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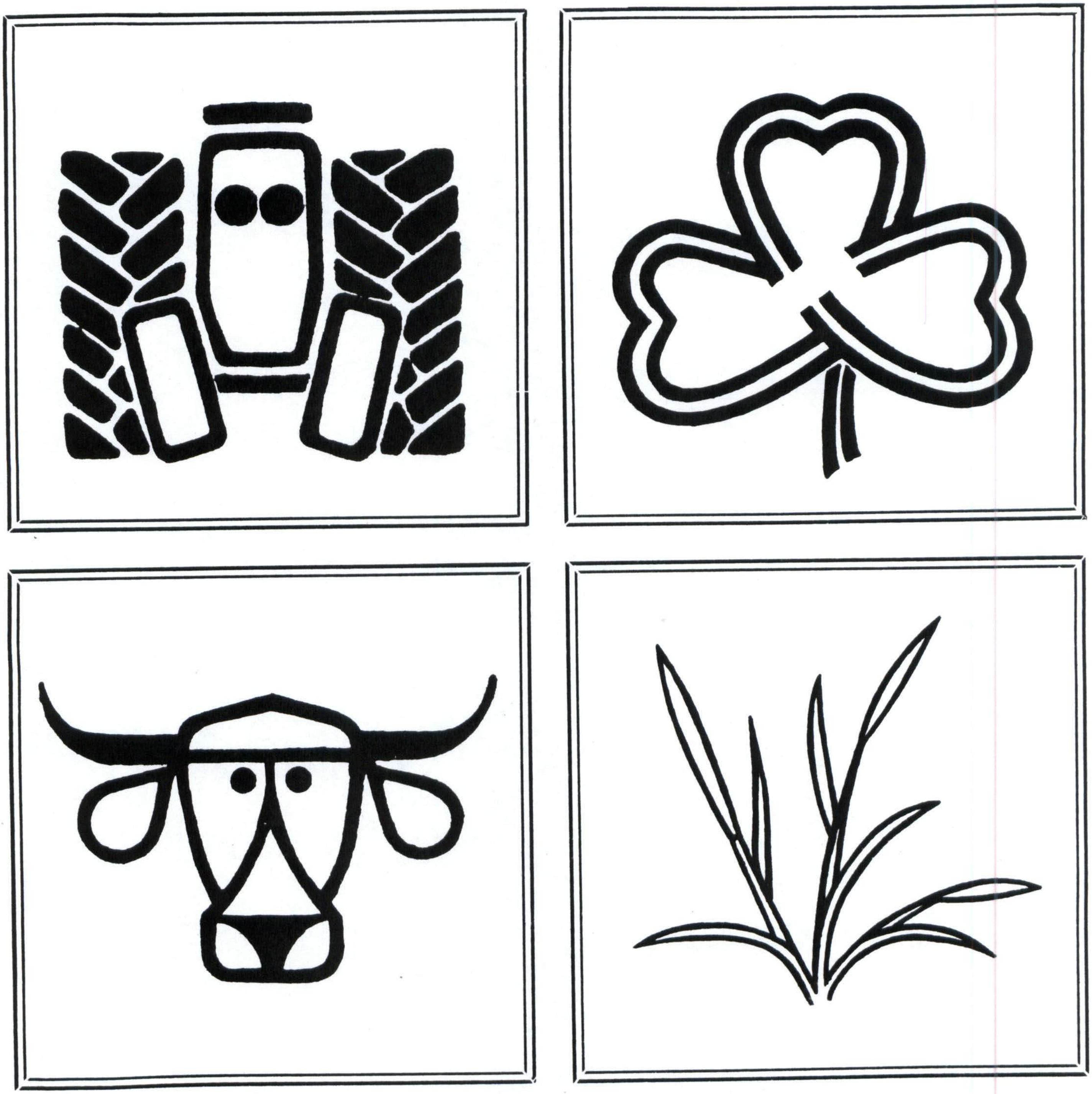

Forage Research in Texas

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Effect of Drought, Nitrogen and Sulfur on Alkaloid and Nitrate Concentrations in Pearl Millet

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SUMMARY

Three levels of nitrogen (N), 112, 224, and 336 kg N/ha (100, 200 and 300 lbs/ac); two levels of sulfur (S) 0 and 56 kg S/ha (0 and 50 lbs/ac); and two sprinkler irrigation treatments (irrigated versus nonirrigated) were applied to pearl millet to examine the influence on total alkaloid and nitrate concentrations in pearl millet leaves and stems. Hybrid pearl millet 'Millex 24'[1] was grown in the field on a Darco soil during the hot, dry summer of 1980 in East Texas. Sulfur had little effect on alkaloid and nitrate concentrations; whereas, increasing N rates elevated nitrate levels--particularly in irrigated plants--and also elevated alkaloid levels. In this study, drought stress did not significantly affect alkaloid levels. Leaf tissue, which made up 62% of the whole plant sample, contained higher levels of total alkaloid and lower levels of nitrate than stem tissue. In all cases, whole plant total alkaloid levels were fairly low. Whole plant nitrate levels were high enough to be considered potentially toxic only with very high rates of N fertilization (336 kg/ha) combined with irrigation.

Introduction

Pearl millet is frequently planted in late spring to provide mid-summer annual grazing for young growing cattle or for lactating dairy cows. It has been reported that pearl millet became unpalatable when growing under apparent drought stress conditions in East Texas. Laboratory analyses revealed that the unpalatable millet forage contained higher than normal levels of total alkaloids and potentially toxic levels of nitrates relative to palatable, apparently unstressed millet. The objectives of the studies reported here were to 1) examine the effects of plant water status and N and S fertilization on total alkaloid and nitrate concentrations in pearl millet; and 2) analyze leaf and stem tissue to better define the sites of alkaloid and nitrate accumulation in pearl millet.

Procedure

Studies were conducted in the field during the dry, hot summer of 1980 on an upland Darco soil (Grossarenic Paleudult; loamy, siliceous, thermic) in East Texas. Hybrid pearl millet 'Millex 24' was sown at 20 lbs/acre in 10-inch rows on 2 June 1980.

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[1]'Millex 24' hybrid pearl millet was provided by the Northrup-King Seed Company.

Experiment design was a split-split plot replicated four times. Whole plot was irrigation treatment, subplot was N fertilization rate, and sub-subplot was S application rate. All plants received a blanket application of 112 kg N, 112 kg P_2O_5, and 112 kg K_2O per acre on 15 June 1980. Additional N was applied as ammonium nitrate to achieve the following N treatments as kg N/ha: 1) 112, 2) 224, and 3) 336. Sulfur was applied as gypsum to half the plots at 56 kg S/ha. Irrigation treatments were 1) adequate sprinkler irrigation to prevent drought stress, and 2) no irrigation for the duration of the study. The millet plants received approximately 2 inches of rain from sowing date through 21 June 1980. No rain occurred past this date until harvest on 12 July 1980. Harvest date was based on reduced leaf elongation rate in nonirrigated plants, pressure bomb readings, and visible drought status.

Pearl millet plants were sampled 37 days past emergence, prior to flag leaf emergence. Samples were taken in the afternoon, frozen at -18°C and later separated into two components: leaf blades, and stems with leaf sheaths attached. These components were chopped and a portion of the plant tissue was analyzed for total alkaloid content. Another portion was oven dried and used for dry weight determination and nitrate analysis. Nitrate concentrations were determined by shaking dried plant tissue with deionized water, filtering, and measuring the nitrate content of the filtrate with an Orion nitrate ion electrode (model 92-97). Total basic alkaloids were extracted from frozen grass and measured by titration with p-toluene-sulfonic acid. Nitrate and total alkaloid content were calculated and reported on a dry weight basis. "Whole plant" refers to the total above ground plant sample. Whole plant nitrate and alkaloid levels were calculated proportionately from leaf and stem concentrations and leaf:stem ratios.

Leaf elongation rate, leaf xylem water potential, and soil water pressure were used as indicators of plant and soil water status in the studies conducted. Soil moisture and leaf xylem water potential were measured at sampling time. Leaf elongation rate is reported from 6 July through sampling date.

Results and Discussion

Pearl millet leaves were the site of higher alkaloid accumulation; whereas, stems were the site for higher nitrate levels. The mean leaf alkaloid concentration at 46 ppm total alkaloid was significantly higher than the mean stem concentration at 16 ppm ($P<0.01$). Mean leaf nitrate concentration, 5,133 ppm, was significantly lower than mean stem nitrate concentration, 14,049 ppm ($P<0.01$). At sampling time, drought status measurements differed significantly between irrigated and nonirrigated plants (Table 1).

Though mean alkaloid concentrations were slightly higher in nonirrigated millet than in irrigated plants, leaf and whole plant alkaloid levels were not significantly influenced by irrigation during the drought, N, and S study. Stem alkaloid levels differed statistically between irrigation treatments but the difference was too small to be meaningful (Table 2). Increasing N fertilization rate elevated alkaloid concentrations significantly. Figure 1 shows the linear regression of alkaloid concentration on N fertilization rate with 52% of the variability in whole plant alkaloid concentration being associated with N fertilization rate. Pearl millet whole plant nitrate concentration was significantly increased by irrigation ($P<0.01$), and by increasing N fertilization rate ($P<0.01$). However, there was a significant interaction of irrigation and N fertilization rate on plant nitrate concentration (Figure 2). While nitrate levels in nonirrigated and irrigated millet were relatively close at the lowest N rate, irrigated millet nitrate levels were nearly twice as high as levels in nonirrigated plants at the highest N rate. Sulfur application had little effect on either alkaloid or nitrate levels (Tables 3 and 4). Lower nitrate levels in nonirrigated plants may in part be due to water-deprived plants pushing their roots below the nitrate-containing zone of soil. The restricted amount of rain or applied water to these nonirrigated plots may have prevented leaching of the applied fertilizer N into this lower root zone. Alkaloid levels were low in this study relative to those previously reported for pearl millet in East Texas, possibly because the millet hybrid used in this study may be an inherently low alkaloid line (1) and is genetically different from 'Millex 23' which was the line previously reported to become unpalatable. Whole plant nitrate concentrations entered the potentially toxic range (which begins at 15,000 to 20,000 ppm nitrate) only when plants were irrigated and fertilized at 336 kg N/ha, which may not be an economically suitable rate of N fertilization.

Literature Cited

1. Krejsa, Beverly B., F. M. Rouquette, Jr., L. R. Nelson, E. C. Holt, and B. J. Camp. 1982. Total alkaloid and nitrate content of eleven pearl millet lines. Forage Research in Texas CPR 4024:67-69.

Table 1. Plant and soil water status in irrigated and nonirrigated Millex 24 pearl millet during the drought, N, and S study.

	Water status measurements		
Treatment	Soil water pressure (kPa)[3]	Leaf xylem water potential (kPa)	Leaf elongation rate (cm/48 hrs)
Irrigated	-26 a[1]	-249 a[2]	36.9 a[2]
Nonirrigated	-1520 b	-408 b	20.4 b

[1]Means within this column followed by the same letter are not significantly different at the 0.01 level.

[2]Means within this column followed by the same letter are not significantly different at the 0.05 level.

[3]One kPa is equivalent to 0.145 psi.

Table 2. Millex 24 pearl millet leaf, stem, and whole plant alkaloid concentrations under two irrigation rates in the drought, N, and S study.

	Alkaloid concentration (ppm)		
Treatment	Leaf	Stem	Whole Plant
Irrigated	39 a[1]	19 a[2]	32 a[1]
Nonirrigated	53 a	13 b	37 a

[1]Means within this column followed by the same letter are not significantly different at the 0.1 level.

[2]Means within this column followed by the same letter are not significantly different at the 0.05 level.

Table 3. Millex 24 pearl millet leaf, stem, and whole plant alkaloid concentration under two S rates.

	Alkaloid concentration (ppm)		
S rate (kg/ha)	Leaf	Stem	Whole Plant
0	46 a[1]	15 a	34 a
56	47 a	16 a	35 a

Table 4. Millex 24 pearl millet leaf, stem, and whole plant NO_3 concentrations under two S rates.

	Nitrate concentration		
S rate (kg/ha)	Leaf	Stem	Whole Plant
0	5,101 a[1]	13,889 a	8,208 a
56	5,164 a	14,209 a	8,336 a

[1]Means within a column followed by the same letter are not significantly at the 0.1 level.

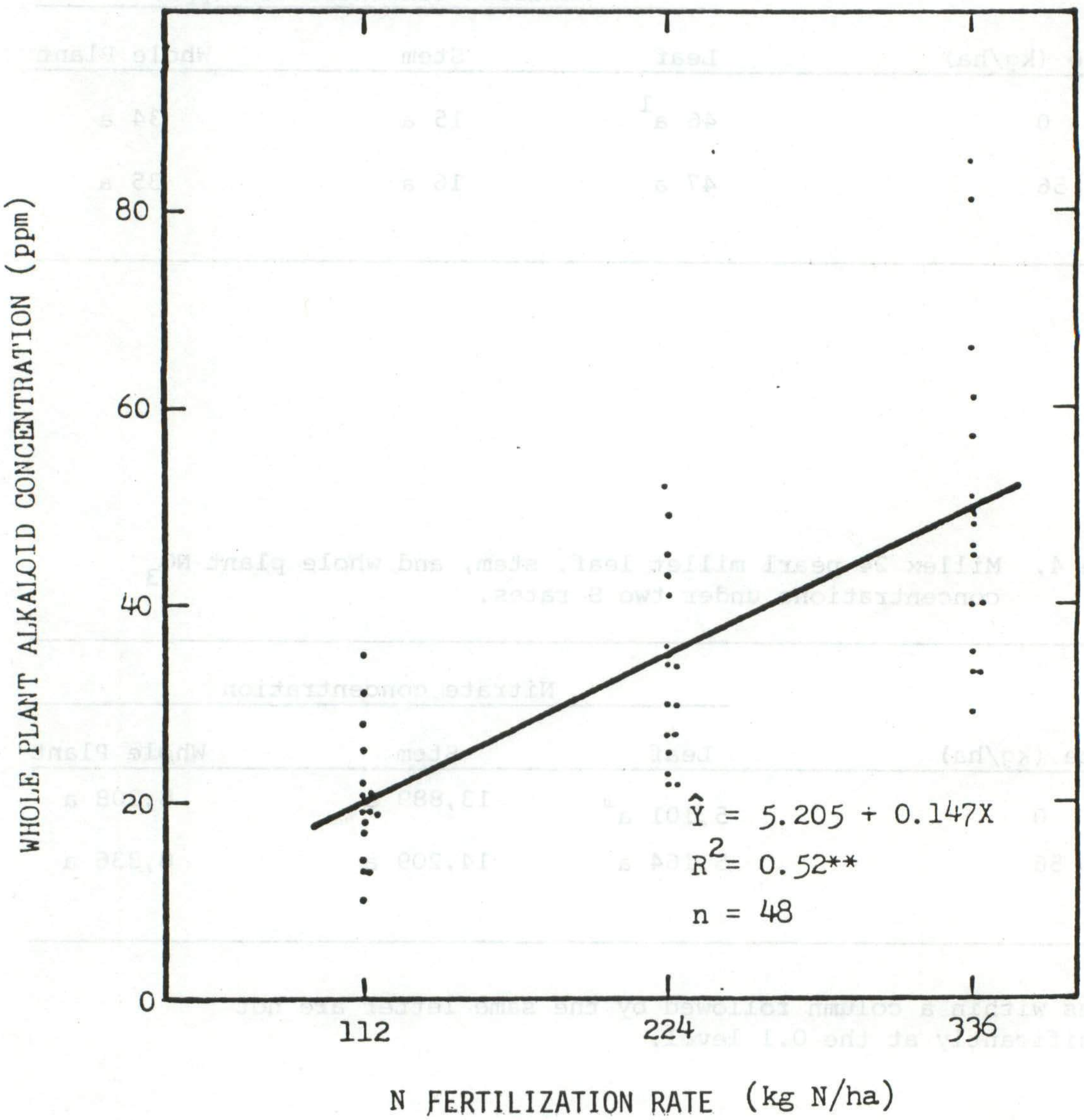

Figure 1. Regression of whole plant alkaloid concentration on N fertilization rate.

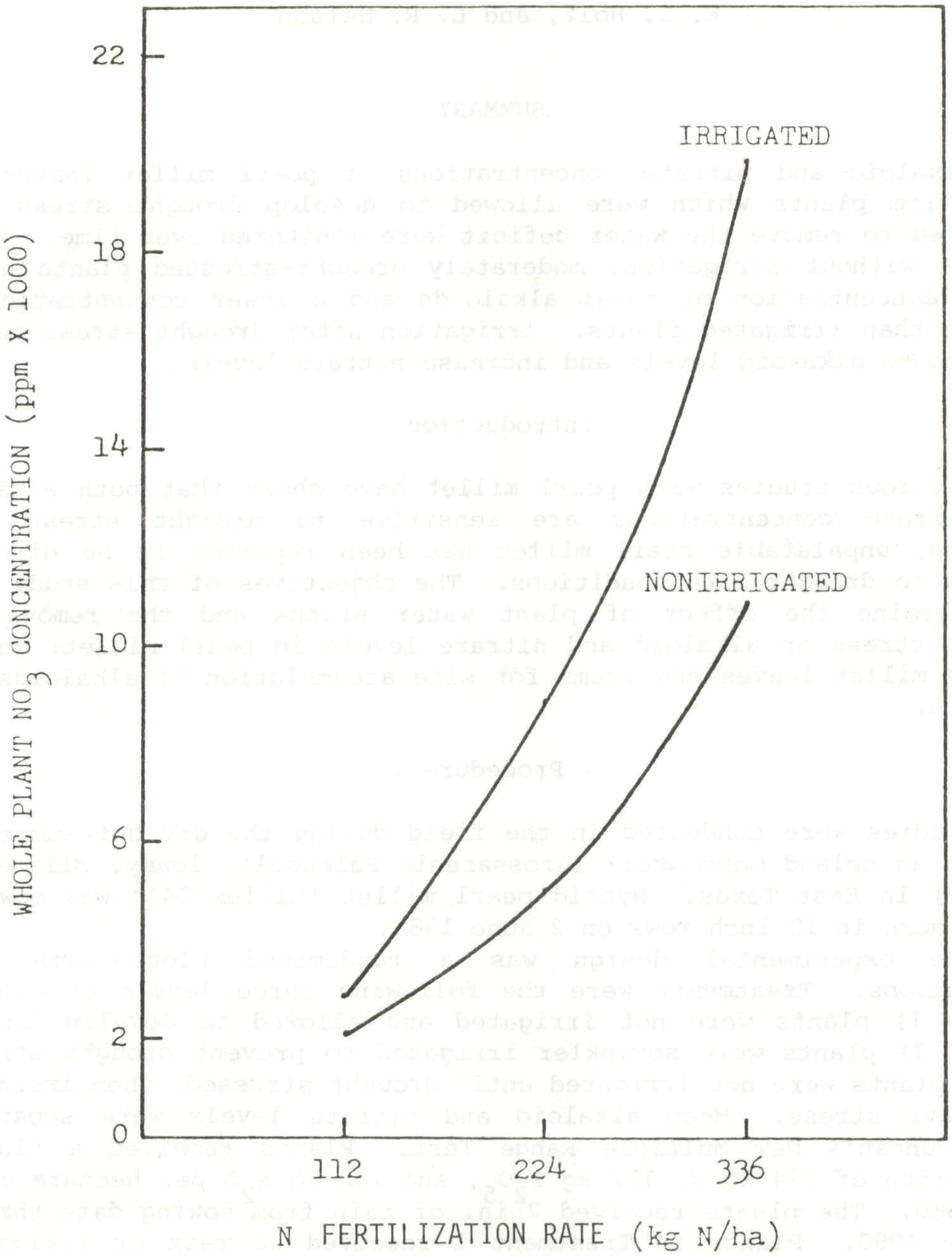

Figure 2. Interaction of irrigation and N fertilization rate for whole plant NO_3 content.