THE EFFECT OF SOIL WATER AND POTASSIUM ON GRASS TETANY RELATED COMPONENTS OF CEREAL FORAGES

by

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I would like to take this opportunity to thank all those who contributed so much in helping me attain this goal. I would especially like to thank my committee members for their time, guidance, and encouragement, and also my loving wife for her support and patience especially during the last few months.

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INTRODUCTION

The use of fertilization and plant breeding as tools for increasing forage production of introduced cool-season grasses has enjoyed a great deal of popularity, especially in recent years. However, increased production has usually been the primary aim and seldom is any consideration given to the mineral content of the forage. Andre Voison (36) stated that "variations in the yield and biological quality of plants do not necessarily follow a parallel course," and that increasing use of fertilizers has created mineral imbalances in forages, which has increased the incidence of many mineral-related animal health problems such as grass tetany.

Grass tetany, a metabolic disorder of ruminants resulting from low blood serum Mg concentration, is usually fatal if not treated soon after symptoms appear. Cases of grass tetany have been recognized for more than 100 years but it was not until 1930 that studies by the Dutch scientist, Sjollema, revealed its association with blood serum Mg levels. Since then extensive studies have revealed that grass tetany is not entirely due to a dietary deficiency of Mg, but is the result of several interrelated factors. As no simple solution exists, the focus of recent research has been to find the most economical and effective means of controlling it.

Research was initiated at Kansas State University in 1975 to study the influence of soil, fertilizer, and climatic factors on forage quality indices of grass tetany. In previous work, D. E. Karlen (19) and Ray Lamond (23) studied the influence of nitrogen form, Mg fertilization, liming, soil temperature, soil water content, and plant cultivar on these indices. My objectives were: (1) to study the influence of K fertilization, soil water content, and plant variety on forage quality as a continuation and expansion of D. E. Karlen's work; (2) to compare the mineral content of five species of cereal grains grown at two soil water contents; and (3) to study the influence of K-rate and method of K application on the quality of wheat forage grown on low K soils.

LITERATURE REVIEW

Grass tetany generally occurs in the late fall and early spring in cattle grazing lush, green pastures, and is believed to be related to the animal's dietary intake of Mg and the animal's ability to use the Mg taken in. It is reported most frequently in cattle grazing cool-season grasses in humid and sub-humid climates. However, cases have been reported in the semi-arid regions of the western United States (27). The disorder can affect animals of any age and either sex, but occurs most frequently in older, lactating females (17, 26, 36). During the past few years the problem has been intensified by the increasing use of fertilizers, more intensive pasture use, and more productive grasses and animals (37).

"Taken as a whole, grass tetany may not affect a very high percentage of cows," however, losses to individual herds may be quite devastating. A survey of several counties in West Virginia found an estimated 1.4% of the lactating cows were stricken each year with losses as high as 10% on individual farms. In Great Britain it was estimated that 1% to 5% of the lactating cows were affected by grass tetany each year with losses running as high as 30% of those affected (36). In view of the high unit value of livestock it's obvious that grass tetany is costing the livestock industry millions of dollars each year, and that equitable solutions need to be found.

Some of the factors associated with the occurrence of grass tetany are low forage Mg levels, the N, Ca, and K content of the forage, the equivalent ratio of K/(Ca+Mg) in the forage, the increased rate of passage of green forage as compared to dry feed, high levels of milk production, age of the animal, weather conditions and animal stress (24). Critical levels commonly associated with a tetanigenic forage, one which has a high probability of inducing grass tetany, are a Mg content of less than 0.2%, more than 2.5% K, an equivalent ratio of K/(Ca+Mg) greater than 2.2, less than 0.25% Na, and a weight ratio of K:Na exceeding 8.0 (17, 36). These values have been established over the years from studies of pastures on which grass tetany occurred. Although not definite, they are useful as guidelines to predict whether or not a forage is "tetany prone."

As previously stated, the increasing use of fertilizer, both organic and inorganic, has increased the incidence of diet related disorders in grazing aminals. "Pasture fertilization with N, K, or both, has been implicated in grass tetany for some time" (37). Several studies have been done relating the type and amount of fertilizer applied to the incidence of grass tetany. The results of these studies, though quite varied, have provided many insights into the influence of fertilizers on plant composition and their ultimate influence on animal health.

Potassium fertilizer has been more frequently implicated in grass tetany than any other fertilizer. DeGroot, cited by Wilkinson and Stuedemann (37), reported that K fertilization of pastures depressed blood serum Mg levels in grazing cattle. Fontenot (8) found that feeding sheep a high protein, high K ration decreased Mg absorption by 41%. Voison (36) theorized that since "the monovalent cation K^+ is absorbed and accumulated by plant cells much more rapidly and to a greater degree than divalent cations such as Ca^{++} and Mg^{++}, the herbage's content of K would increase considerably and suddenly following application of K fertilizers, creating or accentuating various mineral imbalances." Generally this has held in that potassium fertilizers usually increase the concentration of K in the forage significantly (9, 13). Potassium fertilization also tends to depress forage concentrations of Ca (9, 20) and Mg (16, 20, 31, 32).

This increase in K coupled with the decrease in Ca and Mg results in a relatively large increase in the equivalent ratio of K/(Ca+Mg) (9). Another influence of K fertilization is to decrease the plant concentration of Na (20, 36), when this is coupled with a high K content, the plant ratio of K:Na is greatly increased easily exceeding the critical level of 8.0.

Although potassium is the fertilizer most frequently implicated in grass tetany, nitrogen is the one most frequently applied to pastures so a great deal of research has been done concerning its use and influence on forage quality. Generally, N fertilization increases the potential tetany hazard of forage primarily due to its influence on plant composition (7). Nitrogen generally increases plant concentrations of K as well as Ca, Mg, and Na (31). This effect, however, depends largely on the soil supply of these elements. If they are present in abundance, the increased growth associated with N fertilization will increase the uptake and possibly plant concentrations of these elements, however, if the supply is limited plant concentrations will likely be reduced (6). This is well illustrated in data collected by Kemp (20) who found that when the plant K concentration exceeded 2.0%, N fertilization increased it, when it was less then 2.0%, N fertilization further depressed it.

Another, somewhat indirect, way N fertilization enhances the possibility of grass tetany is by influencing the botanical composition of the pasture. Nitrogen dressings markedly reduce the amount of clover and other legumes found in pastures (32), and since legumes tend to have a greater Mg concentration and lower cation ratio than grasses (17), the resulting pasture would be more likely to produce grass tetany. The influence of plant species is discussed in more detail later in this paper.

As mentioned earlier, the mineral composition of herbage is influenced by seasonal changes as well as soil conditions and fertility practices. Magnesium content tends to be highest in the summer and lowest in the late fall and early spring (20). These seasonal variations would seem to indicate that there are major climatic factors influencing the relationship between soil Mg and forage Mg. One such factor could be the soil water content. McNaught et al. (29), citing Schuffelin and Koenigs, pointed out that wet soil conditions favor higher concentrations of monovalent ions, especially K, in the soil solution and lower concentrations of divalent ions. Soil moisture, therefore, could have an important effect on Mg and Ca levels in forages. Another theory contends that since appreciably more Mg and Ca can be supplied by mass flow than is taken up by plant roots, increasing the soil water content would not appreciably increase the uptake of Ca and Mg. However, because the mean path length for the diffusion of K to the plant roots would decrease as soil water content increased, more K would be taken up when moisture is adequate than when the soil is drier, unless soil aeration was decreased to a critical level (25).

A study on a fescue pasture in Georgia revealed that forage from poorly drained areas of the pasture had Mg contents of .18% to .25% while forage from nearby well drained areas had .27% to .40% Mg (3). Karlen et al. (18) found that "the primary effect of increased soil moisture content was to decrease average leaf Ca concentrations." They concluded that "Ca and Mg concentrations were generally depressed by high soil water, while K concentrations remained unchanged or increased slightly." This resulted in a higher K/(Ca+Mg) equivalent ratio in 7 out of 11 samples which indicated that forages grown under wet soil conditions would tend to be more likely to produce tetany in grazing animals.

The increased incidence of grass tetany on nearly saturated soils has also lead researchers to investigate the influence of soil O_2 on the mineral composition of forage (3,4). Results from these studies were varied and contradicted some of the findings already mentioned. One reason these contradictions may have occurred is that the researchers regulated soil O_2 by altering the O_2 content of the soil air and not by saturating the soils. Perhaps a hydroponics experiment where O_2 is controlled by bubbling it into the solution would provide data similar to that observed in the soil water experiments.

Although grass tetany is not a simple dietary deficiency of Mg it is generally accepted that increasing the intake of available dietary Mg will prevent its occurrence. This can be done by; (1) increasing plant levels of Mg through fertilization; (2) adding Mg concentrates to the animal's feed or water; or (3) providing grazing animals with plants that contain more Mg through selection and plant breeding efforts (37).

Most researchers agree that it is possible to increase plant Mg concentrations by fertilizing acid, coarse-textured soils with Mg. At the same time "most published research leads to the conclusion that it is difficult to increase the concentration of Mg in plants grown on fine-textured soils, especially if they are calcareous and high in exchangeable K" (5), as most soils of the western United States are. So although fertilization may help in some instances its usefulness is limited to certain soil types.

As mentioned earlier, several animal health problems have been associated with mineral imbalances in the foods they consume. Unlike frequencies of contagious and infectious diseases, the occurrence of these disorders has been increasing (36). The prevailing attitude has been that nutrient disorders in plants can be corrected by fertilization and that feed supplementation can correct the mineral deficiencies or imbalances of animal diets (14). But as already pointed out, use of fertilizers is not completely effective in combating mineral imbalances in forages, and "the increasing frequency of mineral related health problems indicates that diet supplementation (also) is not completely effective" (14).

One of the principle aims in breeding of pasture plants should be to develop improved varieties which are not only more productive but also of desirable chemical composition from the viewpoint of ruminant nutrition. It is also "important to assess the components of genetic and environmental variation in chemical constituents which are considered to have nutritional significance for ruminants" (1). Differences in the behavior of different species of plants is due primarily to inherent differences in their abilities to take up certain ions rather than to properties peculiar to a soil type (30). Thus, breeding feed and forage cultivars to provide adequate mineral concentrations for animals deserves further investigation (14).

"Probably the most marked differences in mineral concentration between economically important forage species occur between grasses and legumes" (31). On the average, legumes contain more Mg, Ca, and P than grasses (36). J. R. Todd (35) compared several species of forage plants and found that of the grasses studied, timothy had the lowest Mg content while cocksfoot and the rye grasses contained the most. The highest Mg concentrations were found in the clover species. Gross and Jung (10) studied the mineral concentration of several temperate-origin forages and found considerable consistency in cultivar ranking for Mg accumulation in the grasses studied. Legume species and cultivars, however, differed greatly in Mg concentration. They also found that the grasses differed markedly in their equivalent ratio of K/(Ca+Mg). They felt that the large differences in mineral levels between cultivars and the consistency of cultivar ranking over a wide temperature range suggest that cultivar selection for Mg accumulation would be rewarding.

In a comparison of several different cereal forages, Mayland et al. (26) found that rye had the highest Ca and Mg content and the lowest equivalent ratio while the wheat cultivars had the lowest Ca and Mg levels. Oats and barley were intermediate in Ca and Mg concentrations, however barley had the highest K content which resulted in it also having the largest equivalent ratio. They concluded that each of the forages studied had at least one chemical parameter that tended to impose a risk of tetany and that the differences among wheat cultivars indicate that the tetany hazard may be reduced through plant breeding. Based on their data they estimated the tetany hazard of the forages studied follows the order wheat > oats = barley > rye.

Karlen et al. (18) studied the cation concentrations of three varieties of hard red winter wheat. They found significant cultivar differences for Ca and Mg concentration in all samplings of nonvernalized plant material but only in one sampling following vernalization. They also reported significant differences in equivalent ratios of K/(Ca+Mg) among cultivars.

Kleese et al. (22) studied 12 varieties of barley and 12 varieties of wheat. They found significant differences in the accumulation of several elements among most of the plant materials studied. They reported that differences in accumulation due to years and locations were generally small and insignificant and suggested that a single environment may suffice when screening genotypes for differences in mineral accumulation. They also reported finding cultivars of barley and wheat with Mg concentrations more than adequate for ruminant nutrition which further strengthens Gross and Jung's (10) conclusion that cultivar selection for Mg accumulation might be beneficial.

Thill and George (34), comparing the cation concentration and cation ratios of nine cool season grasses, found only four (reed canarygrass, orchardgrass, tall oatgrass, and Canada wildrye) had equivalent ratios of K/(Ca+Mg) which exceeded the critical level. They concluded that K concentration is the factor most responsible for grasses being characterized as having a high or low equivalent ratio and that daily fluctuations in Ca and Mg concentrations were responsible for the daily variation of the equivalent ratio. Sleper et al. (33) studied the heritability of plant mineral concentration and the equivalent ratio of K/(Ca+Mg) in tall fescue and concluded that Mg and Ca were more responsible than K for a low or high equivalent ratio. Many discrepancies such as this exist in the literature and need to be clarified through further research.

From the foregoing discussion it is evident that most researchers agree that the plant accumulation of elements essential to animal nutrition is under genetic control and that many of the mineral-related problems in animal health could be reduced through plant breeding. However, Hill and Jung (15) suggest that before attempting to alter the mineral concentration of forages, plant breeders should consider the following: (1) the mineral concentrations of the companion feeds and forages to be fed with the forage under consideration; (2) that element concentrations generally cannot be changed independently of each other; and (3) how genetically induced changes in mineral concentration affect their availability to animals.

Many factors are involved in the etiology of grass tetany and a great deal of literature has been published on the subject. Only a general overview of the problem has been provided with emphasis being placed on those factors related to the research presented in this thesis. More complete reviews have been written including a special publication by the American Society of Agronomy (4, 5, 7, 8, 23, 25, 34, 37), D. L. Grunes (11), and Grunes et al. (12).

The data presented here is from three different experiments which were conducted between August, 1979 and December, 1980. The core of the research involved two growth chamber studies, one conducted in the Fall of 1979 and one in the fall of 1980. For convenience and clarity each experiment will be discussed separately.

Experiment I

Materials & Methods:

Four varieties of hard red winter wheat (*Triticum aestivum*) - Centurk, Eagle, Newton, and Tam 105 - were germinated in a growth chamber kept at 25 C. Sealed containers were used for germination to avoid possible wheat curl mite infestation. After 10 days the containers were placed in a vernalization chamber with 8 hour days and dept at 2.5 C for 54 days.

The seedlings were then removed from the containers and transplanted into plastic pots containing 3 kg of a Parsons silt loam soil. The Parsons soil is classified as a Mollic Albaqualf, it has a fine silty texture with no predominant clay type, and formed under a thermic temperature regime (Table 1). The soil had been air dried, screened to remove large clods, and fertilized with 45 ppm N and 100 ppm P as reagent grade monoammonium phosphate. Twelve pots of each variety were planted with five seedlings being planted in each pot.

The pots were placed at random in a growth chamber with a controlled daylength of 14 hours and day/night temperatures of 20 C and 13 C, respectively. The pots were rotated every other day to avoid possible placement effects. Light was provided by both flourescent and incandescent lamps located approximately 60 cm above the soil surface.

Fourteen days were allowed for seedling establishement before initiating treatments. The treatments consisted of two levels of soil water, 60% and 125% of field capacity, [1] and two K rates, 390 and 780 ppm as KCl. The treatments were replicated three times. Soil water levels were monitored by taking random

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[1]Field capacity was determined using a moisture release curve which had been constructed for a disturbed sample of the soil using a pressure plate apparatus. This work was done by Dr. Loyd Stone of the Evapotranspiration Lab at Kansas State.

Table 1. Soil Characteristics for the plowlayer of the Parsons soil loam soil used in Experiment I.

pH[1]	5.4	Available P	23 ppm[4]
CEC[2]	13.0 meq/100g	Exchangeable K	86 ppm[5]
Bulk Density[3]	1.3 g/cm^3	Exchangeable Ca	2290 ppm[6]
		Exchangeable Mg	276 ppm[6]

1. Determined using a 1:1 mixture of soil and distilled deionized water (28).
2. CEC was determined by saturating the exchange complex with Ca using 1 N $CaCl_2$ and 1 N CaOAc, rinsing with alcohol to remove excess Ca, and then extracting with 1 N NH_4OAc adjusted to pH 7.0.
3. Determined by dividing the weight of the soil by the volume of the pots.
4. Determined using the Bray-1 test for Phosphorus (21).
5. Determined using 1 N NH_4OAc pH 7.0 extracts and flame emission (2).
6. Determined from the same extracts as K using atomic absorption after a 1:20 dilution with a 0.5% solution of Lanthanum oxide to reduce anion interference.

soil samples with a small probe (Figure 1) every other day and determining water content of the samples gravimetrically. Based on the average water content of the samples from each soil water level, water was added to the pots on alternate days to maintain the desired water content.

Plant tissue samples were taken 10, 20, and 30 days after treatment initiation by clipping to a stubble height of 5 cm. The plant samples were weighed and then dried at 55 C in a forced air oven. Dry weights were then recorded and the samples ground to pass a 1 mm mesh screen. Quarter gram samples of the dried material were digested in 7.5 ml of a 1:1 mixture of nitric and perchloric acids and analyzed for total K, Ca, and Mg. Potassium determinations were made using flame emission and Ca and Mg were determined by atomic absorption using a 0.5% solution of Lanthanum oxide to reduce anion interference. The data were then analyzed by the GLM procedure of SAS and means compared using calculated LSD values. The SAS data set for this experiment has been reproduced in Appendix Table 1.

Results and Discussion:

Statistical analysis of this data was inconclusive for two reasons. First, there was a large amount of variability in the data, both between and within varieties, soil water levels, and K rates, particularly at the earlier sampling dates. This variability was probably due to variation in the moisture content of the individual pots. Second, poor growth in some of the pots resulted in small samples which often could not be analyzed and therefore resulted in missing data. Nevertheless, the experiment did provide some insight into the varietal differences that do exist and the influence of soil water on the chemical composition of wheat plants.

Figure 1.

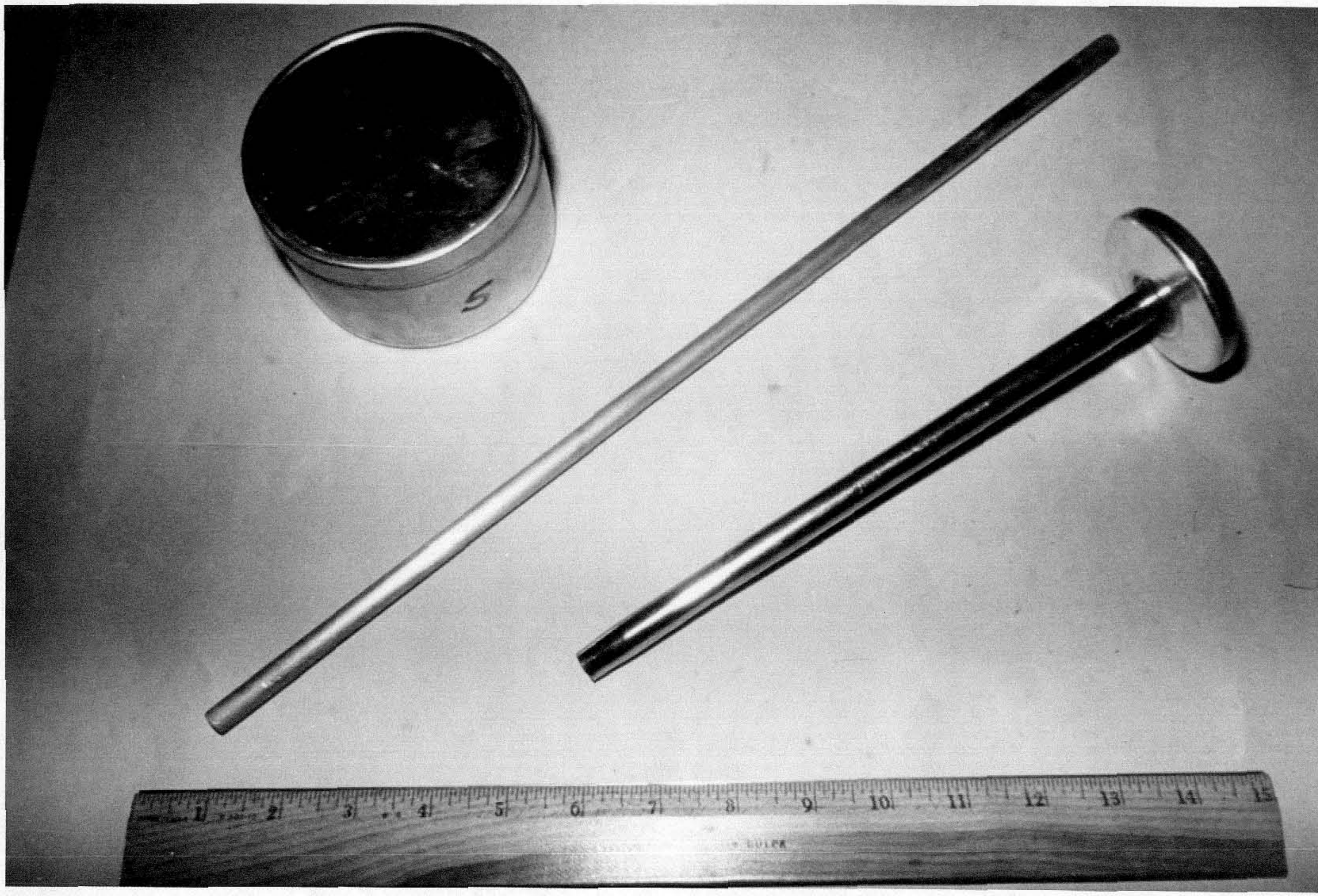

Figure 1: Probe and sample can used to take soil samples from pots for soil water determinations.

The analysis of the data revealed a significant interaction between soil water and varieties for all variables but K and dry weight at the first sampling date and for K, Mg and dry weight at the second sampling date. No significant interactions occurred at the third sampling date. Plots of these interactions (Figure 2) revealed that on the first sampling date the higher level of soil water when compared with the lower level significantly increased the Ca content of Tam 105, significantly decreased the Mg content of Eagle, and significantly decreased the cation ratio of Tam 105 while significantly increasing the cation ratio of Eagle. On the second sampling date the higher level of soil water significantly increased the K and Mg content of Newton, significantly increased the Mg content of Tam 105, and significantly decreased the Mg content of Centurk. It should be noted that although means for Centurk were plotted on the first sampling date no comparisons could be made due to missing observations in the data set.

Due to the presence of interaction in the experiment at the first two sampling dates comparisons of main effects were made using least squares means taken over replication and K rate, as there was no significant effect due to K rate at these two dates, and calculated LSD values (Tables 2 & 3). Comparisons of main effects at the third sampling date were made using least squares means taken over all other factors, as no interaction was present, and calculated LSD values (Table 4).

Comparison of varieties revealed a fair amount of consistency in ranking, particularly for total yield expressed as dry weight and percent dry matter. Generally, Centurk had the lowest dry weights and lowest dry matter percentages while Newton usually had the highest yield and Tam 105 the highest dry matter content.

Figure 2: Plots of significant soil water by variety interactions for the first and second sampling dates (Means taken over K rate and replication).

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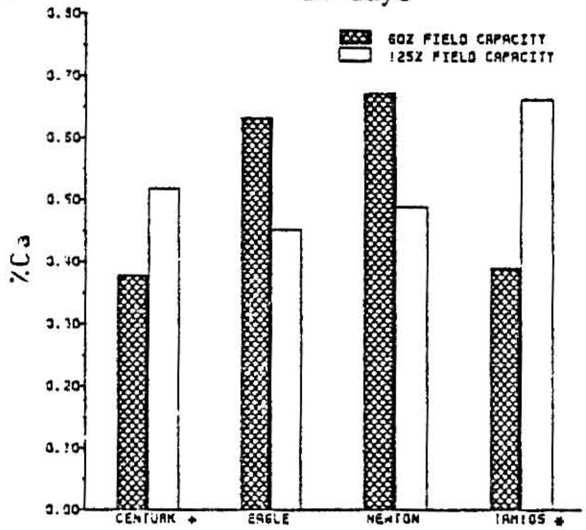

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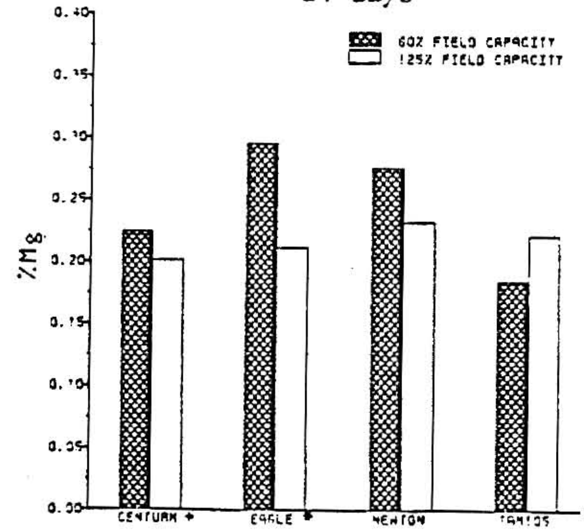

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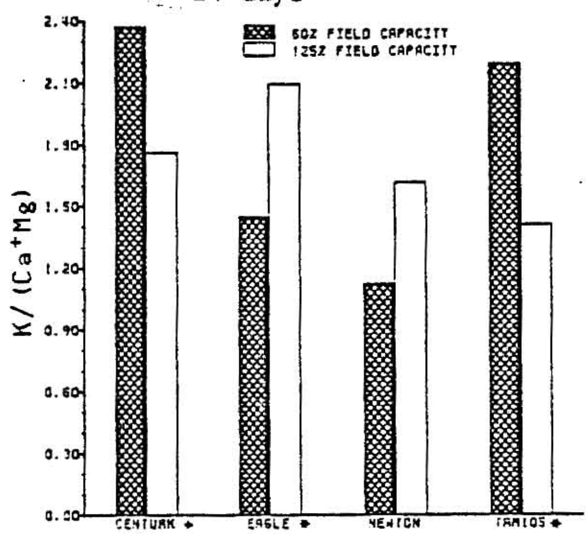
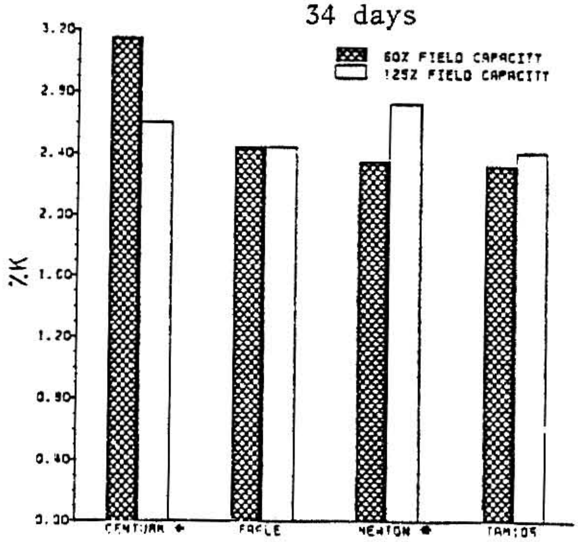


34 days



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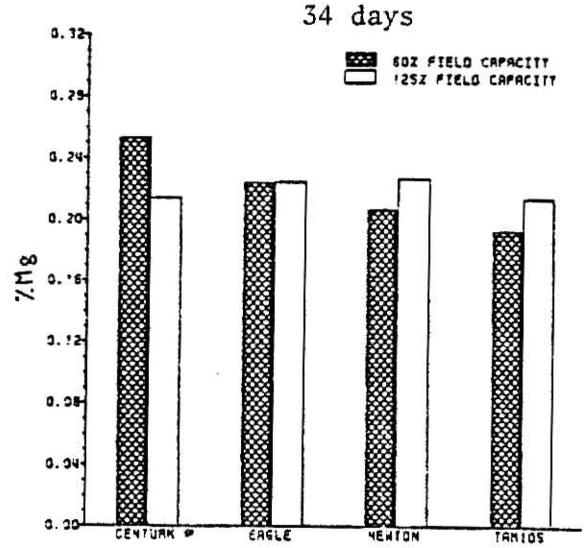

* Indicates significance at the .05 level.
\+ Date for Centurk cannot be compared due to missing samples.
** Days after vernalization.

Table 2: Chemical composition, dry matter yield, and %. dry matter of forage from four varieties of wheat grown at two soil water controls 24 days after vernalization (means taken over K rate and replication).

Variety	Soil Water (%FC)	Dry Weight (g)	Dry Matter (%)	%K	%Ca	%Mg	K/(Ca+Mg) [1]
Centurk	60	0.06	13.21	----+	----+	----+	----+
Eagle	60	0.18	20.60	3.14	0.63	0.30	1.45
Newton	60	0.33	21.47	2.41	0.67	0.28	1.12
Tam 105	60	0.16	20.73	2.87	0.39	0.19	2.19
Centurk	125	0.16	22.36*	2.56*	0.50*	0.20*	1.80*
Eagle	125	0.26	20.22	3.24	0.45	0.21	2.10
Newton	125	0.26	21.02	2.70	0.49	0.23	1.62
Tam 105	125	0.22	23.29	2.25	0.66	0.22	1.41
LSD (.05) [2]		0.10	3.39	0.59	0.22	0.05	0.61
LSD (.05) [3]			3.56	0.62	0.23	0.05	0.70

1. Milliequivalent ratio calculated from individual replications.

2. LSD values for making comparisons between varieties and soil water levels.

3. LDS values for making comparisons with the indicated means (*).

* Means estimated using only five values.

\+ Means were not estimable due to missing data

Table 3: Chemical composition, dry matter yield, and % dry matter of forage from four varieties of wheat grown at two soil water contents 34 days after vernalization (means taken over K rate and replication).

Variety	Soil Water (%FC)	Dry Weight (g)	Dry Matter (%)	%K	%Ca	%Mg	$\frac{K}{(Ca+Mg)}$[1]
Centurk	60	0.16	16.07	3.15	0.58	0.25	1.62
Eagle	60	0.38	18.98	2.45	0.57	0.22	1.34
Newton	60	0.53	20.97	2.36	0.56	0.21	1.35
Tam 105	60	0.38	23.24	2.33	0.48	0.19	1.50
Centurk	125	0.38	15.39*	2.59*	0.54*	0.21*	1.55*
Eagle	125	0.61	17.08	2.45	0.52	0.22	1.43
Newton	125	0.70	18.52	2.73	0.58	0.23	1.47
Tam 105	125	0.47	19.41	2.42	0.53	0.21	1.47
LSD (.05)[2]		0.23	4.46	0.32	0.15	0.02	0.29
LSD (.05)[3]			4.68	0.33	0.16	0.03	0.30

1. Milliequivalent ratio calculated from individual replications.
2. LSD values for making comparisons between varieties and sil water levels.
3. LSD values for making comparisons with the indicated means (*).

* Means estimated using only five values.

Table 4: Influence of the experimental main effects on the chemical composition of wheat forage 44 days after vernalization (means taken over all other factors and replication).

Main Effect	Level	Dry Weight (g)	Dry Matter (%)	%K	%Ca	%Mg	$\frac{K}{(Ca+Mg)}$ [1]
Moisture	60 %FC	0.27	20.64	2.65	0.50	0.21	1.60
	125 %FC	0.72	19.19	2.45	0.45	0.22	1.59
LSD (.05)		0.15	1.35	0.23	0.04	0.01	0.18
K rate	390 ppm	0.52	19.93	2.51	0.50	0.23	1.47
	780 ppm	0.47	19.90	2.59	0.46	0.20	1.72
LSD (0.05)		0.15	1.35	0.23	0.04	0.01	0.18
Variety	Centurk	0.38	18.86	2.89*	0.47*	0.23*	1.77*
	Eagle	0.63	19.68	2.69	0.48	0.22	1.65
	Newton	0.57	20.18	2.30	0.54	0.22	1.33
	Tam 105	0.40	20.94	2.32	0.42	0.19	1.65
LSD (.05)		0.21	1.91	0.31	0.05	0.02	0.25
LSD (.05) [2]				0.33	0.05	0.02	0.26

1. Milliequivalent ratio calculated from individual replications.
2. LSD values for making comparisons with the indicated means (*).
* Means estimated using only ten values.

Chemically there was less consistency in the data and soil water content seemed to influence the ranking at the first two dates. Generally, Centurk and Eagle had the highest levels of K while Tam 105 and Newton had the lowest, however, at 125% FC the K content of Newton was higher. Tam 105 usually had the lowest contents of Ca and Mg except for the Ca content at 125% FC where it was replaced by Eagle. There was no consistency for the cation ratio of K/(Ca+Mg) and all varieties at all dates were below the 2.2 critical level above which a forage is thought to be more likely to induce tetany.

Significant soil water effects were observed for percent dry matter at the first and third sampling dates, dry weight at the second and third sampling dates, and for Mg and Ca content at the first and third dates, respectively. Generally, the higher level of soil water decreased plant dry matter content, increased total dry matter production, and depressed the Ca and Mg content of the forage. It appears that the primary influence of the higher level of soil water was to reduce variability among varieties.

Significant K rate effects were only observed at the third sampling date where the higher rate significantly depressed the Ca and Mg content of the forage and significantly increased the cation ratio.

This experiment shows that varietal differences in chemical composition do exist and that Mg levels greater than 0.2% along with K concentrations less than 2.5% can be obtained in wheat forage. It demonstrated that high soil water tends to reduce variability among varieties. Also, it further emphasized that high rates of K fertilizer increase the risk of grass tetany by depressing plant levels of Ca and Mg.

Experiment II

Materials & Methods:

Five species of cereal grains - barley (Hoerdeum cereale), oats (Avena sativa), rye (Secale cereale), wheat (Triticum aestivum), and triticale, a cross between rye and wheat, - were germinated in 12 by 9 inch aluminum trays filled with vermiculite. After the seedlings were about 10 cm tall the trays were placed in a vernalization chamber with 8 hour days and kept at 3 C for 4 to 6 weeks.

Twenty plants of each species were then transplanted in flats that were 14 inches long, 12 inches wide, and 6 inches deep. The flats were filled with 38 pounds (17.2 kg) of a Parsons silt loam soil. The Parsons soil is classified as a Mollic Albaqualf, it has a fine silty texture with no predominant clay type, and formed under a thermic temperature regime (Table 5). The soil had been air dried and screened to remove large clods, and had been fertilized with 45 ppm N and 100 ppm P as reagent grade monoammonium phosphate, and 380 ppm K and KCl.

The flats were then placed in a growth chamber with 12 hour days and day/night temperatures of 18 C and 6.7 C, respectively. They were rotated every other day to reduce placement effects. After four days to allow the plants to become established, treatments were initiated. The treatment structure consisted of two levels of soil water, 60% and 125% of field capacity, replicated three times. Soil water levels were maintained by daily weighing and watering of each flat (Figure 3).

After one week the plants were harvested by clipping to a stubble height of 5 cm and the day/night temperatures were increased to 22 C and 13 C, respectively. Plants were sampled weekly for three more weeks, again by clipping to a stubble height of 5 cm.

Table 5. Soil Characteristics for the plowlayer of the Parsons silt loam soil used in Experiment II.

pH[1]	5.4	Available P	23 ppm[4]
CEC[2]	13.0 meq/100g	Exchangeable K	86 ppm[5]
Bulk Density[3]	1.3 g/cm^3	Exchangeable Ca	2290 ppm[6]
		Exchangeable Mg	276 ppm[6]

1. Determined using a 1:1 mixture of soil and distilled deionized water (28).
2. CEC was determined by saturating the exchange complex with Ca using 1 N $CaCl_2$ and 1 N CaOAc, rinsing with alcohol to remove excess Ca, and then extracting with 1 N NH_4OAc adjusted to pH 7.0
3. Determined by dividing the weight of the soil by the volume of the flats.
4. Determined using the Bray-1 test for Phosphorus (21).
5. Determined using 1 N NH_4OAc pH 7.0 extracts and flame emission (2).
6. Determined from the same extracts as K using atomic absorption after a 1:20 dilution with a 5% solution of Lanthanum oxide to reduce anion interference.

Figure 3.

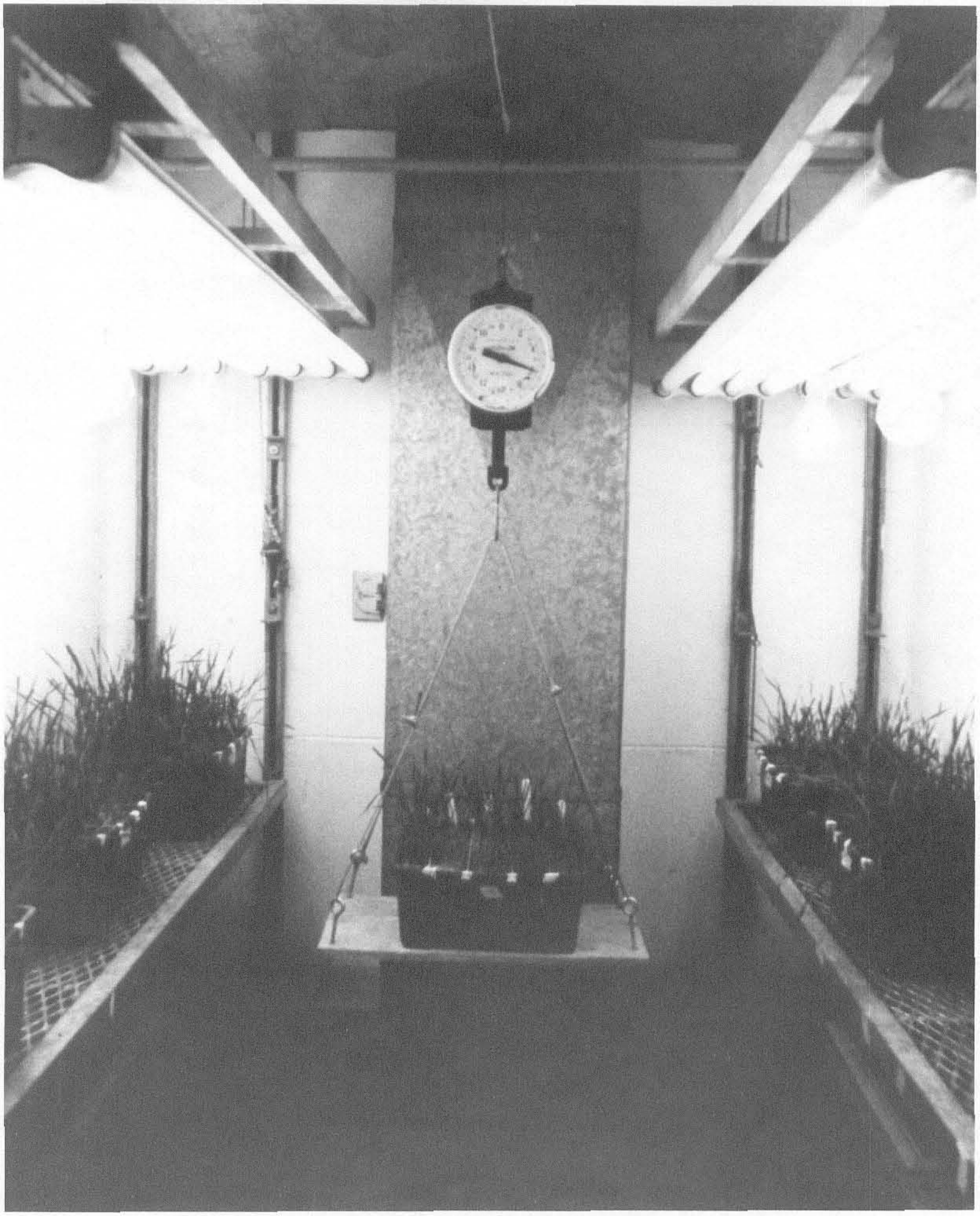

Figure 3: Platform and scale used for weighing the flats to maintain soil water levels.

The plant samples were weighed and then dried at 55 C in a forced air oven. Dry weights were recorded and the samples ground to pass a 1 mm mesh screen. Quarter gram samples were digested in a 7.5 ml of a 1:1 mixture of nitric and perchloric acids and determinations of total K, Ca, Mg and Na were made. Potassium and Na determinations were made using flame emission, Ca and Mg determinations by atomic absorption using a 0.5% solution of Lanthanum oxide to reduce anion interference. The data were then analyzed using the ANOVA procedure of SAS and means compared using calculated LSD values. The SAS data set for this experiment has been reporduced in Appendix Table 2.

Results & Discussion:

The use of flats instead of individual pots allowed much better control of the soil water content and therefore greatly reduced the variability between individual samples that had been noticed in the first experiment. As a result, species differences were more clearly defined and were remarkably consistent from date to date.

Statistical analysis of the data indicated that there were significant interactions between soil water levels and species for K and Mg on the second and third sampling dates, Na on the last three dates, and the K:Na ratio on the second date. This presence of interaction indicates that the effects of soil water and plant species on the forage quality indices measured are not independent of each other.

To further examine these interactions plots were constructed to compare the low and high soil water levels within each species (Figures 4 & 5). These plots revealed that the high soil water level significantly increased the K content of barley at the second sampling date and of oats and rye at the third sampling date, but didn't significantly change the K content of the other species.

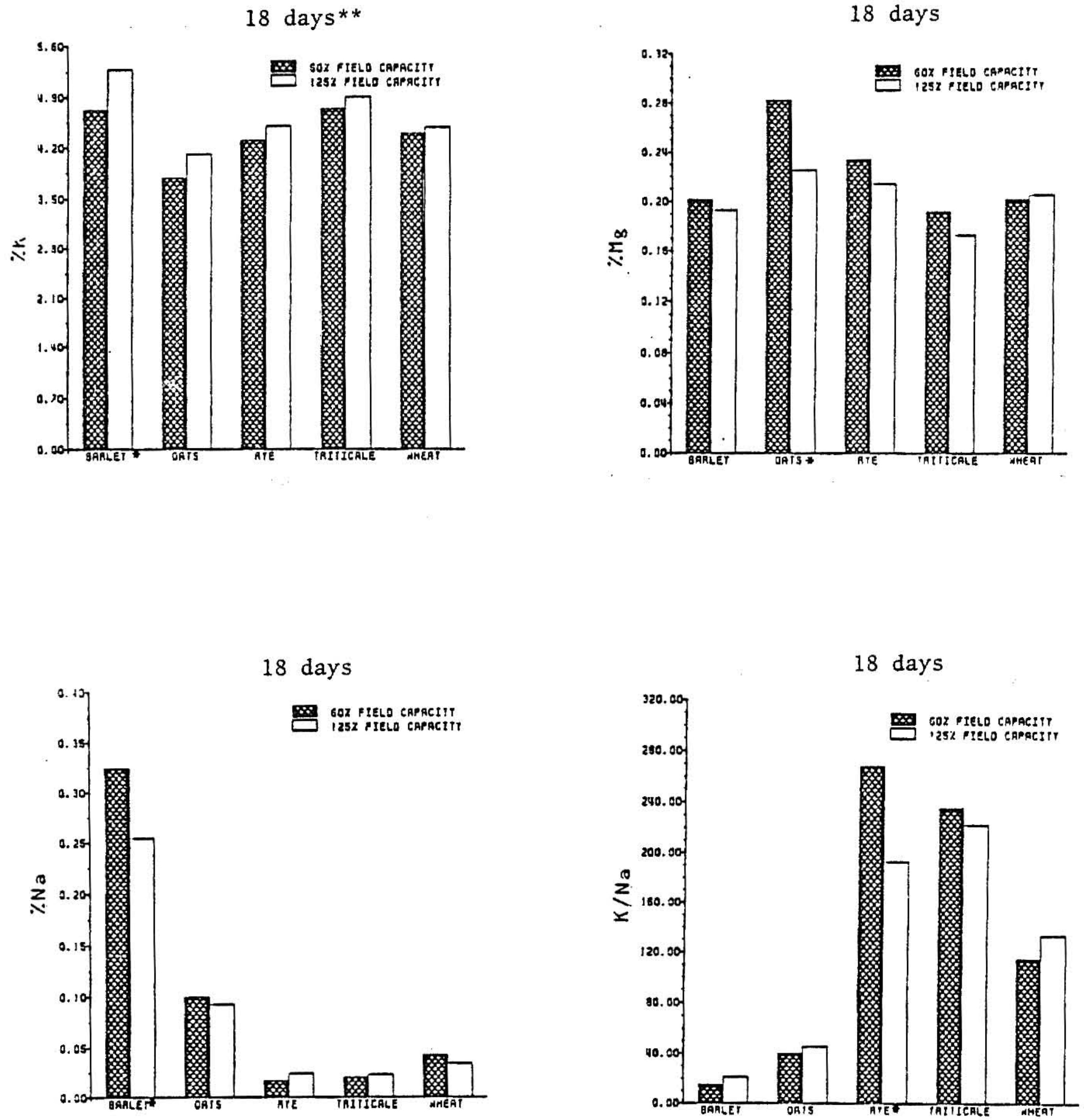

Figure 4: Plots of significant soil water by species interactions for the second sampling date (Means taken over replications).

* Indicates a significant difference due to soil water at the .05 level.

** Days after vernalization.

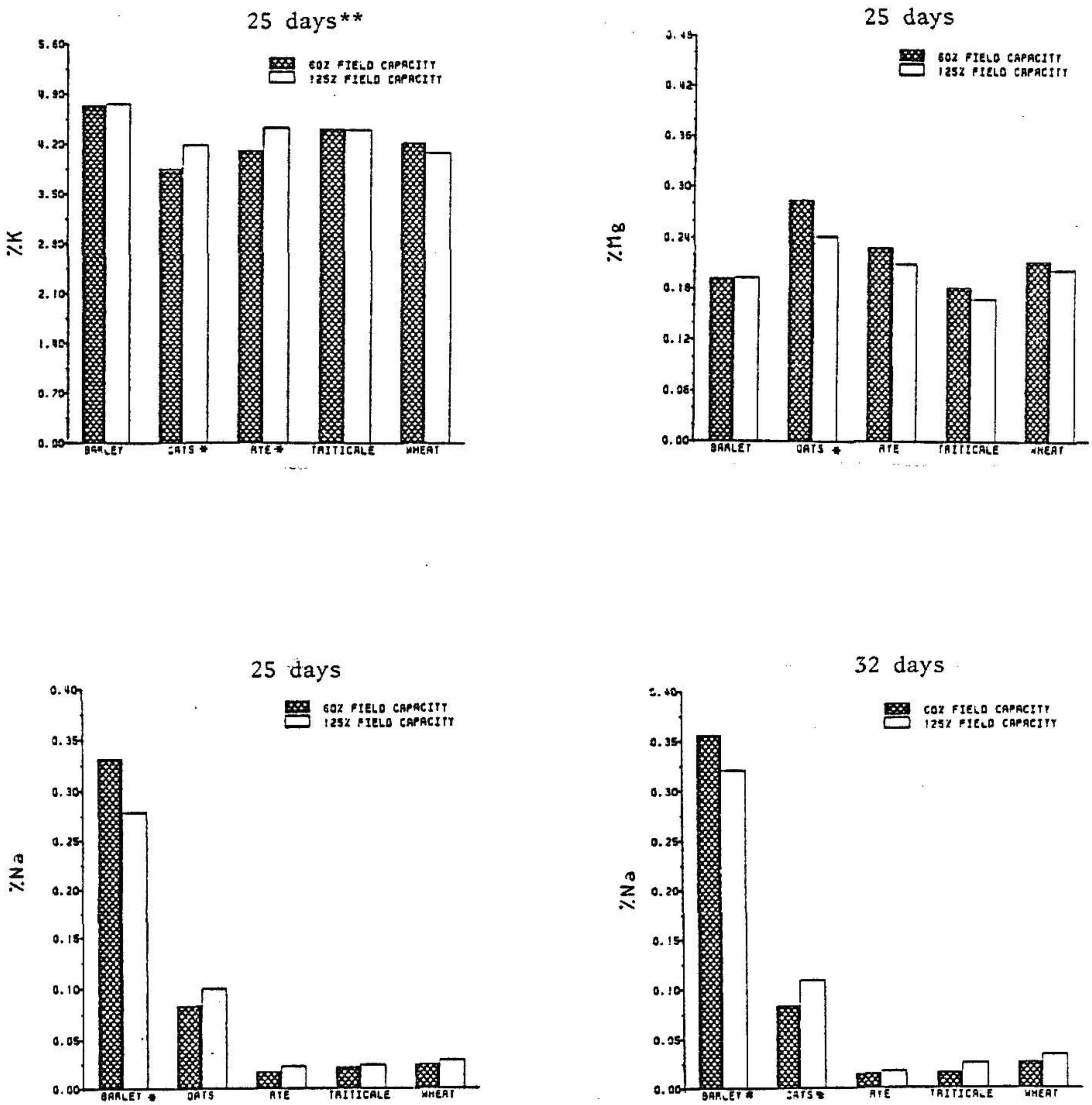

Figure 5: Plots of significant soil water by species interactions for the third and fourth sampling dates. (Means taken over replications).

* Indicates a significant difference due to soil water at the .05 level.

** Days after vernalization.

High soil water also significantly depressed the Mg content of oats and the Na content of barley at the second and third sampling dates, and significantly reduced the K:Na ratio in rye on the second sampling date. Again, no significant changes occurred in the other species. The most striking example of interaction between soil water and species occurred on the fourth sampling date where high soil water significantly increased the Na content of oats but significantly decreased the Na content of barley.

Due to the presence of interaction in the experiment, main effect variables were compared only within a given level of the other variable. Comparisons were made using least squares means and calculated LSD values (Table 6-9).

When species were compared for total yield on a dry weight basis at 60% of field capacity (FC), the only species with consistently high yields was triticale for all samplings, however, its yield was only significantly higher than the others at the second sampling date. At 125% FC there was little significance and no consistent ordering by species among the four dates. When dry matter contents, expressed as a percentage of fresh weight, were compared, oats, rye, and wheat generally had the highest dry matter contents while barley and triticale had the lowest. This was true at both 60% FC and 125% FC.

Chemical content comparisons of the various species also demonstrated remarkable consistency both between sampling dates and soil water levels. Oats had a significantly lower K content than the others at all four sampling dates when grown at 60% FC and for the first two dates when grown at 125% FC, but was only below the 2.5% critical level, above which a forage is considered more likely to induce tetany, on the first sampling date. Barley and triticale generally had the highest K contents, always exceeding the critical level. Oats consistently had the highest levels of Ca and Mg compared to the other

Table 6: Chemical composition, dry matter yield, and % dry matter of forage from five species of cereal grains grown at two soil water contents 11 days after vernalization (means taken over replications).

Species	Soil Water Content (%FC)	Dry Weight (g)	% Dry Matter	%K	%Ca	%Mg	%Na	$\frac{K}{(Ca+Mg)}$[1]	K/Na[2]
Barley	60	0.12	20.08	2.97	0.85	0.44	0.41	0.96	8.00
Oats	60	0.21	24.56	2.33	0.87	0.36	0.11	0.82	21.29
Rye	60	0.15	19.80	3.41	0.70	0.35	0.04	1.38	96.94
Triticale	60	0.26	19.58	2.94	0.56	0.30	0.03	1.44	102.25
Wheat	60	0.26	22.14	2.88	0.60	0.28	0.05	1.40	55.97
Barley	125	0.11	19.51	3.24	0.77	0.40	0.36	1.16	9.33
Oats	125	0.19	23.78	2.40	0.77	0.32	0.09	0.95	26.45
Rye	125	0.19	18.53	3.36	0.60	0.29	0.03	1.59	97.83
Triticale	125	0.22	19.36	3.41	0.52	0.26	0.03	1.83	107.63
Wheat	125	0.26	21.16	2.97	0.49	0.25	0.04	1.69	81.03
LSD (.05)[3]		0.06	2.22	0.38	0.07	0.03	0.09	0.24	27.63
LSD (.05)[4]		0.08	3.63	0.55	0.12	0.05	0.10	0.28	27.46

1. Milliequivalent ratio calculated from individual replications.
2. Weight ratio calculated from individual replications.
3. LSD for comparing species within a given level of soil water.
4. LSD for comparing the two soil water contents within a given species.

Table 7: Chemical composition, dry matter yield, and % dry matter of forage from five species of cereal grain grown at two soil water contents 18 days after vernalization (means taken over replications).

Species	Soil Water Content (%FC)	Dry Weight (g)	% Dry Matter	%K	%Ca	%Mg	%Na	$\frac{K}{(Ca+Mg)}$ [1]	K/Na [2]
Barley	60	0.17	13.89	4.72	0.44	0.20	0.32	3.14	14.72
Oats	60	0.22	18.04	3.79	0.53	0.28	0.10	1.95	39.63
Rye	60	0.20	16.35	4.31	0.41	0.23	0.02	2.79	267.68
Triticale	60	0.28	15.23	4.74	0.41	0.19	0.02	3.37	234.86
Wheat	60	0.21	16.17	4.40	0.46	0.20	0.04	2.86	114.10
Barley	125	0.22	13.08	5.28	0.38	0.19	0.25	3.86	21.26
Oats	125	0.26	16.62	4.12	0.41	0.22	0.09	2.71	45.36
Rye	125	0.26	16.03	4.51	0.36	0.21	0.02	3.27	192.41
Triticale	125	0.30	14.20	4.91	0.36	0.17	0.02	3.90	221.94
Wheat	125	0.25	15.72	4.48	0.40	0.20	0.03	3.13	132.96
LSD (.05) [3]		0.05	1.21	0.18	0.06	0.02	0.03	0.38	42.76
LSD (.05) [4]		0.10	2.04	0.31	0.09	0.03	0.04	0.61	53.09

1. Milliequivalent ratio calculated from individual replications.
2. Weight ratio calculated from individual replications.
3. LSD for comparing species within a given level of soil water.
4. LSD for comparing the two soil water contents within a given species.

Table 8: Chemical composition, dry matter yield, and % dry matter of forage from five species of cereal grains grown at two soil water contents 25 days after vernalization (means taken over replications).

Species	Soil Water Content (%FC)	Dry Weight (g)	% Dry Matter	%K	%Ca	%Mg	%Na	K/(Ca+Mg)[1]	K/Na[2]
Barley	60	0.31	14.15	4.74	0.39	0.19	0.33	3.45	14.37
Oats	60	0.30	17.82	3.85	0.50	0.28	0.08	2.05	49.39
Rye	60	0.31	17.24	4.10	0.39	0.23	0.02	2.77	245.12
Triticale	60	0.34	16.21	4.41	0.38	0.18	0.02	3.34	218.46
Wheat	60	0.26	17.41	4.22	0.44	0.21	0.02	2.75	181.04
Barley	125	0.51	11.92	4.47	0.39	0.19	0.28	3.44	14.25
Oats	125	0.50	14.70	4.18	0.47	0.24	0.10	2.50	43.28
Rye	125	0.52	15.41	4.43	0.36	0.21	0.02	3.22	199.71
Triticale	125	0.45	14.39	4.40	0.35	0.17	0.02	3.62	181.07
Wheat	125	0.39	15.95	4.09	0.36	0.20	0.03	3.04	141.36
LSD (.05)[3]		0.08	1.59	0.23	0.06	0.02	0.03	0.44	60.43
LSD (.05)[4]		0.18	2.38	0.33	0.08	0.04	0.04	0.50	59.68

1. Milliequivalent ratio calculated from individual replications.
2. Weight ratio calculated from individual replications.
3. LSD for comparing species within a given level of soil water.
4. LSD for comparing the two soil water contents within a given species.

Table 9: Chemcial composition, dry matter yield, and % dry matter of forage from five species of cereal grains grown at two soil water contents 32 days after vernalization (means taken over replications).

Species	Soil Water Content (%FC)	Dry Weight (g)	% Dry Matter	%K	%Ca	%Mg	%Na	K / (Ca+Mg) [1]	K/Na [2]
Barley	60	0.37	14.37	4.68	0.46	0.20	0.36	3.00	13.19
Oats	60	0.35	19.17	3.80	0.62	0.29	0.08	1.77	50.55
Rye	60	0.38	18.42	4.13	0.39	0.22	0.01	2.88	305.24
Triticale	60	0.39	16.96	4.42	0.42	0.19	0.02	3.14	291.73
Wheat	60	0.28	19.89	4.30	0.52	0.22	0.02	2.48	179.90
Barley	125	0.66	11.75	5.34	0.44	0.21	0.32	3.48	16.72
Oats	125	0.65	14.28	4.38	0.51	0.27	0.11	2.38	41.06
Rye	125	0.72	15.17	4.74	0.41	0.22	0.02	3.16	280.12
Triticale	125	0.54	14.52	4.91	0.38	0.16	0.02	3.91	199.33
Wheat	125	0.37	15.96	4.44	0.45	0.21	0.03	2.87	136.40
LSD (.05) [3]		0.14	2.30	0.27	0.07	0.02	0.03	0.54	83.86
LSD (.05) [4]		0.25	2.73	0.66	0.08	0.02	0.03	0.65	85.91

1. Milliequivalent ratio calculated from individual replication.
2. Weight ratio calculated from individual replication.
3. LSD for comparing specieswithin a given level of soil water.
4. LSD for comparing the two soil water contents within a given species.

species, while triticale consistently had the lowest levels. Barley had significantly higher levels of Na than the other species at all dates and at both levels of soil water. It was followed by oats which, with the exception of the first sampling date, always contained signficantly more Na than the other three species.

The significant differences between species in chemical composition naturally carried over to the two ratios that were calculated. As one might expect, the equivalent ratio of K/(Ca+Mg) was lowest in oats and highest in barley and triticale. At the first sampling date all species had cation ratios less than the critical 2.2 value, however, at the other dates only oats grown at 60% FC remained below the critical level. Barley and oats consistently had significantly lower K/Na ratios than the other species. The high Na content of barley consistently produced the lowest ratio, however, only on the first sampling date at 60% FC was the ratio near the 8.0 critical value above which a forage is considered more likely to produce tetany in grazing animals. The K/Na ratio of oats was always higher than that of barley but never significantly different.

Soil water content also had a significant influence on forage chemical composition, dry matter yield, and dry matter content. Again, due to the significant interactions, comparisons can only be made within a given species (Tables 6-9).

Comparisons of the dry matter yield of forages grown at the two soil water levels showed that the higher water content significantly increased the dry matter yield of barley, oats, and rye on the last two sampling dates. When the dry matter content of forage grown at the two water levels was compared, it was found that high soil water significantly decreased the dry matter content of oats at the third and fourth sampling dates, and decreased the dry matter content of oats, rye, and wheat at the fourth sampling date.

The influence of soil water on the chemical composition of all species also demonstrated remarkable consistency. High levels of soil water generally increased the K content of the plants with significant increases being observed for barley and oats at the second date, oats and rye at the third date, and barley at the fourth date. At the same time, high levels of soil water tended to depress plant concentrations of Ca and Mg. Significant differences were observed in the Ca content of oats at the second and fourth sampling dates, the Ca content of wheat at the third sampling date, the Mg content of oats at the second, thrid, and fourth sampling dates, and the Mg content of triticale at the fourth sampling date. This general increase of plant K along with a decrease in plant Ca and Mg resulted in a general overall increase in the cation ratio. A significant increase was observed for triticale and wheat at the first sampling date, for barley and oats at the second sampling date, and for triticale at the fourth sampling date.

The influence of soil water on plant Na was seldom significant due to the low Na content in all species but barley and oats. However, high levels of soil water significantly depressed the Na content of barley at all but the first sampling date, and significantly increased the Na content of oats at the fourth sampling date.

In general there was no significant influence of soil water on the K/Na ratio, except for rye at the second sampling date and triticale at the fourth sampling date, where high levels of soil water significantly depressed the ratio although it remained well above the critical level.

Plots of the individual variables by species and date were made within a given level of soil water to study how they varied as the plants matured (Figures 6 - 9). As expected, dry weight or plant yield increased steadily, however, a sudden drop in the percent dry matter was noticed between dates one and two. Evidently, increasing the temperature in the growth chamber after the first sampling date increased plant growth resulting in more succulent forage.

The temperature change also influenced the chemical composition of the plants. The plots at both soil water levels show an increase in K content of the forage and a decrease in the Ca and Mg content associated with the increase in temperature. This resulted in a dramatic increase in the cation ratio. The temperature change had no apparent influence on Na, and the K/Na ratio increased only in some species, probably due to increased plant K. These trends were observed at both levels of soil water.

This experiment clearly demonstrates that there are significant differences in the chemical composition of cereal grain forages and further illustrates the deleterious effects high soil water has on forage quality. Based on the critical levels associated with grass tetany it appears that all of the species studied have at least one characteristic which could induce tetany in the grazing animal. Overall, oats appears to have the most desirable characteristics while triticale and barley, appear to be the most likely to induce grass tetany.

Figure 6. Plant K, Ca, and Mg and the cation ratio plotted by species over time for plants grown at 60% of field capacity.

LEGEND

——— BARLEY
········ OATS
+----- RYE
— — — TRITICALE
—·· WHEAT

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

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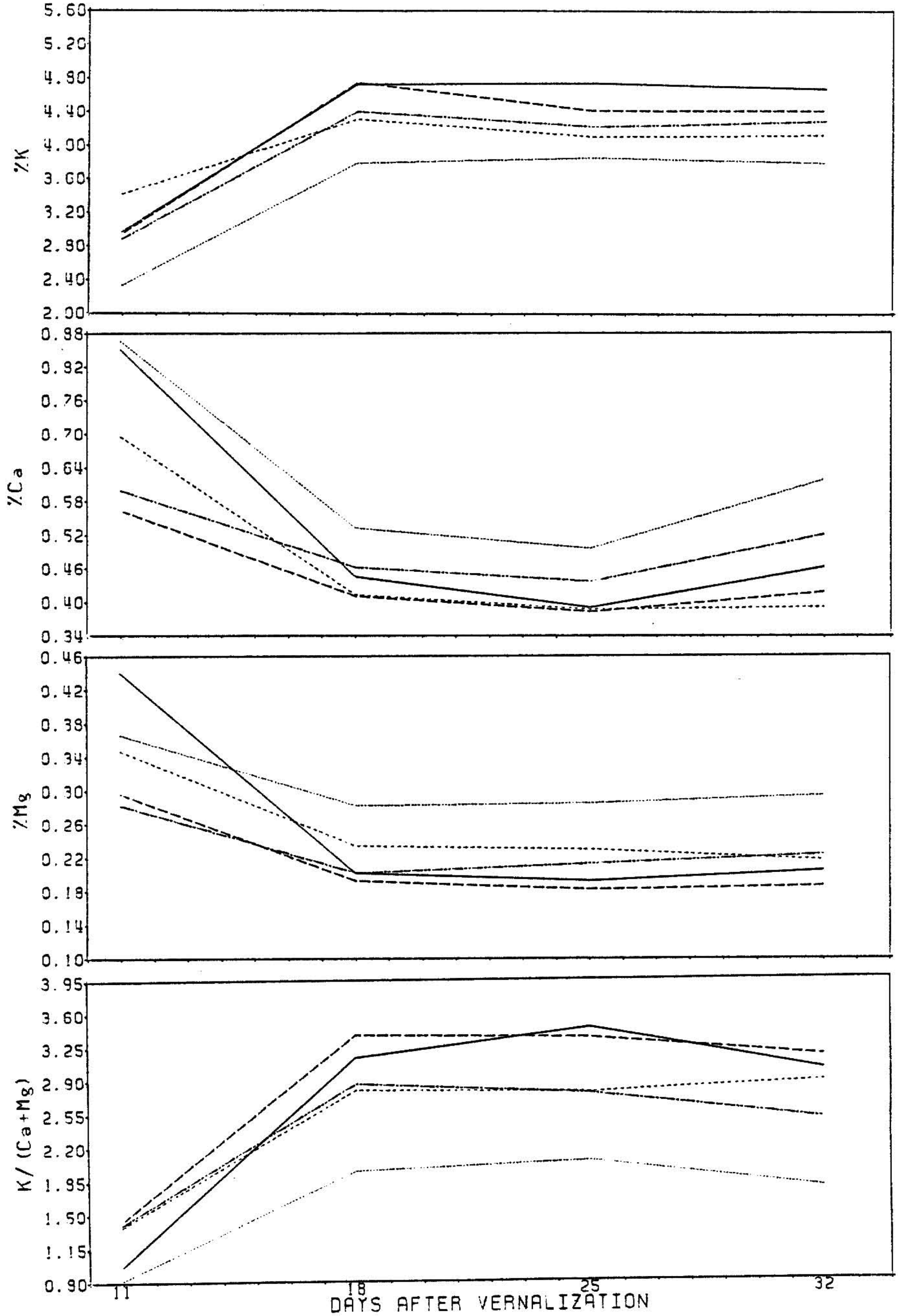
5.60
5.20
4.80
4.40
4.00
3.60
3.20
2.80
2.40
2.00
%K
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0.92
0.76
0.70
0.64
0.58
0.52
0.46
0.40
0.34
%Ca
0.46
0.42
0.38
0.34
0.30
0.26
0.22
0.18
0.14
0.10
%Mg
3.95
3.60
3.25
2.90
2.55
2.20
1.85
1.50
1.15
0.90
K/(Ca+Mg)
11
18
25
32
DAYS AFTER VERNALIZATION

Figure 7. Plant Na, the ratio of K:Na, total dry weight, and % dry matter plotted by species over time for plants grown at 60% of field capacity.

LEGEND

- ___ BARLEY
- ...... OATS
- --- RYE
- -- TRITICALE
- _.. WHEAT

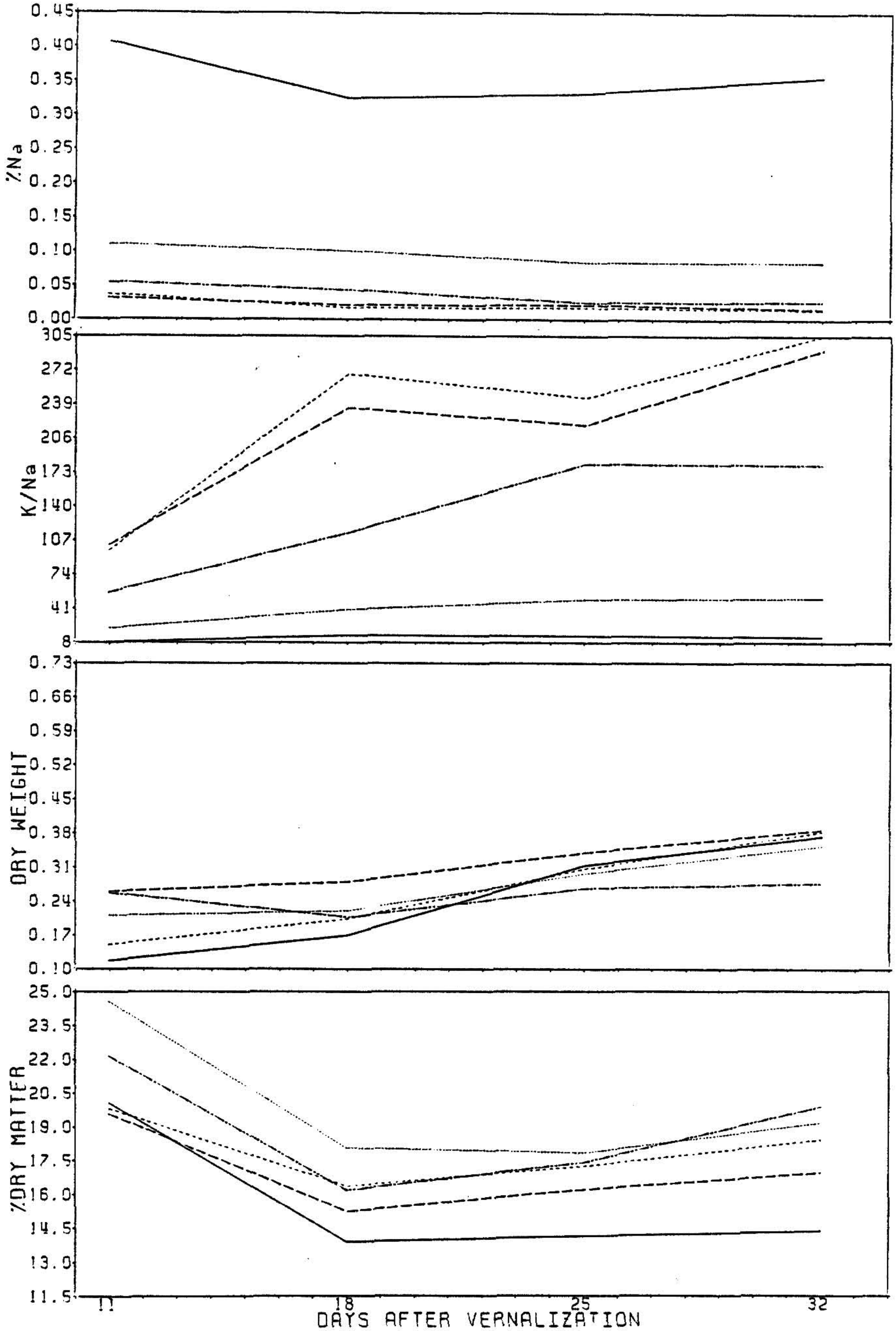

%Na
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
K/Na
305
272
239
206
173
140
107
74
41
8
DRY WEIGHT
0.73
0.66
0.59
0.52
0.45
0.38
0.31
0.24
0.17
0.10
%DRY MATTER
25.0
23.5
22.0
20.5
19.0
17.5
16.0
14.5
13.0
11.5
11
18
25
32
DAYS AFTER VERNALIZATION

Figure 8. Plant K, Ca, and Mg and the cation ratio plotted by species over time for plants grown at 125% of field capacity.

LEGEND

—— BARLEY
...... OATS
--- RYE
-- TRITICALE
—.. WHEAT

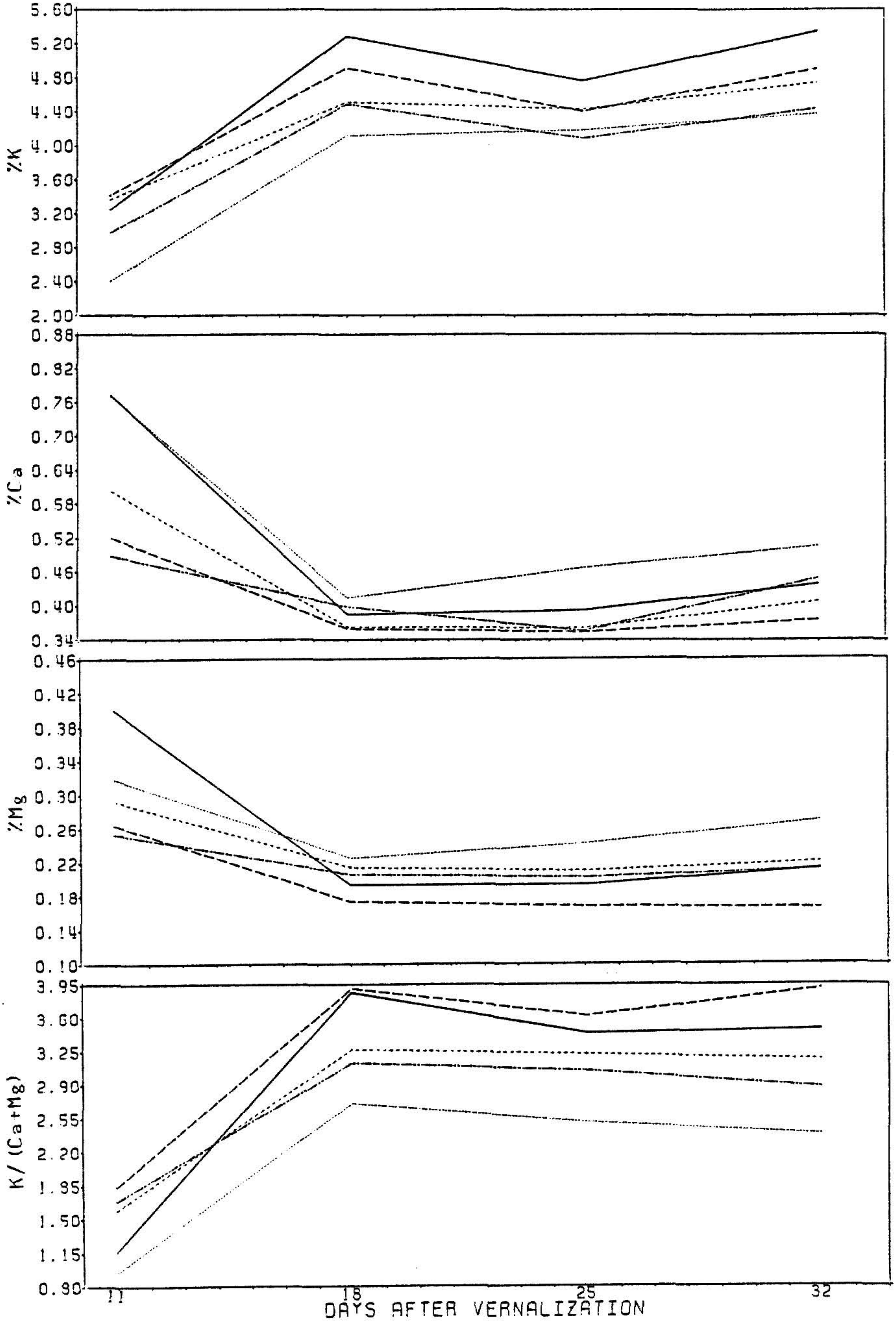
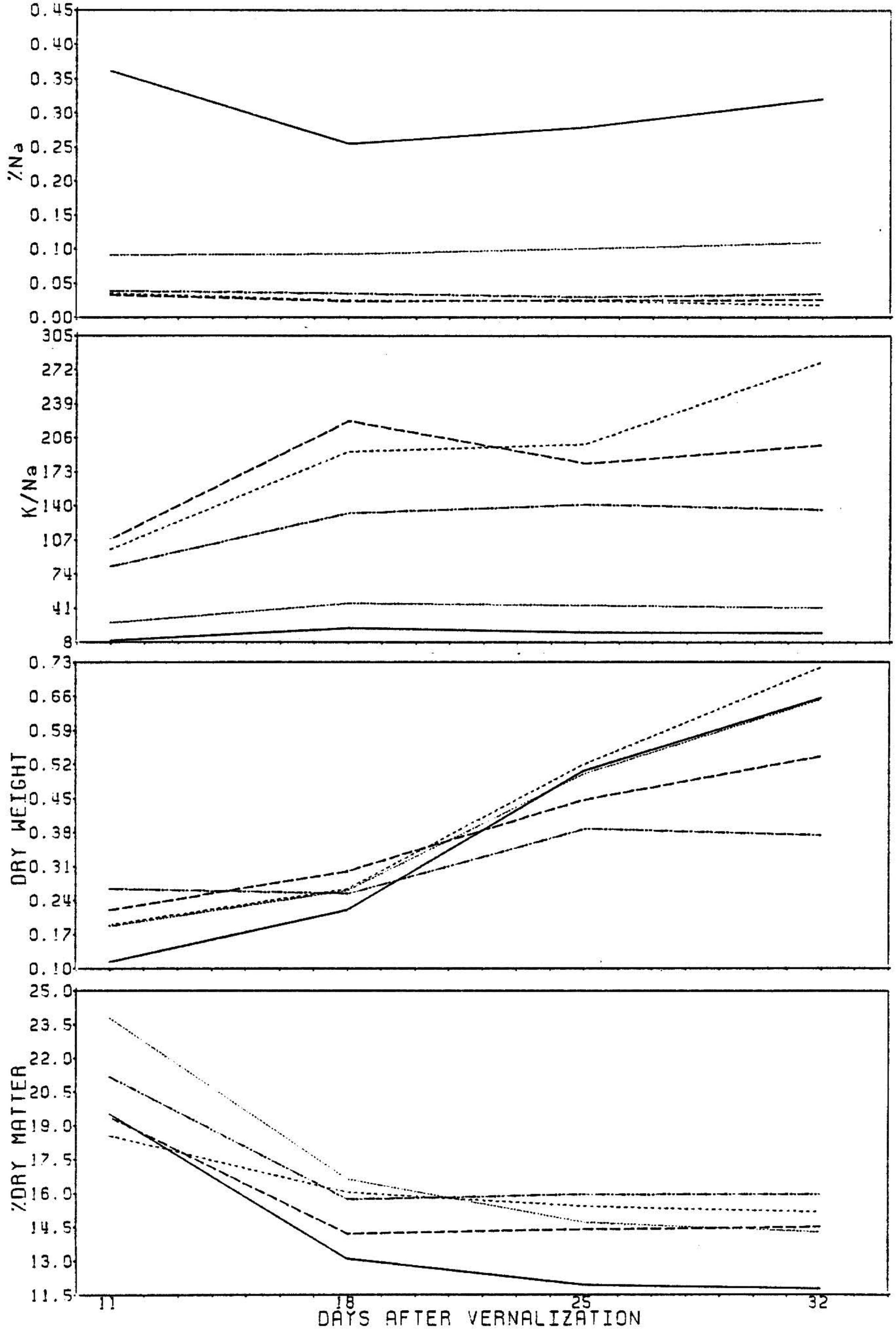

%K
5.60
5.20
4.80
4.40
4.00
3.60
3.20
2.80
2.40
2.00
%Ca
0.88
0.82
0.76
0.70
0.64
0.58
0.52
0.46
0.40
0.34
%Mg
0.46
0.42
0.38
0.34
0.30
0.26
0.22
0.18
0.14
0.10
K/(Ca+Mg)
3.95
3.60
3.25
2.90
2.55
2.20
1.85
1.50
1.15
0.90
11
18
25
32
DAYS AFTER VERNALIZATION

Figure 9. Plant Na, the ratio of K:Na, total dry weight, and % dry matter plotted by species over time for plants grown at 125% of field capacity.

LEGEND

—— BARLEY
...... OATS
--- RYE
-- TRITICALE
—.. WHEAT


0.45
0.40
0.35
0.30
%Na 0.25
0.20
0.15
0.10
0.05
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305
272
239
206
K/Na 173
140
107
74
41
8
0.73
0.66
0.59
0.52
DRY WEIGHT 0.45
0.38
0.31
0.24
0.17
0.10
25.0
23.5
22.0
%DRY MATTER 20.5
19.0
17.5
16.0
14.5
13.0
11.5
11
18
25
32
DAYS AFTER VERNALIZATION

Experiment III

Materials & Methods:

A field experiment was conducted near the Southeast Kansas Experiment Field at Parsons, Kansas, during the spring of 1980 to determine the effectiveness of various rates of potassium applied by broadcast and knifed methods in increasing the yield of winter wheat (Triticum aestivum) grown on these low K soils. Since K fertilization has been implicated in grass tetany, forage samples were taken from the plots at three different times to determine the influence of the different K treatments on the forage quality indices related to grass tetany.

Most of the soils in this area are Parsons silt loams and are classified as Mollic Albaqualfs. The soils have a fine silty texture, no predominant clay type, and formed under a thermic temperature regime. Chemical analysis of the soil was performed using the standard procedures of the KSU Soil Testing Laboratory and the results are shown in Table 10.

There were seven treatments; a check, 30, 60, and 90 pounds per acre of K_2O broadcast, and 30, 60, and 90 pounds per acre of K_2O knifed. These treatments were replicated four times in a randomized complete block design. Treatments were applied to the plots on September 24, 1979, and Newton wheat was planted on October 17th.

Grab samples were taken April 10th, 25th, and May 2nd. In this part of Kansas the wheat usually breaks dormancy around mid-March and reaches the jointing stage the first of May. The first two samples were taken while the plants were still vegetative and the third sample just as the plants were beginning to joint. The samples were dried at 55 C in a forced air over and ground to pass a 1 mm mesh screen. Quarter gram samples were digested in 2.0 ml

Table 10: Soil characteristics for Experiment III. Samples were taken April 10th and values shown are means taken over replication.

K Rate & Method [1]	pH[2]	Bray 1[3] P	Exchangeable[4] K	Ca	Mg
		ppm			
0	6.6	7.4	85	1760	235
30 B	6.5	7.6	84	1540	182
30 K	6.6	8.0	82	1490	161
60 B	6.5	7.7	81	1560	166
60 K	6.6	7.2	80	1580	206
90 B	6.6	8.4	82	1540	163
90 K	6.5	7.6	82	1530	176

1. B = Broadcast   K = Knifed   K Rate = pounds K_2O per acre.
2. Determined using a 1:1 mixture of soil and distilled deionized water (28).
3. See reference 21.
4. Determined using 1 N NH_4OAc pH 7.0 extracts. Potassium was determined using flame emission, Ca and Mg by atomic absorption after diluting the extract 1:20 with a 0.5% solution of Lanthanum oxide to reduce anion interference (2).

of sulfuric acid using several 1.0 ml aliquots of H_2O_2 to oxidize the organic compounds. Determinations for total N, P, and K were made on these digests, N and P were determined by a colorimetric procedure using a Technicon Auto-analyzer, and K was determined by flame emission. Second quarter gram samples of the tissue were digested in 7.5 ml of a 1:1 mixture of nitric and perchloric acids. Calcium and Mg determinations were made on these digests using atomic absorption and a 0.5% solution of Lanthanum oxide to reduce anion interference. The data were analyzed using the GLM procedure of SAS and means compared using calculated LSD values. The SAS data set for this experiment has been reproduced in Appendix Table 3.

Results & Discussion:

No P fertilizer was added to these plots and the site proved to be deficient in P as another study in the same field showed marked response to P fertilization. Therefore, because phosphorus was probably limiting growth, the response to K may be different under optimal P conditions, compared to those found under the poor P status of this study.

Statistical analysis revealed that overall there were no significant differences in plant nutrient uptake due to the different treatments. However, study of the means taken over replications (Table 11) did reveal the following trends.

As would be expected plants grown on the check plots had the lowest K content while those grown at the higher K application rates usually had the most. The plants in the check plots also tended to have higher concentrations of Ca and Mg while those grown with 30 lb/A K knifed and 60 lb/A K broadcast for some reason had the lowest concentrations. This resulted in plants from

Table 11: Chemical composition of wheat forage as influenced by K rate and method of K application (means taken over replications).

K Rate &[1] Method	%N	%P	%K	%Ca	%Mg	$\frac{K}{(Ca+Mg)}$[2]
			April 10			
0	3.28	0.17	2.63	0.32	0.11	2.66
30 B	3.38	0.17	2.86	0.32	0.12	2.92
30 K	3.34	0.17	2.79	0.32	0.11	2.86
60 B	3.26	0.17	2.70	0.28	0.10	3.03
60 K	3.36	0.18	2.88	0.33	0.12	2.82
90 B	3.42	0.17	2.86	0.33	0.11	2.86
90 K	3.48	0.18	2.87	0.32	0.12	2.88
LSD (.05)	0.29	0.01	0.31	0.04	0.01	0.53
			April 25			
0	3.38	0.22	2.72	0.36	0.13	2.46
30 B	3.34	0.21	2.74	0.35	0.13	2.56
30 K	3.45	0.22	2.88	0.34	0.12	2.69
60 B	3.46	0.22	2.84	0.32	0.12	2.82
60 K	3.66	0.22	2.76	0.35	0.13	2.57
90 B	3.36	0.21	2.84	0.35	0.12	2.64
90 K	3.53	0.22	2.86	0.33	0.13	2.70
LSD (.05)	0.47	0.03	0.34	0.06	0.02	0.60
			May 2			
0	3.07	0.21	2.04	0.43	0.13	1.63
30 B	3.04	0.22	2.20	0.41	0.13	1.84
30 K	2.80	0.22	2.16	0.37	0.12	1.98
60 B	2.79	0.22	2.12	0.39	0.12	1.85
60 K	3.15	0.21	2.18	0.41	0.13	1.80
90 B	2.96	0.21	2.16	0.43	0.13	1.72
90 K	3.06	0.21	2.12	0.38	0.12	1.89
LSD (.05)	0.29	0.01	0.32	0.04	0.01	0.34

1. B = Broadcast K = Knifed K Rate = pounds K_2O per acre.
2. Milliequivalent ratio calculated from individual replications.

the check plots having the lowest cation ratios while plants from the treatments with 60 lb/A K broadcast and 90 lb/A K knifed had the highest cation ratios. The P content of the plants was fairly uniform probably due to limited P availability while N content seemed to be enhanced by the higher K application rates.

Comparison of the chemical composition from date to date revealed a general increase in plant concentration of Ca and Mg as the plants matured resulting in a decrease of the equivalent cation ratios. The K, N, and P content of the plants increased between April 10th and April 25th and then decreased, with K and N levels becoming lower than those on April 10.

In general the data from this experiment was too variable to draw any definite conclusions as to the influence of K rate and method of K application on the chemical composition of wheat.

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APPENDIX

TABLE I

SAS DATA SET FOR EXPERIMENT I - FALL 1979
DATE=1

VARIETY	MOISTURE	KRATE	REP	WETWT	DRYWT	%DRY MATTER	%K	%CA	%MG	RATIO
CENTURK	60	LOW	1	0.13	0.01	7.69	.	.	.	.
CENTURK	60	LOW	2	0.93	0.20	21.51	3.61	0.37	0.21	2.57
CENTURK	60	LOW	3	0.65	0.13	20.00	3.30	0.39	0.24	2.17
CENTURK	60	HIGH	1	0.14	0.01	7.14	.	.	.	.
CENTURK	60	HIGH	2	0.08	0.00	6.25	.	.	.	.
CENTURK	60	HIGH	3	0.12	0.02	16.67	.	.	.	.
CENTURK	125	LOW	1	0.00	0.00	.	.	.	.	.
CENTURK	125	LOW	2	0.85	0.22	25.88	2.48	0.37	0.14	2.14
CENTURK	125	LOW	3	1.24	0.26	20.97	2.91	0.49	0.20	1.81
CENTURK	125	HIGH	1	1.04	0.21	20.19	3.02	0.48	0.22	1.82
CENTURK	125	HIGH	2	0.80	0.18	22.50	2.90	0.31	0.16	2.55
CENTURK	125	HIGH	3	0.33	0.07	21.21	1.36	0.54	0.28	0.50
EAGLE	60	LOW	1	1.13	0.22	19.47	3.26	0.47	0.31	1.42
EAGLE	60	LOW	2	0.83	0.16	19.28	3.27	0.65	0.33	1.40
EAGLE	60	LOW	3	0.91	0.17	18.68	3.59	0.71	0.33	1.62
EAGLE	60	HIGH	1	0.98	0.22	22.45	2.57	0.66	0.29	1.15
EAGLE	60	HIGH	2	0.34	0.08	23.53	2.92	0.49	0.20	1.83
EAGLE	60	HIGH	3	1.19	0.24	20.17	2.75	0.61	0.31	1.27
EAGLE	125	LOW	1	1.22	0.28	22.95	2.47	0.38	0.19	1.84
EAGLE	125	LOW	2	1.06	0.22	20.75	3.02	0.35	0.21	2.12
EAGLE	125	LOW	3	0.83	0.18	21.69	3.40	0.36	0.19	2.62
EAGLE	125	HIGH	1	1.17	0.23	19.66	3.25	0.46	0.24	1.97
EAGLE	125	HIGH	2	2.46	0.40	16.26	3.65	0.48	0.22	2.24
EAGLE	125	HIGH	3	1.15	0.23	20.00	3.58	0.64	0.24	1.79
NEWTON	60	LOW	1	1.40	0.29	20.71	2.13	0.75	0.32	0.85
NEWTON	60	LOW	2	0.86	0.18	20.93	2.33	0.55	0.26	1.72
NEWTON	60	LOW	3	1.72	0.38	22.09	1.66	0.62	0.25	0.92
NEWTON	60	HIGH	1	1.95	0.45	23.08	2.38	0.84	0.33	0.88
NEWTON	60	HIGH	2	1.36	0.28	20.59	2.52	0.57	0.23	1.36
NEWTON	60	HIGH	3	1.82	0.39	21.43	2.24	0.70	0.26	1.03
NEWTON	125	LOW	1	1.63	0.38	23.31	2.07	0.50	0.25	1.18
NEWTON	125	LOW	2	1.28	0.28	21.88	2.54	0.56	0.25	1.33
NEWTON	125	LOW	3	1.29	0.27	20.93	2.83	0.53	0.26	1.53
NEWTON	125	HIGH	1	1.72	0.32	18.60	2.35	0.48	0.24	1.38
NEWTON	125	HIGH	2	0.74	0.14	18.92	3.45	0.43	0.21	2.29
NEWTON	125	HIGH	3	0.80	0.18	22.50	2.95	0.43	0.20	2.00
TAM105	60	LOW	1	1.53	0.28	18.30	2.52	0.26	0.11	2.92
TAM105	60	LOW	2	0.32	0.07	21.87	2.98	0.32	0.16	2.58
TAM105	60	LOW	3	0.65	0.12	18.46	3.56	0.42	0.24	2.26
TAM105	60	HIGH	1	0.48	0.10	20.83	2.59	0.47	0.22	1.58
TAM105	60	HIGH	2	0.69	0.15	21.74	3.12	0.44	0.20	2.08
TAM105	60	HIGH	3	0.95	0.22	23.16	2.46	0.43	0.18	1.73
TAM105	125	LOW	1	1.14	0.26	22.81	2.40	0.37	0.18	1.82
TAM105	125	LOW	2	1.24	0.30	24.19	2.28	0.31	0.15	2.09
TAM105	125	LOW	3	0.60	0.16	26.67	1.40	0.58	0.27	0.50
TAM105	125	HIGH	1	0.73	0.17	23.29	2.65	0.33	0.16	2.26
TAM105	125	HIGH	2	1.12	0.22	19.64	2.57	0.82	0.26	1.23
TAM105	125	HIGH	3	0.82	0.19	23.17	1.80	1.16	0.31	0.55

TABLE 1 CONT...

SAS DATA SET FOR EXPERIMENT I - FALL 1979
DATE=2

VARIETY	MOISTURE	KRATE	REP	WETWT	DRYWT	%DRY MATTER	%K	%CA	%MG	RATIO
CENTURK	60	LOW	1	0.54	0.09	16.67	3.92	0.50	0.26	2.18
CENTURK	60	LOW	2	2.07	0.42	20.29	2.34	0.57	0.24	1.24
CENTURK	60	LOW	3	1.41	0.29	20.57	2.60	0.57	0.25	1.36
CENTURK	60	HIGH	1	0.32	0.03	9.38	3.33	0.61	0.25	1.66
CENTURK	60	HIGH	2	0.25	0.03	12.00	3.33	0.61	0.25	1.66
CENTURK	60	HIGH	3	0.40	0.07	17.50	3.38	0.61	0.27	1.63
CENTURK	125	LOW	1	0.09	0.00	0.00	.	.	.	.
CENTURK	125	LOW	2	2.01	0.38	18.91	2.50	0.52	0.18	1.56
CENTURK	125	LOW	3	3.78	0.72	19.05	2.55	0.43	0.22	1.67
CENTURK	125	HIGH	1	2.79	0.51	18.28	2.65	0.40	0.20	1.87
CENTURK	125	HIGH	2	2.63	0.55	20.91	2.25	0.45	0.19	1.50
CENTURK	125	HIGH	3	0.79	0.12	15.19	3.08	1.00	0.28	1.08
EAGLE	60	LOW	1	1.89	0.35	18.52	2.60	0.48	0.22	1.59
EAGLE	60	LOW	2	1.80	0.31	17.22	2.78	0.60	0.26	1.38
EAGLE	60	LOW	3	1.22	0.23	18.85	2.75	0.57	0.25	1.45
EAGLE	60	HIGH	1	3.16	0.61	19.30	2.15	0.58	0.22	1.18
EAGLE	60	HIGH	2	1.50	0.31	20.67	2.21	0.64	0.21	1.15
EAGLE	60	HIGH	3	2.43	0.47	19.34	2.20	0.55	0.20	1.28
EAGLE	125	LOW	1	4.65	0.73	15.70	2.18	0.54	0.24	1.19
EAGLE	125	LOW	2	3.10	0.52	16.77	2.40	0.48	0.23	1.44
EAGLE	125	LOW	3	2.93	0.51	17.41	2.43	0.46	0.22	1.52
EAGLE	125	HIGH	1	3.88	0.69	17.78	2.64	0.52	0.23	1.50
EAGLE	125	HIGH	2	5.78	1.01	17.47	2.60	0.42	0.21	1.76
EAGLE	125	HIGH	3	1.21	0.21	17.36	2.44	0.68	0.23	1.19
NEWTON	60	LOW	1	2.68	0.51	19.03	2.25	0.56	0.21	1.27
NEWTON	60	LOW	2	2.06	0.41	19.90	2.30	0.52	0.21	1.35
NEWTON	60	LOW	3	2.33	0.50	21.46	2.47	0.53	0.20	1.47
NEWTON	60	HIGH	1	2.88	0.63	21.88	2.45	0.68	0.23	1.19
NEWTON	60	HIGH	2	2.26	0.51	22.57	2.17	0.50	0.19	1.37
NEWTON	60	HIGH	3	3.05	0.64	20.98	2.50	0.54	0.20	1.46
NEWTON	125	LOW	1	4.77	0.91	19.08	2.33	0.57	0.23	1.27
NEWTON	125	LOW	2	4.91	0.88	17.92	2.55	0.57	0.23	1.36
NEWTON	125	LOW	3	3.91	0.73	18.67	2.75	0.54	0.22	1.56
NEWTON	125	HIGH	1	3.00	0.58	19.33	2.87	0.69	0.25	1.34
NEWTON	125	HIGH	2	2.61	0.52	19.92	2.87	0.56	0.23	1.56
NEWTON	125	HIGH	3	3.64	0.59	16.21	3.00	0.55	0.21	1.72
TAM105	60	LOW	1	1.15	0.40	34.78	2.40	0.45	0.20	1.57
TAM105	60	LOW	2	1.80	0.39	21.67	2.25	0.52	0.19	1.38
TAM105	60	LOW	3	1.55	0.31	20.00	2.57	0.50	0.19	1.62
TAM105	60	HIGH	1	1.57	0.33	21.02	2.23	0.48	0.17	1.49
TAM105	60	HIGH	2	1.89	0.36	19.05	2.33	0.51	0.24	1.31
TAM105	60	HIGH	3	2.18	0.50	22.94	2.20	0.42	0.16	1.62
TAM105	125	LOW	1	2.97	0.63	21.21	2.36	0.43	0.21	1.56
TAM105	125	LOW	2	3.80	0.69	18.16	2.63	0.42	0.21	1.77
TAM105	125	LOW	3	0.59	0.12	20.34	2.33	0.67	0.23	1.13
TAM105	125	HIGH	1	3.59	0.67	18.66	2.30	0.41	0.21	1.54
TAM105	125	HIGH	2	2.55	0.49	19.22	2.27	0.35	0.18	1.78
TAM105	125	HIGH	3	1.06	0.20	18.87	2.62	0.86	0.24	1.06

TABLE 1 CONT...

SAS DATA SET FOR EXPERIMENT I - FALL 1979
DATE=3

VARIETY	MOISTURE	KRATE	REP	WETWT	DRYWT	%DRY MATTER	%K	%CA	%MG	RATIO
CENTURK	60	LOW	1	1.00	0.19	19.00	3.43	0.54	0.25	1.84
CENTURK	60	LOW	2	2.21	0.46	20.81	2.65	0.54	0.23	1.48
CENTURK	60	LOW	3	1.87	0.42	22.46	2.34	0.53	0.24	1.30
CENTURK	60	HIGH	1	0.39	0.08	20.51	3.47	0.51	0.24	1.97
CENTURK	60	HIGH	2	0.21	0.02	9.52	.	.	.	.
CENTURK	60	HIGH	3	0.44	0.10	22.73	3.41	0.46	0.23	2.09
CENTURK	125	LOW	1	0.21	0.03	14.29	.	.	.	.
CENTURK	125	LOW	2	2.43	0.49	20.16	2.47	0.41	0.21	1.68
CENTURK	125	LOW	3	4.77	0.93	19.50	2.87	0.50	0.26	1.58
CENTURK	125	HIGH	1	3.32	0.63	18.98	2.73	0.42	0.22	1.78
CENTURK	125	HIGH	2	4.04	0.82	20.30	2.73	0.42	0.21	1.81
CENTURK	125	HIGH	3	1.82	0.33	18.13	2.47	0.36	0.16	2.04
EAGLE	60	LOW	1	0.73	0.16	21.92	3.38	0.56	0.21	1.90
EAGLE	60	LOW	2	1.57	0.33	21.02	2.35	0.49	0.23	1.39
EAGLE	60	LOW	3	0.36	0.07	19.44	3.44	0.58	0.25	1.76
EAGLE	60	HIGH	1	2.22	0.50	22.52	2.07	0.46	0.18	1.39
EAGLE	60	HIGH	2	2.05	0.43	20.98	2.34	0.38	0.17	1.83
EAGLE	60	HIGH	3	2.80	0.61	21.79	2.68	0.55	0.20	1.55
EAGLE	125	LOW	1	5.80	1.13	19.48	2.20	0.49	0.27	1.22
EAGLE	125	LOW	2	6.97	1.31	18.79	2.75	0.44	0.25	1.66
EAGLE	125	LOW	3	5.08	0.84	16.54	2.47	0.44	0.23	1.55
EAGLE	125	HIGH	1	5.14	0.98	19.07	2.70	0.54	0.22	1.54
EAGLE	125	HIGH	2	5.60	1.06	18.93	2.55	0.42	0.22	1.68
EAGLE	125	HIGH	3	0.70	0.11	15.71	3.33	0.44	0.18	2.30
NEWTON	60	LOW	1	1.38	0.29	21.01	2.17	0.60	0.23	1.13
NEWTON	60	LOW	2	0.69	0.14	20.29	3.05	0.51	0.22	1.80
NEWTON	60	LOW	3	1.17	0.24	20.51	2.50	0.51	0.22	1.48
NEWTON	60	HIGH	1	1.17	0.23	19.66	2.46	0.68	0.24	1.17
NEWTON	60	HIGH	2	1.24	0.27	21.77	2.44	0.41	0.18	1.79
NEWTON	60	HIGH	3	1.44	0.29	20.14	1.97	0.56	0.21	1.12
NEWTON	125	LOW	1	4.33	0.89	20.55	1.97	0.64	0.28	0.92
NEWTON	125	LOW	2	5.34	0.98	18.35	2.25	0.52	0.24	1.25
NEWTON	125	LOW	3	4.20	0.79	18.81	2.03	0.55	0.23	1.12
NEWTON	125	HIGH	1	4.05	0.90	22.22	2.25	0.48	0.20	1.41
NEWTON	125	HIGH	2	4.51	0.92	20.40	2.10	0.52	0.22	1.21
NEWTON	125	HIGH	3	4.77	0.88	18.45	2.35	0.45	0.21	1.51
TAM105	60	LOW	1	0.93	0.20	21.51	2.78	0.48	0.20	1.75
TAM105	60	LOW	2	1.37	0.29	21.17	2.10	0.49	0.20	1.32
TAM105	60	LOW	3	1.84	0.39	21.20	2.05	0.43	0.19	1.40
TAM105	60	HIGH	1	1.51	0.32	21.19	2.03	0.40	0.17	1.52
TAM105	60	HIGH	2	0.79	0.18	22.78	2.88	0.48	0.19	1.86
TAM105	60	HIGH	3	1.30	0.28	21.54	2.07	0.38	0.16	1.63
TAM105	125	LOW	1	4.22	0.90	21.33	1.93	0.45	0.20	1.26
TAM105	125	LOW	2	3.44	0.68	19.77	1.97	0.37	0.23	1.34
TAM105	125	LOW	3	1.03	0.21	20.39	2.38	0.40	0.20	1.65
TAM105	125	HIGH	1	5.20	0.97	18.65	1.97	0.42	0.23	1.26
TAM105	125	HIGH	2	1.04	0.20	19.23	2.88	0.37	0.17	2.29
TAM105	125	HIGH	3	0.80	0.18	22.50	2.78	0.31	0.16	2.49

TABLE 2

SAS DATA SET FOR EXPERIMENT II - FALL 1980
DATE=1

SPECIES	MOISTURE	REP	WETWT	DRYWT	%DRY MATTER	%K	%CA	%MG	%NA	RATIO	K/NA
BARLEY	60	1	0.54	0.11	20.37	2.78	0.80	0.45	0.55	0.92	5.05
OATS	60	1	0.90	0.20	22.22	2.60	0.76	0.35	0.11	1.01	22.61
RYE	60	1	0.76	0.14	18.42	3.58	0.70	0.35	0.04	1.44	95.33
TRITICAL	60	1	1.43	0.29	20.28	2.76	0.55	0.29	0.03	1.38	102.22
WHEAT	60	1	1.04	0.22	21.15	3.00	0.59	0.30	0.06	1.43	50.00
BARLEY	60	2	0.51	0.11	21.57	2.80	0.84	0.46	0.39	0.90	7.27
OATS	60	2	0.61	0.16	26.23	2.15	0.87	0.37	0.10	0.75	21.86
RYE	60	2	0.59	0.12	20.34	3.18	0.67	0.36	0.04	1.29	79.38
TRITICAL	60	2	0.90	0.18	20.00	3.03	0.57	0.33	0.04	1.40	72.80
WHEAT	60	2	1.10	0.25	22.73	3.09	0.53	0.26	0.04	1.66	74.85
BARLEY	60	3	0.71	0.13	18.31	3.33	0.91	0.41	0.29	1.07	11.67
OATS	60	3	1.07	0.27	25.23	2.23	0.97	0.38	0.11	0.71	19.39
RYE	60	3	0.92	0.19	20.65	3.48	0.71	0.34	0.03	1.41	116.11
TRITICAL	60	3	1.68	0.31	18.45	3.03	0.56	0.27	0.02	1.53	131.74
WHEAT	60	3	1.33	0.30	22.56	2.54	0.68	0.29	0.06	1.12	43.05
BARLEY	125	1	0.46	0.08	17.39	3.15	0.83	0.44	0.46	1.04	6.85
OATS	125	1	0.92	0.20	21.74	2.72	0.80	0.33	0.10	1.04	26.29
RYE	125	1	0.90	0.17	18.89	3.38	0.66	0.31	0.04	1.47	92.27
TRITICAL	125	1	1.01	0.20	19.80	3.40	0.52	0.29	0.03	1.74	113.33
WHEAT	125	1	1.20	0.26	21.67	2.92	0.52	0.28	0.04	1.52	67.91
BARLEY	125	2	0.52	0.10	19.23	3.55	0.78	0.39	0.34	1.28	10.44
OATS	125	2	0.81	0.19	23.46	2.52	0.81	0.32	0.09	0.96	27.96
RYE	125	2	1.17	0.20	17.09	3.65	0.59	0.30	0.04	1.73	99.55
TRITICAL	125	2	1.12	0.21	18.75	3.58	0.52	0.25	0.04	1.96	93.48
WHEAT	125	2	1.57	0.32	20.38	3.31	0.49	0.23	0.03	1.95	110.33
BARLEY	125	3	0.73	0.16	21.92	3.03	0.71	0.37	0.28	1.18	10.71
OATS	125	3	0.65	0.17	26.15	1.97	0.70	0.30	0.08	0.84	25.11
RYE	125	3	1.02	0.20	19.61	3.05	0.55	0.27	0.03	1.57	101.67
TRITICAL	125	3	1.28	0.25	19.53	3.25	0.51	0.25	0.03	1.81	116.07
WHEAT	125	3	0.98	0.21	21.43	2.67	0.45	0.24	0.04	1.60	64.85

TABLE 2 CONT...

SAS DATA SET FOR EXPERIMENT II - FALL 1980
DATE=2

SPECIES	MOISTURE	REP	WETWT	DRYWT	%DRY MATTER	%K	%CA	%MG	%NA	RATIO	K/NA
BARLEY	60	1	0.93	0.13	13.98	4.63	0.48	0.21	0.36	2.86	12.85
OATS	60	1	1.08	0.20	18.52	3.75	0.50	0.29	0.10	1.95	35.71
RYE	60	1	1.09	0.18	16.51	4.23	0.46	0.26	0.02	2.42	230.91
TRITICAL	60	1	1.28	0.21	16.41	4.67	0.47	0.21	0.02	2.95	233.33
WHEAT	60	1	1.02	0.18	17.65	4.43	0.50	0.22	0.04	2.62	102.31
BARLEY	60	2	0.97	0.15	15.46	4.65	0.38	0.19	0.28	3.47	16.76
OATS	60	2	1.02	0.19	18.63	3.77	0.51	0.26	0.07	2.05	51.36
RYE	60	2	1.03	0.18	17.48	4.20	0.42	0.21	0.01	2.80	315.00
TRITICAL	60	2	1.60	0.25	15.63	4.60	0.38	0.19	0.02	3.42	245.33
WHEAT	60	2	1.43	0.22	15.38	4.27	0.39	0.18	0.03	3.14	162.86
BARLEY	60	3	1.88	0.23	12.23	4.90	0.47	0.21	0.34	3.09	14.57
OATS	60	3	1.59	0.27	16.98	3.85	0.58	0.29	0.12	1.86	31.82
RYE	60	3	1.66	0.25	15.06	4.50	0.36	0.23	0.02	3.16	257.14
TRITICAL	60	3	2.78	0.38	13.67	4.97	0.38	0.18	0.02	3.75	225.91
WHEAT	60	3	1.42	0.22	15.49	4.50	0.49	0.20	0.06	2.82	77.14
BARLEY	125	1	1.48	0.19	12.84	5.07	0.40	0.20	0.29	3.57	17.27
OATS	125	1	1.54	0.26	16.88	4.07	0.43	0.24	0.09	2.56	45.28
RYE	125	1	1.50	0.25	16.67	4.42	0.39	0.23	0.03	2.95	153.91
TRITICAL	125	1	1.80	0.26	14.44	4.75	0.34	0.17	0.02	3.87	250.00
WHEAT	125	1	1.44	0.22	15.28	4.38	0.42	0.21	0.04	2.93	112.90
BARLEY	125	2	1.61	0.22	13.66	5.25	0.35	0.18	0.20	4.16	25.61
OATS	125	2	1.77	0.28	15.82	4.27	0.37	0.21	0.08	3.07	52.72
RYE	125	2	1.92	0.30	15.63	4.65	0.31	0.19	0.02	3.79	186.00
TRITICAL	125	2	2.18	0.31	14.22	4.99	0.37	0.17	0.03	3.87	178.21
WHEAT	125	2	2.08	0.33	15.87	4.49	0.39	0.20	0.03	3.17	144.84
BARLEY	125	3	1.96	0.25	12.76	5.54	0.41	0.19	0.26	3.87	20.90
OATS	125	3	1.40	0.24	17.14	4.00	0.45	0.23	0.10	2.49	38.10
RYE	125	3	1.52	0.24	15.79	4.45	0.39	0.22	0.02	3.06	237.33
TRITICAL	125	3	2.37	0.33	13.92	4.99	0.36	0.17	0.02	3.97	237.62
WHEAT	125	3	1.31	0.21	16.03	4.59	0.39	0.20	0.03	3.28	141.15

TABLE 2 CONT...

SAS DATA SET FOR EXPERIMENT II - FALL 1980
DATE=3

SPECIES	MOISTURE	REP	WETWT	DRYWT	%DRY MATTER	%K	%CA	%MG	%NA	RATIO	K/NA
BARLEY	60	1	1.68	0.24	14.29	4.81	0.38	0.20	0.33	3.52	14.42
OATS	60	1	1.52	0.27	17.76	3.93	0.48	0.31	0.09	2.03	45.70
RYE	60	1	1.42	0.23	16.20	4.19	0.42	0.26	0.02	2.51	257.69
TRITICAL	60	1	1.43	0.24	16.78	4.32	0.43	0.19	0.02	2.58	182.11
WHEAT	60	1	1.03	0.19	18.45	4.30	0.48	0.22	0.02	2.61	215.00
BARLEY	60	2	1.90	0.29	15.26	4.57	0.37	0.18	0.30	3.55	15.44
OATS	60	2	1.35	0.24	17.78	3.74	0.47	0.25	0.06	2.15	66.44
RYE	60	2	0.99	0.20	20.20	3.83	0.40	0.20	0.02	2.68	191.67
TRITICAL	60	2	1.78	0.30	16.85	4.38	0.34	0.17	0.01	3.64	291.67
WHEAT	60	2	1.67	0.29	17.37	3.58	0.40	0.20	0.02	2.79	199.00
BARLEY	60	3	3.18	0.41	12.89	4.84	0.42	0.20	0.36	3.27	13.26
OATS	60	3	2.12	0.38	17.92	3.89	0.53	0.29	0.11	1.97	36.02
RYE	60	3	3.20	0.49	15.31	4.29	0.34	0.22	0.01	3.12	286.00
TRITICAL	60	3	3.20	0.48	15.00	4.54	0.38	0.19	0.02	3.39	181.60
WHEAT	60	3	1.95	0.32	16.41	4.39	0.43	0.22	0.03	2.86	129.12
BARLEY	125	1	3.94	0.48	12.18	4.67	0.40	0.19	0.31	3.36	14.92
OATS	125	1	3.47	0.49	14.12	4.01	0.46	0.24	0.09	2.39	42.66
RYE	125	1	3.40	0.51	15.00	4.31	0.32	0.21	0.02	3.30	195.91
TRITICAL	125	1	3.22	0.45	13.98	4.58	0.30	0.16	0.02	4.21	190.83
WHEAT	125	1	2.46	0.37	15.04	4.16	0.35	0.20	0.03	3.14	154.07
BARLEY	125	2	4.13	0.49	11.86	4.65	0.38	0.18	0.25	3.53	18.38
OATS	125	2	4.06	0.56	13.79	4.34	0.40	0.22	0.08	2.92	53.58
RYE	125	2	3.74	0.57	15.24	4.44	0.37	0.20	0.02	3.23	246.67
TRITICAL	125	2	3.23	0.45	13.93	4.30	0.36	0.16	0.02	3.50	179.17
WHEAT	125	2	3.06	0.48	15.69	3.91	0.36	0.19	0.03	2.93	130.33
BARLEY	125	3	4.69	0.55	11.73	4.98	0.40	0.21	0.27	3.43	18.44
OATS	125	3	2.78	0.45	16.19	4.20	0.54	0.26	0.13	2.21	33.60
RYE	125	3	3.00	0.48	16.00	4.54	0.39	0.21	0.03	3.13	156.55
TRITICAL	125	3	2.88	0.44	15.28	4.33	0.40	0.18	0.02	3.16	173.20
WHEAT	125	3	1.81	0.31	17.13	4.19	0.35	0.21	0.03	3.06	139.67

TABLE 2 CONT...

SAS DATA SET FOR EXPERIMENT II - FALL 1980
DATE=4

SPECIES	MOISTURE	REP	WETWT	DRYWT	%DRY MATTER	%K	%CA	%MG	%NA	RATIO	K/NA
BARLEY	60	1	1.47	0.23	15.65	4.35	0.46	0.20	0.33	2.82	13.05
OATS	60	1	1.40	0.27	19.29	3.60	0.61	0.30	0.08	1.65	42.35
RYE	60	1	1.64	0.32	19.51	3.81	0.44	0.24	0.01	2.33	254.00
TRITICAL	60	1	1.56	0.28	17.95	4.05	0.44	0.20	0.02	2.69	238.24
WHEAT	60	1	0.84	0.16	19.05	4.00	0.55	0.22	0.03	2.27	150.00
BARLEY	60	2	2.42	0.32	13.22	4.78	0.45	0.20	0.34	3.14	14.02
OATS	60	2	1.63	0.31	19.02	3.78	0.59	0.27	0.05	1.87	74.12
RYE	60	2	0.57	0.19	19.59	3.82	0.39	0.21	0.02	2.65	229.00
TRITICAL	60	2	2.17	0.37	17.05	4.39	0.41	0.18	0.01	3.22	292.67
WHEAT	60	2	1.60	0.38	23.75	4.36	0.47	0.22	0.02	2.68	256.47
BARLEY	60	3	4.00	0.57	14.25	4.91	0.48	0.21	0.39	3.04	12.49
OATS	60	3	2.50	0.48	19.20	4.01	0.65	0.30	0.11	1.78	35.18
RYE	60	3	3.56	0.64	16.16	4.76	0.34	0.20	0.01	3.66	432.73
TRITICAL	60	3	3.21	0.51	15.89	4.82	0.40	0.18	0.01	3.51	344.29
WHEAT	60	3	1.72	0.29	16.86	4.53	0.54	0.24	0.03	2.49	133.24
BARLEY	125	1	4.83	0.58	12.01	5.12	0.47	0.22	0.34	3.16	15.19
OATS	125	1	4.26	0.60	14.08	4.38	0.51	0.27	0.09	2.35	47.61
RYE	125	1	4.63	0.68	14.69	4.61	0.37	0.22	0.02	3.24	256.11
TRITICAL	125	1	3.74	0.52	13.90	4.92	0.32	0.15	0.02	4.38	223.64
WHEAT	125	1	2.27	0.37	16.30	4.27	0.44	0.21	0.03	2.79	152.50
BARLEY	125	2	5.01	0.60	11.98	5.51	0.43	0.21	0.32	3.65	17.38
OATS	125	2	5.19	0.73	14.07	4.71	0.45	0.26	0.11	2.73	44.02
RYE	125	2	4.42	0.69	15.61	5.00	0.45	0.23	0.02	3.08	312.50
TRITICAL	125	2	3.47	0.50	14.41	5.10	0.40	0.17	0.03	3.80	170.00
WHEAT	125	2	2.22	0.37	16.67	4.71	0.52	0.23	0.04	2.70	107.05
BARLEY	125	3	7.00	0.79	11.29	5.40	0.42	0.21	0.31	3.63	17.59
OATS	125	3	4.29	0.63	14.69	4.04	0.56	0.27	0.13	2.06	31.56
RYE	125	3	5.19	0.79	15.22	4.62	0.41	0.21	0.02	3.16	271.76
TRITICAL	125	3	3.87	0.59	15.25	4.70	0.40	0.17	0.02	3.53	204.35
WHEAT	125	3	2.55	0.38	14.90	4.34	0.39	0.20	0.03	3.11	149.66

TABLE 3 SAS DATA SET FOR EXPERIMENT III - SPRING 1980
DATE=1

METHOD	K-RATE	BLOCK	%N	%P	%K	%CA	%MG	RATIO
CHECK	0	1	3.25	0.18	2.16	0.37	0.12	1.97
BROAD	30	1	3.23	0.16	2.40	0.38	0.12	2.13
BROAD	60	1	3.31	0.18	2.65	0.29	0.11	2.89
BROAD	90	1	3.36	0.17	2.58	0.30	0.10	2.83
KNIFE	30	1	3.28	0.17	2.75	0.28	0.11	3.07
KNIFE	60	1	3.30	0.18	2.77	0.32	0.12	2.75
KNIFE	90	1	3.52	0.18	2.94	0.33	0.12	2.86
CHECK	0	2	3.00	0.16	2.74	0.30	0.11	2.90
BROAD	30	2	3.31	0.18	3.02	0.30	0.12	3.09
BROAD	60	2	3.40	0.18	3.09	0.30	0.11	3.23
BROAD	90	2	3.45	0.18	3.18	0.30	0.12	3.30
KNIFE	30	2	3.47	0.17	2.86	0.34	0.13	2.70
KNIFE	60	2	3.42	0.18	3.12	0.34	0.13	2.86
KNIFE	90	2	3.35	0.17	2.83	0.33	0.12	2.75
CHECK	0	3	3.10	0.17	2.79	0.30	0.11	2.99
BROAD	30	3	3.45	0.18	3.35	0.27	0.11	3.84
BROAD	60	3	3.18	0.17	2.48	0.26	0.09	3.03
BROAD	90	3	3.39	0.17	2.99	0.35	0.12	2.77
KNIFE	30	3	3.60	0.17	2.77	0.35	0.12	2.56
KNIFE	60	3	3.22	0.17	2.91	0.32	0.11	2.97
KNIFE	90	3	3.38	0.17	2.87	0.29	0.11	3.14
CHECK	0	4	3.75	0.19	2.82	0.32	0.12	2.78
BROAD	30	4	3.52	0.17	2.69	0.32	0.12	2.63
BROAD	60	4	3.14	0.15	2.60	0.28	0.10	2.96
BROAD	90	4	3.48	0.16	2.67	0.35	0.11	2.56
KNIFE	30	4	3.02	0.17	2.78	0.28	0.11	3.11
KNIFE	60	4	3.52	0.18	2.71	0.34	0.11	2.67
KNIFE	90	4	3.65	0.19	2.85	0.33	0.12	2.77

TABLE 3 CONT... SAS DATA SET FOR EXPERIMENT III - SPRING 1980
DATE=2

METHOD	K-RATE	BLOCK	%N	%P	%K	%CA	%MG	RATIO
CHECK	0	1	3.10	0.19	2.52	0.38	0.13	2.20
BROAD	30	1	3.08	0.20	2.33	0.36	0.13	2.09
BROAD	60	1	3.79	0.23	2.80	0.31	0.11	2.89
BROAD	90	1	3.64	0.23	3.00	0.35	0.11	2.85
KNIFE	30	1	3.44	0.21	3.17	0.35	0.12	3.00
KNIFE	60	1	3.90	0.23	2.78	0.34	0.12	2.66
KNIFE	90	1	3.40	0.19	2.78	0.31	0.12	2.78
CHECK	0	2	3.62	0.21	2.65	0.41	0.13	2.16
BROAD	30	2	3.60	0.23	2.70	0.31	0.12	2.76
BROAD	60	2	3.29	0.21	2.90	0.30	0.11	3.01
BROAD	90	2	3.57	0.23	2.85	0.31	0.12	2.90
KNIFE	30	2	3.53	0.21	2.88	0.35	0.13	2.62
KNIFE	60	2	3.31	0.21	2.63	0.35	0.12	2.45
KNIFE	90	2	4.08	0.25	3.17	0.36	0.12	2.85
CHECK	0	3	3.41	0.24	3.17	0.33	0.11	3.13
BROAD	30	3	2.89	0.20	3.09	0.31	0.11	3.18
BROAD	60	3	3.58	0.25	3.00	0.35	0.12	2.81
BROAD	90	3	3.44	0.22	2.90	0.36	0.13	2.55
KNIFE	30	3	3.70	0.24	2.75	0.38	0.14	2.29
KNIFE	60	3	3.51	0.20	2.85	0.30	0.12	2.96
KNIFE	90	3	3.40	0.20	2.55	0.35	0.14	2.26
CHECK	0	4	3.40	0.22	2.55	0.33	0.14	2.36
BROAD	30	4	3.78	0.23	2.85	0.41	0.16	2.19
BROAD	60	4	3.20	0.20	2.67	0.34	0.12	2.57
BROAD	90	4	2.78	0.18	2.60	0.36	0.13	2.28
KNIFE	30	4	3.13	0.20	2.70	0.30	0.11	2.84
KNIFE	60	4	3.92	0.24	2.80	0.41	0.15	2.21
KNIFE	90	4	3.23	0.22	2.92	0.30	0.13	2.92

TABLE 3 CONT... SAS DATA SET FOR EXPERIMENT III - SPRING 1980
DATE=3

METHOD	K-RATE	BLOCK	%N	%P	%K	%CA	%MG	RATIO
CHECK	0	1	3.18	0.20	1.80	0.44	0.13	1.42
BROAD	30	1	3.16	0.22	1.86	0.42	0.13	1.50
BROAD	60	1	2.98	0.24	2.05	0.43	0.13	1.63
BROAD	90	1	2.90	0.22	2.22	0.45	0.13	1.71
KNIFE	30	1	2.98	0.21	2.41	0.41	0.12	2.04
KNIFE	60	1	3.11	0.21	1.93	0.43	0.13	1.54
KNIFE	90	1	2.82	0.21	1.78	0.45	0.14	1.33
CHECK	0	2	3.12	0.20	2.13	0.43	0.13	1.69
BROAD	30	2	3.00	0.21	1.97	0.45	0.14	1.48
BROAD	60	2	2.57	0.20	1.76	0.39	0.12	1.55
BROAD	90	2	3.08	0.22	2.13	0.43	0.14	1.66
KNIFE	30	2	2.68	0.22	1.82	0.34	0.11	1.76
KNIFE	60	2	3.00	0.20	2.10	0.37	0.12	1.91
KNIFE	90	2	2.99	0.20	1.96	0.35	0.12	1.82
CHECK	0	3	2.59	0.20	2.17	0.38	0.13	1.86
BROAD	30	3	2.82	0.21	2.65	0.37	0.13	2.36
BROAD	60	3	2.88	0.22	2.23	0.39	0.12	1.94
BROAD	90	3	2.94	0.20	2.23	0.41	0.13	1.86
KNIFE	30	3	2.88	0.22	2.12	0.35	0.11	2.01
KNIFE	60	3	3.21	0.20	2.55	0.40	0.13	2.13
KNIFE	90	3	3.21	0.21	2.25	0.31	0.10	2.37
CHECK	0	4	3.39	0.23	2.05	0.45	0.14	1.54
BROAD	30	4	3.20	0.23	2.34	0.40	0.12	2.02
BROAD	60	4	2.72	0.23	2.42	0.36	0.11	2.27
BROAD	90	4	2.92	0.21	2.05	0.41	0.13	1.65
KNIFE	30	4	2.68	0.22	2.27	0.36	0.12	2.10
KNIFE	60	4	3.29	0.23	2.15	0.45	0.14	1.61
KNIFE	90	4	3.22	0.23	2.50	0.41	0.13	2.05

THE EFFECT OF SOIL WATER AND POTASSIUM ON GRASS TETANY RELATED COMPONENTS OF CEREAL FORAGES

by

STUART COREY BRUBAKER

B.S., Kansas State University, 1979

AN ABSTRACT OF A MASTER'S THESIS

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Grass tetany, a metabolic disorder of ruminants resulting from low blood serum Mg concentrations, is usually fatal if not treated soon after symptoms appear. It generally occurs in the late fall and early spring in cattle grazing lush, green pastures and is believed to be related to the animals dietary intake of Mg and the ability of the animal to use the Mg.

Research was initiated at Kansas State University in 1975 to study the influence of soil and climatic factors on forage quality indices of grass tetany. These indices include plant concentrations of K, Mg, and Na, the equivalent ratio of K/(Ca+Mg), and a weight ratio of K:Na. Critical levels associated with these indices are Mg concentrations less than 0.2%, K concentrations greater than 2.5%, Na levels lower than 0.25%, equivalent ratios greater than 2.2, and a K:Na ratio greater than 8.0.

The objectives of the research presented here were to study the influence of K fertilization, high levels of soil water, and plant species or variety on the chemical composition of cereal grain forages. Two growth chamber studies and one field study were conducted between June, 1979 and December, 1980 to satisfy these objectives.

In the first growth chamber experiment the influence of soil water and K fertilization on the chemical composition of four varieties of winter wheat (Triticum aestivum) was studied. It was found that significant differences between wheat varieties do exist and that it is possible to have greater than 0.2% Mg and less than 2.5% K in the same plant. The study further emphasized the deleterious effects of high levels of soil water and high rates of K fertilization in that wheat forage grown under these conditions would be more likely to produce tetany in grazing animals.

The second growth chamber experiment further examined the influence of soil water on forage quality and compared the chemical composition of five species of cereal grain forages. Significant differences were found between species for many of the factors studied. The study showed that barley (Hoerdeum cereale) forage would be the most likely to produce tetany while oats (Avena sativa) would be the least likely. Again, the deleterious effects of high levels of soil water on forage quality were observed.

The field study was conducted to determine the influence of different rates of K fertilization and different methods of K application on the chemical composition of wheat forage. Unfortunately, poor plant growth due to limited phosphorus availability masked any effect the treatments may have had.