4. Effect of P Fertilization on PO4-P in Crowns of Winter Wheat with Varying Stages of Growth, Stillwater 1981 and 1982, and Lahoma 1982.

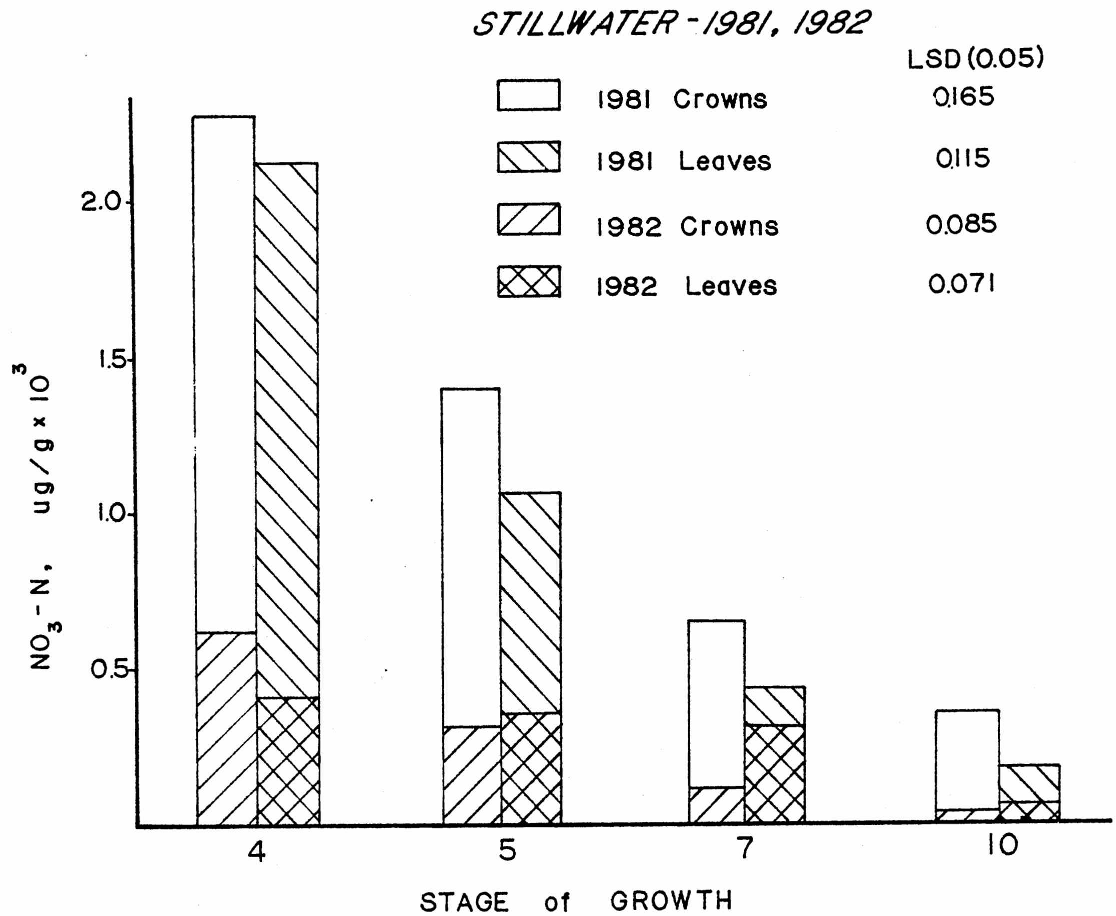

Figure 5. Effect of Stage of Growth on NO3-N in Crowns and Leaves of Winter Wheat averaged over N Rates, Stillwater 1981 and 1982.

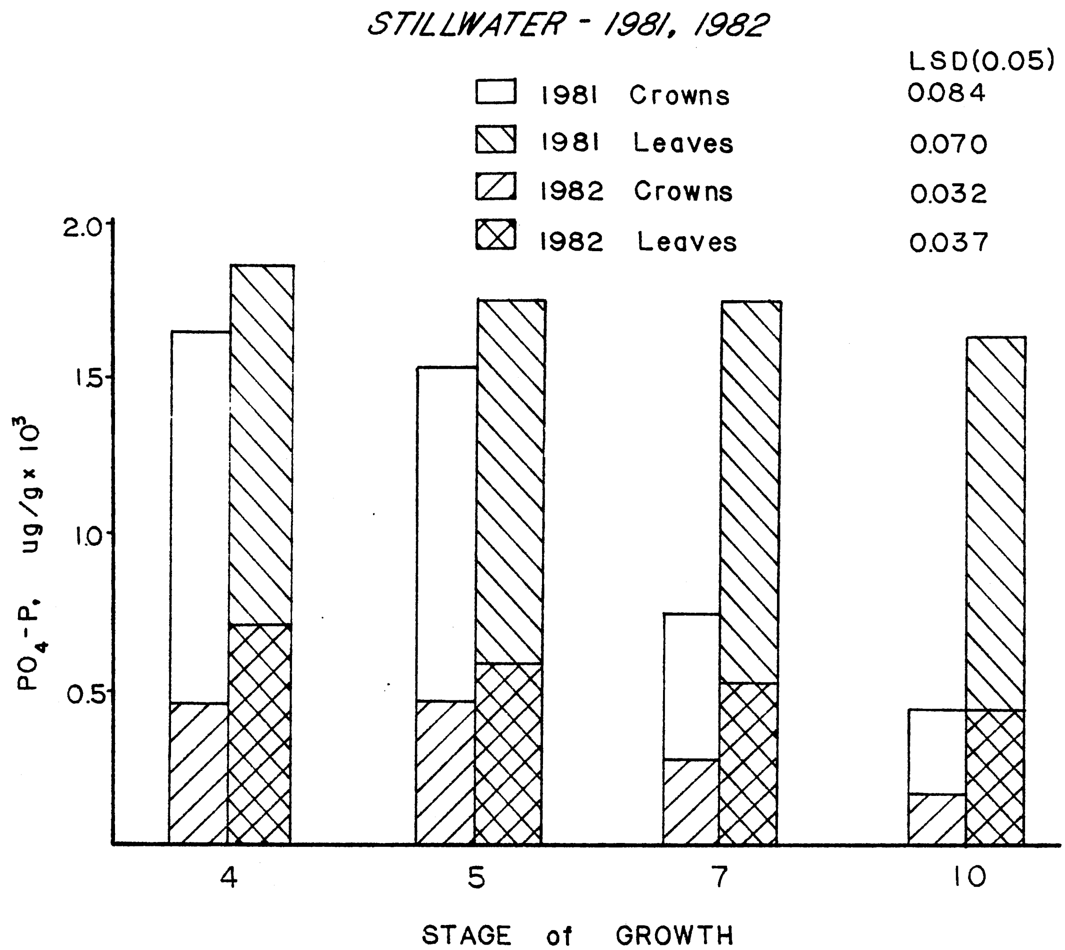

Figure 6. Effect of Stage of Growth on PO4-P in Crowns and Leaves of Winter Wheat averaged over P Rates, Stillwater 1981 and 1982.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Significant correlations existed for various tissue testing variables and yield at all locations. Highest correlation coefficients from simple linear regression were obtained for NO3-N and PO4-P in the crowns and leaves at stages four and five. Use of tissue analysis in diagnosing the nutritional needs of the plant for further fertilization where needed, must take place at or before stage five.

The whole plant excluding the roots appears to be a suitable parameter for NO3-N and PO4-P tissue testing in wheat at stages four and five.

Quadratic regression in establishing critical levels for tissue testing variables provided limited success. The certainty at which these levels are established is a crucial parameter for subsequent recommendations. Therefore further research must be conducted in order to solidify these critical values.

Stepwise regression that included tissue testing, pre-plant soil test indexes and fertilizer applied, increased the accuracy in predicting yield above the use of any independent tissue analyses.

Environmental conditions during the sampling season play a significant role in the use of tissue testing for diagnostic purposes. Tissue tests proved to be highly significant for crown and leaf NO3-N and PO4-P at stages four and five when rainfall was limited. Limited significance was shown for crown and leaf PO4-P and NO3-N in the prediction of yield during a wet year. Future tissue testing in Oklahoma should include a simple method of obtaining daily soil moisture levels, such that this fluctuating independent variable might be included to enhance the yield prediction model.

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APPENDIXES

TABLE VIII

DAYS FROM A SIGNIFICANT RAINFALL

Location	Sampling Date	Growth Stage	Days from Rainfall	
			26 mm	7 mm
Stillwater	3/6/81	4	80	26
Stillwater	3/24/81	5	9	9
Stillwater	4/8/81	7	24	10
Stillwater	4/17/81	10	33	3
Stillwater	3/8/82	4	36	27
Stillwater	3/18/82	5	46	4
Stillwater	4/3/82	7	61	7
Stillwater	4/28/82	10	86	3
Lahoma	3/9/82	4	37	3
Lahoma	3/25/82	5	11	11
Lahoma	4/12/82	7	29	16
Lahoma	5/7/82	10	9	1
Haskell	3/10/82	4	42	25
Haskell	4/5/82	5	51	3
Haskell	4/29/82	5-10	75	1
Haskell	5/19/82	10	7	2

TABLE IX

CRITICAL LEVELS FROM QUADRATIC REGRESSION

Location	Stage	Part	NO3-N	PO4-P
Lahoma 1982	4	Crowns	2227	2372
	4	Leaves	1719	> 3400
	5	Crowns	4894	3008
	5	Leaves	5058	>2458
	7	Crowns	4518	735
	7	Leaves	4910	1594
	10	Crowns	2527	566
	10	Leaves	657	1383
Stillwater 1982	4	Crowns	1134	694
	4	Leaves	914	674
	5	Crowns	872	592
	5	Leaves	1279	673
	7	Crowns	302	442
	7	Leaves	455	706
	10	Crowns	54	170
	10	Leaves	185	340
Stillwater 1981	4	Crowns	> 3500	2423
	4	Leaves	3827	2296
	5	Crowns	2490	1791
	5	Leaves	2059	2196
	7	Crowns	1378	1135
	7	Leaves	914	1837
	10	Crowns	1017	244
	10	Leaves	492	942
Haskell 1982**	4	Crowns	3070	1775
	4	Leaves	3580	1890
	5	Crowns	4100	600
	5	Leaves	5350	690
	7	Crowns	5700	1100
	7	Leaves	5500	1050
	10	Crowns	2580	390
	10	Leaves	1300	710

** Simple linear regression used. (four quadrant determination)

TABLE X

CROWN NO3-N USED TO PREDICT LEAF NO3-N

Location	Year	Growth Stage	R	R^2
Lahoma	1982	4	.039	.197
		5	.705	.840
		all stages	.613	.783
Stillwater	1981	4	.854	.924
		5	.789	.888
		all stages	.869	.932
Stillwater	1982	4	.743	.862
		5	.812	.901
		all stages	.690	.831
Haskell	1982	all stages	.591	.768
Magruder	1982	all stages	.001	.023
Magruder	1981	all stages	.938	.969

TABLE XI

RATIO OF NO3-N TO PO4-P

Location	Part	Stage			
		4	5	7	10
		NO3-N : PO4-P			
Mag-81	Crowns	1.4 : 1	1 : 2	1 : 4	1 : 3
Mag-81	Leaves	1.4 : 1	1 : 2.2	1 : 3.8	1 : 7.4
Mag-82	Crowns	1.1 : 1	1 : 2	1 : 3	1 : 3.4
Mag-82	Leaves	1 : 10	1 : 7	1 : 2.9	1 : 3.8
Stw-81	Crowns	1.4 : 1	2 : 1	1 : 1.2	1 : 1.2
Stw-81	Leaves	1.2 : 1	1 : 1.8	1 : 4	1 : 8
Stw-82	Crowns	1.3 : 1	1 : 1.5	1 : 2.3	1 : 8
Stw-82	Leaves	1 : 1.4	1 : 1.4	1 : 2.3	1 : 6.4
Lah-82	Crowns	1.7 : 1	2 : 1	4 : 1	1.5 : 1
Lah-82	Leaves	1 : 2	2 : 1	1.1 : 1	1 : 1.5
Has-82	Crowns	2 : 1	6.5 : 1	6.5 : 1	6 : 1
Has-82	Leaves	3.4 : 1	7.6 : 1	5.8 : 1	2.7 : 1

TABLE XII

NITRATE-NITROGEN AND PHOSPHATE-PHOSPHORUS RATIOS IN CROWNS AND LEAVES

Location	Stage			
	4	5	7	10
	-------- PO4-P crowns vs. PO4-P leaves -----------			
Lah-82	1 : 1.1	1.1 : 1	1 : 1.6	1 : 2.4
Stw-81	1 : 1.3	1 : 1.1	1 : 2.5	1 : 3.6
Stw-82	1 : 1.2	1 : 1	1 : 2.5	1 : 2.7
Has-82	1 : 1	1 : 1.1	1 : 1.3	1 : 2
	-------- NO3-N crowns vs. NO3-N leaves -----------			
Lah-82	2 : 1	1.1 : 1	3 : 1	1 : 1.1
Stw-81	1.1 : 1	1.3 : 1	1.5 : 1	2 : 1
Stw-82	1.5 : 1	1 : 1.1	1 : 2.8	1 : 3
Has-82	1 : 1.5	1 : 1.3	1 : 1	1.1 : 1

TABLE XIII

LSD's FOR LOCATIONS BY STAGE
LSD (0.05)

Location	Treatments	Variable Crown	Stage	Variable LSD	Yield LSD
Lahoma-82	1,8,9,10,11	PO4-P	4	475	306
			5	606	
			7	328	
			10	128	
Stillwater-81	3,5,6,7,10	PO4-P	4	391	279
			5	308	
			7	217	
			10	147	
Stillwater-82	3,5,6,7,10	PO4-P	4	131	286
			5	127	
			7	86	
			10	44	
Lahoma-82	1,2,3,4,5, 6,7	NO3-N	4	575	337
			5	852	
			7	1095	
			10	419	
Stillwater-81	1,2,3,4,10	NO3-N	4	460	190
			5	525	
			7	446	
			10	331	
Stillwater-82	1,2,3,4,10	NO3-N	4	411	445
			5	337	
			7	89	
			10	74	

TABLE XIV

DETERMINATION OF DIFFERENCES BETWEEN CROWNS AND LEAVES FOR NO3-N AND PO4-P BY STAGE

Location	Stage	Variable	F calc	OSL	t calc	OSL
STW-82	4	NO3-N	1.006	osl > .25	.35	osl > .25
	5	"	1.08	osl > .25	.16	osl > .25
	7	"	1.16	osl > .25	.54	osl > .25
	10	"	1.08	osl > .25	.10	osl > .25
STW-81	4	"	1.10	osl > .25	.67	osl > .25
	5	"	1.12	osl > .25	1.07	osl > .10
	7	"	1.07	osl > .25	.52	osl > .25
	10	"	1.23	osl > .25	.38	osl > .25
LAH-82	4	"	1.01	osl > .25	5.83	.001>osl
	5	"	1.01	osl > .25	1.63	osl > .10
	7	"	1.006	osl > .25	4.29	.001>osl
	10	"	1.002	osl > .25	.16	osl > .25
HAS-82	4	"	1.02	osl > .25	4.13	.001>osl
	5	"	1.313	osl > .25	1.90	osl > .05
	7	"	1.52	osl > .25	.06	osl > .25
	10	"	1.16	osl > .25	.57	osl > .25
STW-82	4	PO4-P	1.08	osl > .25	.39	osl > .25
	5	"	1.23	osl > .25	.66	osl > .25
	7	"	1.13	osl > .25	.64	osl > .25
	10	"	1.42	osl > .10	.79	osl > .20
STW-81	4	"	1.31	osl > .10	.40	osl > .25
	5	"	1.36	osl > .10	.45	osl > .25
	7	"	1.02	osl > .25	1.81	osl > .05
	10	"	1.67	.10 > osl	2.36	.012>osl
LAH-82	4	"	1.21	osl > .25	.74	osl > .20
	5	"	1.03	osl > .25	.82	osl > .20
	7	"	1.26	osl > .10	1.33	osl > .20
	10	"	1.10	osl > .25	1.60	osl > .05
HAS-82	4	"	1.09	osl > .25	.14	osl > .25
	5	"	1.02	osl > .25	.08	osl > .25
	7	"	1.45	osl > .25	.19	osl > .25
	10	"	1.11	osl > .25	.47	osl > .25

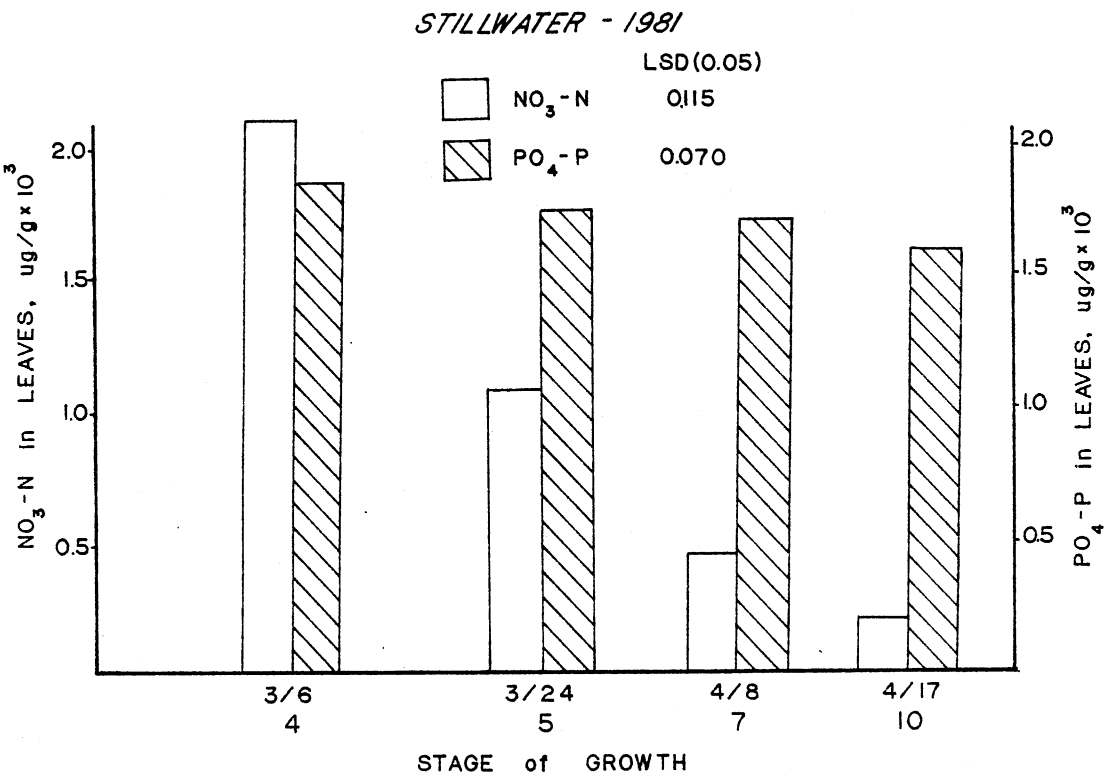

Figure 7. NO3-N and PO4-P in Leaves at 4 Stages of Growth; Averaged over Treatments. 1980-81 Crop Year, Stillwater.

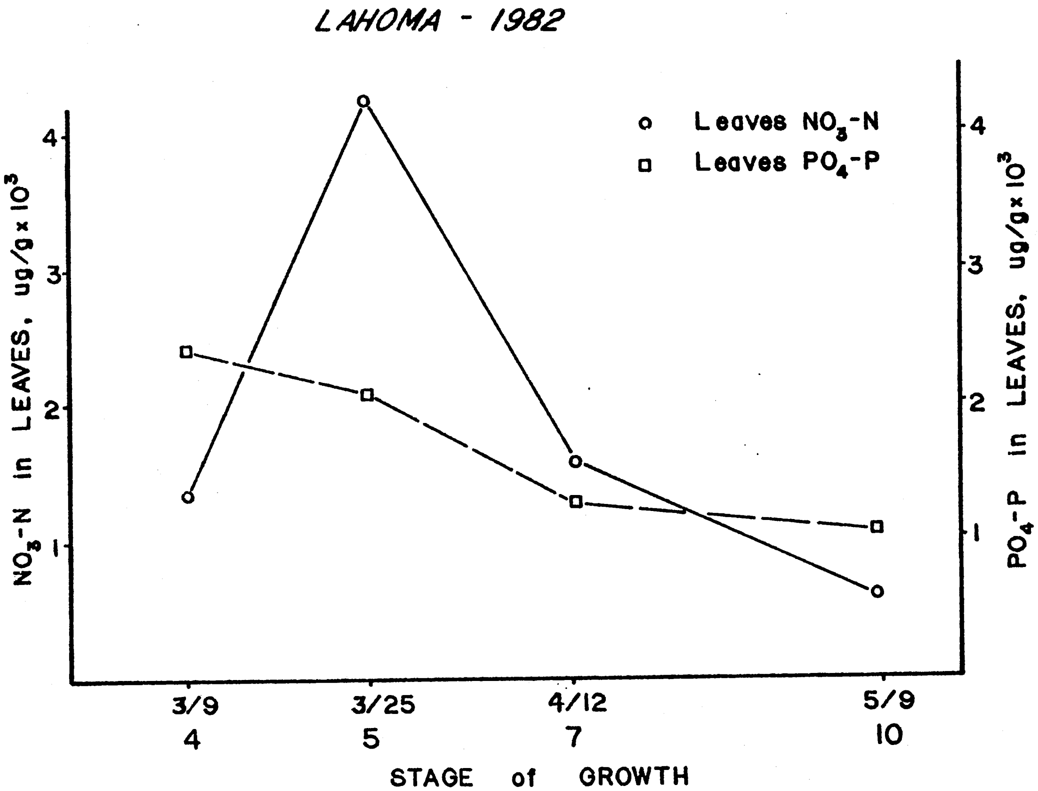

Figure 8. NO3-N and PO4-P in Leaves at 4 Stages of Growth; Averaged over Treatments. 1981-82 Crop Year, Lahoma.

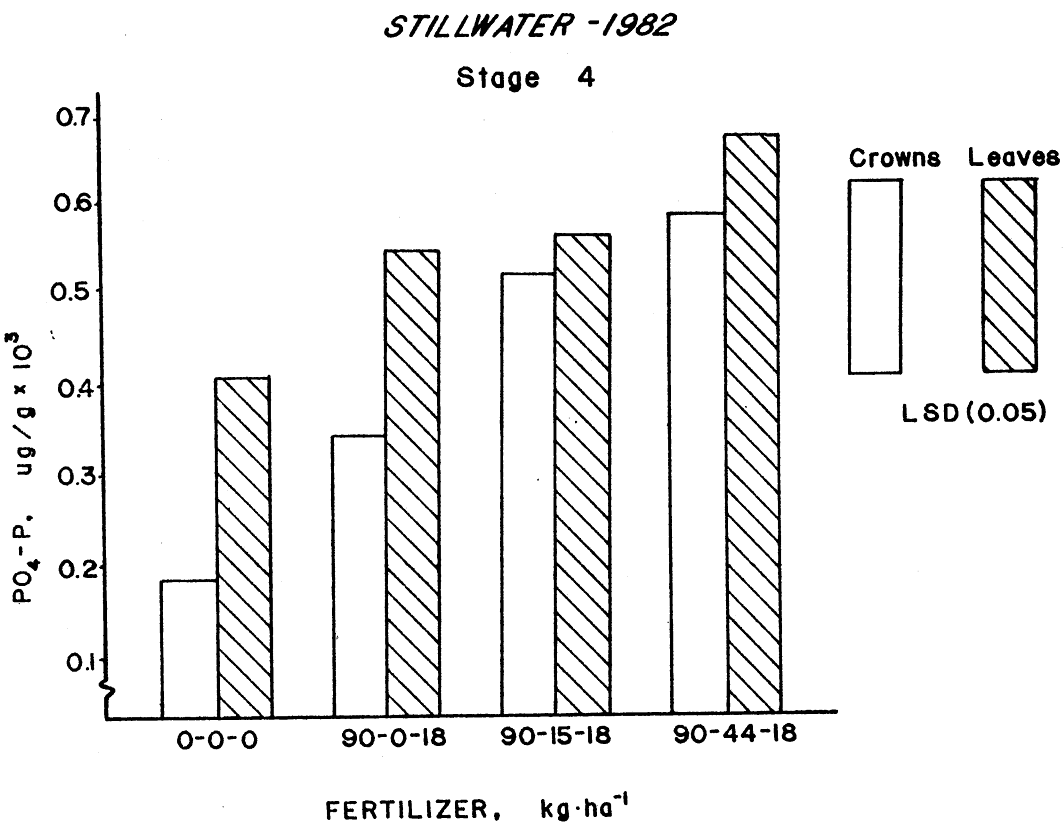

Figure 9. PO4-P Concentration in Crowns and Leaves in Selected P Treatments, Stillwater 1982.

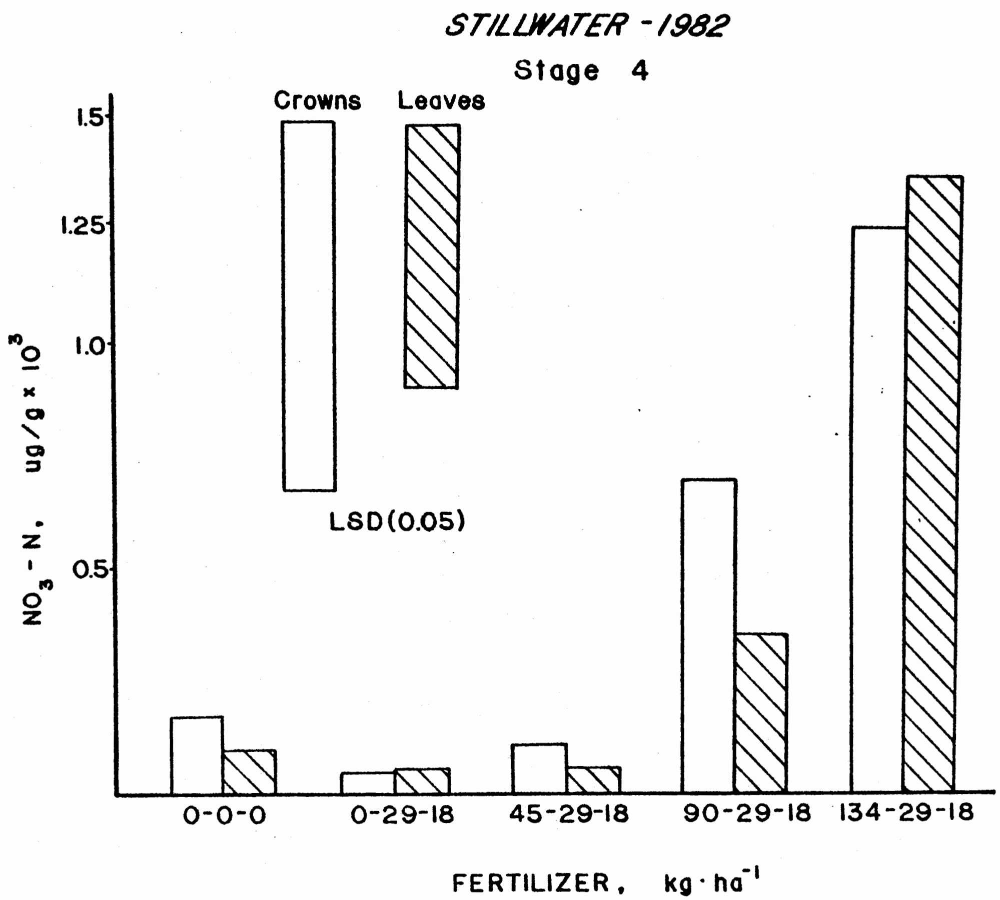

Figure 10. NO3-N Concentration in Crowns and Leaves in Selected N Treatments, Stillwater 1982.

TABLE XV

DETERMINATION OF DIFFERENCES BETWEEN YEARS AT STILLWATER

Stage	Part	Variable	F calc	OSL	t calc	OSL
4	crown	NO3-N	5.53	.005 > osl@	14.8	.0001 > osl**
4	leaf	NO3-N	6.15	.005 > osl@	15.2	.0001 > osl**
5	crown	NO3-N	1.14	osl > .25	3.55	.005 > osl**
5	leaf	NO3-N	1.10	osl > .25	2.19	.05 > osl*
7	crown	NO3-N	1.55	osl > .10	1.37	osl > .10
7	leaf	NO3-N	1.94	osl > .02	.32	osl > .25
10	crown	NO3-N	1.48	osl > .10	1.25	osl > .20
10	leaf	NO3-N	1.97	osl > .02	.29	osl > .25
4	crown	PO4-P	1.36	osl > .10	2.16	.05 > osl*
4	leaf	PO4-P	1.03	osl > .25	2.24	.05 > osl*
5	crown	PO4-P	1.57	osl > .10	2.58	.025 > osl*
5	leaf	PO4-P	2.64	.005 > osl@	11.36	.0001 > osl**
7	crown	PO4-P	2.83	.005 > osl@	3.58	.005 > osl**
7	leaf	PO4-P	2.45	.025 > osl@	8.76	.0001 > osl**
10	crown	PO4-P	2.27	.025 > osl@	2.48	.025 > osl*
10	leaf	PO4-P	1.93	.10 > osl	3.2	.005 > osl**

@ estimates of variances of the two populations were significantly different
** means were significantly different at the .01 level
* means were significantly different at the .05 level

$$\sigma^2_{81} = \sigma^2_{82}$$

$$F = \frac{L\ MSE}{S\ MSE}\quad \frac{df\ num}{df\ den} \quad : \quad S_{x81-x82} = \sqrt{\frac{(n81-1)xMSE81 + (n82-1)xMSE82}{(n81+n82)-2}}$$

$$t\ calc = \frac{x81 - x82 - 0}{S_{x81-x82}}$$

$$\sigma^2_{81} \neq \sigma^2_{82}$$

$$S_{x81-x82} = \frac{MSE81}{n81} + \frac{MSE82}{n82}$$

$$t' = (x81-x82)/\sqrt{\frac{MSE81}{n81} + \frac{MSE82}{n81}}$$

VITA

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