RESPONSE OF THREE FORAGE LEGUMES TO SOIL MOISTURE STRESS

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ABSTRACT
Plants of Centrosema pubescens, Lablab purpureus and Stylosanthes guianensis grown separately in pots under green house conditions, were subjected to moisture stress conditions of 100, 75, 50, and 25% field capacity (FC) and the effect on plant growth characteristics assessed. Soil moisture stress significantly reduced plant height, shoot and root dry weights, particularly in Lablab and Stylosanthes. Root/shoot ratio on the other hand increased as soil moisture regime decreased. A change in moisture stress from 100 to 25 % FC reduced nodule numbers by 37, 19 and 9 % in Lablab, Stylosanthes and Centrosema respectively and decreased nitrogen fixed by 32, 9, and 0.4 % in Stylosanthes, Lablab and Centrosema respectively. The mean P content of the plants decreased with decreasing soil moisture content while, that of K increased as moisture stress increased. The overall plant performance pointed to Centrosema as a more favoured forage plant for dry environments .

Keywords: *Crop productivity, legumes, food security, water use efficiency*

INTRODUCTION
Forage legumes improve soil fertility through the return of nitrogen fixed to the soil and the addition of substantial amounts of organic matter when used as mulch (Francis, 1989). However, these benefits are often masked by a combination of socioeconomic constraints and the interactions between soil stresses and other environmental factors that influence plant growth. While farmers on one hand are often reluctant to grow crops, which give no immediate economic benefit, the legumes on the other hand, are adversely affected by unfavourable environmental factors. Under tropical conditions periods of water shortage of varying length and severity are a common environmental hazard to which planted forage legumes are exposed during the growing season. Plant growth, biomass yield and N accumulation become limited (Houngnandan et al, 2001), making their contribution to improving soil fertility uneconomical, particularly where there may be trade-offs associated with the usage of the legumes for different purposes such as providing fodder (Giller et al., 2005). Although there is an increasing understanding of drought response in many crop plants, few attempts to measure these responses in forage legumes

have been made especially in tropical forage legumes. It is in this context that this study was undertaken to assess the performance of three forage legumes under varying soil moisture regimes. Additionally, it is to complement the efforts of the Generation Challenge Programme on Water and Food (2006), that seeks to select, improve and develop plant genotypes with enhanced water use efficiency and/ or plants that require moderately low soil moisture to express their genetic potential for adequate production, in environments with water shortage during the growing season.

MATERIALS AND METHODS

The experiment was conducted in a green house at the Soil Research Institute, Kwadaso-Kumasi (6^o 40' N, 1^o 40' W). Day/night temperature and relative humidity during the experimental period were $30/25^0$ C and 38/36 % respectively. The soil used, Plinthic Acrisol (FAO, 1998) was collected from the experimental field of the Soil Research Institute. Values obtained from the chemical analysis of the soil were: pH (water) 5.2; and N and P, 0.13 and 1.25mg kg^{-1} respectively. The test legumes were *Centrosema pubescens*, *Lablab purpureus* and *Stylosanthes guianensis,*(hereafter referred to as *Centrosem*a, *Lablab* and *Stylosanthes* respectively). These legumes were chosen on the basis of their growth potential, suitability for soil fertility improvement and palatability as herbage for livestock. Plastic pots were each filled with 1.5kg of soil to give a bulk density of 1.3 g cm^{-3} and saturated with water from the base in a rectangular tank. The pots were covered with polythene sheets to prevent evaporation and allowed to drain freely for 48 hours to maintain a soil water potential of -0.036 bars, equivalent to soil field capacity. The stress treatment was applied as a sequence of soil drying and rewatering cycles by withholding water until soil water content reached values equivalent to -15 bars and then the pots were rewatered to a soil water content equivalent of -0.036 bars. Daily pot weight was recorded and soil water content (%) by weight calculated to obtain levels of 100, 75, 50 and 25% field capacity (FC). These values were maintained by daily weighing and watering. Four seeds of each legume were sown in each pot. There were four replications for each set of treatment giving a total of 48 pots. After emergence two plants were left per pot. A modified Broughton and Dillworth (1971) basal dressing of nutrients was applied to each pot before planting. Each pot was then mulched with 100 g acid washed sand to minimize surface evaporation. All the legumes were grown without water stress by frequent watering to maintain soil field capacity, until 15 days after emergence. Luffa (*Luffa cylindrical*) was a reference crop used for the calculation of nitrogen fixed by the total nitrogen difference method. Harvesting of whole plants was done at 45 days after planting. Oven dry (75^0 C) weight of shoot and roots were recorded and nodule numbers counted. Total N and P in plant materials were determined calorimetrically (Parkinson and Allen 1975) and K by flame photometry. Data were processed by two-way analysis of variance and means were compared by Duncan's Multiple Range Test. All differences were tested at the 5 % level

RESULTS AND DISCUSSIONS

Soil moisture stress caused differences in plant height which varied from 34.1 to 53.6 cm in the order 100%> 75%>50% >25% FC (Table 1). The magnitude of moisture stress in reducing plant height varied with the type of cover crop in the order of *Lablab* (66%) > *Centrosema* (19%) > *Stylosanthes* (13%). This is indicative of the level of response or tolerance of the crops to moisture stress which would have been masked if only the main effect of moisture had been studied as observed in many studies on the effect of moisture stress on crops. The importance of this observation is in screening crops for moisture stress tolerance, an aid to plant breeding and selection of suitable forage crops for arid ecologies.

As soil moisture decreased from 100% FC through 75% FC, 50% FC to 25% FC, a consistent decrease in shoot dry weight was observed giving a range of 1.58 to 3.36 g/plant for 25% FC and 100 FC respectively, which corre-

Table 1: **Effect of crop type moisture stress and their interaction on plant height (cm) at four sampling periods**

Treatment	4 weeks	5 weeks	6 weeks	7 weeks
Crop				
C_1	16.12	19.17	38.10	49.08
C_2	16.36	20.29	25.60	31.33
C_3	24.08	46.65	53.00	59.57
LSD (5%)	2.23	4.42	5.22	4.74
Moisture regime % FC				
100%	17.68	29.78	45.30	53.61
75%	20.33	29.60	42.50	51.50
50%	19.84	30.50	38.40	47.42
25%	17.57	24.30	29.50	34.11
LSD (5%)	2.58	5.10	6.03	5.47
Crop x moisture interaction				
C_1 100	18.08	22.08	53.00	64.50
C_1 75	17.40	21.38	47.10	60.00
C_1 50	16.70	21.42	33.80	49.67
C_1 25	12.30	13.97	18.60	22.17
C_2 100	16.58	22.17	26.70	33.00
C_2 75	14.58	18.17	24.20	32.50
C_2 50	17.68	21.50	26.70	31.17
C_2 25	16.58	19.32	25.00	28.67
C_3 100	18.37	45.98	56.30	63.33
C_3 75	29.00	49.25	56.30	62.00
C_3 50	25.13	48.58	54.70	61.53
C_3 25	23.83	39.67	44.80	51.50
LSD (5%)	4.46	8.84	10.44	9.48
CV (%)	14.1	18.40	15.90	12.10

Where: C_1 – *Lablab purpureus* C_2 – *Stylosanthes guianensis* C_3 – *Centrosema pubescens*

sponds to a decrease of 53% in shoot dry weight (Table 2). While the main effect of soil moisture regime gives a general reduction in shoot dry matter with decreasing soil moisture, it reveals nothing about the magnitude of response of the individual forage crops. This gap is filled by the results of the forage crop x soil moisture regime interaction which showed a moisture change from 100% to 25% FC to reduce shoot dry matter of *Stylosanthes*, *Lablab* and *Centrosema* by 85, 60 and 31 per cent respectively. The implication is that *Stylosanthes* and *Lablab* are more sensitive to moisture stress and suggests that the general effects of water deficit, which is dependent on cell division, elongation and differentiation, may not be necessarily affected to the same extent in the crops. At a moisture stress level of 25% FC, *Centrosema* is therefore the preferred forage crop both on the basis of drought tolerance and amount of biomass produced which is very crucial for legume species intended for use in managed fallows to provide effective ground cover against erosion and suppress weeds.

A decline in soil moisture from 100 FC to 25% FC caused a root yield decline of 81, 71 and 3 per cent in *Stylosanthes*, *Lablab*, and *Centrosema* respectively, similar to that observed in shoot dry weight, and consistent with root-shoot growth relationships. At 3% reduction in root dry weight, the roots of *Centrosema* were the least affected by moisture stress (Table 2). This further provides an added advantage to the suitability of *Centrosema* as a forage legume for dry areas.

The amount of dry matter incorporated into the roots per plant was 17%, 27% and 36% for *Stylosanthes*, *Centrosema* and *Lablab* respectively for a change of soil moisture regime from 100% FC to 25% FC (Table 2). The effect of soil moisture regime revealed an increasing root/shoot ratio as the level of soil moisture stress increased. This accords with reported observations by Sharp et al., (1988), Stasovski and Peterson (1991), and indicates that in dry soils, despite increasing soil strength, root growth is usually much less depressed than shoot growth, leading to a typical increase in root/shoot dry weight ratio.

The cover crop x soil moisture interaction significantly (P = 0.05) influenced the forage production of nodules with numbers at the various moisture regimes following a trend of *Stylosanthes* > Centrosema > *Lablab* with interaction means ranging from 32 to 132 (Table 3). Although, *Stylosanthes* significantly produced the highest number of nodules, it was the least effective in translocating photosynthate to the nodules, as exemplified by the least nodule dry weight recorded. The formation of nodules on all the test crops under the extreme stress condition implies that homologous rhizobia population in the soil tolerated the stress condition. This accords with the assertion that rhizobia maintain viability in soil held under extremely low water potential and that rhizobial osmoregulatory mechanism may play a significant role in nodule initiation and development under water stress (Leung and Bottomley, 1994).

Table 2: Effect of crop type, moisture stress and their interaction on shoot and root dry weight and root⁄shoot ratio

Treatment	shoot (g/ plant)	Root (g⁄ plant)	root⁄shoot ratio
Crop			
C_1	3.39	1.14	0.36
C_2	2.05	0.32	0.17
C_3	2.92	0.76	0.27
LSD (5%)	0.38	0.11	0.07
Moisture regime % FC			
100%	3.36	0.89	0.22
75%	3.24	0.83	0.25
50%	2.47	0.72	0.27
25%	1.58	0.52	0.32
LSD (5%)	0.44	0.12	0.08
Crop x moisture interaction			
C_1 100	4.89	1.49	0.31
C_1 75	3.83	1.24	0.33
C_1 50	2.95	1.07	0.36
C_1 25	1.92	0.78	0.44
C_2 100	3.30	0.52	0.12
C_2 75	2.78	0.48	0.16
C_2 50	1.60	0.19	0.17
C_2 25	0.51	0.10	0.22
C_3 100	3.37	0.68	0.20
C_3 75	3.13	0.78	0.26
C_3 50	2.85	0.92	0.29
C_3 25	2.32	0.66	0.33
LSD (5%)	0.76	0.21	0.14
CV (%)	16.10	17.00	30.50

Where: C_1 – *Lablab purpureus* C_2 – *Stylosanthes guianensis* C_3 – *Centrosema pubescens*

Table 3: Effect of crop type, moisture stress and their interaction on nodule numbers, nodule dry weight and nitrogen fixed.

Treatment	Nodule numbers	Nodule dry weight (g/plt)	N-fixed (%)
Crop			
C_1	40.30	0.30	2.52
C_2	116.90	0.18	1.90
C_3	82.40	0.28	2.39
LSD (5%)	10.85	0.04	0.42
Moisture regime % FC			
100%	86.90	0.30	2.52
75%	79.10	0.28	2.57
50%	83.30	0.24	2.22
25%	70.20	0.18	1.78
LSD (5%)	12.52	0.05	0.49
Crop x moisture interaction			
C_1 100	51.00	0.41	2.93
C_1 75	38.70	0.33	3.05
C_1 50	39.30	0.27	2.24
C_1 25	32.30	0.18	1.35
C_2 100	124.70	0.19	1.96
C_2 75	110.00	0.17	1.91
C_2 50	132.30	0.20	2.37
C_2 25	100.70	0.15	1.33
C_3 100	85.00	0.30	2.66
C_3 75	88.70	0.34	2.75
C_3 50	78.30	0.26	2.03
C_3 25	77.70	0.21	2.65
LSD (5%)	21.69	0.08	0.85
CV (%)	16.10	19.70	22.1

Where: *C_1 – Lablab purpureus* *C_2 – Stylosanthes guianensis* *C_3 – Centrosema pubescens*

Nodule dry weights at 50, 75, and 100% FC were significantly (P = 0.05) higher than that at 25% FC. The performance of the cover crops at the different soil moisture regimes with respect to nodule dry weight did not follow a consistent trend. At the 100% and 50% FC, nodule dry weight was in the order of lablab > *Centrosema* > *Stylosanthes*. The trend at 75% and 25% FC was Centrosema > *Lablab* > *Stylosanthes*.

The significance of nodulation in legumes for plant growth and yield is the fixation of nitrogen. In this context, forage crops that are superior in nitrogen fixation are preferable as observed in *Lablab* and *Centrosema* (Table 3). Even in this case, the plant that fixes more nitrogen under moisture stress, as in the case of *Centrosema*, is an obvious choice in dry agroecologies since water stress limits many processes of nodule activity (Parsons et al. 1993; Gonzalez et al., 1995).

The nutrient content of forage crops is very important with respect to using them as animal feed or for soil fertility improvement. The mean P content of the crops decreased with decreasing soil moisture content giving a range of 0.23 to 0.52% for 25% FC and 100% FC respectively (Table 4). Since these crops were grown in the same medium, the variations in their nutrient contents may reflect their genetic potential in nutrient uptake as observed by Marschner (1995). The plant content of K on the other hand increased as moisture stress increased with the K content of *Stylosanthes*, *Lablab* and *Centrosema* increasing by 39, 30

Table 4: **Effect of crop type, moisture stress and their interaction on phosphorus and potassium concentration**

Treatment	Phosphorus conc. (%)	Potassium conc. (%)
Crop		
C_1	0.32	0.79
C_2	0.26	0.65
C_3	0.56	0.70
LSD (5%)	0.10	0.16
Moisture regime % FC		
100%	0.52	0.70
75%	0.47	0.77
50%	0.30	0.74
25%	0.23	0.76
LSD (5%)	0.12	0.18
Crop x moisture interaction		
C_1 100	0.33	0.65
C_1 75	0.45	0.76
C_1 50	0.22	0.81
C_1 25	0.27	0.93
C_2 100	0.34	0.49
C_2 75	0.31	0.59
C_2 50	0.25	0.72
C_2 25	0.15	0.80
C_3 100	0.88	0.64
C_3 75	0.64	0.83
C_3 50	0.45	0.83
C_3 25	0.26	0.86
LSD (5%)	0.21	0.31
CV (%)	32.9	25.1

Where: C_1 – *Lablab purpureus* C_2 – *Stylosanthes guianensis* C_3 – *Centrosema pubescens*

and 26% respectively for a moisture change from 100 to 25% FC, corroborating the observation of Sangakkara et al., (1996).

A major consideration in the choice of crops for their tolerance to moisture stress conditions is their nutrient use efficiency (NUE) defined as dry matter produced per unit nutrient (Marschner, 1995). An examination of the forage crop x soil moisture regime showed phosphorus NUE of *Stylosanthes* and *Centrosema* to increase with decreasing soil moisture regime and potassium, NUE to decrease with increasing moisture stress.

The present study suggests that *Centrosema* had significant genetic potential to tolerate moisture stress which may be useful in breeding programmes for drought tolerant forage legumes for water stress habitats.

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