THE EFFECTS OF POTASSIUM ON STRESS-INDUCED STALK LODGING OF GRAIN SORGHUM (SORGHUM BICOLOR)

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by

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INTRODUCTION

Stalk lodging of grain sorghum before harvest has been a major problem in much of Kansas in recent years. Southeast Kansas, in particular, has suffered extremely heavy lodging in the past because of its shallow (thus drouthy) and old soils and the consequent moisture and fertility strain these soils place on crops.

Severe lodging can cause many problems including reduction in yield and difficulty in harvesting. Grain sorghum has become an increasingly important crop in Kansas, so the financial loss from heavy lodging can affect farmer, cattleman, and consumer.

Work in other Midwest states with corn has demonstrated a correlation between K fertilization and lodging. Various studies have also suggested that balancing N and K fertilization is necessary to alleviate lodging of corn. In Kansas, however, studies were needed to determine the factors affecting the early lodging of grain sorghum under stress conditions.

Recognizing these needs, a study was formulated with the following objectives: 1) to investigate the relationship of K fertilization to stress-induced lodging of grain sorghum, 2) to study the relationships of N and K fertilization on stalk lodging, 3) to examine the effects of planting date on stress-induced lodging, 4) to determine the variations among varieties in stalk lodging response to planting date and K-fertility levels, 5) and to investigate the factors affecting the morphology of the sorghum stalk and the relationship of these stalk factors to lodging.

hydrate content. They found CO_2 release and O_2 uptake (respiration) were accelerated by K-deficiency, while CO_2 uptake and O_2 release (photosynthetic CO_2 fixation) were slightly lower in K-deficient leaves. Normal leaves were found to contain 2.51 mg chlorophyll dm^{-2} leaf area at 27 days while K-deficient leaves of the same age contained only 0.77 mg dm^{-2}. This reduction in chlorophyll content of K-deficient tissue could explain the observed reduction in photosynthesis -- daily productivity reduced from 8888 moles CO_2 dm^{-2} for normal plants to 4048 moles CO_2 dm^{-2} for K-deficient plants.

Iron is necessary for chlorophyll production. In K-deficient plants, iron tends to accumulate at the nodes perhaps inducing an iron deficiency in leaves and thereby reducing the chlorophyll content (30).

Hartt (8) found that the rate of photosynthetic CO_2 absorption decreased when the K content in sugarcane tissue fell below 0.4%. A normal blade containing 1.61% K exhibited a photosynthetic rate of 17.20 ml CO_2 $dm^{-2}hr^{-1}$, while a K-deficient blade (0.14% K) photosynthesized only 2.10 ml CO_2 $dm^{-2}hr^{-1}$.

Ozbun et al. (24) observed that a K-deficiency slightly increased dark CO_2 fixation. They proposed that K-deficiency leads to an accumulation of phosphoenol pyruvic acid (PEP), the substrate for CO_2 fixation by PEP carboxylase. Since pyruvic kinase requires K, a build up in PEP might be expected in K-deficient tissue. The accumulation of malic acid in K-deficient tissue may be a reflection of the observed increase in dark CO_2 fixation (24).

REVIEW OF LITERATURE

Potassium has long been associated with stalk strength in corn and other crops. Several workers have demonstrated a correlation between stalk strength, stalk rot, lodging and K fertility level (1,12,13,14,17,20,21,23,25,26,27,36).

The role of K in plants is somewhat harder to define than some of the other elements because it does not combine permanently in cell structures. Rather, K functions in the chemistry of the cell sap to influence plant growth in the following ways (30):

Relationship of K to Photosynthesis and Respiration; Potassium influences total leaf area by increasing the size of leaves through the size and number of cells, increasing leaf numbers (in indeterminate plants), and by increasing the length of life of the leaves (30). Other workers (17) have reported a leaf area decrease from 1.44 dm^2 in normal plots to 0.98 dm^2 for K-deficient plots.

CO_2 uptake is influenced by K levels through the function of K on stomatal opening and closing, and the effect of K-deficiency on chlorophyll content of leaves. Munson (19) cites a critical level for K of 1.5% in corn leaves for optimum stomatal opening for photosynthesis. Jackson and Volk (9) cite work by Moss and Cooper with corn and alfalfa indicating that photosynthesis is restricted when leaf K concentrations (in corn or alfalfa) are below 1.5-2.0%. Ozbun, Volk, and Jackson (24) have conducted experiments with excised leaves of normal and K-deficient Phaseolus vulgaris in which they made comparative measurements of gas exchange processes, chlorophyll content and carbo-

Respiration rate has been shown to increase with K-deficiency. Ozbun et al. (24) have proposed that this increase may be due to increased activity of the pentose phosphate pathway involving increased activity of glucose-6-phosphate dehydrogenase and 6-phospho-gluconate dehydrogenase. This was supported by the presence of higher concentrations of soluble carbohydrates in K-deficient tissue than in normal tissue -- 13 mg/g fresh weight in K-deficient tissue opposed to 2 mg/g in normal tissue.

Light may be associated with the effect of K on photosynthesis, since K additions seem to be more effective in cool summers with less sunlight (30). Jackson and Volk(9) cite work dating from 1922 to 1966 which historically establishes a relationship between K-deficiency and decreased net photosynthesis at light-limiting as well as light-saturating conditions. Ozbun et al. (24) hold that the restriction in photosynthesis at low light intensities in K-deficient leaves may be due partially to increased photorespiration.

Relationship of K to Carbohydrate Manufacture and Translocation; Adequate K favors rapid sugar formation and translocation (30). Sugar levels are of particular interest because of the positive correlation between the amount of sugar in the pith tissue and resistance to stalk rot (14). Martens and Arny (15) have reported that KCl treatment (as compared with no K, no Cl^-, and Cl^- only) decreases reducing sugar levels and increases non-reducing sugar levels. From a review of the literature, Jackson and Volk (9) concluded that K-deficiency generally hinders

the condensation of simple sugars to more complex carbohydrate forms.

Further evidence that K is related to carbohydrate manufacture is the fact that K-deficiency produces chaffy ears in corn due to a lack of proper starch formation and cellulose formation is low due to reduced carbohydrate and lignin production (30).

The effect of K nutrition on translocation may be one of the most important aspects of the role of K in plants. Hartt (8) has done extensive work using ^{14}C in sugarcane to trace the route of photosynthates. Solution-grown sugarcane plants were fed labelled $^{14}CO_2$ in a feeding chamber. Plugs were taken from the fed leaves at various time intervals and analyzed for translocation by radioactivity counts. The fed part of K-deficient blades consistently retained higher percentages of ^{14}C than the fed part of normal blades. The distance ^{14}C was translocated down the blade and down the stalk at any sampling time was less in the K-deficient plant than in the normal plant indicating that translocation was not halted, merely slowed down.

The greatest percentage of inhibition of translocation from the fed part of the plant (75-93%) in Hartt's (8) study occurred in leaves with no visible symptoms of K-deficiency. Thus, Hartt concluded that the visible symptoms of K-deficiency as such did not cause the decrease in translocation.

When Hartt (8) varied the moisture content of sugarcane plants and effects on translocation were noted, the effects resembled K-deficiency effects -- translocation velocity in low moisture plants was depressed, and distribution of ^{14}C, trans-

location to roots, and profile development were decreased. With short periods of translocation (90 min.-5 hrs), ^{14}C was lower in storage joints of low moisture plants. With longer periods of translocation (24 hrs-6 wks), the trend was reversed with low moisture plants containing more ^{14}C in storage joints than high moisture plants. The high moisture plants had used the photosynthates for growth, whereas the low moisture plants had simply stored the photosynthates. The same results were obtained when K-deficient (corresponding to low moisture) and normal (corresponding to high moisture) plants were compared (8).

Potassium deficiency has been associated with low moisture content, but since there was no consistent correlation between K-deficiency and percent moisture Hartt (8) surmised that K-deficiency does not affect translocation simply by its effect upon moisture content. Translocation was measured 24 hours after feeding K-deficient and K-adequate sugarcane plants (8). The K-deficient plant retained 95.5% of the absorbed ^{14}C and the normal leaf retained only 11.3% of the absorbed ^{14}C. Thus, K-deficiency retards both photosynthesis and translocation.

As K-deficiency becomes more severe, it affects translocation before it affects photosynthesis (8). Thirty minutes after supplying +K and -K leaves with $^{14}CO_2$, ^{14}C-sucrose was found to be lower in the fed part of the +K plant than in the -K plant indicating inhibition of translocation in the -K plant. However, when total counts were ascertained, it was found that the -K plant contained more ^{14}C-sucrose than the +K plant (-K, 12.20×10^6 cpm; +K, 11.45×10^6 cpm), indicating that photosynthesis was not

affected by the K-deficiency.

Translocation from the leaf to the stalk did occur in the K-deficient sugarcane plant (8). After 8 days, the relative total counts in the +K and -K plant stalks were 18,300 and 22,600 counts/stalk respectively. The higher count in the -K stalk could be explained by the assumption that the photosynthate was simply stored in the stalk whereas in the +K plant, photosynthate was utilized for growth.

Importance of Balanced Fertility; Usherwood (36) found that as N increases yields, the amount of K required by the crop increases, because even when the soil tests medium to high in K content and some K has been added, the amount of K in the crop tissue often declines as the amount of N added increases. Munson (20) reports that when N uptake is plotted vs K uptake, an r value of 0.986 is obtained. Thus, as more N is added to the soil, more K must be added if the soil can't supply enough K to match the N added. Parks (27) has stated that stalk lodging in corn increases when soil available K drops below 202 kg/ha and becomes acute when the K level drops below 112 kg/ha.

A whole plant N/K (%) ratio of 1 proves most desirable for corn (36). When the ratio exceeds 1, stalk rot increases. In experiments with corn in Wisconsin (36), it has been found that balancing N and K rates have delayed breakdown and death of corn pith tissue. With the proper N-K balance, percent dead stalks for a given hybrid was reduced by 40%. Severity of stalk rot has been found to increase with increasing N rates and decrease with increasing K rates (23,26). Where N and K fertilization

were balanced, rot severity was much less than where excess N was applied (23).

High sugar levels associated with disease resistant corn may be partially responsible for alleviating organismic rot due to conditions of high osmotic pressures and improper nutrient supply for the rot organisms (36). Rapid growth associated with high N rates develops succulent tissue that may be conducive to the development of disease organisms. Illinois has reported (36) a high rate of bacterial blight in corn with high N and low K.

Boswell and Parks (1) theorize that if carbohydrates are utilized for protein synthesis as fast as they are produced (as with high NO_3^- fertilization), plants with thin cell walls and consequently weak stems may develop. Low K may cause a retardation in protein synthesis which may result in an accumulation of nitrogen compounds (e.g. NH_4^+) which are toxic to plants (30).

The amount of K necessary to balance N fertilization depends upon: 1) N rate -- no response to N at low levels of available K; 2) moisture -- best responses to K fertilization (in regard to balancing N) occur under moisture stress or excess moisture; 3) temperature -- low temperature reduces K absorption (36).

In conjunction with the previously mentioned roles of K in plants, K has been associated with the activation or stimulation of over 25 enzymes (17). For example, K^+ activates formyltetrahydrofolate synthetase which is necessary for the formation of coenzyme F. CoF is necessary, in turn, for the biosynthesis of the purine nucleotide, inosinic acid. Inosinic acid is the parent compound of other purine nucleotides, dinucleotides and

other metabolites. All of these substances are involved in energy and group transfers, electron transport, and nucleic acid formation.

The Role of K Fertilizers in Lodging; Liebhardt et al. (13) have postulated three mechanisms for the breakdown of parenchyma cells which lead to lodging in corn; 1) cell wall deterioration, 2) excessive translocation due to the polarizing effect of the ear, and 3) inhibition of protein synthesis. To test these hypotheses, field corn was grown on K fertilized soil (253 kg exch. K/ha) and on the same soil without K fertilization (140 kg exch. K/ha).

Potassium in the lower stalk on the fertilized plots ranged from 2.4% at pre-silk to 1.5% at maturity; the upper stalk ranged from 2.3%-1.2% K at pre-silk and maturity. Without K fertilization, the lower and upper stalk K contents ranged from 0.4-0.2% and 0.5-0.4% respectively at pre-silk and maturity. The K-deficient stalks demonstrated an increase in cellulose content from 20.3% at pre-silk to 38.2% at maturity. The increase in cellulose content was greatest between late dent and maturity -- the time when stalk breakdown is proceeding most rapidly. The cellulose content in K-adequate plants remained essentially constant throughout the season. The sugar content of the stalk showed similar trends, only opposite to cellulose in direction; sugar content in the stalk was maximum at pre-silk (31.6%) and minimum at maturity (11.6%) in the K-deficient plants, while the K-adequate plants retained a constant amount of sugar in the stalks.

Other observations made by Liebhardt et al. (13) were;

1) insoluble N content decreased with time in K-deficient plants while soluble protein and non-protein N fluctuated with time, 2) the three N fractions remained relatively constant in K-adequate plants, and 3) K-deficiency symptoms were severe where no K was applied (breakdown of stalk and roots).

Cell wall deterioration was negated as the primary mechanism of K-related parenchyma breakdown because cellulose increased as parenchyma breakdown progressed with time. Liebhardt et al. ~~(13)~~ supported translocation of carbohydrates from the stalk to the grain as an important mechanism of breakdown because 1) K-deficient plants with the ears removed showed no pith disintegration, 2) removal of the lower 6 leaves (ear retained) of a normal plant caused parenchyma breakdown and typical symptoms of K-deficiency in the kernels.

Since photosynthate movement and velocity are limited in leaves of K-deficient plants and the lower leaves of a K-deficient plant are an insignificant source of photosynthate (because of lower productivity and shortened life) ~~(13)~~, a greater proportion of carbohydrate stored in the lower stalk of a K-deficient plant will have to be mobilized to fill the demands of the developing ear. Liebhardt et al. ~~(13)~~ theorized that as a result of exhaustive translocation from the lower stalk and roots, the parenchyma cells disintegrate, producing a weaker stalk and subsequently leading to lodging.

Their data support the above theory as there were no significant differences in density between fertility levels when the corn stalks were sampled at 10 weeks from emergence. However,

after the tenth week, there was a sharp decrease in the pith density of K-deficient stalks. The K-deficient stalks remained consistently lower in pith density than the normal stalks throughout the rest of the growing season.

Daynard et al. ~~(5)~~ report a similar trend in decline of corn stalk dry weight 2-3 weeks after mid-silking, corresponding to a period of rapid dry matter accumulation in the ear. This reduction in dry weight appeared to be related to translocation of carbohydrates out of the stalk, since there was no comparable decline in stalk residue dry weight.

In a series of histological examinations of sections of brace roots of corn, Liebhardt and Murdock ~~(12)~~ demonstrated that parenchyma breakdown in K-deficient tissue began 7 days after silking. Potassium deficient plants matured earlier resulting in accelerated parenchyma breakdown.

Liebhardt et al. ~~(13)~~ found that where K was not applied, there was a general trend for the N in the stalk to go from insoluble protein to soluble protein to non-protein N as the corn matured, implying an internal enzymatic degradation of protein to amino acids, resulting in premature senescence. The insoluble protein may be structural in nature and bound to other structural material. The soluble protein may be enzymic since it appears in cellular solution or in suspension in the cytoplasm. If these assumptions are true, the K-deficient stalk may lack sufficient amounts of enzymatic material needed for normal metabolism. This would mean that synthesis reactions in this area would probably proceed at a slower rate, which may hasten senescence.

Nelson (21) has reported researchers' results demonstrating a strong negative correlation between percent lodging and amount of available K per hectare while noting that K fertilization builds strong brace roots and stalks leading to decreased lodging. Pappelis and Boone (25) have reported that plants (corn) treated with K fertilization showed much less dead stalk tissue than untreated (K-deficient) corn plants.

The Effects of K Fertilizers on Stalk Rot Organisms; In work with rot resistant varieties of corn, Martens and Arny (14) discovered that KCl and Cl^- treatments increased the severity of lesions caused by artificial inoculation of Diplodia sp. They surmised that this increase was due to the artificial method of inoculation. Under natural conditions, the pathogen must enter through the roots and, thus, to the stalk. This natural advance may be delayed by KCl or Cl^- treatments resulting in decreased stalk rot incidence. However, by artificial inoculation, the roots and lower stalk are by-passed and subsequent fungal growth is rapid.

Christensen and Wilcoxson (3) cite literature reporting that the accumulation of aluminum and iron in corn plants renders the corn more subject to invasion by stalk rot organisms and that application of phosphate and lime reduced the severity of stalk rotting. The accumulation of these Al and Fe compounds, especially when K is low in the soil, was thought to interfere with normal translocation of photosynthates from leaves to roots.

Since much root infection and nodal discoloration usually occur before silking, Christensen and Wilcoxson (3) discounted simple breakdown of pith tissue as the major source of stalk rot.

They further concluded that the Al and Fe compounds predisposed the plants to root infection and stalk and nodal rot. Excessive accumulation of Al and Fe may occur in plant tissue even when these elements do not occur in toxic concentrations in the soil (3). Aluminum, especially, has a tendency to accumulate in the plates in vascular tissue and in the scutellum of kernels, thus interfering with normal translocation. Accumulation of heavy metals in nodes is a common symptom of K-deficiency in corn (30). Under K-deficient conditions, nodal disintegration may occur in the absence of pathogenic organisms (3). Christensen and Wilcoxson (3) found applied lime and phosphorus tie up Al and Fe in the soil and prevent plants from absorbing excessive quantities of their salts. /stop here.

Thayer and Lansing (34) obtained similar results when working with Gibberella stalk and root rot of corn.

Katsanos et al. (10) discovered a correlation between Colletotrichum graminicola infected areas and dead areas in sorghum stalks (r=0.97). C. graminicola mycelia were present only in areas of dead cells which corresponded to dead areas in uninoculated plants with the same treatment (i.e., inoculated and uninoculated plants with leaves removed, roots cut or inflorescence removed). In general, they found that leaf removal (removing the distal 2/3 of leaves) and root cutting increased rates of pith breakdown in sorghum stalks, while inflorescence removal reduced the rate of pith breakdown. These results correspond to the corn experiments by Liebhardt et al. (13) cited earlier.

Comparisons of K Fertilizers; Various K fertilizers have

been compared to study their abilities to alleviate stalk lodging. Younts and Musgrave (37) compared KCl, K_2SO_4, and KPO_3 as sources of K. They discovered that stalk rot incidence in corn was decreased with increased KCl application, but relatively unaffected with increased K_2SO_4 or KPO_3 applications. The Cl^- ion, they concluded, was an important factor in K fertilization. In the field experiments, high rates of Cl^- had little effect on the percentage of other elements in the corn leaves. However, there was a close negative correlation between the percent plants with stalk rot and the percent Cl^- in the corn leaves. The high Cl^- rates delayed maturity of the corn which may have delayed Gibberella attack. Potassium source had no significant effect on the K or N content of the corn leaves.

Research conducted in Alaska by Laughlin et al. (11) showed K_2SO_4 treatments consistently and significantly out-yielded KCl treated bromegrass plots. The marked difference between performance of the two K sources was interpreted to suggest a S deficiency rather than superiority of K_2SO_4 as a K source.

The effect of the anions of K-fertilizers on lodging is still controversial. Results in New York (16) indicate that KCl is much more effective in reducing lodging than K_2SO_4, implying that Cl^- is important in reducing lodging. Conversely, results from Wisconsin (16) indicate that Cl^- had little effect on lodging -- plots with Cl^- had 64 lodged plants, plots without Cl^- had 65 lodged plants. In the same experiment, K was very effective in reducing lodging.

Fujiwara and Torii (6) report that increased Cl^- supply in-

creases the contents of K, Ca, and Mg in young rice plants. However, as the plants aged, Cl^- produced no significant differences in nutrient uptake. Greenway (7) states that passive Cl^- uptake increases linearly with the growth medium concentration of Cl^-, thus the more Cl^- added with K fertilizers, the more Cl^- taken up by the plant. Pitman (29) found that beet root tissue will take up more Cl^- from a $KCl+CaCl_2$ solution than from a straight KCl solution of equal Cl^- concentration.

Uptake of anions is limited by diffusion across a negatively charged membrane (roots) (29). The membrane can be rendered more permeable to anions in the presence of divalent cations, rather than monovalent cations. Thus, when Ca^{++} is present in the solution, uptake of Cl^- may be enhanced, and Cl^- may in turn limit K^+ uptake.

The following lists other factors in the soil or plant which may influence Cl^- uptake; 1) corn grown with NH_4^+ nutrition may contain more PO_4^{-3}, SO_4^{-2}, and Cl^- and less Ca^{+2} and Mg^{+2} than when grown with NO_3^- fertilization (4), 2) a P deficiency may increase Cl^- uptake (4), 3) increased transpiration rates may increase passive Cl^- uptake (7).

Rogalev (31) claims that Cl^- and SO_4^{-2} ions affect vegetative mass formation to the same degree. However, sulfate seemed to accelerate the development of the reproductive organs of clover, tomatoes, and corn. Mitsui et al. (18) worked with bean plants to study Cl^- and SO_4^{-2} absorption and translocation. Chloride is translocated to young leaves and seems to be involved with photosynthesis. Sulfate was found to accumulate in roots, then

be translocated to young leaves where it was involved in the synthesis of S-proteins.

METHODS AND MATERIALS

Three sites in Southeast Kansas were chosen for experimental areas in 1972. The locations were in Bourbon, Crawford, and Wilson counties and were situated on Lula silt loam (Bourbon and Crawford counties) and Bates silt loam (Wilson county) soil types (Table 1). Nitrogen and potassium variables were used in Bourbon and Crawford counties in a randomized complete block design (Table 2). A split-split-plot design was used in Wilson county with planting date as the main plot, K-rate as the sub-plot, and variety as the sub-sub plot (Table 3).

Leaf samples were taken from all plots at the 6-8 leaf stage and at boot stage for N, P, and K analyses. The top fully extended leaves were randomly sampled from the middle two rows of each plot for the analyses (second leaf from top of plant at boot stage). The leaf samples were air dried at 60°C for 72 hours, then ground in a Wiley mill to pass a 2 mm screen. A 0.5 g sample from each plot was weighed and digested in 10 mls concentrated H_2SO_4 (with small piece copper wire) on the hot plate. The digest was brought to 100 ml from which aliquots were taken for the N, P, and K analyses. Nitrogen content of the samples was determined by steam distillation (2), P by vanado-molybdate yellow procedure[1/] using a model 6C Coleman Spectrophotometer at 420 mμ, and K by flame photometry on a model 146 Perkin-Elmer flame photometer. The resultant data were subjected to analysis of variance.

1/ Adapted from Chapman and Pratt. 1961. Methods of analysis for soils, plants, and waters. University of Calif., Riverside.

Table 1. Analysis of soil from experimental sites in Bourbon, Crawford, and Wilson counties, Kansas. Kansas State University Soil Testing Lab.

County	Depth	NH_4^+	NO_3^-	Total Inorganic N	Exch. Ca	Exch. Mg	pH	ECC[1/]	O.M.	Avail. P	Exch. K
		ppm			ppm	ppm		kg/ha	%	kg/ha	kg/ha
Bourbon	0-15 cm*	9.3	13.5	22.8	2144	155	5.8	4667	2.6	33.6	308
	15-30 *	6.6	5.4	12.0	2499	144	5.6	5973	2.6	10.1	279
	30-60 *	6.1	3.7	9.8	2486	161	5.6	5600	1.8	5.6	353
	60-90 *	6.4	5.7	12.1	3368	179	5.6	5227	1.6	3.4	477
Crawford	0-15 cm*	7.8	11.4	19.2	2691	158	6.5	1867	2.6	13.4	279
	15-30 *	8.6	9.1	17.7	2437	158	6.1	4107	2.5	6.7	268
	30-60 *	6.2	4.5	10.7	2752	150	5.9	4480	1.7	4.5	344
	60-90 +	4.2	4.2	8.4	4455	122	6.2	3360	1.5	4.5	463
Wilson	0-15 cm**	---	---	---	----	---	6.0	4928	---	17.9	190
	15-30 +	---	---	---	----	---	5.4	5600	---	20.2	178
	30-45 +	---	---	---	----	---	5.4	6720	---	6.7	254
	45-60 +	---	---	---	----	---	5.5	5600	---	3.4	335
	60-75 +	---	---	---	----	---	5.6	5600	---	3.4	383

* All values average of 3 reps.
+ All values one rep only.
**All values average of 5 blocks.
1/ECC -- effective calcium carbonate requirement.

Table 2. Experimental design for Bourbon and Crawford county studies.

Treatment		K-Carrier
N	K	
kg/ha		
0	0	---
84	0	---
168	0	---
252	0	---
0	74.6	KCl
84	74.6	KCl
168	74.6	KCl
252	74.6	KCl
0	149.3	KCl
84	149.3	KCl
168	149.3	KCl
252	149.3	KCl
0	298.6	KCl
84	298.6	KCl
168	298.6	KCl
252	298.6	KCl
0	149.3	K_2SO_4
84	149.3	K_2SO_4
168	149.3	K_2SO_4
252	149.3	K_2SO_4

Plots 3.66m x 12.19m. All plots received 24 kg P/ha. Nitrogen as urea. Seeding rate = 123,450 plants/ha. Each treatment replicated three times.

County	Variety	Planting Date	Row Width	Prev. Crop
Bourbon	Acco 109	May 18, 1972	96.5 cm	Soybeans
Crawford	Prairie Valley PV 735	May 8, 1972	91.4 cm	Sorghum

Table 3. Experimental design for Wilson county study.

Complete factorial of:

Planting Dates

April 19
May 16
June 16

K-Rates

kg/ha

0
74.6
149.3
298.6

Varieties

Asgrow Dorado
RS 626
Funks G522
Acco R1090
DeKalb C42A
NC+ 70X

All treatments replicated three times.
Date plots, 9.14m x 42.67m.
K-rate plots within date plots, 9.14m x 10.67m.
Variety plots within K-rate plots, 1.52m x 9.14m.

Two 76.2 cm wide rows for each variety.

Pre-plant fertilization; 168 kg N/ha and 24 kg P/ha.

Planted at 123,450 plants/ha.

Herbicide; Herban 21A.

Potassium supplied as KCl.

Stalk samples were collected from the Wilson county study at physiological maturity. Physiological maturity was determined by plucking seeds from the sorghum head and inspecting the scutellum. When the scutellum of seeds from top to bottom of the head had all darkened, the plant was considered to be at physiological maturity. Five stalk samples from mature plants from the first 1.5 m of each plot were cut off at ground level and stripped of leaves. Fifteen-cm sections were cut from the base of the stalk and from the peduncle (including the top node) and these sections were dried at 38°C for 7 days with the leaf sheathes intact so that the stalks would dry slowly to limit cracking and shrinking.

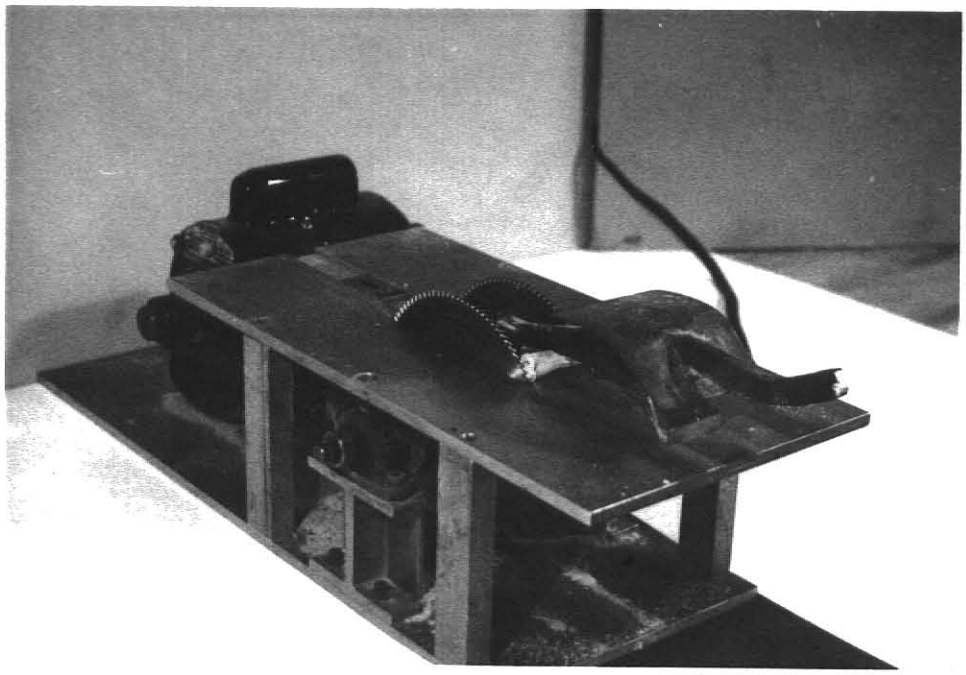
A 5 cm section was subsequently cut from each dried stalk sample (Figure 1). The 5 cm peduncle section included that area immediately above the top node. In was attempted to include the same number of nodes (two) in each 5 cm base section and to begin the section at the same relative position on the stalk (the second internode above the brace roots). The stalk sections were weighed, diameter determined by an outside caliper, and crushed for strength determinations (38).

Cuushing strength was determined by placing stalk sections individually in a hydraulic press and crushing longitudinally. The hydraulic pressure was read from a pressure gauge at the breaking point and recorded (Figure 1)[2/]. The crushed stalk samples were then ground in a Wiley mill to pass a 2 mm screen and a 1 g sample extracted with 70 ml boiling water, brought to

2/ Equipment and instruments from Dr. M.S. Zuber, Univ. of Missouri.

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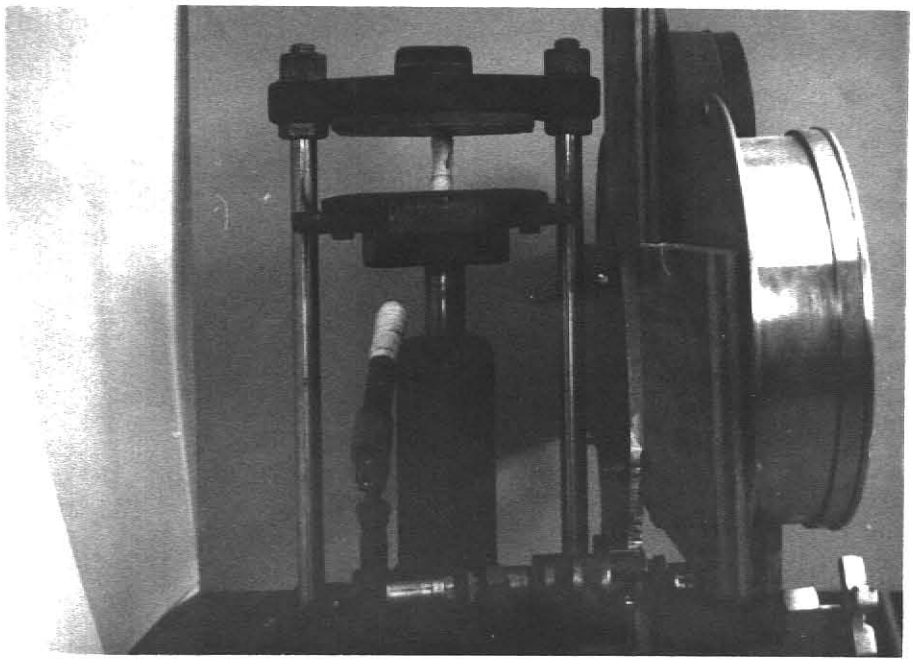


Figure 1. Saw used to cut sorghum stalk sections into 5 cm sections (top). (Bottom) Hydraulic press used to determine crushing strength of stalks -- stalk section in press (top-center of picture); strength recorded on dials (right). Instruments compliments of M.S. Zuber, Univ. of Missouri, Columbia, Mo.

100 ml with distilled, deonized water, analyzed for K by flame photometry and for Cl^- by colorimetric titration.

For the Cl^- analysis, 10 ml of the extract were titrated with 0.0282 N $AgNO_3$ with 0.5 ml K_2CrO_4 indicator (2 g K_2CrO_4/100 ml H_2O). The end point occurred with the first permanent faint red color[3/]. The stalk data were subjected to statistical analyses for analysis of variance, simple linear correlation, and multiple regression.

Lodging notes were taken at all sites at harvest time. All plants were counted in the center two rows of each plot and any plant leaning more than 45° from the vertical was considered lodged. No effort was made to distinguish between main plants and tillers. Lodging data were subjected to analysis of variance, simple linear correlation, and multiple regression statistical analyses.

Harvest at all sites was accomplished by means of hand-cutting the heads from the center two rows of each plot, air-drying at $60^\circ C$ for 72 hours, then threshing with a plot thresher. The grain yields were adjusted to 12.5% moisture and subjected to analysis of variance.

3/ From Method of analysis of irrigation water. Compiled by R.H. Follett. 1966. Colorado State University.

RESULTS AND DISCUSSION

The results will be discussed in the order of leaf tissue analysis, yield, lodging, and stalk characteristics with each site considered individually within each section and a summary of findings at the end of each section.

Leaf Tissue Analysis

Bourbon county. Nitrogen treatments had no discernable effect on leaf composition (N,P,K) at either the 6-leaf stage or boot stage in Bourbon county.

Potassium treatments, however, affected both N and K levels in the leaves at the 6-leaf stage (Appendix Table 1). Nitrogen levels in the leaves decreased as leaf K levels increased with increasing K applications. The literature suggests that non-protein-nitrogen accumulates under K-deficiency conditions (32,33,35), but the N in question here is total N. However, Teel (33) cites works which indicate a similar downward trend in N and N-fractions with increasing K concentrations in orchard-grass and soybeans. Pesek (28) cites work which reports evidence that K may interfere with the absorption of N causing reduced N concentrations.

By the time of the boot stage sampling, all significant treatment differences in N and K concentrations in the leaf had disappeared. Nitrogen and K concentrations were lower at the boot stage than at the earlier sampling date (Appendix Table 1) probably because of the diluting effect of plant growth. The N-treatment by K-treatment interaction on leaf percent K can be

seen in Figure 2. Nitrogen-treatments appeared to have little effect on leaf percent K.

Phosphorus concentrations, in contrast to N and K concentrations, were higher in the boot stage leaves than in the young leaves, perhaps because P accumulation subsequent to the 6-leaf stage occurred more rapidly than growth-dilution.

Potassium-source affected N and K concentrations in the young plant leaves. Leaves from K_2SO_4-treated plots had significantly higher N and K concentrations at the 6-leaf stage (K concentrations significant at 10% level). By boot stage, however, there were no significant differences between KCl- and K_2SO_4-treated plots in leaf nutrient concentrations (Appendix Table 1).

Crawford county. Increasing N-rates increased leaf N concentrations at both the 7-leaf and boot stages of development (Appendix Table 2). Phosphorus and K concentrations were relatively unaffected by N-treatment with the exception of a low P value at the boot stage for the no-N plots compared with the N-treated plots.

Leaf K concentration response to K-treatments was more marked at the Crawford county site than in Bourbon county, although again by the boot stage sampling, there were no significant differences in nutrient concentrations between treatments (compare K-summaries in Appendix Tables 1 and 2). In Crawford, as in Bourbon county, N concentration in the leaves tended to drop as K treatments increased, but differences were not statistically significant in the Crawford county data.

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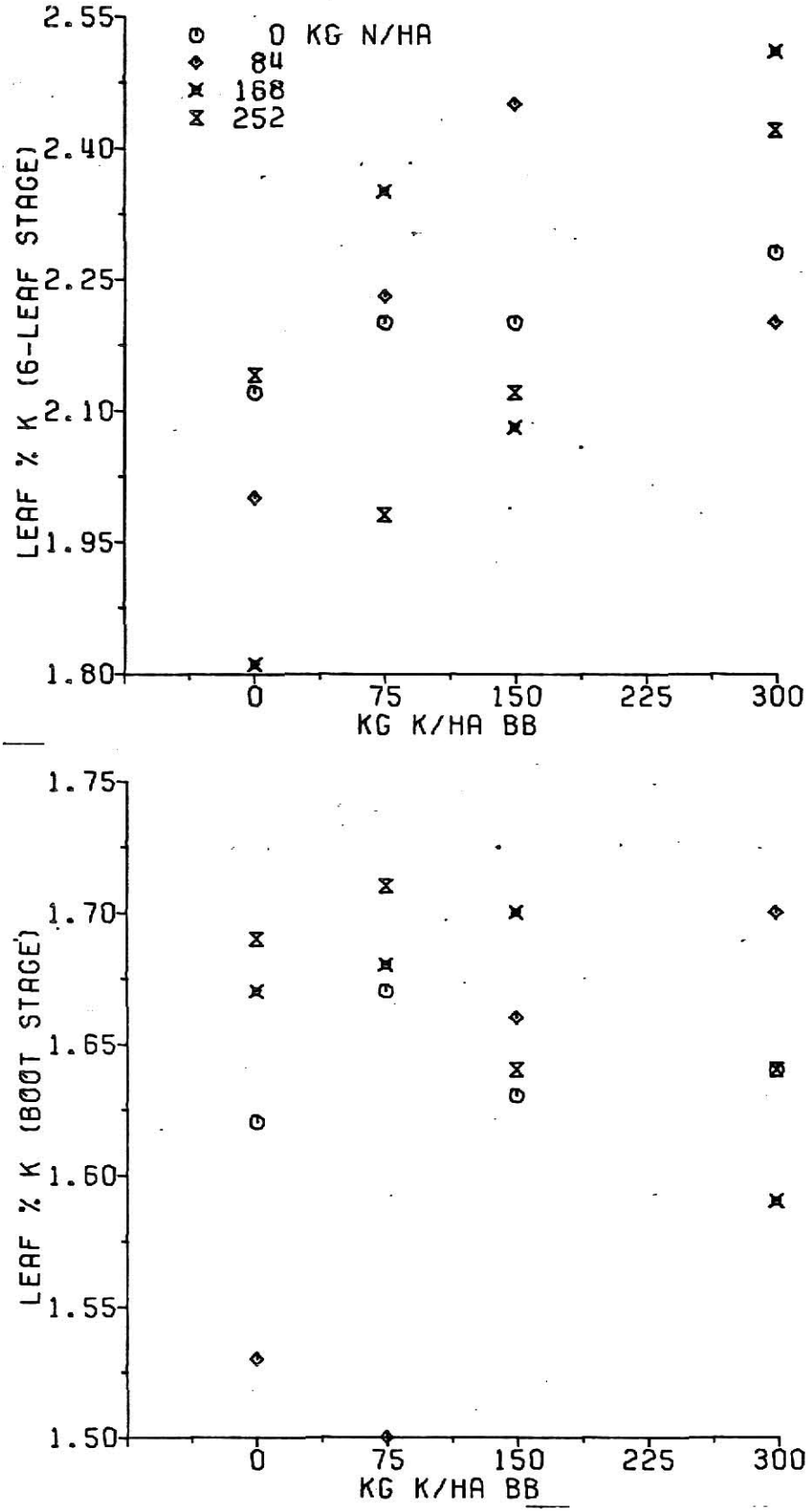


Figure 2. Effects of N and K treatments on leaf K concentration in grain sorghum. Bourbon county, Kansas. Acco 109.

Leaf nutrient concentrations showed the same tendencies in Crawford as in Bourbon county with respect to plant age; N percentages predictably declined with maturity while P concentrations increased between the early sampling date and boot stage.

Nitrogen-treatment by K-treatment interactions on leaf percent K (Figure 3) showed little effect of N-treatments, although more often than not, where N was withheld leaf K concentrations were low compared to N-treated plots. Note the good response to K-fertilization in terms of leaf K concentrations.

Effects of K-source were similar to those previously discussed (compare K-source summaries for Appendix Tables 1 and 2). Potassium sulfate-treated plots again demonstrated the highest N and K percentages in the leaf, although non-significant at the 5% level. Potassium chloride and K_2SO_4 should be expected to produce similar results.

Wilson county. Leaf nutrient concentration responses to K-fertilization in the two previous studies were substantiated in Wilson county (Figures 4,5, and 6). Although N concentrations were depressed by increasing K-rates only in the second planting date (whereas the other sites showed a consistent downward trend in leaf N as leaf K increased), leaf K concentrations increased consistently with increasing K-rates in every planting date (compare K-summaries in Appendix Tables 3, 4, and 5). Increasing K-rates also alleviated visible K-deficiency symptoms (Figures 7, 8, 9, and 10). Notice the burning of the leaf margins in Figures 7 and 8 with the low rates of K and the diminishing symptoms in Figures 9 and 10 with the higher rates of K.

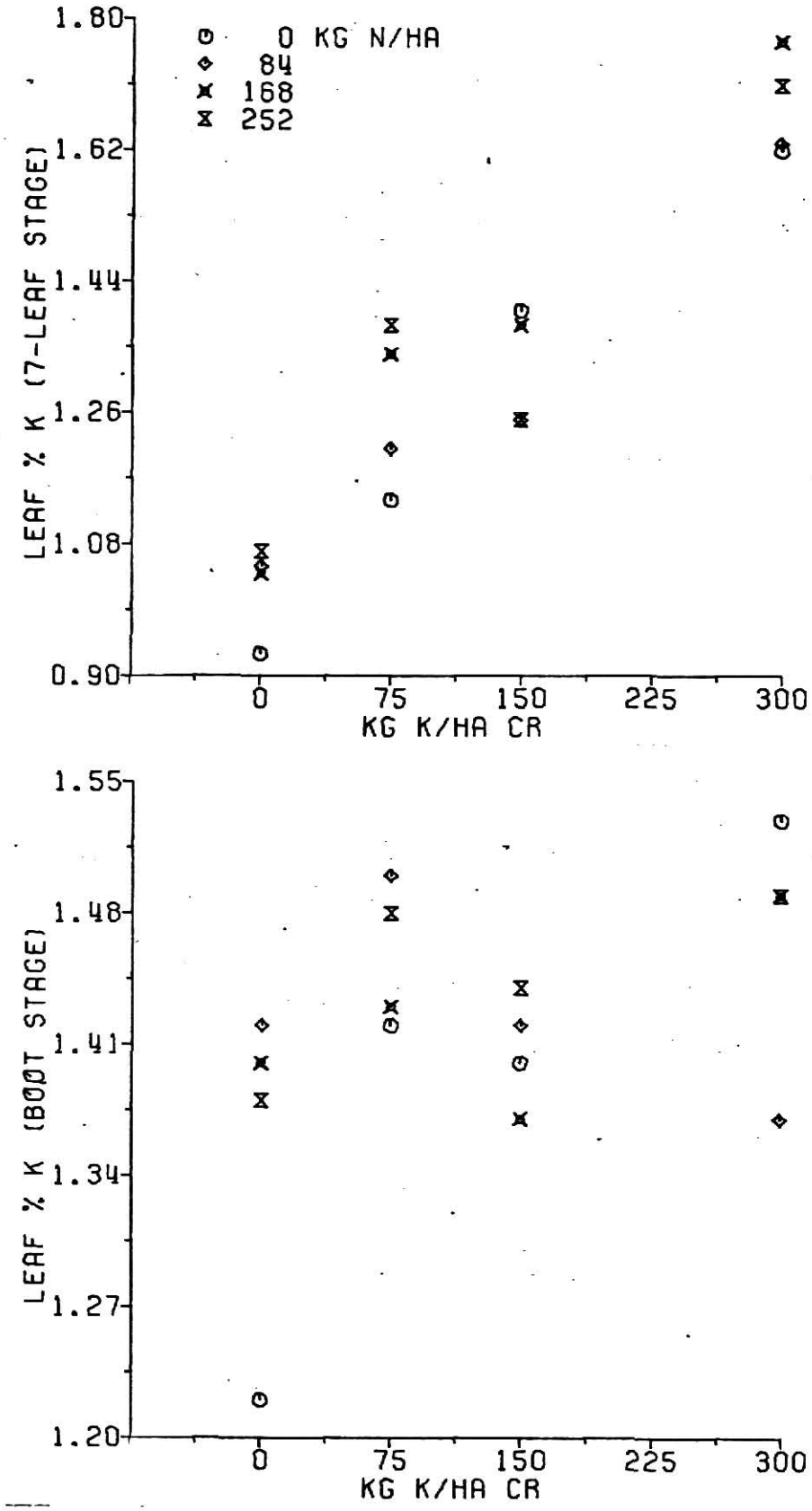


Figure 3. Effects of N and K treatments on leaf K concentration in grain sorghum. Crawford county, Kansas. Prairie Valley PV 735.

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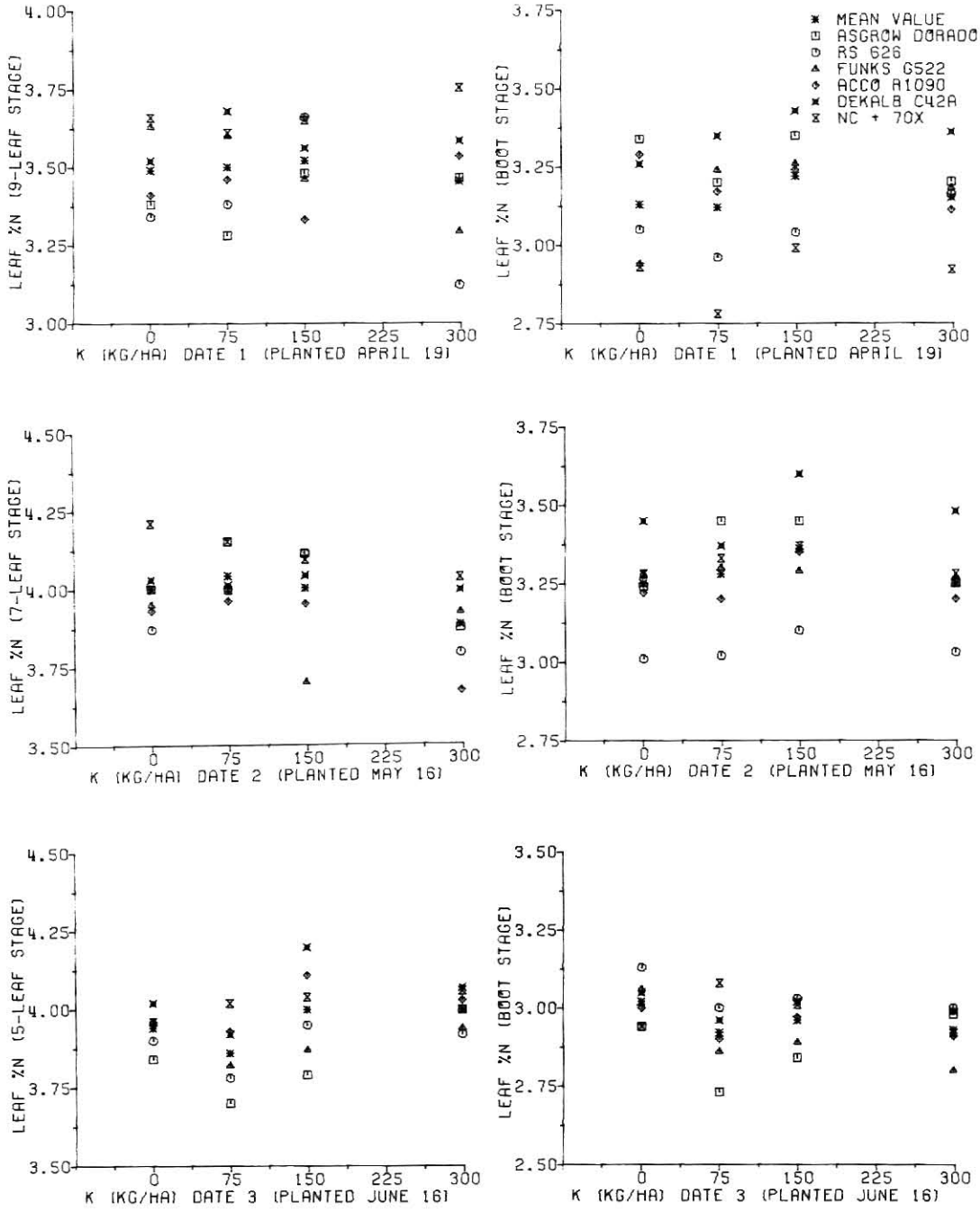


Fig. 4. EFFECT OF K TREATMENTS, PLANTING DATE, AND SAMPLING DATE ON NITROGEN CONTENT OF SIX GRAIN SORGHUM VARIETIES

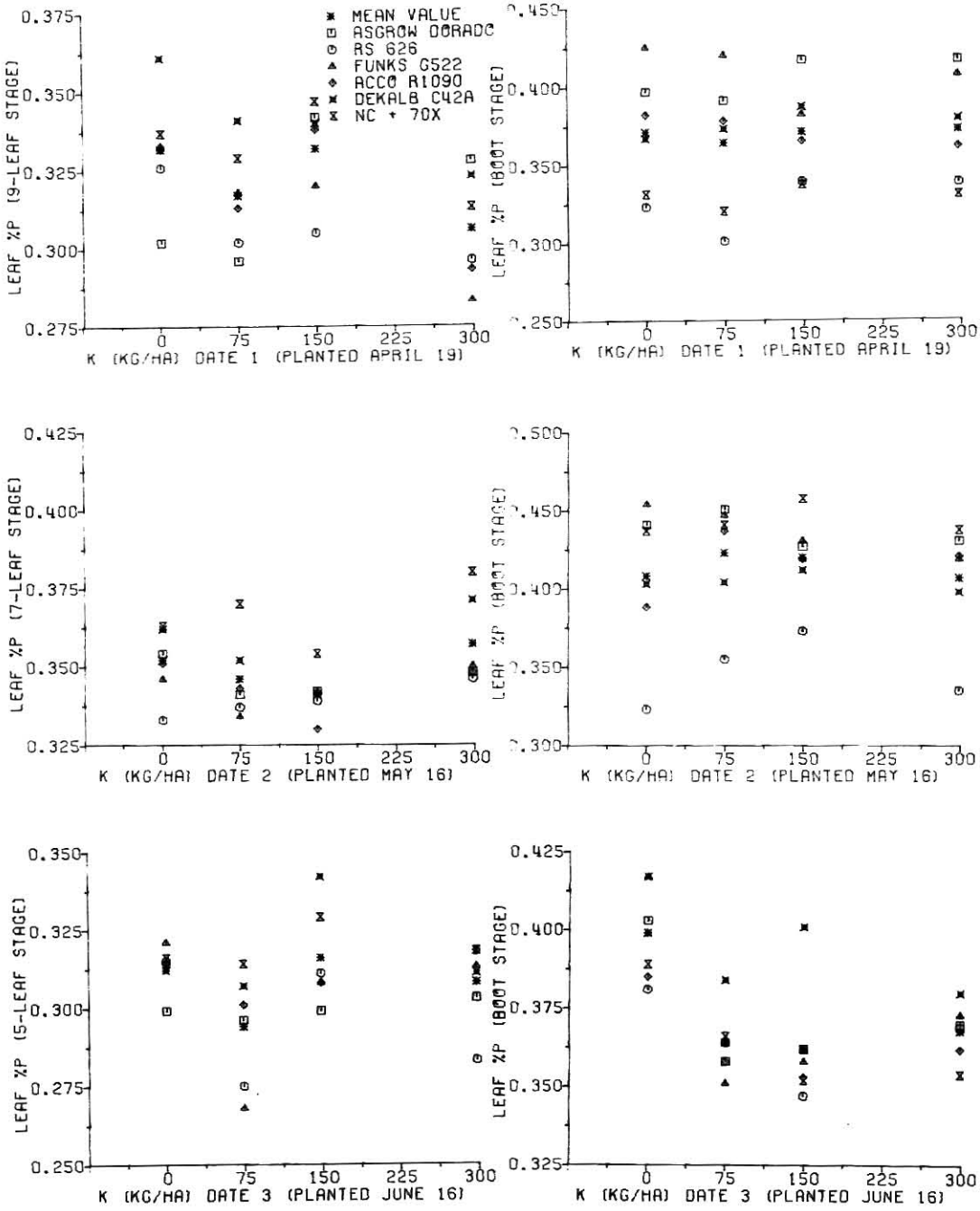


Fig. 5. EFFECTS OF K TREATMENTS, PLANTING DATE, AND SAMPLING DATE ON PHOSPHORUS CONTENT OF SIX GRAIN SORGHUM VARIETIES

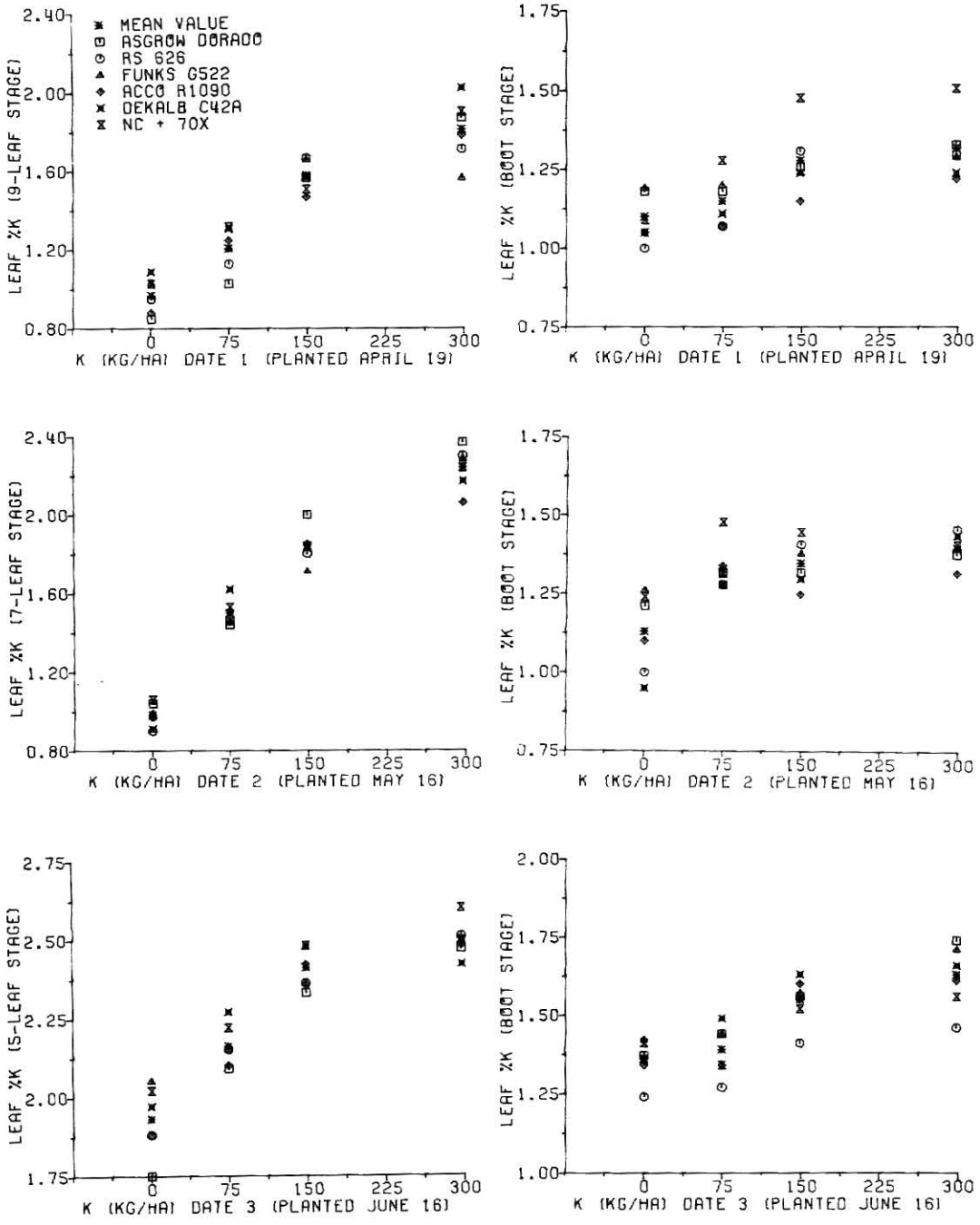


Fig. 6. EFFECTS OF K TREATMENTS, PLANTING DATE AND SAMPLING DATE ON POTASSIUM CONTENT OF SIX GRAIN SORGHUM VARIETIES

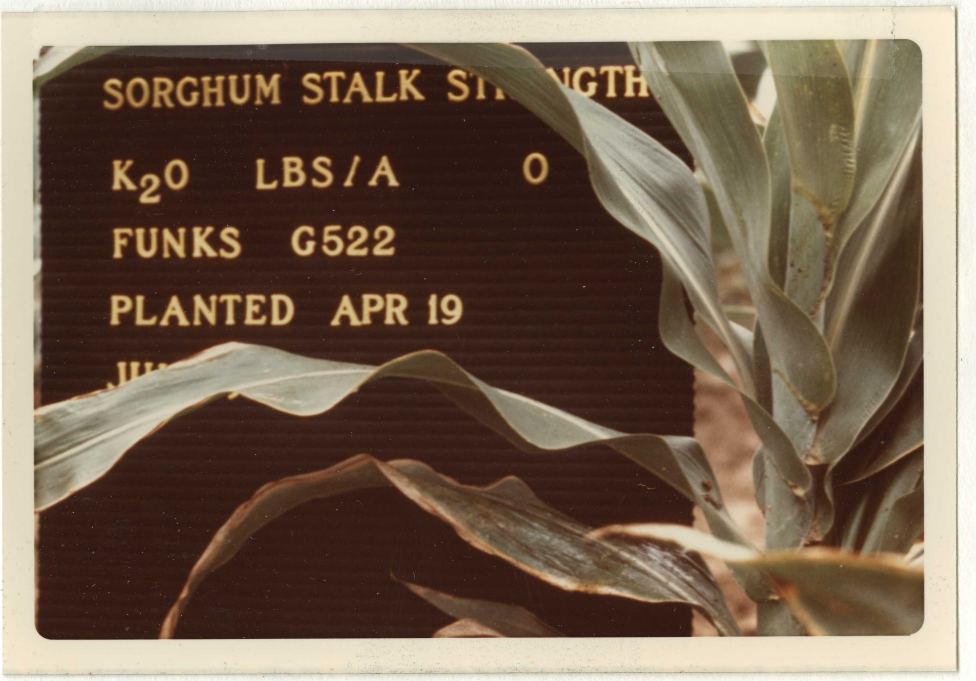


Figure 7. K-deficiency symptoms at 0 kg K/ha. Note marginal firing of lower leaves. Funks G522, 79 days after planting. Wilson county.



Figure 8. K-deficiency symptoms at 74.6 kg K/ha. Note marginal firing of lower leaves -- compare degree of visible symptoms with Figure 7. Wilson county. Funks G522, 79 days after planting.



Figure 9. Effect of K-treatments on K-deficiency symptoms. 149.3 kg K/ha. Note tip-firing on lower leaves and lack of symptoms on upper leaves. Compare with Figures 7 and 8. Wilson county. Funks G522, 79 days after planting.

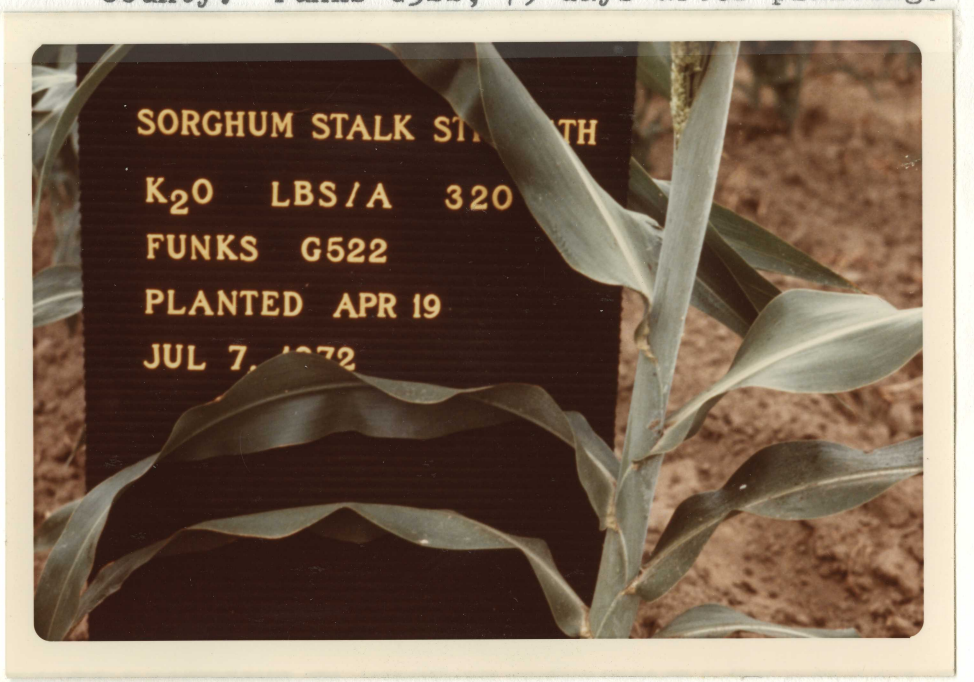


Figure 10. Effects of K-treatments on K-deficiency symptoms. 298.6 kg K/ha. Note lack of marginal firing or any other K-deficiency symptoms. Wilson county. Funks G522, 79 days after planting.

As at the other sites, P remained unaffected by K-treatments. Unlike the other two sites, though, there were still significant differences between leaf K-concentrations at the boot stage. The general upward trend in K concentration with increasing K-rates was maintained as plants matured. Increasing plant maturity was accompanied by declining N and K concentrations as observed at the other sites. However, the P concentration of the leaves increased with advancing maturity.

Varietal differences are rather difficult to summarize due to the variation possible with 6 varieties of differing parentage, 3 widely spaced planting dates, and 2 sampling dates at widely spaced stages of maturity. However, some general observations can be made. Nitrogen and P concentrations showed more variability between varieties at both sampling dates and three planting dates than did K concentrations (Figures 4, 5, and 6 and variety summaries, Appendix Tables 3, 4, and 5). The early sampling date showed no significant K-concentration differences between varieties in any of the three planting dates. By boot stage, some statistically significant differences in K concentrations between varieties had developed, but these differences were small.

When values for each nutrient were averaged over both sampling dates and all planting dates for each variety, further generalities surfaced. DeKalb C42A and NC+ 70X produced more above-mean values than any of the other varieties. DeKalb C42A N and P concentrations were above the mean; NC+ 70X was above the mean in N, P, and K concentrations. Asgrow Dorado and Funks G522 proved to be about average in all values. RS 626 and Acco

R1090 were consistently lower than the other varieties in N, P, and K concentrations (Acco R1090 was average in P concentrations, but low in N and K).

These differences between varieties point out some of the difficulties encountered when attempting to make general observations and recommendations for a particular crop. One can recommend a certain ideal concentration of an element for a crop, but that concentration may represent an adequate amount for one variety and a deficiency for another variety. Variations such as these make interpretation of tissue analysis data rather difficult.

Significant differences between leaf N and K concentrations were produced at both sampling dates by the three planting dates. Some of the differences could be explained by weather factors and subsequent effects on soil and plant relationships. Some of the differences were possibly due to the differing stages of maturity of the plants at the early sampling dates for each planting date.

Summary. Plants grown at the Bourbon county site were consistently higher than plants from the Crawford or Wilson county sites in all leaf N, P, and K values. This may be because the Bourbon county site had the highest fertility level of the three locations and perhaps the best weather conditions. The Crawford county site produced the lowest leaf nutrient concentration averages for both sampling dates, with the exception of the boot-stage K concentration average which was between Bourbon and Wilson county averages.

Soil and weather differences between sites and effects of varieties are obvious sources of variation, but general trends were supported at all locations. Nitrogen treatments had no discernable effects on leaf K concentrations, but K treatments tended to reduce N concentrations. Leaf K concentrations in young plant leaves rose steadily with increasing K-rates, but as plants matured the differences between treatments diminished.

Larger differences in K concentrations as affected by K applications were observed in Wilson county than at the other two locations. This is probably due to the increased response to added K at the lower K-fertility level in Wilson county.

Potassium sulfate produced higher N and K concentrations early in the season than KCl, but by boot stage, differences between KCl and K_2SO_4 treatments were nil.

In all cases, except for Crawford county, N and K concentrations were generally reduced from early sampling date to boot stage, but P concentrations increased in the same interval.

Grain Yield

Bourbon county. There were no significant differences in grain yield produced by varying N rates, K-rates or K-source. The yields were reasonably high and therefore seemed to indicate that the crop was placed under little, if any, moisture or fertility stress. However, a statistically significant N-treatment by K-treatment interaction showed that where no N is supplied, increasing K-rates depress yields (Figure 11). Under adequate N fertility levels, increasing K-rates had a positive effect on grain yield.

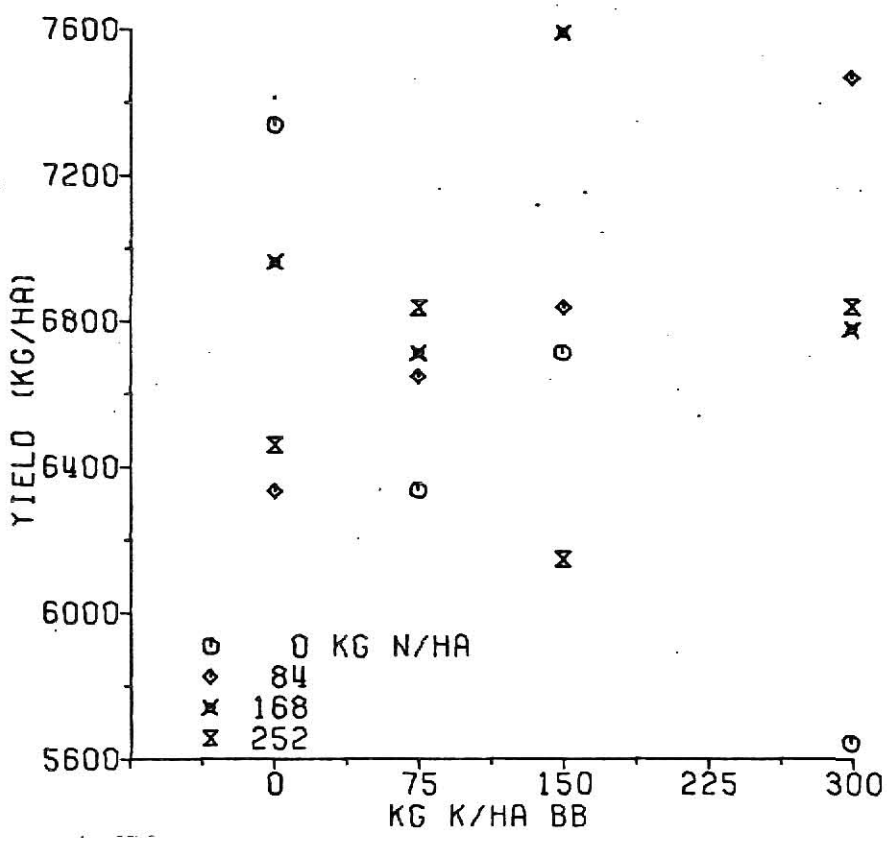


Figure 11. Effects of N and K treatments on grain yield of grain sorghum. Bourbon county, Kansas. Acco 109.

Crawford county. Although grain yields were not found to be significantly affected by N-rates, K-rates, or K-sources, the control plots (0-N and 0-K) produced the lowest yields (Figure 12). The first increment of N or K (84 kg N/ha and 74.6 kg K/ha) produced yield increases of 689.7 kg/ha and 376.2 kg/ha, respectively, over the 0 kg N and K plots. This yield increase was generally maintained with the other fertilizer increments.

Potassium chloride-treated plots produced an average of 318.5 kg/ha more than K_2SO_4-treated plots. In Bourbon county, KCl-treated plots outyielded K_2SO_4 plots by only 62.7 kg/ha. On the basis of the small numbers of samples involved, 12 plots at both locations, and the small yield differences, it would be presumptuous to declare that KCl is the better source of K.

Wilson county. Three planting dates at one month intervals were established to enhance the possibility of subjecting the sorghum to environmental stress (particularly moisture stress). Only two of the three planting dates produced any grain. The third date, planted on June 16, 1972, became infested with sorghum midge which destroyed virtually all of the grain. The first planting date, April 19, produced yields substantially lower than the second planting date, May 16. Average yields of both planting dates were lower than those from the Bourbon or Crawford county sites.

The low yields of the first planting date can be partially attributed to poor stand. The site received a heavy rain shortly after planting which compacted the soil and caused poor emergence.

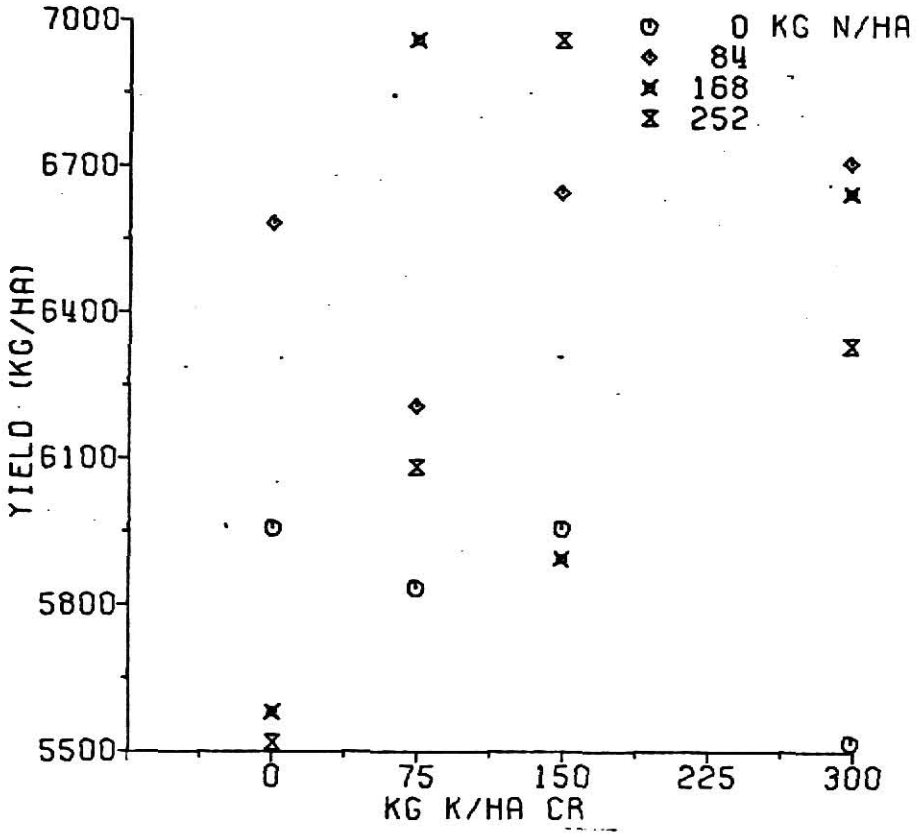


Figure 12. Effects of N and K treatments on grain yield of grain sorghum. Crawford county, Kansas. Prairie Valley PV 735.

Cool temperatures during the early season slowed growth. Although the plants tillered significantly stands remained thin. There was no yield response to K fertilization with the first planting date, but significant differences did exist between the varieties (Figure 13).

The second planting date produced better yields than the first, but again there were no significant differences in grain yield between K-rates (Figure 14). With this planting date, however, there was a large difference between the yield of the no-K plots and that of the 74.6 kg K/ha plots, 1558.5 kg/ha. As in the first planting date, significant yield differences existed between varieties with a range of 1077.3 kg/ha between the lowest yielding variety (RS 626) and the highest (Acco R1090).

In comparing yield and leaf nutrient content data, it is interesting to note that the varieties which were above the mean in nutrient concentrations were not necessarily those that produced above-mean yields. Acco R1090 and RS 626 which were below the mean in leaf nutrient content were split, with Acco R1090 above the mean yield and RS 626 below. Asgrow Dorado and Funks G522 were average in nutrient content, but both were above the mean yield. DeKalb C42A and NC+ 70X were above the mean nutrient content, but both were below the mean yield. These observations suggest that we need to know more about the correlation of nutrient content to yield in the various varieties rather than trying to average nutrient content of all the varieties. When a better understanding of this correlation is gained, perhaps wiser selections of breeding stock can be made to accentuate

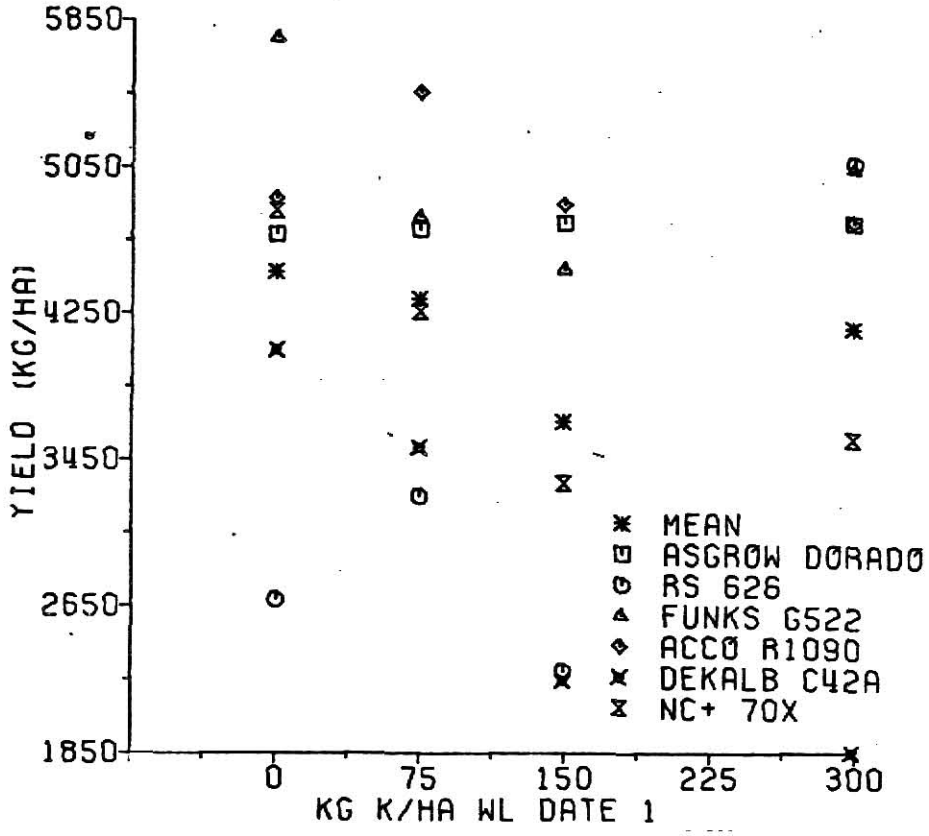


Figure 13. Effects of K treatments on grain yields of six grain sorghum varieties. Wilson county.

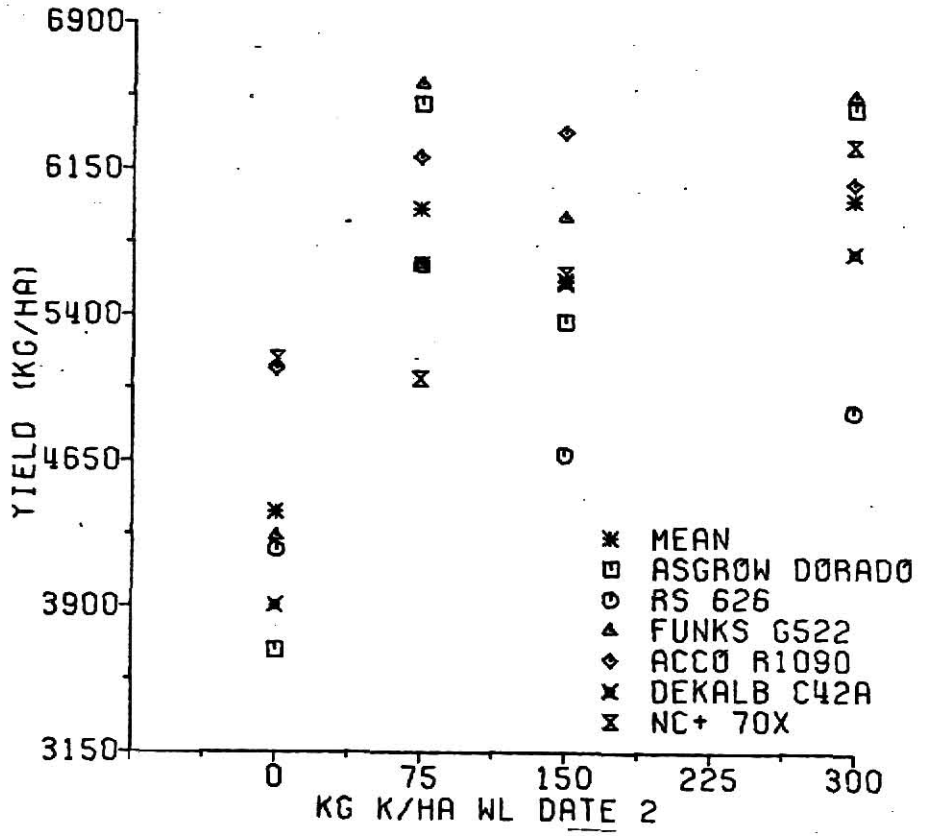


Figure 14. Effects of K treatments on grain yields of six grain sorghum varieties. Wilson county.

the yield response to nutrient composition.

Summary. Yield was positively affected more by balanced N and K fertilization than by the influence of either N or K levels alone in Bourbon and Crawford counties. The varietal trends in yield in the first planting date at the Wilson county site showed no consistent response to K fertilization. However, by the second planting date, K fertilization produced a general upward trend in grain yield.

Lodging

Bourbon county. There was no lodging at the Bourbon county site. This site received rainfall at strategic times during the season and, accordingly, was not subjected to severe moisture stress. The soil was more fertile than the other locations (Table 1) and this could have been another contributing factor to attaining good stalk strength. Acco 109 was not tested elsewhere, so the effects of environment and soil cannot be separated from varietal effects.

Crawford county. The Crawford county site suffered more from lodging than the Bourbon county location, although the exchangeable K at the two sites differed little. This points to the hypothesis that environmental or varietal factors may have influenced plant responses to added K more than soil factors. There was an interesting trend in lodging as affected by N-rates (Figure 15), although the differences between treatments weren't statistically significant. The trend suggests that lodging is increased by added N since there was a 3% difference in lodging between 0 kg N/ha plots and average lodging of plots treated with

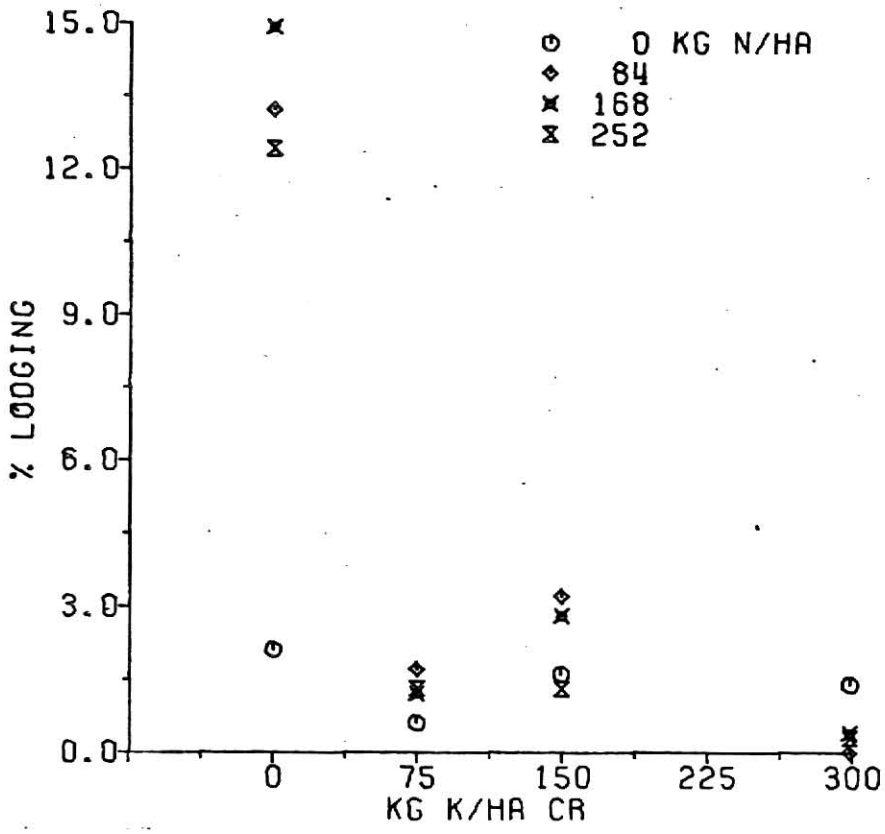


Figure 15. Effects of N and K treatments on stalk lodging of grain sorghum. Crawford county. Prairie Valley PV 735.

84 to 252 kg N/ha (Appendix Table 2). The N-K fertilizer balance affected the visible symptoms of stalk rotting as well as lodging (Figure 16).

Boswell and Parks (1) have theorized that if carbohydrates are utilized for protein synthesis as quickly as they are produced (as with high N fertility) plants with thin cell walls and consequently weak stems may develop.

Illinois workers (37) have noted the same trends with corn and reason that the succulent tissue produced under high N fertility may be conducive to the development of disease organisms. Usherwood (37) cites work which suggests that a whole plant N/K (%) ratio of 1 should be maintained with corn to reduce lodging. This study did not entail whole plant analyses to compare a similar relationship with grain sorghum. The N/K ratio concept suggests that it is not the N fertility level per se that affects lodging, but rather the balance between the nutrients.

Although lodging was not severe at this location, K fertilization had a marked effect on reducing it (Figure 15). The sorghum was harvested much earlier than normal. If it had been left standing in the field for a longer period, perhaps lodging would have been more severe. There was no significant difference between K-rates, but the difference between no added K and some added K was striking. Observations like this in the past prompted this study. Much work has been done with corn and other cereals indicating a relationship between K fertility and lodging (1,11,12,14,17,20,21,23,25,26,27,37). Tisdale and Nelson (35) and Salisbury and Ross (32) list lodging as one of the symptoms

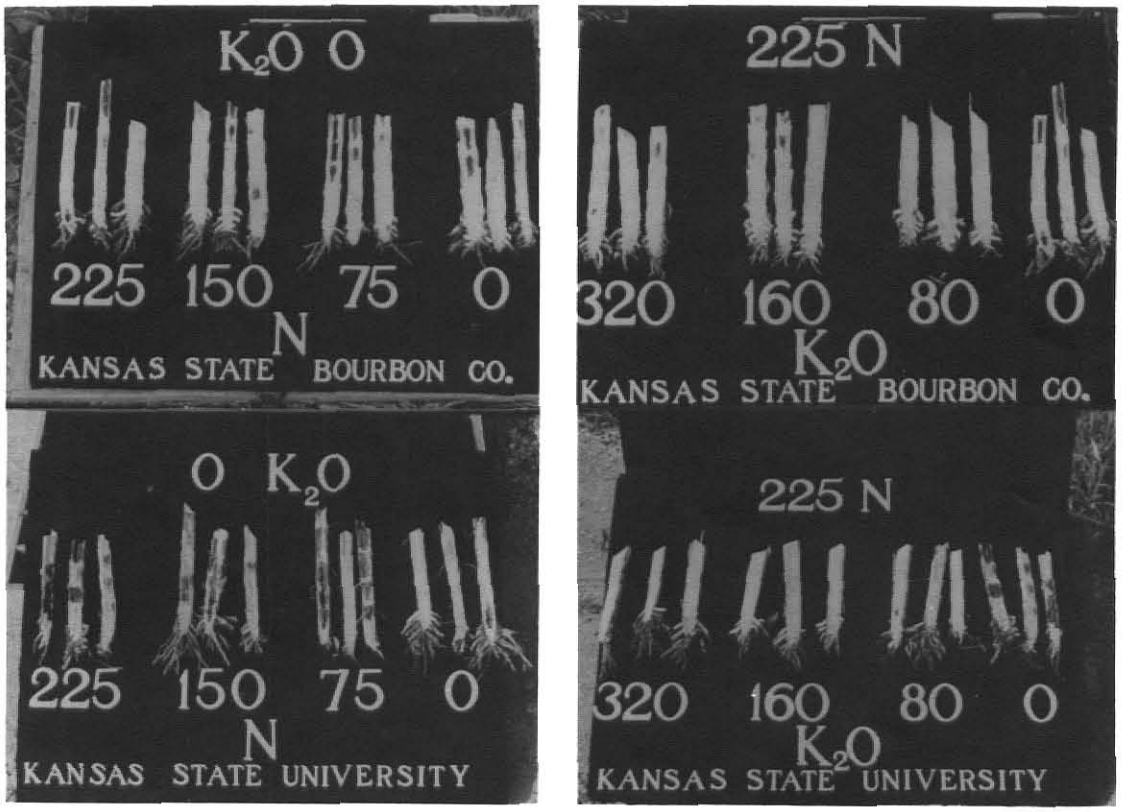


Figure 16. Effects of N and K treatments on visual presence of stalk rot in grain sorghum. Note that stalk rot tended to increase with increased rates of N and to decrease with increasing applications of K. Also note that N and K exerted more influence at the Crawford county site (lower) than at the Bourbon county site (upper).

Rates of N -- 252, 168, 84, and 0 kg N/ha.

Rates of K -- 298.6, 149.3, 74.6, and 0 kg K/ha.

Bourbon county -- variety, Acco 109

Crawford county -- variety, Prairie Valley PV 735.

associated with K deficiency. The data from this location help to establish the relationship between lodging and K nutrition for grain sorghum.

The source of K had no significant effect on lodging (Appendix Table 2), although the KCl plots had somewhat less lodging than the K_2SO_4 plots. Although not statistically significant, the difference between KCl and K_2SO_4 plots supports a trend observed by other workers. Younts and Musgrave (37) compared KCl, K_2SO_4, and KPO_3 as K sources and found that KCl reduced lodging in corn while increased rates of K_2SO_4 and KPO_3 had no effect on lodging. Because the K source did not affect the concentration of other ions in the corn leaves and because Cl^- ion concentration in the leaves showed a high negative correlation with stalk rot, they concluded that the Cl^- ion must be important in preventing lodging. The results from this study do not fully support the above mentioned conclusions, for K_2SO_4-treated plots did reduce lodging as compared to the no-K plots.

Wilson county. The first planting date (April 19) demonstrated a significant difference between lodging in no-K plots and lodging in K-treated plots (Figure 17). As in Crawford county, there were no significant differences between K-rates, but the difference between no K added and some K added was large indicating that the lowest K-rate, 74.6 kg K/ha, was sufficient to reduce lodging on this soil and under the existing weather conditions.

The sorghum planted on May 16 suffered more severe lodging than the first planting date, possibly because stands were heavier making moisture and fertilizer competition greater.

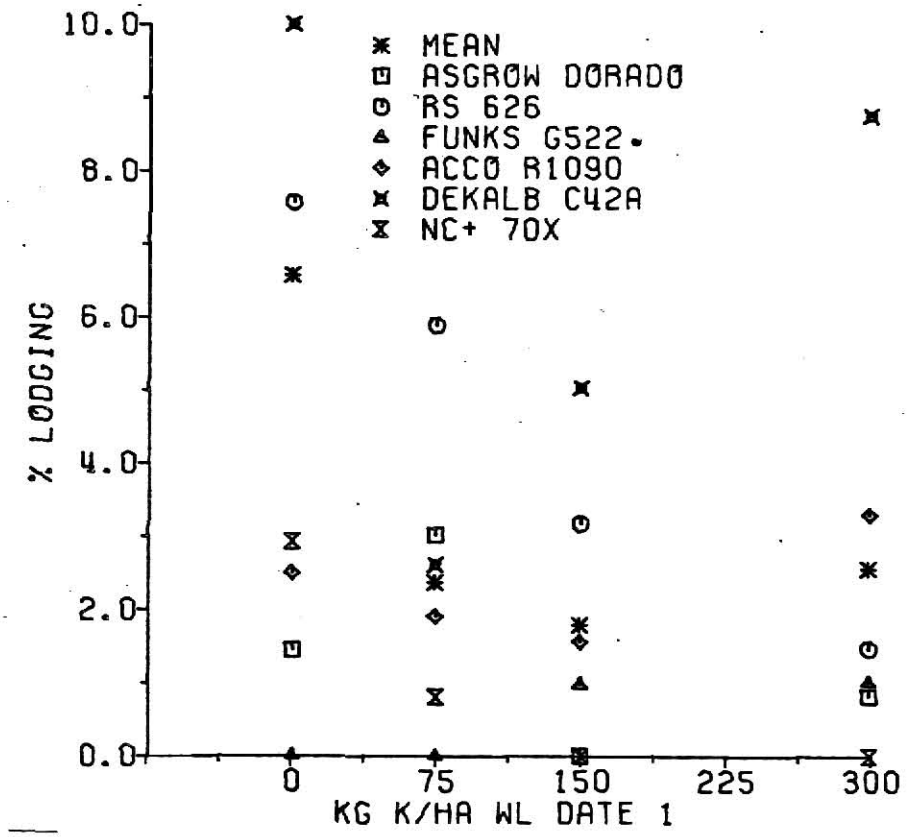


Figure 17. Effects of K treatments on stalk lodging of six grain sorghum varieties. Wilson county.

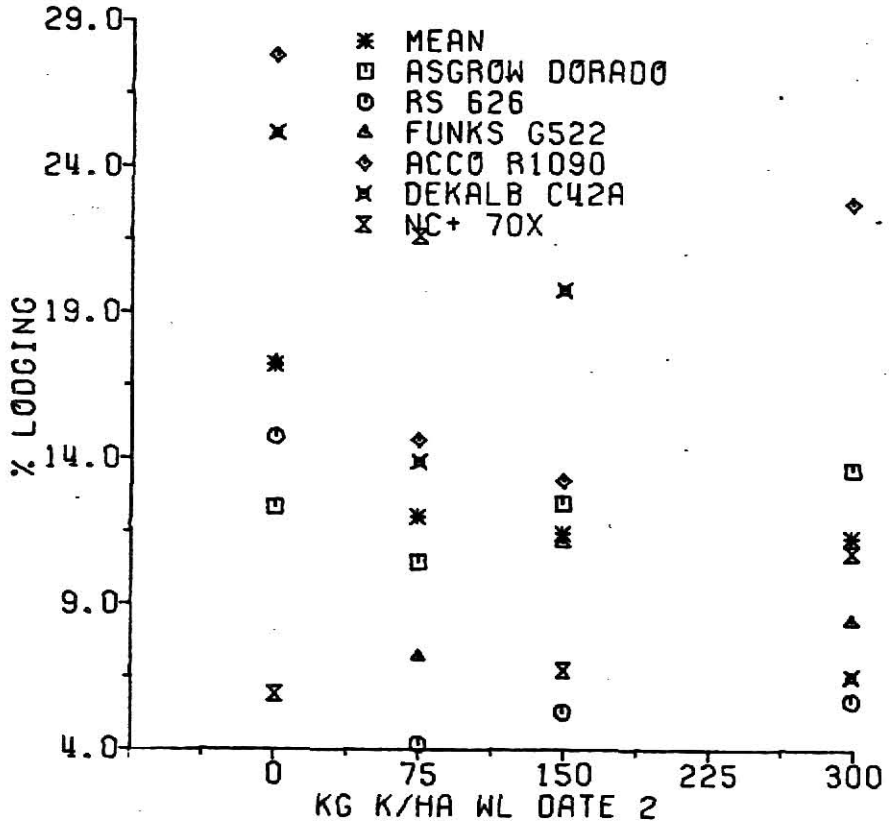


Figure 18. Effects of K treatments on stalk lodging of six grain sorghum varieties. Wilson county.

Weather conditions may have produced more stress at more sensitive growth stages in the second date than in the first date, also. Lodging response to K fertilization was less in the second date than in the first (Figure 18). There were no significant differences between K-rates or between no-K and K-added plots in percent lodging, however, the no-K plots did have the most consistently severe lodging.

Varietal differences in lodging were significant for both planting dates, although varieties responded differently to environmental and fertility conditions for each planting date. RS 626 and DeKalb C42A were above the mean percent lodging for the first planting date, whereas Acco R1090 and DeKalb C42A were above the mean for the second planting date (Figures 17 and 18).

Significant variety-K-rate interactions were noted for both dates, too. For the first date, RS 626, DeKalb C42A, and NC+ 70X seemed to be affected by K with decreasing lodging as K-rates increased (Appendix Table 3 and Figure 17). The other varieties remained unaffected by K additions. RS 626, Funks G522, Acco R1090, and DeKalb C42A were the varieties responding to K treatments in the second planting date (Appendix Table 4 and Figure 18).

RS 626 and DeKalb C42A evidently were not suited to the environment for RS 626 yielded low in both dates and DeKalb C42A yielded very low in the first planting date and suffered very high lodging in both dates. These observations may indicate that these two varieties were under particular environmental stress. The fact that both varieties responded to added K with

reduced lodging in both dates may indicate that K may affect lodging more under stress conditions than under more normal conditions.

Summary. Potassium fertilization tended to reduce lodging in Crawford and Wilson counties but not to the same degree in every case. Lodging showed a negative correlation to percent K in young leaves ($r=-0.429$) in Crawford county, but the correlation was nil in Wilson county with both planting dates. Lodging seems to be more related to morphological, environmental and varietal factors than to nutrient levels in the plant. The effects of morphology on lodging are considered in the next section of this paper.

Stalk Characteristics

Wilson county. In an attempt to find plant characteristics which may affect lodging, several stalk characteristics (%K, ppm Cl^-, weight, diameter, and crushing strength of 5 cm section) were measured on stalk samples taken from physiologically mature plants from the plots of the first and second planting dates in Wilson county.

Potassium and Cl^- concentrations were closely related in the base and peduncle sections at both planting dates (Tables 5, 6, 7, and 8). This might be expected since the K-source was KCl and both ions would be present in approximately equal quantities in the soil where KCl was applied. Except for the first planting date, Cl^- concentrations in peduncle sections were not as closely related to K-rates as were K concentrations, nevertheless the correlations of Cl^- concentration and K-rates were generally significant.

Table 4. Effects of planting date, potassium rates and variety on correlations of crushing strength of grain sorghum stalks with various stalk characteristics. Wilson county, David Voth Farm. 1972.

	Planting Date	Base Section Wt (gm)	Base Section Dia (cm)	Base Section Density (gm/cm^3)	Base Section Wt/Cir (gm/cm)	Peduncle Section Wt (gm)	Peduncle Section Dia (cm)	Peduncle Section Density (gm/cm^3)	Peduncle Section Wt/Cir (gm/cm)
April 19	1	0.651**	0.220	0.083	0.415**	0.779**	0.689**	0.181	0.477**
May 16	2	0.777**	0.073	0.374**	0.770**	0.756**	0.610**	0.026	0.729**
kg K/ha									
0	- 1	0.601**	0.006	0.253	0.580*	0.857**	0.826**	-0.405	0.430
	2	0.758**	0.039	0.432	0.758**	0.633**	0.426	0.226	0.548*
74.6	- 1	0.580*	0.512*	-0.317	0.041	0.805**	0.781**	-0.505*	-0.123
	2	0.748**	0.201	0.206	0.653**	0.776**	0.432	0.368	0.734**
149.3	- 1	0.804**	0.492*	0.077	0.435	0.778**	0.630**	0.021	0.647**
	2	0.650**	-0.173	0.426	0.741**	0.693**	0.569*	0.057	0.525*
298.6	- 1	0.659**	0.114	0.151	0.464*	0.815**	0.629**	0.153	0.707**
	2	0.862**	0.143	0.351	0.842**	0.847**	0.887**	-0.559*	0.543*
Asgrow Dorado	- 1	0.548	0.355	0.395	0.650*	0.880**	0.902**	0.386	0.791**
	2	0.613*	-0.007	0.515	0.849**	0.771**	0.546	0.268	0.618*
RS 626	- 1	0.671*	0.611*	-0.096	0.347	0.400	0.202	0.051	0.366
	2	0.683*	0.311	0.249	0.716**	0.686*	0.786**	-0.683*	0.284
Funks G522	- 1	0.899**	0.373	0.588*	0.856**	0.592*	0.499	-0.184	0.403
	2	0.579*	0.079	0.452	0.750**	0.731**	0.519	0.473	0.751**
Acco R1090	- 1	0.713**	-0.471	0.890**	0.947**	0.796**	0.583*	0.044	0.767**
	2	0.941**	0.618*	0.415	0.806**	0.576*	0.476	0.494	0.575*
DeKalb C42A	- 1	0.367	-0.230	0.317	0.577*	0.918**	0.823**	-0.158	0.753**
	2	0.601*	-0.123	0.793**	0.852**	0.764**	0.614*	0.530	0.743**
NC+ 70X	- 1	0.637*	0.608*	0.045	0.556	0.565	0.600*	0.099	0.781**
	2	0.861**	0.225	0.749**	0.857**	0.741**	0.441	0.758**	0.798**

**Indicates significance at 0.01 level
* Indicates significance at 0.05 level

Table 5. Pearson product moment correlation coefficients between sorghum stalk base characteristics. Wilson county, first planting date.

% K	1.000						
ppm Cl^-	0.639**	1.000					
Strength	-0.411**	-0.487**	1.000				
Diameter	-0.090	-0.103	0.243*	1.000			
Stalk Wt	-0.263*	-0.503**	0.714**	0.424**	1.000		
%Lodging	-0.128	-0.117	0.085	-0.200	-0.042	1.000	
K-Rate	0.672**	0.414**	-0.187	0.071	0.008	-0.202	1.000
	K	Cl^-	Str	Dia	Wt	Lodging	K-Rate

** Significant at 0.01
* Significant at 0.05

Table 6. Pearson product moment correlation coefficients between sorghum stalk peduncle characteristics. Wilson county, first planting date.

% K	1.000						
ppm Cl^-	0.722**	1.000					
Strength	0.047	-0.195	1.000				
Diameter	0.302**	0.043	0.687**	1.000			
Stalk Wt	0.029	-0.221	0.777**	0.761**	1.000		
%Lodging	0.064	0.010	-0.336**	-0.225	-0.205	1.000	
K-Rate	0.141	0.234*	0.043	0.029	-0.004	-0.202	1.000
	K	Cl^-	Str	Dia	Wt	Lodging	K-Rate

** Significant at 0.01
* Significant at 0.05

Table 7. Pearson product moment correlation coefficients between sorghum stalk base characteristics. Wilson county, second planting date.

% K	1.000						
ppm Cl^-	0.650**	1.000					
Strength	-0.258*	-0.389**	1.000				
Diameter	-0.086	0.042	0.073	1.000			
Stalk Wt	-0.126	-0.250*	0.777**	0.501**	1.000		
%Lodging	-0.310**	-0.210	0.003	0.095	0.013	1.000	
K-Rate	0.649**	0.383**	0.085	0.098	0.246*	-0.206	1.000
	K	Cl^-	Str	Dia	Wt	Lodging	K-Rate

** Significant at 0.01
* Significant at 0.05

Table 8. Pearson product moment correlation coefficients between sorghum stalk peduncle characteristics. Wilson county, second planting date.

% K	1.000						
ppm Cl^-	0.871**	1.000					
Strength	0.271*	0.295*	1.000				
Diameter	0.541**	0.542**	0.618**	1.000			
Stalk Wt	0.285*	0.286*	0.756**	0.752**	1.000		
%Lodging	0.047	0.086	0.048	0.216	-0.004	1.000	
K-Rate	0.227	0.195	-0.023	-0.104	0.016	-0.206	1.000
	K	Cl^-	Str	Dia	Wt	Lodging	K-Rate

** Significant at 0.01
* Significant at 0.05

Due to this close correlation between K and Cl^- concentrations in the plant tissue, any attempt to separate the effects of the two elements on plant characteristics was confounded. With the realization that K and Cl^- concentrations in the plant do vary directly with each other, the effects of KCl treatments on plant characteristics will be expressed in terms of K effects.

The percent K of the 5 cm base section of the stalks of the first planting date increased markedly with increasing K-rates, but remained fairly constant between varieties (Appendix Table 6). However, the base percent K had only a very small and insignificant relationship to lodging in the first planting date (Table 5).

The percent K of the base sections of the second planting date proved to be a better predictor of lodging than the same measurement in the first planting date (Table 7). Although the r value is small (r=-0.310) it is significant at the 1% level and is negative, indicating that increasing plant K concentrations may be related to decreased lodging.

The three morphological characteristics of the stalk bases for both planting dates, diameter, weight, and crushing strength, were not affected by K-rates (Appendix Tables 6 and 7) nor did correlations with stalk percent K show any consistent or predictable trends (Tables 5 and 7). All three characteristics were negatively correlated with base percent K, although not all correlations were significant. This is contrary to what was expected. It was assumed that since K fertilization was associated with decreased lodging, it might also be associated with improved morphological characteristics which might be connected

with less lodging (e.g., bigger, denser, and stronger stalks). However, in this study, neither chemical composition of the stalk nor measured morphological characteristics had any significant or consistent correlation with reduced lodging.

Work by Zuber et al. (38) has shown good correlation between corn stalk characteristics, especially rind thickness, weight and crushing pressure, and lodging. Rind thickness was not measured in this experiment, but linear and quadratic regressions between stalk base section weight, diameter, and crushing strength were performed against lodging. Extremely low R^2 values were obtained in all cases indicating that lodging was determined more by physiological or organismic factors than by morphological factors.

In the light of Zuber's work (38) which indicated that stalk strength was significantly correlated with lodging in corn, several regression analyses were performed to determine stalk characteristics which affect crushing strength. For base sections of the stalk, weight and the weight divided by circumference (wt/cir) were consistently and highly correlated with crushing strength (Table 4, Figures 19 and 22). The high correlations of weight and crushing pressure are in agreement with those reported by Zuber for corn.

The wt/cir measurement is a proposed approximation of rind thickness derived by considering Zuber's (38) correlation of rind thickness and weight ($r=0.86$) and a knowledge of the distribution of the rind in the stalk. Most of the weight of the stalk section is due to rind; the pith is light and porous. The circumference takes into account the amount of rind present in a stalk

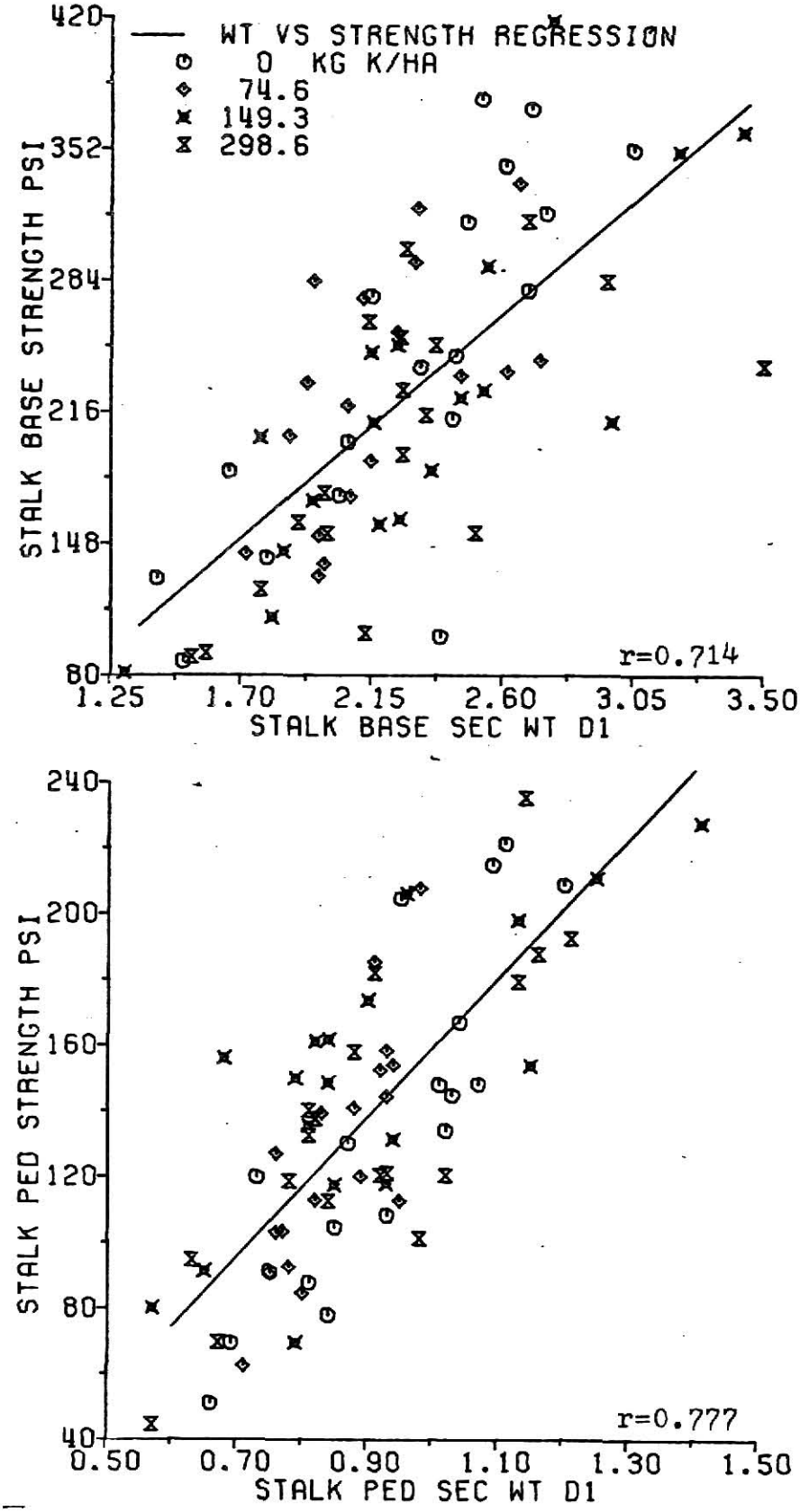


Figure 19. Effect of weight of 5 cm stalk section crushing strength. Planting date 1, Wilson county.

section for the rind is distributed around the outside of the stalk. Thus by combining the weight of the stalk and the diameter of the stalk into a single term, it is hoped that an approximation of the total amount of rind in the stalk will be the result. This measurement gave good agreement with Zuber's correlation of rind thickness and crushing strength (r=0.87) (38) (Table 4).

Diameter and density were poorly correlated with crushing pressure of the stalk bases (Table 4). Zuber et al. (38) reported a correlation r=0.330 for diameter versus crushing pressure. The data from this study produced lower correlations than this because many of the large stalks were rotted (Figures 20 and 23). Density proved poorly correlated with crushing pressure because quite often, the densest stalks were also the smallest which were simply too diminutive to support any pressure.

Tables 9 and 14 present some of the multiple regression formulas for cushing strength. Prediction curves for K and Cl^- in the stalk base accounted for only a small portion of the data variability, but some of the multiple correlations were significant indicating that with more data and larger sample sizes, stronger correlations might result. Regression lines for stalk section weight versus crushing strength produced highly significant R values (Tables 9 and 14, Figures 19 and 22). Stalk section diameter versus crushing strength regressions are depicted in Figures 20 and 23. Notice the large number of large diameter stalks with very low crushing strengths.

Diameter and weight of the stalk base sections from both

Table 9. Linear and Quadratic Regressions of Stalk Base Characteristics (X) vs Stalk Base Crushing Strength (Y). Wilson county, David Voth Farm. 1972.
FIRST PLANTING DATE -- APRIL 19

Treatment	X	Intercept	Regression Coefficients		Multiple Correlation
			X	X^2	R
0 kg K/ha	%K	351.345	-128.916	18.685	0.599*
74.6		387.484	-145.176	28.370	0.460
149.3		785.892	-380.450**	57.845**	0.700**
298.6		122.736	72.558	-13.643	0.436
0 kg K/ha	ppm Cl^-	287.962	-0.065	-0.001	0.620**
74.6		28.698	2.298	-0.006	0.366
149.3		527.366	-2.393*	0.004	0.718**
298.6		-90.411	2.914	-0.007	0.502*
	Section Wt	-68.950	128.812**		0.714**
	Section Dia	104.950	94.714*		0.243*

* Indicates significance at 0.05 level.
** Indicates significance at 0.01 level.

Table 10. Linear and Quadratic Regressions of Stalk Peduncle Characteristics (X) vs Peduncle Crushing Strength (Y). Wilson county, David Voth Farm. 1972
FIRST PLANTING DATE -- APRIL 19

X	Intercept	Regression Coefficients		Multiple Correlation
		X	X^2	R
%K	96.872	15.154	-1.368	0.061
ppm Cl^-	105.150	0.583	-0.002	0.220
Section Wt	-53.136	212.280**		0.777**
Section Dia	-116.043	313.893**		0.687**

** Indicates significance at 0.01 level.

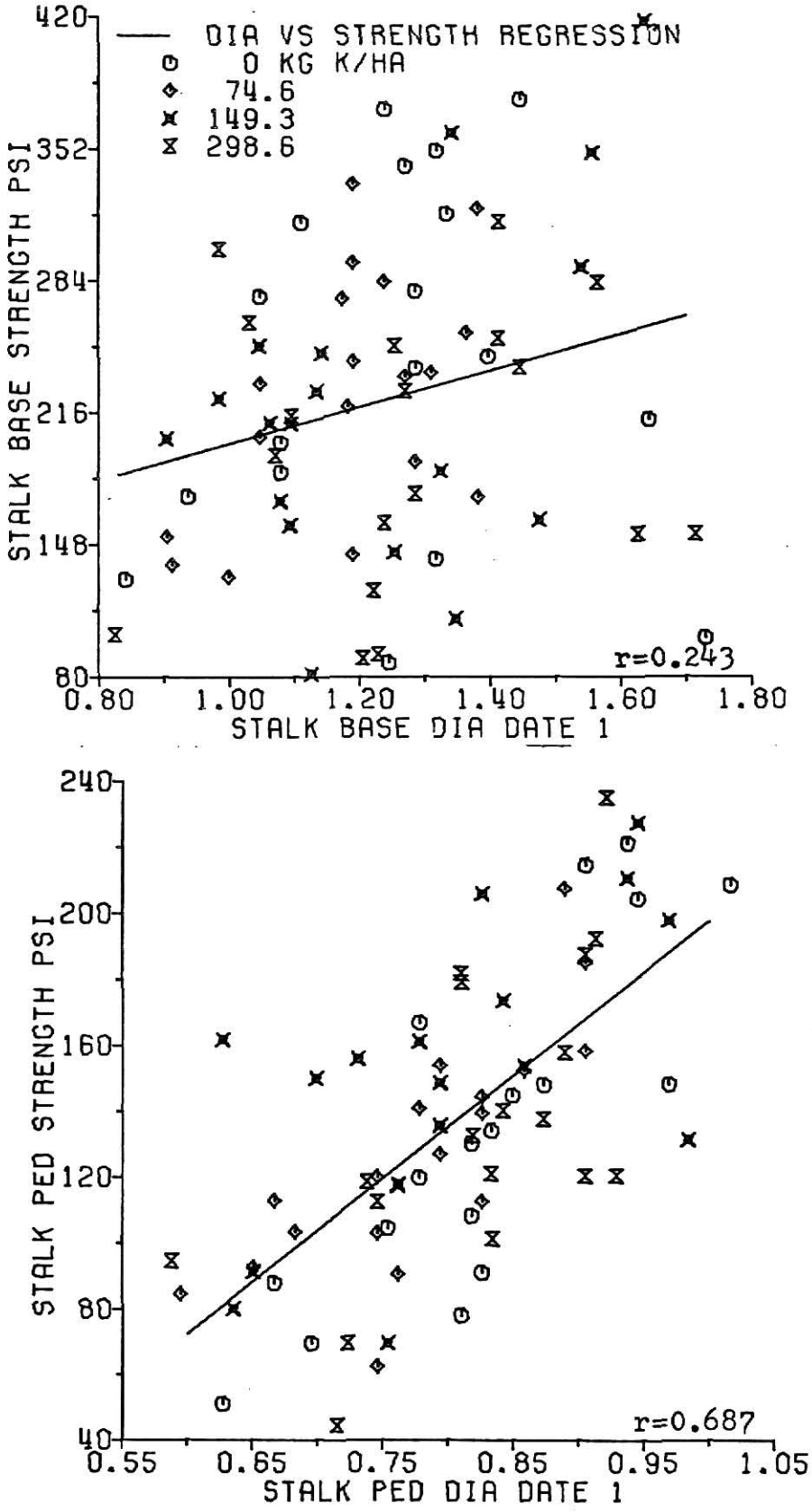


Figure 20. Effect of diameter of 5 cm stalk sections on section crushing strength. Planting date 1, Wilson county.

planting dates showed fair correlation (Tables 5 and 7), but the r values were lower than might be expected. Quite often, medium to large diameter stalks had suffered rot and were powdery and light-weight, thus lowering the correlation. Refer to prediction equations for base section weight in Tables 11 and 16 and Figures 21 and 24.

Diameter of the stalk base sections was not affected by any of the controlled or measured parameters of this study (except variety -- Appendix Tables 6 and 7) nor did diameter affect any of the other stalk base characteristics to any great extent, except for its correlation with stalk section weight (Tables 4, 5, and 7).

Peduncle K and Cl^- concentrations were only slightly affected by K-treatments. The stalk base section response to K-treatments in terms of K and Cl^- concentrations was marked, but not so in the peduncle sections. It can be seen from Appendix Tables 6 and 7 in K-summary blocks that there were differences in K and Cl^- concentrations in the peduncle between no-K plots and K-treated plots, but differences between K-treatments were small.

Potassium treatments affected morphological and strength characteristics of the peduncle sections little more than for the base sections. The only signigicant correlation in the first planting date between chemical composition of the stalk and morphological characteristics was a positive correlation between peduncle section diameter and section K concentration. However, in the second planting date, K and Cl^- concentrations significantly affected all three measured characteristics, weight,

Table 11. Linear and Quadratic Regressions of Stalk Base Characteristics (X) vs Stalk Base Section Weight (Y). Wilson county, David Voth Farm. 1972
FIRST PLANTING DATE -- APRIL 19

Treatment	X	Intercept	Regression Coefficients		Multiple Correlation
			X	X^2	R
0 kg K/ha	%K	2.724	-0.364	-0.027	0.686**
74.6		3.756	-1.779*	0.453*	0.665**
149.3		3.867	-0.979	0.139	0.350
298.6		2.360	0.108	-0.040	0.411
0 kg K/ha	ppm Cl^-	2.748	-0.004**		0.783**
74.6		2.652	-0.002		0.459*
149.3		3.210	-0.004**		0.600**
298.6		2.746	-0.002		0.334
	Section Dia	1.128	0.914**		0.424**

* Indicates significance at 0.05 level.
** Indicates significance at 0.01 level.

Table 12. Linear and Quadratic Regressions of Stalk Peduncle Characteristics (X) vs Peduncle Section Weight (Y). Wilson county, David Voth Farm. 1972
FIRST PLANTING DATE -- APRIL 19

X	Intercept	Regression Coefficients		Multiple Correlation
		X	X^2	R
%K	0.846	0.016	-0.001	0.030
ppm Cl^-	1.051	-0.001		0.221
Section Dia	-0.130	1.272**		0.761**

** Indicates significance at 0.01 level.

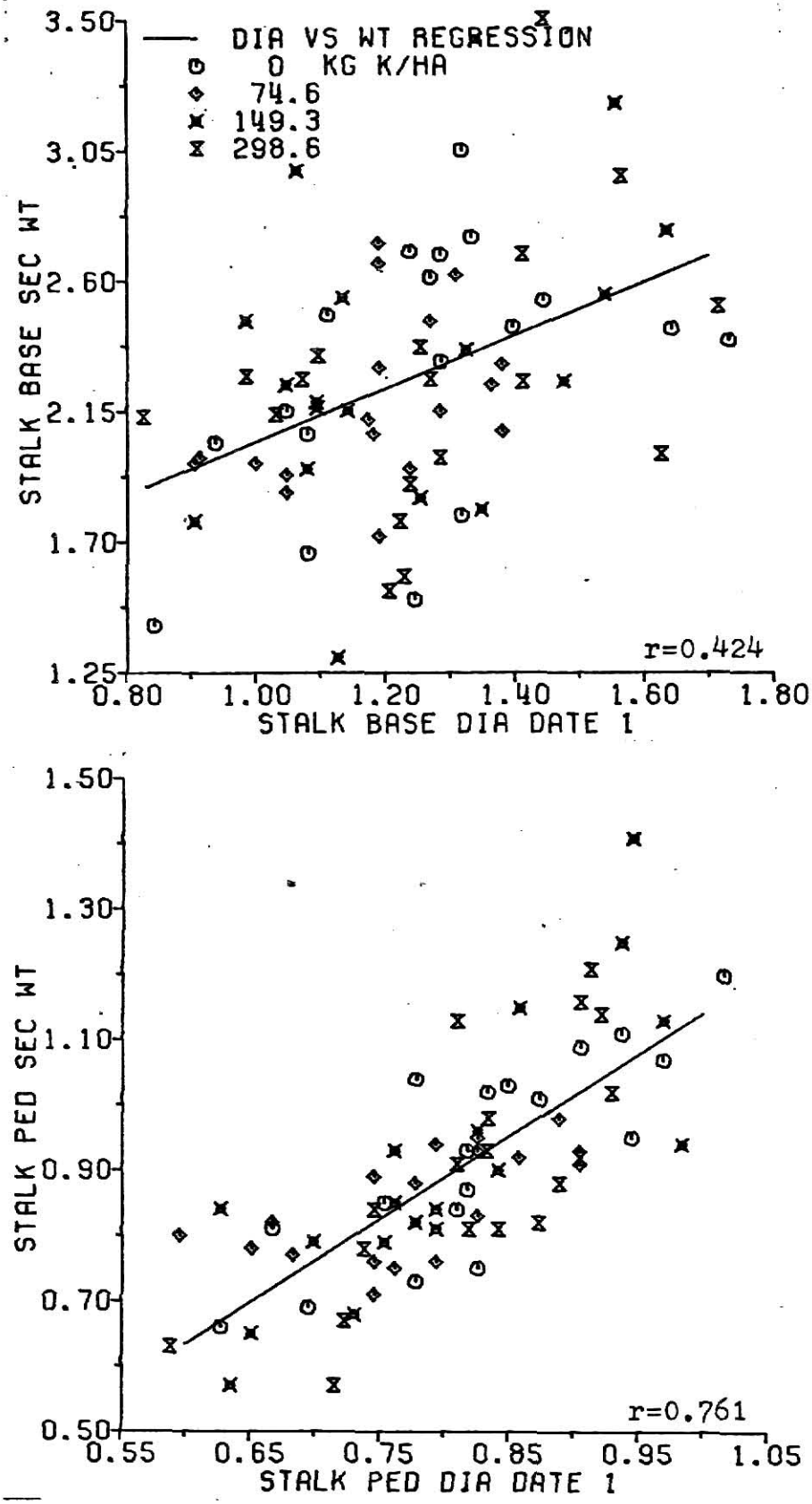


Figure 21. Correlation of diameter and weight of 5 cm stalk sections of grain sorghum. Wilson county, first planting date.

diameter, and crushing strength, although the correlation for diameter was the only one of any magnitude (Tables 6, 8, 13, and 18).

Stalk characteristic correlations with crushing pressure of the peduncle supported those obtained for the base sections (Tables 4, 6, and 8). Weights and wt/cir ratios were highly correlated with crushing strength (Figures 19 and 22), while density was poorly correlated with strength. However, the peduncle diameter showed much better correlation with strength than the base diameter (Figures 20 and 23). This can be attributed to the fact that the peduncle diameter was much more highly correlated with the peduncle section weight than diameter and weight of the base sections (Figures 21 and 24). Perhaps the better correlation of weight and diameter in the peduncle was due to less rotting in the peduncle than in the base.

The characteristics of stalk base and peduncle sections were highly correlated for the data from both planting dates (Appendix Tables 8 and 9).

Summary. Stalk characteristics for both base and peduncle sections were only slightly affected by K-treatments and had little discernable effect on lodging. Weight and wt/cir ratio were found to be the best indicators of stalk crushing strength.

Table 13. Linear and Quadratic Regressions of Stalk Peduncle Characteristics (X) vs Peduncle Section Diameter (Y). Wilson county, David Voth Farm. 1972
FIRST PLANTING DATE -- APRIL 19

X	Intercept	Regression Coefficients		Multiple Correlation
		X	X^2	R
%K	0.427	0.132	-0.011	0.334**
ppm Cl^-	0.339	0.005	-0.000014*	0.301**

* Indicates significance at 0.05 level.
** Indicates significance at 0.01 level.

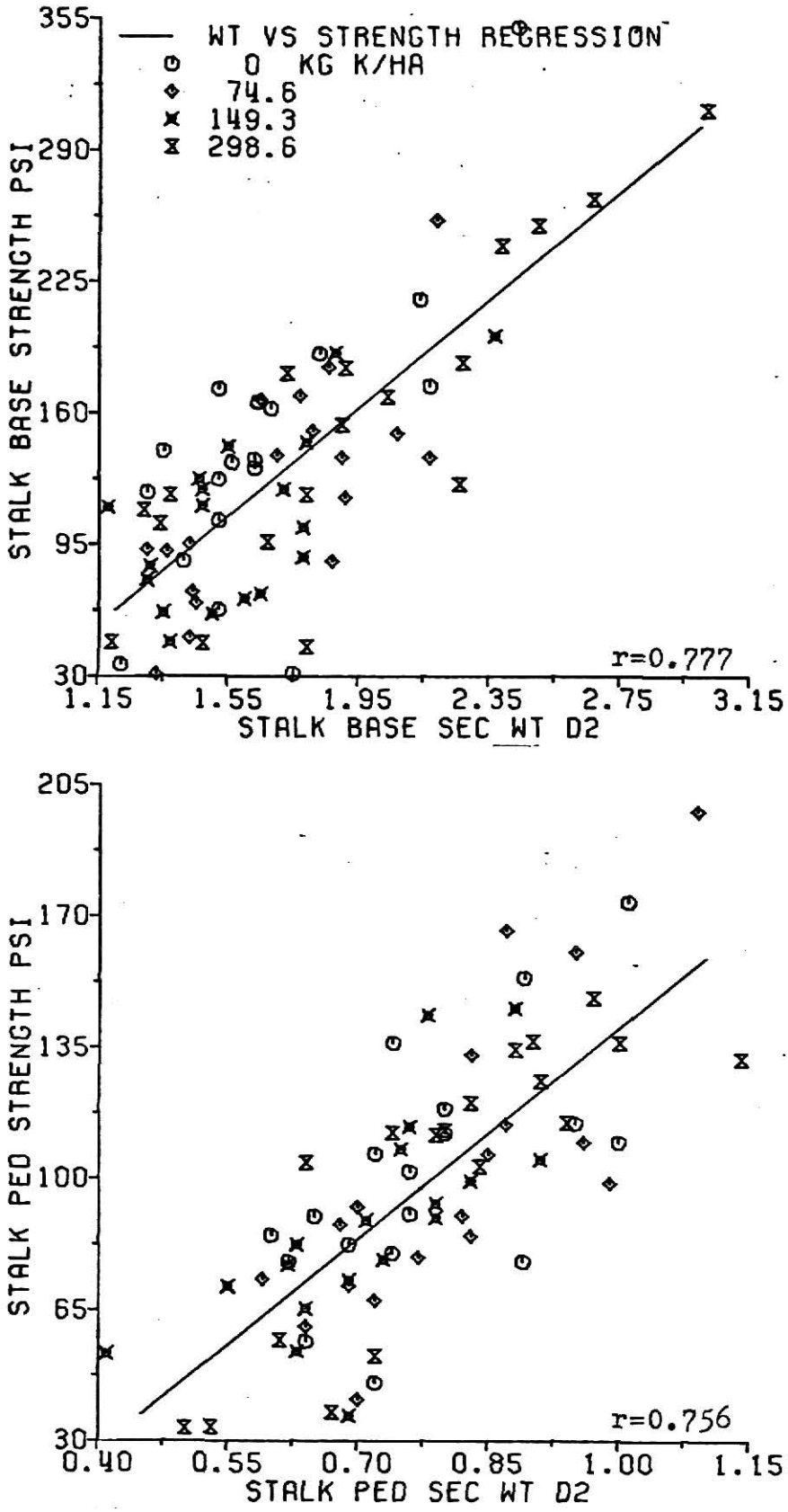


Figure 22. Effect of weight of 5 cm stalk section crushing strength. Planting date 2, Wilson county.

Table 14. Linear and Quadratic Regressions of Stalk Base Characteristics (X) vs Stalk Base Crushing Strength (Y). Wilson county, David Voth Farm. 1972
SECOND PLANTING DATE -- MAY 16

Treatment	X	Intercept	Regression Coefficients		Multiple Correlation
			X	X^2	R
0 kg K/ha	%K	142.917	112.657	-138.629	0.436
74.6		268.779	-124.776	22.767	0.440
149.3		234.506	-82.256	11.802	0.291
298.6		407.612	-121.995	10.598	0.614**
0 kg K/ha	ppm Cl^-	190.299	-0.122	-0.001	0.393
74.6		288.631	-0.011	0.001	0.561*
149.3		469.911	-0.030	0.006	0.360
298.6		149.346	0.598	-0.002	0.496*
	Section Wt	-97.885	133.197**		0.774**
	Section Dia	102.248	23.214		0.073

* Indicates significance at 0.05 level.
** Indicates significance at 0.01 level.

Table 15. Linear and Quadratic Regressions of Stalk Peduncle Characteristics (X) vs Peduncle Crushing Strength (Y). Wilson county, David Voth Farm. 1972
SECOND PLANTING DATE -- MAY 16

X	Intercept	Regression Coefficients		Multiple Correlation
		X	X^2	R
%K	-129.523	97.589**	-9.980**	0.437**
ppm Cl^-	-120.006	2.098**	-0.005**	0.414**
Section Wt	-47.841	187.948**		0.756**
Section Dia	-120.346	274.873**		0.618**

** Indicates significance at 0.01 level.

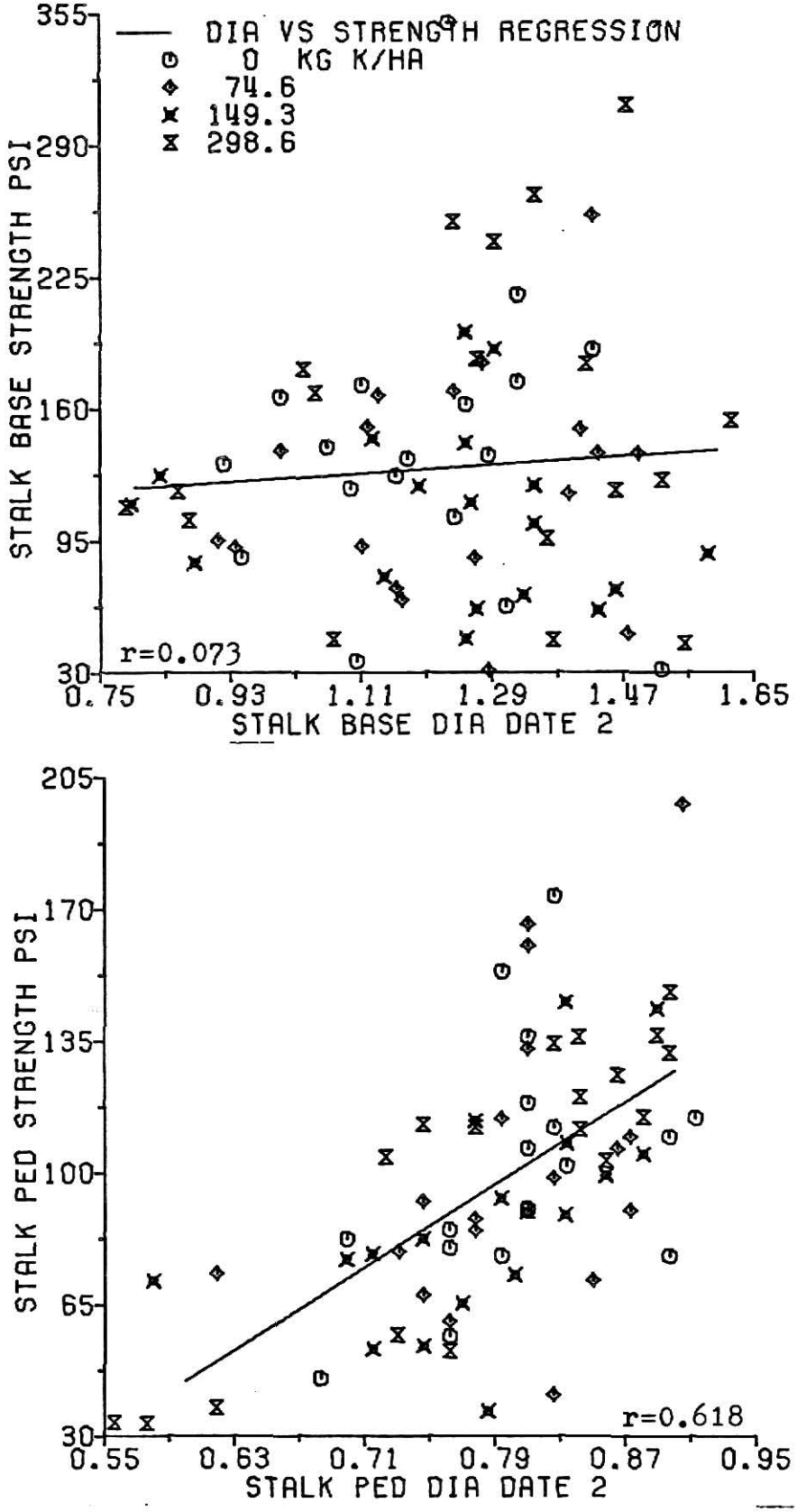


Figure 23. Effect of diameter of 5 cm stalk sections on section crushing strength. Planting date 2, Wilson county.

Table 16. Linear and Quadratic Regressions of Stalk Base Characteristics (X) vs Stalk Base Section Weight (Y). Wilson county, David Voth Farm. 1972
SECOND PLANTING DATE -- MAY 16

Treatment	X	Intercept	Regression Coefficients		Multiple Correlation
			X	X^2	R
0 kg K/ha	%K	1.799	-0.090	-0.132	0.278
74.6		2.004	-0.202	0.023	0.269
149.3		2.263	-0.343	0.032	0.453
298.6		3.433	-0.786	0.083	0.455
0 kg K/ha	ppm Cl^-	1.918	-0.002		0.303
74.6		2.400	-0.004*		0.576*
149.3		1.992	-0.002		0.289
298.6		2.420	-0.002		0.275
	Section Dia	0.570	0.933**		0.501**

* Indicates significance at 0.05 level.
** Indicates significance at 0.01 level.

Table 17. Linear and Quadratic Regressions of Stalk Peduncle Characteristics (X) vs Peduncle Section Weight (Y). Wilson county, David Voth Farm. 1972
SECOND PLANTING DATE -- MAY 16

X	Intercept	Regression Coefficients		Multiple Correlation
		X	X^2	R
%K	0.146	0.254*	-0.024	0.352**
ppm Cl^-	0.593	0.00092*		0.286*
Section Dia	-0.293	1.346**		0.752**

* Indicates significance at 0.05 level.
** Indicates significance at 0.01 level.

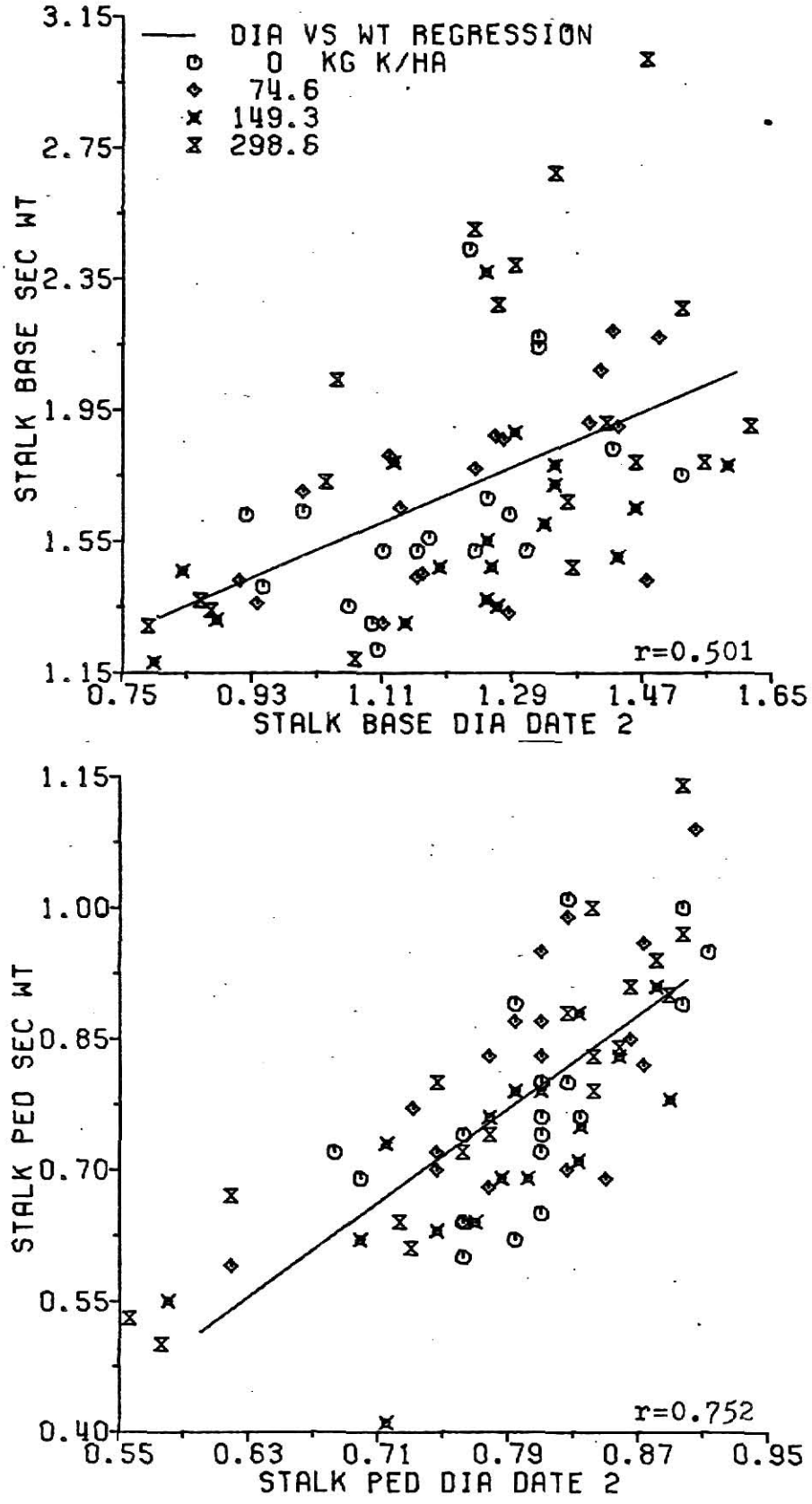


Figure 24. Correlation of diameter and weight of 5 cm stalk sections of grain sorghum. Wilson county, first planting date.

Table 18. Quadratic Regressions of Stalk Peduncle Characteristics (X) vs Peduncle Section Diameter (Y). Wilson county, David Voth Farm. 1972
SECOND PLANTING DATE -- MAY 16

X	Intercept	Regression Coefficients		Multiple Correlation
		X	X^2	R
%K	0.168	0.249**	-0.023**	0.650**
ppm Cl^-	0.141	0.006**	-0.000013**	0.644**

** Indicates significance at 0.01 level.

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CONCLUSIONS

Where lodging of grain sorghum occurred in this three site study, added K helped to alleviate it and, at low K fertilization rates, added N increased lodging. However, lodging did not appear to be consistently highly correlated with the concentration of K or Cl^- in plant tissue (leaves and stalks) or with morphological characteristics of the sorghum stalks. Weight and diameter of the sorghum stalks were only slightly affected by K-treatments, but weight was found to be highly correlated with stalk strength.

Lodging, under the existing circumstances of this study, was affected by factors other than those measured. The data from this one-year study indicate that further work is needed to investigate different fertilizer materials and combinations, varying weather patterns (implies more than one year's data), and genetic variability of grain sorghum.

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VITA

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APPENDIX

Appendix Table 1. Nitrogen-Potassium effects on yield, lodging and leaf composition of grain sorghum. Bourbon county, Elwin Eremel Farm. 1972

Treatments					Leaf Composition					
					6 Leaf Stage			Boot Stage		
N	K	K Carrier	Grain[1/] Yield	Lodging[2/]	N	P	K	N	P	K
kg/ha			kg/ha	%	%	%	%	%	%	%
0	0	---	7335.9	---	4.33	0.401	2.12	3.15	0.443	1.62
84	0	---	6332.7	---	4.31	0.413	2.00	3.24	0.433	1.53
168	0	---	6959.7	---	4.42	0.408	1.81	3.58	0.483	1.67
252	0	---	6458.1	---	4.58	0.424	2.14	3.31	0.454	1.69
0	74.6	KCl	6332.7	---	4.35	0.424	2.20	3.25	0.454	1.67
84	74.6	KCl	6646.2	---	4.25	0.437	2.23	3.24	0.465	1.50
168	74.6	KCl	6708.9	---	4.40	0.417	2.35	3.39	0.469	1.68
252	74.6	KCl	6834.3	---	4.27	0.418	1.98	3.46	0.469	1.71
0	149.3	KCl	6708.9	---	4.15	0.407	2.20	3.43	0.452	1.63
84	149.3	KCl	6834.3	---	4.27	0.411	2.45	3.35	0.463	1.66
168	149.3	KCl	7586.7	---	4.35	0.416	2.08	3.39	0.462	1.70
252	149.3	KCl	6144.6	---	4.24	0.411	2.12	3.52	0.452	1.64
0	298.6	KCl	5643.0	---	4.22	0.359	2.28	3.23	0.464	1.64
84	298.6	KCl	7461.3	---	4.24	0.402	2.20	3.30	0.469	1.70
168	298.6	KCl	6771.6	---	4.34	0.432	2.51	3.31	0.459	1.59
252	298.6	KCl	6834.3	---	4.29	0.423	2.42	3.31	0.451	1.64
0	149.3	K_2SO_4	6646.2	---	4.26	0.398	2.39	3.19	0.393	1.64
84	149.3	K_2SO_4	7398.6	---	4.36	0.423	2.46	3.41	0.438	1.61
168	149.3	K_2SO_4	6019.2	---	4.38	0.413	2.24	3.44	0.470	1.76
252	149.3	K_2SO_4	7022.4	---	4.45	0.411	2.25	3.46	0.469	1.74
	$LSD_{.05}$		1003.2	---	NS	NS	0.33	NS	NS	NS

1/ All values are averages for three replications.
2/ No lodging at this location.

Appendix Table 1. Cont'd. Nitrogen-Potassium effects on yield, lodging and leaf composition of grain sorghum. Bourbon county, Elwin Eremel Farm. 1972

MEAN VALUES:

	Grain Yield kg/ha	Lodging[1/] %	Leaf Composition — 6 Leaf Stage N %	P %	K %	Boot Stage N %	P %	K %
N Summary								
0 kg N/ha	6520.8	---	4.26	0.398	2.20	3.26	0.454	1.64
84	6834.3	---	4.27	0.416	2.22	3.28	0.457	1.60
168	7022.4	---	4.38	0.418	2.19	3.42	0.468	1.66
252	6583.5	---	4.35	0.419	2.17	3.40	0.457	1.67
$LSD_{.05}$	NS	---	NS	NS	NS	NS	NS	NS
K Summary								
0 kg K/ha	6771.6	---	4.41	0.412	2.02	3.32	0.453	1.63
74.6	6646.2	---	4.32	0.424	2.19	3.34	0.464	1.64
149.3	6834.3	---	4.25	0.412	2.22	3.42	0.457	1.66
298.6	6646.2	---	4.27	0.404	2.35	3.29	0.461	1.64
$LSD_{.05}$	NS	---	0.11	NS	0.17	NS	NS	NS
K-Carrier Summary								
KCl	6834.3	---	4.25	0.412	2.22	3.42	0.457	1.66
K_2SO_4	6771.6	---	4.36	0.412	2.33	3.38	0.442	1.69
$LSD_{.05}$	NS	---	0.11	NS	NS	NS	NS	NS

[1/] No lodging at this location.

Appendix Table 2. Nitrogen-Potassium effects on yield, lodging and leaf composition of grain sorghum. Crawford county, Richard Geir Farm. 1972

Treatments					Leaf Composition					
					7 Leaf Stage			Boot Stage		
N	K	K Carrier	Grain Yield[1/]	Lodging	N	P	K	N	P	K
kg/ha			kg/ha	%	%	%	%	%	%	%
0	0	---	5956.5	2.1	3.19	0.328	0.93	2.50	0.335	1.22
84	0	---	6583.5	13.2	3.43	0.316	1.05	2.57	0.350	1.42
168	0	---	5580.3	14.9	3.37	0.300	1.04	2.87	0.361	1.40
252	0	---	5517.6	12.4	3.62	0.336	1.07	3.00	0.361	1.38
0	74.6	KCl	5831.1	0.6	3.34	0.337	1.14	2.64	0.343	1.42
84	74.6	KCl	6207.3	1.7	3.31	0.298	1.21	2.76	0.360	1.50
168	74.6	KCl	6959.7	1.2	3.42	0.310	1.34	2.96	0.383	1.43
252	74.6	KCl	6081.9	1.3	3.53	0.332	1.38	2.92	0.389	1.48
0	149.3	KCl	5956.5	1.6	3.01	0.324	1.40	2.58	0.343	1.40
84	149.3	KCl	6646.2	3.2	3.30	0.315	1.25	2.85	0.383	1.42
168	149.3	KCl	5893.8	2.8	3.46	0.319	1.38	2.87	0.355	1.37
252	149.3	KCl	6959.7	1.3	3.35	0.307	1.25	2.84	0.358	1.44
0	298.6	KCl	5517.6	1.4	3.25	0.330	1.62	2.58	0.345	1.53
84	298.6	KCl	6708.9	0.0	3.30	0.313	1.63	2.87	0.351	1.37
168	298.6	KCl	6646.2	0.4	3.47	0.333	1.77	3.05	0.380	1.49
252	298.6	KCl	6332.7	0.3	3.41	0.302	1.71	2.89	0.357	1.49
0	149.3	K_2SO_4	6270.0	1.6	3.22	0.322	1.54	2.71	0.363	1.49
84	149.3	K_2SO_4	5768.4	6.8	3.40	0.313	1.44	2.59	0.385	1.51
168	149.3	K_2SO_4	5893.8	6.4	3.42	0.300	1.37	3.01	0.381	1.41
252	149.3	K_2SO_4	6270.0	3.3	3.51	0.307	1.41	2.78	0.373	1.45
	$LSD_{.05}$		NS	6.9	0.24	NS	0.30	0.31	NS	NS

[1/] All values are averages for three replications.

Appendix Table 2. Cont'd. Nitrogen-Potassium effects on yield, lodging, and leaf composition of grain sorghum. Crawford county, Richard Geir. 1972

	MEAN VALUES:							
			Leaf Composition					
			7 Leaf Stage			Boot Stage		
	Grain Yield kg/ha	Lodging %	N %	P %	K %	N %	P %	K %
N Summary								
0 kg N/ha	5831.1	1.4	3.20	0.330	1.27	2.57	0.342	1.39
84	6520.8	4.5	3.34	0.310	1.28	2.76	0.361	1.43
168	6270.0	4.8	3.43	0.316	1.38	2.94	0.370	1.42
252	6207.3	3.8	3.48	0.320	1.35	2.91	0.366	1.45
$LSD_{.05}$	NS	NS	0.12	NS	NS	0.11	0.019	NS
K Summary								
0 kg K/ha	5893.8	10.6	3.40	0.320	1.02	2.73	0.352	1.36
74.6	6270.0	1.2	3.40	0.319	1.27	2.82	0.369	1.46
149.3	6395.4	2.2	3.28	0.316	1.32	2.79	0.360	1.41
298.6	6332.7	0.5	3.36	0.320	1.68	2.85	0.358	1.47
$LSD_{.05}$	NS	3.6	NS	NS	0.16	NS	NS	NS
K-Carrier Summary								
KCl	6395.4	2.2	3.28	0.316	1.32	2.79	0.360	1.41
K_2SO_4	6081.9	4.5	3.39	0.311	1.44	2.77	0.375	1.47
$LSD_{.05}$	NS	NS	NS	NS	NS	NS	NS	NS

Appendix Table 3. Effects of planting date, variety and potassium rates on yield, lodging, and leaf composition of grain sorghum. Wilson county, David Voth Farm.
FIRST PLANTING DATE -- APRIL 19, 1972

Treatments				Leaf Composition					
				9 Leaf Stage			Boot Stage		
Variety	K	Grain Yield[1/]	Lodging	N	P	K	N	P	K
	kg/ha	kg/ha	%	%	%	%	%	%	%
Asgrow Dorado	0	4683.7	1.45	3.38	0.302	0.85	3.34	0.397	1.18
	74.6	4715.0	3.02	3.28	0.296	1.03	3.20	0.391	1.18
	149.3	4748.5	0.00	3.48	0.342	1.57	3.35	0.417	1.26
	298.6	4748.5	0.83	3.46	0.328	1.87	3.20	0.417	1.33
RS 626	0	2683.6	7.57	3.34	0.326	0.95	3.05	0.323	1.00
	74.6	3252.0	5.89	3.38	0.302	1.13	2.96	0.301	1.07
	149.3	2292.7	3.17	3.66	0.305	1.67	3.04	0.339	1.31
	298.6	5074.5	1.47	3.12	0.296	1.71	3.16	0.338	1.30
Funks G522	0	5755.9	0.00	3.63	0.333	1.03	2.94	0.425	1.19
	74.6	4779.8	0.00	3.60	0.318	1.21	3.24	0.420	1.20
	149.3	4489.3	0.98	3.46	0.320	1.66	3.26	0.382	1.24
	298.6	5041.1	1.01	3.29	0.282	1.56	3.18	0.407	1.29
Acco R1090	0	4878.1	2.50	3.41	0.332	0.88	3.29	0.382	1.05
	74.6	5463.3	1.91	3.46	0.313	1.25	3.17	0.378	1.07
	149.3	4846.7	1.56	3.33	0.338	1.47	3.24	0.365	1.15
	298.6	4748.5	3.30	3.53	0.293	1.78	3.11	0.361	1.22
DeKalb C42A	0	4048.3	25.00	3.52	0.361	1.09	3.26	0.367	1.05
	74.6	3515.4	2.61	3.68	0.341	1.31	3.35	0.373	1.11
	149.3	2244.7	5.03	3.56	0.340	1.57	3.43	0.387	1.24
	298.6	1853.8	8.76	3.58	0.323	2.02	3.36	0.379	1.24
NC+ 70X	0	4813.3	2.92	3.66	0.337	1.03	2.93	0.331	1.09
	74.6	4259.4	0.81	3.61	0.329	1.32	2.78	0.320	1.28
	149.3	3321.0	0.00	3.65	0.347	1.51	2.99	0.337	1.46
	298.6	3561.4	0.00	3.75	0.313	1.90	2.92	0.330	1.51

1/ All values are averages for three replications.

Appendix Table 3. Cont'd. Effects of planting date, variety and potassium rates on yield, lodging, and leaf composition of grain sorghum. Wilson county, David Voth Farm.
FIRST PLANTING DATE -- APRIL 19, 1972

MEAN VALUES:

	Grain Yield kg/ha	Lodging %	Leaf Composition — 9 Leaf Stage N %	P %	K %	Boot Stage N %	P %	K %
K Summary								
0 kg K/ha	4477.1	6.57	3.49	0.332	0.97	3.13	0.371	1.10
74.6	4330.8	2.37	3.50	0.317	1.21	3.12	0.364	1.15
149.3	3657.2	1.79	3.52	0.332	1.58	3.22	0.371	1.28
298.6	4171.3	2.56	3.45	0.306	1.81	3.15	0.372	1.32
$LSD_{.05}$	NS	3.04	NS	NS	0.26	NS	NS	0.11
Variety Summary								
Asgrow Dorado	4723.9	1.33	3.40	0.317	1.33	3.27	0.405	1.24
RS 626	3325.7	4.52	3.38	0.307	1.37	3.05	0.325	1.17
Funks G522	5016.5	0.50	3.50	0.313	1.37	3.15	0.408	1.23
Acco R1090	4984.1	2.32	3.43	0.319	1.34	3.21	0.372	1.12
DeKalb C42A	2915.5	10.35	3.58	0.342	1.50	3.35	0.377	1.16
NC+ 70X	3988.8	0.93	3.67	0.332	1.44	2.91	0.330	1.33
$LSD_{.05}$	801.0	3.11	0.20	0.018	NS	0.14	0.021	0.06

Appendix Table 4. Effects of planting date, variety and potassium rates on yield, lodging and leaf composition of grain sorghum. Wilson county, David Voth Farm. 1972.
SECOND PLANTING DATE -- MAY 16

Treatments				Leaf Composition					
				7 Leaf Stage			Boot Stage		
Variety	K	Grain[1/] Yield	Lodging	N	P	K	N	P	K
	kg/ha	kg/ha	%	%	%	%	%	%	%
Asgrow Dorado	0	3674.2	12.32	4.00	0.354	1.04	3.24	0.441	1.21
	74.6	6487.4	10.44	4.15	0.341	1.44	3.45	0.451	1.32
	149.3	5365.0	12.45	4.11	0.342	2.00	3.45	0.427	1.38
	298.6	6470.6	13.64	3.87	0.348	2.37	3.25	0.431	1.38
RS 626	0	4194.6	14.73	3.87	0.333	0.90	3.01	0.323	1.00
	74.6	5659.7	4.17	4.00	0.337	1.47	3.02	0.355	1.28
	149.3	4683.7	5.29	4.11	0.339	1.80	3.10	0.373	1.41
	298.6	4909.4	5.68	3.79	0.346	2.30	3.03	0.335	1.46
Funks G522	0	4263.6	17.26	3.95	0.346	0.99	3.28	0.454	1.26
	74.6	6587.7	7.17	3.99	0.334	1.45	3.30	0.447	1.31
	149.3	5900.1	11.11	3.70	0.342	1.71	3.29	0.431	1.38
	298.6	6533.3	8.42	3.92	0.350	2.28	3.27	0.419	1.40
Acco R1090	0	5122.3	27.78	3.93	0.351	0.97	3.22	0.388	1.10
	74.6	6213.6	14.61	3.96	0.343	1.48	3.20	0.437	1.34
	149.3	6339.0	13.22	3.96	0.330	1.85	3.35	0.419	1.25
	298.6	6081.9	22.73	3.67	0.348	2.06	3.20	0.421	1.32
DeKalb C42A	0	3904.1	25.13	4.03	0.362	0.91	3.45	0.403	0.95
	74.6	5661.8	13.86	4.01	0.352	1.62	3.37	0.404	1.28
	149.3	5561.5	19.75	4.04	0.341	1.83	3.60	0.412	1.30
	298.6	5724.5	6.52	3.99	0.371	2.17	3.48	0.396	1.44
NC+ 70X	0	5172.8	5.89	4.21	0.363	1.06	3.28	0.437	1.24
	74.6	5072.4	21.62	4.15	0.370	1.53	3.33	0.441	1.48
	149.3	5609.6	6.72	4.09	0.354	1.84	3.37	0.458	1.45
	298.6	6276.3	10.76	4.03	0.380	2.24	3.28	0.438	1.41

1/ All values are averages for three replications.

Appendix Table 4. Cont'd. Effects of planting date, variety, and potassium rates on yield, lodging, and leaf composition of grain sorghum. Wilson county, David Voth Farm. 1972
SECOND PLANTING DATE -- MAY 16

MEAN VALUES:

	Grain Yield kg/ha	Lodging %	Leaf Composition ---- 7 Leaf Stage ---- N %	P %	K %	----- Boot Stage ----- N %	P %	K %
K Summary								
0 kg K/ha	4388.6	17.19	4.00	0.352	0.98	3.25	0.408	1.13
74.6	5947.1	11.98	4.04	0.346	1.50	3.28	0.423	1.33
149.3	5576.5	11.42	4.00	0.341	1.84	3.36	0.420	1.35
298.6	5999.3	11.29	3.88	0.357	2.24	3.25	0.407	1.40
$LSD_{.05}$	1157.8	NS	0.11	NS	0.23	NS	NS	0.07
Variety Summary								
Asgrow Dorado	5499.3	12.21	4.03	0.346	1.72	3.35	0.437	1.31
RS 626	4861.9	7.47	3.94	0.339	1.62	3.04	0.347	1.29
Funks G522	5821.2	10.99	3.89	0.343	1.60	3.29	0.438	1.34
Acco R1090	5939.2	19.58	3.88	0.343	1.59	3.24	0.417	1.25
DeKalb C42A	5213.0	16.31	4.02	0.357	1.63	3.47	0.404	1.24
NC+ 70X	5532.8	11.24	4.12	0.367	1.67	3.31	0.444	1.40
$LSD_{.05}$	686.9	5.01	NS	0.015	NS	0.12	0.020	0.06

Appendix Table 5. Effects of planting date, variety and potassium rates on yield, lodging, and leaf composition of grain sorghum. Wilson county, David Voth Farm. 1972.

THIRD PLANTING DATE -- JUNE 16

Treatments				Leaf Composition					
				5 Leaf Stage			Boot Stage		
Variety	K	Grain[1/] Yield	Lodging[1/]	N	P	K	N	P	K
	kg/ha	kg/ha	%	%	%	%	%	%	%
Asgrow Dorado	0	---	---	3.84	0.299	1.75	2.94	0.403	1.37
	74.6	---	---	3.70	0.296	2.09	2.73	0.358	1.44
	149.3	---	---	3.79	0.299	2.33	2.83	0.362	1.56
	298.6	---	---	4.00	0.303	2.47	2.98	0.370	1.74
RS 626	0	---	---	3.90	0.315	1.88	3.13	0.381	1.24
	74.6	---	---	3.78	0.275	2.15	3.00	0.364	1.27
	149.3	---	---	3.95	0.311	2.36	3.03	0.347	1.41
	298.6	---	---	3.92	0.283	2.51	3.00	0.369	1.46
Funks G522	0	---	---	3.96	0.321	2.05	3.06	0.417	1.42
	74.6	---	---	3.82	0.268	2.15	2.86	0.351	1.44
	149.3	---	---	3.88	0.308	2.36	2.89	0.358	1.57
	298.6	---	---	3.94	0.313	2.49	2.80	0.373	1.71
Acco R1090	0	---	---	3.96	0.314	1.88	3.00	0.385	1.34
	74.6	---	---	3.93	0.301	2.10	2.90	0.358	1.34
	149.3	---	---	4.11	0.308	2.42	2.97	0.353	1.60
	298.6	---	---	4.03	0.318	2.48	2.91	0.362	1.61
DeKalb C42A	0	---	---	4.02	0.312	1.97	3.05	0.417	1.36
	74.6	---	---	3.92	0.307	2.27	2.96	0.384	1.49
	149.3	---	---	4.20	0.342	2.48	3.02	0.401	1.62
	298.6	---	---	4.07	0.311	2.42	2.99	0.380	1.66
NC+ 70X	0	---	---	3.96	0.316	2.02	2.94	0.389	1.41
	74.6	---	---	4.02	0.314	2.22	3.08	0.366	1.34
	149.3	---	---	4.04	0.329	2.48	3.01	0.352	1.52
	298.6	---	---	4.06	0.318	2.60	2.92	0.354	1.56

1/ No yield on this planting date, thus no lodging notes taken.
2/ All values are for three replication average.

Appendix Table 5. Cont'd. Effects of planting date, variety, and potassium rates on yield, lodging and leaf composition of grain sorghum. Wilson county, David Voth Farm. 1972

THIRD PLANTING DATE -- JUNE 16

MEAN VALUES:

	Grain[1/] Yield kg/ha	Lodging[1/] %	Leaf Composition ---- 5 Leaf Stage ---- N %	P %	K %	----- Boot Stage ----- N %	P %	K %
K Summary								
0 kg K/ha	---	---	3.95	0.313	1.93	3.02	0.399	1.36
74.6	---	---	3.86	0.294	2.16	2.92	0.363	1.39
149.3	---	---	4.00	0.316	2.41	2.96	0.326	1.55
298.6	---	---	4.00	0.308	2.50	2.93	0.368	1.63
$LSD_{.05}$	---	---	NS	NS	0.34	NS	NS	0.16
Variety Summary								
Asgrow Dorado	---	---	3.83	0.299	2.16	2.87	0.373	1.53
RS 626	---	---	3.89	0.296	2.23	3.04	0.365	1.35
Funks G522	---	---	3.90	0.302	2.27	2.90	0.375	1.54
Acco R1090	---	---	4.01	0.310	2.22	2.94	0.364	1.47
DeKalb C42A	---	---	4.05	0.318	2.29	3.00	0.396	1.53
NC+ 70X	---	---	4.02	0.319	2.33	2.99	0.365	1.46
$LSD_{.05}$	---	---	0.13	NS	NS	0.10	NS	0.07

1/ No yield on this planting date, thus no lodging notes taken.

Appendix Table 6.
Effects of planting date, variety and potassium rates on stalk characteristics of grain sorghum. Wilson county, David Voth Farm. 1972.
FIRST PLANTING DATE -- APRIL 19

Treatments		5 cm Base Section					5 cm Peduncle Section				
Variety	K kg/ha	K[1/] %	Cl^- ppm	Wt gm	Dia cm	Strength lbs	K %	Cl^- ppm	Wt gm	Dia cm	Strength lbs
Asgrow Dorado	0	1.20	141	2.21	1.307	333.3	5.31	163	0.95	0.820	167.2
	74.6	2.10	243	1.97	1.265	227.7	5.12	211	0.86	0.773	122.5
	149.3	2.43	188	2.29	1.456	240.5	5.29	173	1.09	0.871	202.4
	298.6	3.56	302	2.41	1.402	229.6	5.75	199	0.97	0.850	157.5
RS 626	0	2.01	137	1.84	0.953	144.0	3.91	143	0.77	0.683	81.1
	74.6	2.03	139	1.98	0.939	140.1	3.80	146	0.78	0.643	93.5
	149.3	3.57	185	2.46	1.043	201.1	3.44	127	0.85	0.696	143.2
	298.6	3.80	210	2.24	0.998	169.9	4.40	164	0.82	0.723	102.8
Funks G522	0	1.00	140	2.30	1.416	210.4	4.96	184	1.02	0.908	166.6
	74.6	1.94	252	2.18	1.350	227.9	4.47	187	0.93	0.820	167.5
	149.3	2.54	231	2.11	1.344	180.2	5.57	225	0.88	0.768	131.2
	298.6	2.97	189	2.08	1.442	193.7	4.81	200	0.94	0.908	132.9
Acco R1090	0	0.79	152	2.07	1.421	142.0	4.86	179	0.97	0.929	168.1
	74.6	1.13	174	2.28	1.183	275.7	5.33	183	0.84	0.826	139.6
	149.3	2.69	226	2.25	1.173	227.4	5.41	204	0.86	0.852	142.7
	298.6	3.50	301	1.73	1.223	124.1	5.66	223	0.81	0.845	136.8
DeKalb C42A	0	1.07	131	2.44	1.133	320.7	5.55	182	0.85	0.793	98.5
	74.6	2.22	227	2.23	1.170	252.9	6.39	247	0.82	0.773	111.2
	149.3	3.18	219	2.29	1.193	240.0	5.63	208	0.85	0.789	131.8
	298.6	2.80	215	2.31	1.244	238.5	6.11	283	0.87	0.789	125.3
NC+ 70X	0	0.53	76	2.80	1.307	337.4	4.04	146	0.99	0.833	129.0
	74.6	1.82	188	2.41	1.183	227.4	5.16	203	0.87	0.831	129.5
	149.3	2.36	229	2.59	1.178	242.7	5.35	190	0.91	0.807	154.6
	298.6	2.86	218	2.71	1.323	238.8	4.57	183	0.99	0.818	160.8

1/ All values are averages for three replications.

Appendix Table 6. Cont'd. Effects of planting date, variety, and potassium rates on stalk characteristics of grain sorghum. Wilson county, David Vith Farm. 1972

FIRST PLANTING DATE -- APRIL 19

	5 cm Base Section					5 cm Peduncle Section				
	K %	Cl^- ppm	Wt gm	Dia cm	Strength lbs	K %	Cl^- ppm	Wt gm	Dia cm	Strength lbs
K Summary										
0	1.10	129	2.28	1.256	248.0	4.77	166	0.93	0.828	135.1
74.6	1.87	204	2.17	1.182	225.2	5.05	196	0.85	0.778	127.3
149.3	2.80	213	2.33	1.231	222.0	5.11	188	0.91	0.797	151.0
298.6	3.25	239	2.25	1.272	199.1	5.22	201	0.90	0.822	136.0
$LSD_{.05}$	0.70	NS	NS	NS	NS	NS	25	NS	NS	NS
Variety Summary										
Asgrow Dorado	2.32	219	2.22	1.358	257.7	5.37	186	0.97	0.828	162.4
RS 626	2.85	168	2.13	0.983	163.8	3.89	145	0.81	0.686	105.2
Funks G522	2.11	203	2.17	1.388	203.0	4.92	199	0.94	0.851	150.0
Acco R1090	2.03	213	2.08	1.250	192.3	5.32	197	0.87	0.863	146.8
DeKalb C42A	2.32	198	2.32	1.185	263.0	5.92	218	0.85	0.786	116.7
NC+ 70X	1.89	178	2.63	1.248	261.5	4.78	181	0.94	0.822	143.5
$LSD_{.05}$	0.74	NS	0.32	0.107	51.8	0.80	28	0.10	0.050	30.0

Appendix Table 7. Effects of planting date, variety, and potassium rates on stalk characteristics of grain sorghum. Wilson county, David Voth Farm. 1972

SECOND PLANTING DATE -- MAY 16

Treatments		5 cm Base Section					5 cm Peduncle Section				
Variety	K kg/ha	K [1/] %	Cl^- ppm	Wt gm	Dia cm	Strength lbs	K %	Cl^- ppm	Wt gm	Dia cm	Strength lbs
Asgrow Dorado	0	0.93	177	1.65	1.339	99.9	4.70	195	0.84	0.850	105.7
	74.6	2.30	225	1.54	1.342	93.1	5.39	206	0.81	0.793	101.9
	149.3	2.37	202	1.67	1.378	95.0	5.02	219	0.77	0.860	110.5
	298.6	2.90	265	1.63	1.318	115.9	5.34	226	0.75	0.773	96.7
RS 626	0	0.86	127	1.56	0.955	128.3	2.82	129	0.72	0.715	69.3
	74.6	3.15	226	1.50	0.950	108.5	3.51	145	0.74	0.715	88.9
	149.3	4.32	254	1.32	0.836	108.0	3.42	136	0.63	0.665	75.5
	298.6	3.57	208	1.33	0.839	112.0	2.63	116	0.67	0.583	34.8
Funks G522	0	0.53	144	1.56	1.236	123.7	4.36	194	0.80	0.839	101.0
	74.6	1.73	199	1.65	1.313	80.1	5.31	207	0.82	0.810	126.1
	149.3	2.54	263	1.68	1.461	75.6	5.11	232	0.82	0.836	102.0
	298.6	2.89	239	1.68	1.453	98.7	5.47	239	0.78	0.789	99.7
Acco R1090	0	0.70	150	1.68	1.199	143.0	3.66	178	0.71	0.802	98.2
	74.6	1.05	139	1.81	1.212	167.3	4.48	199	0.88	0.836	107.2
	149.3	2.03	204	1.77	1.236	144.4	4.37	202	0.74	0.796	82.5
	298.6	1.86	173	2.26	1.185	218.9	4.52	195	0.90	0.828	120.7
DeKalb C42A	0	0.67	199	1.36	1.109	101.2	4.68	228	0.62	0.789	84.1
	74.6	2.38	219	1.74	1.277	90.1	5.83	213	0.75	0.847	72.9
	149.3	2.98	279	1.50	1.217	84.3	5.52	230	0.68	0.767	75.3
	298.6	3.76	266	2.11	1.450	117.9	5.92	257	0.87	0.866	121.0
NC+ 70X	0	0.56	142	2.14	1.329	251.8	3.90	177	0.97	0.839	145.6
	74.6	1.69	158	1.97	1.326	190.5	4.55	186	0.85	0.810	114.5
	149.3	2.28	254	2.58	1.231	136.5	4.43	195	0.62	0.765	79.9
	298.6	2.18	180	2.52	1.294	253.4	5.15	208	0.95	0.870	129.5

1/ All values are averages for three replications.

Appendix Table 7. Cont'd. Effects of planting date, variety, and potassium rates on stalk characteristics of grain sorghum. Wilson county, David Voth Farm. 1972

SECOND PLANTING DATE -- MAY 16

	5 cm Base Section					5 cm Peduncle Section				
	K %	Cl^- ppm	Wt gm	Dia cm	Strength lbs	K %	Cl^- ppm	Wt gm	Dia cm	Strength lbs
K Summary										
0	0.71	157	1.66	1.195	141.3	4.02	184	0.78	0.806	100.6
74.6	2.05	195	1.70	1.237	121.6	4.85	193	0.81	0.800	101.9
149.3	2.75	243	1.59	1.227	107.3	4.64	202	0.71	0.782	87.6
298.6	2.86	222	1.92	1.257	152.8	4.84	207	0.80	0.785	100.4
$LSD_{.05}$	0.34	49	NS	NS	NS	NS	NS	NS	NS	NS
Variety Summary										
Asgrow Dorado	2.12	217	1.62	1.344	101.0	5.11	212	0.79	0.816	103.7
RS 626	2.97	204	1.43	0.895	114.3	3.10	132	0.67	0.669	67.1
Funks G522	1.92	211	1.64	1.366	94.5	5.00	218	0.81	0.818	107.2
Acco R1090	1.41	167	1.88	1.208	168.4	4.26	193	0.81	0.816	102.2
DeKalb C42A	2.45	241	1.68	1.263	98.4	5.49	232	0.73	0.817	88.3
NC+ 70X	1.68	184	2.05	1.295	208.1	4.51	191	0.85	0.821	117.3
$LSD_{.05}$	0.40	41	0.22	0.101	37.9	0.44	23	0.09	0.041	26.2

Appendix Table 8. Pearson product moment correlation coefficients matrix between sorghum stalk base and peduncle characteristics. (B=base, P=peduncle, W=weight, C=circumference, S=crushing strength, V=volume, /=divided by, *=multiplied by.) Wilson county, planting date 1. 1972

** Significance at 0.01
* Significance at 0.05

	W-B	D-B	S-B	W-P	D-P	S-P	W/C-B	W*V-B	W/V-B	W/C-P	W*V-P	W/V-P
W-B	1.000											
D-B	0.424**	1.000										
S-B	0.651**	0.220	1.000									
W-P	0.705**	0.797**	0.464**	1.000								
D-P	0.402**	0.810**	0.300*	0.762**	1.000							
S-P	0.560**	0.687**	0.343**	0.779**	0.689**	1.000						
W/C-B	0.627**	-0.425**	0.415**	0.022	-0.303**	-0.027	1.000					
W*V-B	0.738**	0.905**	0.430**	0.899**	0.732**	0.723**	-0.034	1.000				
W/V-B	0.149	-0.793**	0.083	-0.407**	-0.651**	-0.390**	0.859**	-0.490**	1.000			
W/C-P	0.662**	0.365**	0.375**	0.733**	0.126	0.477**	0.363**	0.596**	0.068	1.000		
W*V-P	0.567**	0.851**	0.378**	0.925**	0.932**	0.775**	-0.160	0.868**	-0.551**	0.436**	1.000	
W/V-P	0.161	-0.371**	-0.005	-0.061	-0.675**	-0.181	0.508**	-0.144	0.576**	0.630**	-0.395**	1.000

Appendix Table 9. Pearson product moment correlation coefficients matrix between sorghum stalk base and peduncle characteristics. (B=base, P=peduncle, W=weight, C=circumference, S=crushing strength, V=volume, /=divided by, *=multiplied by.) Wilson county, planting date 2. 1972

** Significance at 0.01
* Significance at 0.05

	W-B	D-B	S-B	W-P	D-P	S-P	W/C-B	W*V-B	W/V-B	W/C-P	W*V-P	W/V-P
W-B	1.000											
D-B	0.501**	1.000										
S-B	0.777**	0.073	1.000									
W-P	0.806**	0.625**	0.525**	1.000								
D-P	0.636**	0.751**	0.281*	0.752**	1.000							
S-P	0.693**	0.573**	0.496**	0.756**	0.618**	1.000						
W/C-B	0.657**	-0.313**	0.770**	0.357**	0.034	0.270*	1.000					
W*V-B	0.826**	0.881**	0.433**	0.809**	0.752**	0.715**	0.142	1.000				
W/V-B	0.061	-0.805**	0.374**	-0.168	-0.496**	-0.197	0.787**	-0.453**	1.000			
W/C-P	0.652**	0.308**	0.528**	0.851**	0.298*	0.600**	0.483**	0.564**	0.148	1.000		
W*V-P	0.792**	0.712**	0.450**	0.945**	0.906**	0.729**	0.253*	0.846**	-0.304**	0.644**	1.000	
W/V-P	0.073	-0.331**	0.234*	0.153	-0.527**	0.026	0.410**	-0.099	0.542**	0.646**	-0.142	1.000

Appendix Table 10. Analysis of variance -- mean square values. Bourbon county. 1972

Source of Variation	Degrees of Freedom	Grain Yield	Lodging	Leaf Composition					
				6 Leaf Stage			Boot Stage		
				N	P	K	N	P	K
Replicates	2	113.41	---	0.104	0.0018	0.029	0.062	0.0004	0.002
N-rates	3	170.81	---	0.040	0.0012	0.006	0.079	0.0005	0.013
K-rates	3	20.17	---	0.061*	0.0009	0.229**	0.041	0.0003	0.002
N x K	9	245.69*	---	0.016	0.0008	0.091	0.029	0.0004	0.013
Error	30	109.67	---	0.018	0.0008	0.044	0.039	0.0007	0.012
Replicates	2	91.48	---	0.008	0.0017	0.056	0.178	0.0002	0.007
K-Carrier	1	3.38	---	0.075*	0.0000	0.085	0.014	0.0013	0.005
N-rates	3	84.87	---	0.030	0.0003	0.107*	0.034	0.0022	0.013
C x N	3	438.58**	---	0.009	0.0001	0.010	0.027	0.0018	0.006
Error	14	63.27	---	0.015	0.0005	0.022	0.031	0.0005	0.010

Appendix Table 11. Analysis of variance -- mean square values. Crawford county. 1972

Source of Variation	Degrees of Freedom	Grain Yield	Lodging	Leaf Composition					
				7 Leaf Stage			Boot Stage		
				N	P	K	N	P	K
Replicates	2	194.93	24.70	0.137	0.0028	0.167	0.089	0.0025	0.085
N-rates	3	270.20	28.71	0.177**	0.0008	0.035	0.336**	0.0019*	0.007
K-rates	3	130.91	266.26**	0.039	0.0000	0.893**	0.028	0.0006	0.031
N x K	9	174.78	25.66	0.027	0.0006	0.017	0.024	0.0005	0.013
Error	30	138.32	18.56	0.022	0.0006	0.035	0.018	0.0005	0.011
Replicates	2	175.36	7.31	0.008	0.0016	0.132	0.010	0.0031	0.012
K-Carrier	1	157.00	31.17	0.072	0.0002	0.084	0.001	0.0015	0.021
N-rates	3	133.42	17.11	0.137**	0.0003	0.023	0.097	0.0010	0.006
C x N	3	126.49	4.56	0.017	0.0001	0.013	0.052	0.0002	0.002
Error	14	203.05	10.03	0.017	0.0007	0.021	0.068	0.0004	0.006

Appendix Table 12. Analysis of variance -- mean square values. Wilson county, across planting dates. 1972

Source of Variation	Degrees of Freedom	Grain Yield	Lodging	Degrees of Freedom	Leaf Composition					
					5-9 Leaf Stage			Boot Stage		
					N	P	K	N	P	K
Replicates	2	17.65	74.90	2	0.262	0.1009	0.112	0.366	0.0214	0.829
Planting date	1	15926.44	3348.36*	2	5.381**	0.0321	14.024*	1.930**	0.0446	1.344**
Error (D)	2	3620.41	115.86	4	0.299	0.0094	1.025	0.091	0.0337	0.037
K-rate	3	1109.53	224.91	3	0.035	0.0020	8.027**	0.059	0.0012	0.684
D x K	3	2052.92*	5.33	6	0.073	0.0018	0.381*	0.029	0.0029	0.035
Error (K)	12	536.45	76.97	18	0.093	0.0035	0.119	0.055	0.0019	0.021
Variety	5	2390.00**	246.11**	5	0.243**	0.0040**	0.060	0.246**	0.0182**	0.093**
D x V	5	533.19*	143.07**	10	0.056	0.0002	0.030	0.177**	0.0074**	0.038**
K x V	15	231.15	85.80**	15	0.037	0.0002	0.024	0.008	0.0007	0.012*
D x K x V	15	376.61*	62.00**	30	0.030	0.0005	0.022	0.021	0.0004	0.012**
Error (V)	80	208.03	25.55	120	0.042	0.0005	0.032	0.020	0.0007	0.006

Appendix Table 13. Analysis of variance -- mean square values. Wilson county. 1972

Source of Variation	Degrees of Freedom	Grain Yield	Lodging	Leaf Composition					
				9 Leaf Stage			Boot Stage		
				N	P	K	N	P	K
Planting date 1 -- April 19									
Replicates	2	1745.02	7.45	0.092	0.0752	0.884	0.155	0.0058	0.449
K-rates	3	584.13	86.39*	0.015	0.0029	2.493**	0.036	0.0003	0.191**
Error (K)	6	560.35	13.90	0.133	0.0034	0.099	0.033	0.0026	0.018
Variety	5	2444.90**	166.75**	0.155*	0.0019*	0.051	0.306**	0.0154**	0.067**
K x V	15	409.44	50.91**	0.055	0.0006	0.037	0.026	0.0006	0.012
Error (V)	40	239.76	14.24	0.058	0.0005	0.024	0.027	0.0007	0.006
Planting date 2 -- May 16									
Replicates	2	1893.05	183.31	0.600	0.0284	0.503	0.070	0.0029	0.326
K-rates	3	2578.31*	143.85	0.090*	0.0008	5.109**	0.049	0.0012	0.267
Error (K)	6	512.56	140.03	0.017	0.0015	0.079	0.080	0.0004	0.007
Variety	5	478.30*	222.43**	0.106	0.0014**	0.026	0.247**	0.0159**	0.039**
K x V	15	198.33	96.89*	0.029	0.0001	0.021	0.009	0.0006	0.018**
Error (V)	40	176.30	36.85	0.044	0.0004	0.043	0.020	0.0006	0.005
Planting date 3 -- June 16									
Replicates	2	---	---	0.169	0.0162	0.776	0.324	0.0801	0.127
K-rates	3	---	---	0.076	0.0018	1.186*	0.034	0.0054	0.296*
Error (K)	6	---	---	0.130	0.0056	0.179	0.053	0.0027	0.037
Variety	5	---	---	0.094*	0.0012	0.042	0.047*	0.0017	0.063**
K x V	15	---	---	0.013	0.0004	0.011	0.016	0.0003	0.006
Error (V)	40	---	---	0.025	0.0006	0.028	0.014	0.0008	0.008

Appendix Table 14. Analysis of variance -- mean square values. Stalk characteristics. Wilson county, across planting dates. 1972

Source of Variation	Degrees of Freedom	K conc.	Cl^- conc.	Wt	Dia	Strength
			BASE			
Replicates	2	1.395	33898	0.118	0.035	4298
Planting date	1	0.928	2101	10.541*	0.002	298826
Error (D)	2	0.464	20128	0.160	0.034	16785
K-rate	3	33.535**	59416**	0.158	0.020	4411
K x D	3	0.701	5278	0.300	0.021	8395
Error (K)	12	0.459	8804	0.351	0.063	7948
Variety	5	4.692**	6879	0.858**	0.588**	26028**
D x V	5	0.456	6118	0.186	0.022	18446**
K x V	15	0.371	3442	0.098	0.021	4169
D x K x V	15	0.527	2609	0.153	0.016	2843
Error (V)	80	0.513	3132	0.110	0.016	3044
			PEDUNCLE			
Replicates	2	2.118	6076	0.033	0.016	1048
Planting date	1	7.313	2756	0.532*	0.006	55704*
Error (D)	2	0.476	9385	0.022	0.005	1954
K-rate	3	2.910*	5357*	0.015	0.006	119
K x D	3	0.476	777	0.039	0.006	2212
Error (K)	12	0.781	1524	0.080	0.016	3201
Variety	5	13.372**	20746**	0.090**	0.090**	8418**
D x V	5	1.045	1285	0.010	0.004	927
K x V	15	0.255	551	0.019	0.004	1659
D x K x V	15	0.472	822	0.016	0.006*	953
Error (V)	80	0.607	935	0.014	0.003	1188

Appendix Table 15. Analysis of variance -- mean square values. Stalk characteristics. Wilson county. 1972

Source of Variation	Degrees of Freedom	K conc.	Cl^- conc.	Wt	Dia	Strength
		Planting date 1 -- April 19 BASE				
Replicates	2	0.817	50741	0.261	0.013	15032
K-rates	3	16.562**	39780	0.077	0.028	7199
Error (K)	6	0.743	14042	0.512	0.119	11100
Variety	5	1.368	4785	0.470*	0.251**	21941**
K x V	15	0.359	3975	0.118	0.015	6385
Error (V)	40	0.795	3761	0.147	0.017	3940
		PEDUNCLE				
Replicates	2	1.493	12181	0.046	0.017	2493
K-rates	3	0.655	4204	0.018	0.010	1760
Error (K)	6	0.387	948	0.132	0.029	4925
Variety	5	5.658**	7155**	0.049*	0.050**	5675**
K x V	15	0.507	920	0.010	0.004	1398
Error (V)	40	0.933	1124	0.015	0.004	1320
		Planting date 2 -- May 16 BASE				
Replicates	2	1.041	3285	0.018	0.057	2081
K-rates	3	17.674**	24913*	0.380	0.012	7386
Error (K)	6	0.176	3565	0.190	0.006	4861
Variety	5	3.779**	8211*	0.573**	0.359**	26197**
K x V	15	0.539*	2076	0.133	0.022	1696
Error (V)	40	0.230	2504	0.073	0.015	2111
		PEDUNCLE				
Replicates	2	1.101	3280	0.009	0.003	360
K-rates	3	2.731	1931	0.036	0.002	808
Error (K)	6	1.176	2100	0.028	0.003	1242
Variety	5	8.759**	14876**	0.051**	0.044**	3725**
K x V	15	0.221	453	0.025*	0.006*	1195
Error (V)	40	0.280	746	0.012	0.003	1007

THE EFFECTS OF POTASSIUM ON STRESS-INDUCED STALK LODGING OF GRAIN SORGHUM (SORGHUM BICOLOR)

by

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ABSTRACT

Studies were initiated on three sites in Southeast Kansas, in Bourbon, Crawford, and Wilson counties, to study the effects of K fertilization on stalk rot in grain sorghum. N-K interactions were studied at two locations and planting date, K-rate, and variety interactions at the third.

Due to early harvest, only small percentages of lodging were observed at Crawford and Wilson counties (none in Bourbon county) as compared to the potential for lodging that existed later in the season. However, trends were observed in the studies.

With no added K, N tended to increase both lodging and visible symptoms of stalk rotting at Crawford county. Potassium applications at Crawford county decreased visible symptoms of K-deficiency and reduced lodging significantly.

At the Wilson county site the effects of K on lodging were not as clear-cut as in Crawford county. The early planting date showed a significant trend in reduction of lodging with added K, but the second planting date showed little reduction of lodging with K fertilization. Visible symptoms of K-deficiency were alleviated with added K.

Stalk characteristics (weight, diameter, and crushing strength) were determined for the Wilson county location, but showed no response to K fertilization. Stalk characteristics demonstrated no consistent correlation with lodging in this study. Correlations calculated between stalk characteristics indicated that weight and amount of rind are good indexes of stalk strength.