CONCENTRATION, UPTAKE AND USE EFFICIENCY OF N, P AND K IN *PANICUM MAXIMUM* JACQ. CV. TOBIATÃ UNDER WATER STRESS[1]

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ABSTRACT - The concentration, uptake and element use efficiency of N, P and K in *Panicum maximum* cv. Tobiatã, under different conditions of soil moisture were determined in a greenhouse experiment by subjecting the plants to three soil moisture regimes: 1) 45% (field capacity), 2) 29%, and 3) varying from 37% to 27% of soil water content. The evaluations were made at 7, 14, 21 and 28 days after the imposition of the soil moisture condition. The basic treatment design was a factorial combination of soil water status x period of evaluation. A complete randomized design with theree replications was used. Moisture deficit generally increased (N and K) or had no significant effect (P) on nutrient concentration. Uptake of K and N was relatively less affected by water stress than P uptake, which was negatively influenced. The nutrient use efficiency was maximum for P, irrespective of the water regime. Water estress generally had a deleterious effect on the nutrient use efficiency.

Index terms: moisture deficit, nutrient uptake, nutrient use efficiency, nitrogen, phosphorus, potassium.

CONCENTRAÇÃO ABSORÇÃO E EFICIÊNCIA DE USO DE N, P E K EM *PANICUM MAXIMUM* JACQ. CV. TOBIATÃ SOB ESTRESSE HÍDRICO

RESUMO - Foram determinadas, em casa de vegetação, a concentração, a absorção e a eficiência de utilização de N, P e K em *Panicum maximum* cv. Tobiatã, sob três regimes de umidade do solo: 1) 45% (capacidade de campo), 2) 29%, e 3) variando de 37% a 27% de água no solo. As avaliações foram feitas aos 7, 14, 21 e 28 dias após a imposição dos regimes de umidade. O delineamento utilizado foi inteiramente casualizado, com três repetições, em arranjo fatorial com regime de umidade x época de avaliação. A concentração dos elementos geralmente aumentou (N e K) ou não foi significativamente afetada (P) pelo estresse hídrico. A absorção de K e de N foi relativamente menos afetada pelo estresse hídrico do que a de P, a qual foi negativamente influenciada. A eficiência de uso foi máxima para o P em todos os regimes de umidade. O estresse hídrico, em geral, causou um efeito negativo na eficiência de uso dos nutrientes estudados.

Termos para indexação: nutrientes, nitrogênio, fósforo, potássio, capim.

INTRODUCTION

Reduced water supply resulting from variability in rainfall is a common feature of tropical environments. For tropical pasture species, water stress is also the most common environmental hazard experienced by these plants.

In spite of the agronomical importance of the mineral status of forage plants to pasture and animal production, there is only limited information on the influence of water deficits

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on their mineral content, particularly in tropical grasses (C_4).

It is well known that plants grown under water stress generally show differences in their chemical composition when compared to those grown with adequate water supply (Viets Junior 1972, Clark 1981, Pitman 1981, Sharpley & Reed 1982, Izzo et al. 1989).

A higher N content within green laminae and stems of water-stressed *Panicum maximum* has been reported by Wilson & NG (1975). However, this difference, in favor of water-stressed plants was smaller when plants of the same stage of physiological development were compared.

Higher N and lower P content were foud by Abdel Rahman et al. (1971) in some tropical and sub-tropical forage grasses and legumes subjected to soil moisture stress. An increased leaf N level in C_3 and C_4 forage grasses under soil moisture stress was also reported by Misha & Singh (1982). In addition, it was stated by the latter that both the concentration and net uptake of P and K declined with increasing water stress.

In grain sorghum under water stress Eck & Musik (1979) observed a decrease in P and no significant influence on K concentration in plant tissue. Irrigation increased the uptake of N, P and K in *Lolium perenne* and alfalfa, with a smaller effect on N (Maertens 1981).

This paper presents the effects of water stress on N, P and K nutrient concentration, uptake and use efficiency in tropical forage grass *Panicum maximum* Jacq. cv. Tobiatã under three soil moisture regimes.

MATERIALS AND METHODS

Cultural details

Seeds of *Panicum maximum* Jacq. cv. Tobiatã were germinated in seed trays containing sand. At the three leaf stage (18 days after sowing) the plants were transplanted to 23 cm diameter plastic pots (two plants per pot) lined with polyethylene bags containing 4 kg of an air dry Eutrortox (Latossolo Roxo Eutrófico) with known moisture retention curve (Dias Filho et al. 1989). Each pot, before planting, had the P and K levels raised, respectively, to 130 and 150 ppm. Also, 5 ppm of B, 10 ppm of Fe, 10 ppm of Mn, 10 ppm of Zn, 5 ppm of Cu and 1 ppm of Mo were added to each pot. Seventeen days after transplantation, 300 ppm of N were applied per pot.

Watering treatments

Prior to day 23 after transplantation, all plants were grown without water stress by frequent watering to maintain the soil at field capacity (45% of soil water content by weight on an oven dry basis). The water stress regimes commenced on day 41 from sowing, six days after the N fertilization. The soil moisture regimes were: field capacity (45% of soil water content), constant water stress (29% of soil water content), and progressive water stress (37, 33, 29 and 27% of soil water conent). In the latter, each soil moisture condition lasted one week.

Harvests

Destructive harvests of the whole plant tops were made on days 48, 55, 62 and 69 from sowing (7, 14, 21 and 28 days of watering regime). For the progressive water stress regime each harvest coincided with the end of a stress cycle (one week).

The samples were oven dried, weighed and ground to fine powder.

Nutrient concentration

Nutrient concentration was expressed as the % of the mineral element per total dry matter production of shoots.

Analysis of N was carried out by the micro-Kjeldahl method. Phosphorus and K were estimated by nitro-percloric digestion procedure, followed by atomic absorption spectrophotometry (Zagatto et al. 1981).

Nutrient uptake and use efficiency

Nutrient uptake was calculated as the product of dry matter yield and percentage of nutrient concentration in the sample of the grass tops harvested. So, uptake here means the amount of nutrient transported from the roots to the shoots instead of the root ion uptake.

The nutrient use efficiency was estimated as the amount of dry matter produced per unit of nutrient transported to the shoots.

Design

The basic treatment design was a factorial combination of soil water conditions and harvest dates. A complete randomized design with three replications was used.

RESULTS AND DISCUSSION

Nutrient concentration

The concentration of N and K generally increased with the water stress treatments and that of N, P, and K declined with plant age (Table 1).

Nitrogen

Irrespective of the moisture regime experienced by the plants, in the first harvest N concentration was similar among water regime. However, water-stressed plants showed a higher (P<0.01) N concentration in all subsequent evaluations (Table 1). This result agrees with most published data (e.g. Reichman & Grunes 1966, Belesky et al. 1982, Misha & Singh 1982) where it is state that N accumulates in plants undergoing moisture stress. According to Rehatta et al. (1979), this increase in the concentration of N is due to a reduction in plant growth during soil water stress.

TABLE 1. Concentration[1] (% of dry matter) of N, P, and K in *Panicum maximum* cv. Tobiatã under four periods of different watering regimes.

Watering regimes	Days of watering regimes			
	7	14	21	28
	% N			
Field capacity	3.47aA	2.24bB	1.12bC	0.73bC
Constant WS[2]	3.47aA	2.75bB	1.19aC	1.80aC
Progressive WS	3.44aA	3.08aA	2.28aB	1.68aB
	% P			
Field capacity	0.23aA	0.14aB	0.10aC	0.11aBC
Contant WS	0.20aA	0.15aB	0.13aBC	0.11aC
Progressive WS	0.22aA	0.17aB	0.12aC	0.12aC
	% K			
Field capacity	2.32bA	1.33bB	0.74bBC	0.60aC
Constant WS	3.00aA	2.13aB	1.45aC	0.90aC
Progressive WS	2.81aAB	1.94aB	1.15abC	1.01ac

[1] Small letters show significant differences within days. Capital letters show significant differences within watering regimes. Means followed by the same letter are not significantly different at the 1% level of probability, according to Tukey's Multiple Range Test.

[2] WS = Water stress.

Nitrogen concentration decreased with plant age, however, the decrease rate was less evident on plants subjected to the progressive water stress regime (Table 1) as a possible consequence of the more drastic changes on soil moisture condition periodically experienced by these plants.

Phosphorus

Contrarily to what has been generally reported (Misha & Sing 1982, Krizek et al. 1985) the moisture stress had little influence on P concentration (Table 1). The dilution effect caused by the greater dry matter production of the non-stressed plants (Dias Filho et al. 1989) presumably influenced this condition. Also, the reduction in ageing (slower ontogenetic development) normally caused by water stress (Van Soest et al. 1978, Wilson 1983) and observed in this study (Dias Filho 1986) may also have influenced this circumstance.

Potassium

Moisture stress played and important role in determining the K concentration in plant tissue.

Except for the last harvest (28 days) when there was no difference (P>0.01) among soil water regimes, the deficiency in soil moisture content caused an increase (P<0.01) in K concentration in plant tissue (Table 1).

The higher K concentration of the water--stressed plants in this study may have resulted from the role of this ion on leaf osmotic adjustment (Turner & Begg 1978, Pitman 1981).

Ford & Wilson (1981) also found higher K concentration in two C_4 pasture grasses subjected to water stress, and associated this with the osmotic adjustment role played by this ion.

Nutrient uptake

Nitrogen - Nitrogen uptake was higher (P<0.01) for unstressed plants in the first harvest, but similar among water regimes for all other harvest dates (Table 2).

According to assumptions made by Van Keulen (1981), N uptake under moisture shortage conditions may be governed by both the reduced rate of dry matter production and the more difficult transport processes in the soil to the roots. This metabolic (dry matter production) influence on N uptake may be mainly due to the transpiration potential of plants with more photosynthetic area, as this process may have a great influence on N uptake (Pitman 1981).

TABLE 2. Uptake[1] (mg in plant tops) of N, P and K in *Panicum maximum* cv. Tobiatã under four periods of different watering regimes.

Watering regimes	Days of watering regimes			
	7	14	21	28
	mg N			
Field capacity	1.063aA	972aAB	712aBC	514aC
Constant WS[2]	727bA	789aA	803aA	730aA
Progressive WS	608bA	766aA	790aA	776aA
	mg P			
Field capacity	69aAB	63aB	65aAB	84aA
Constant WS	36bA	38bA	45bA	52bA
Progressive WS	47bA	50abA	51bA	49bA
	mg K			
Field capacity	711aA	572aAB	465aB	443aB
Constant WS	522bA	533aA	506aA	413aA
Progressive WS	585abA	549aAB	473aAB	408aB

1 Small letters show significant differences within days. Capital letters show significant differences within watering regimes. Means followed by the same letter are not significantly different at the 1% level of probability, of Tukey's Multiple Range Test.

2 WS = Water stress.

It may therefore be state that in the present experiment, the reduced dry matter production of the water-stressed plants (Dias Filho et al. 1989) and, consequently, the greater transpiration potential of the wet plants, led to the higher N uptake in non-stressed plants observed at the first harvest (Table 2).

Also, as affirmed by Rehatta et al. (1979), reduced N uptake is found in situations of moisture shortage, when compared to adequate soil water conditions with equal N availability.

The progressive decrease of N uptake observed in the field capacity plants with time (Table 2), may have arisen from a carry-over effect of a decline in the soil N, available to the rapidly growing and N demanding unstressed plants. Unlike unstressed plants, water-stressed plants showed a similar (P>0.01) N uptake throughout the evaluation periods.

Phosphorus - Water stress was associated with a decline on P uptake (Table 2). Izzo et al. (1989), Gerakis et al. (1975), Reichman & Grunes (1966) and others have shown that P uptke of water-stressed plants is less than that of plants grown with adequate water supply.

Greenway & Klepper (1968) stated that transpiration may be an important mechanism in P flow to the shoot. Considering that in this study unstressed plants, due to their higher photosynthetic area (Dias Filho et al. 1989) probably had a higher transpiration potential relatively to the water-stressed plants, water flow may have had an important role in the observed P uptake.

Potassium - Unlike P, K uptake was relatively less affected by water stress. Pitman (1981) reported that K uptake persists at low rates of water flow. This condition, according to Bowling (1968), would be more evident under situations of low external K concentration in the soil solution, the uptake being mainly an active transport mechanism. On the other hand, when the external solute concentration of K is high, transpiration can increase the uptake of this ion by the roots (Pitman 1981). These may explain the higher ($P<0.01$) K uptake found in this study in unstressed plants only in the first harvest. During this period, due to the probable higher K concentration in the soil solution, transpiration may have been the main process involved in K uptake, negatively affecting the water-stressed plants.

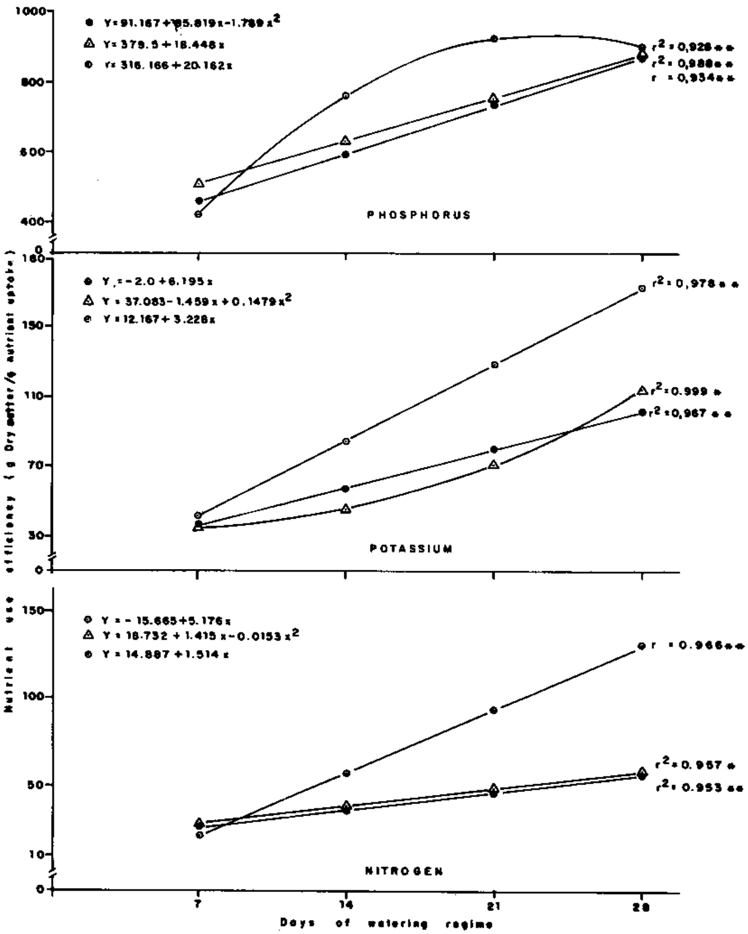

FIG. 1. Phosphorus, potassium and nitrogen use efficiency in *Panicum maximum* cv. Tobiatã under four periods of watering regimes. o, Field capacity; Δ, constant water stress; and ●, progressive water stress.

Nutrient use efficiency

Nitrogen - Nitrogen use efficiency (NUE) was similar ($P>0.01$) for the three soil moisture regimes upt to the second harvest and then higher ($P<0.01$) for unstressed plant in the third and fourth harvest (Fig. 1).

Unlike the wet plants, which showed an increasing ($P<0.01$) NUE with time, there was no difference ($P>0.01$) among periods for both water-stressed regimes.

The similar NUE at the first and, to some extent, at the second harvests, irrespective of water regime, may indicate that the wet plants were experiencing a luxury consumption of N.

Phosphorus - Of the three elements, P showed the maximum use efficiency, irrespective of the water regime experienced by the plants.

The P use efficiency (PUE) was similar among water regimes, except for the third harvest, when PUE of wet plants was higher ($P<0.01$) than that of water-stressed plants (Fig. 1).

Potassium - The K use efficiency (KUE) was similar ($P>0.01$) among water regimes up to the second week, however, wet plants had a higher ($P<0.01$) KUE at the third and fourth harvest (Fig. 1).

The KUE found in the wet plants from the second harvest onwards, highter than in the water-stressed plants, might be linked to a preferential use of this ion in osmotic regulation of the stressed plants (Ford & Wilson 1981), as no difference among water regimes was found for K uptake during the same period (Table 2).

CONCLUSIONS

1. Moisture deficit generally increased (N and K) or had no significant influence (P) on nutrient concentration (% of dry matter).

2. Potassium and N uptake (mg in plant tops) were relatively less affected by water stress than P uptake, which was negatively influenced.

3. Moisture deficit generally had a negative effect on N, P and K use efficiency.

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