Growth and Phosphorus Concentrations of *Centrosema pubescens* Benth in Flowing Solution Culture under Differing Defoliation Regimes

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ABSTRACT

An experiment was carried out to investigate the effect of several defoliation regimes on growth and tissue P concentration of centro grown in flowing nutrient solution at eight constant solution P concentrations, viz. 0.06, 0.24, 0.7, 3, 9, 26, 87 and 264 μ.M

Eight flowing culture units were employed, each being randomly assigned a solution P concentration. Within each unit four methods of defolliation x three cutting intervals x three replications were established using a randomized block design. Phosphorus treatments were imposed 13 days after pregerminated seeds were transferred into the flowing culture units which contained basal nutrients only. Defoliation treatments were initiated 29 days later. At this time, plants were cut down to stubble heights of 2.5, 7.5 and 12.5 cm, while in a fourth treatment all leaves were removed from the plants. Cutting intervals of 7, 14 and 21 days were imposed on plants in each of the four defoliation treatments over the 42 days experimental period which followed the initial defoliation. These cutting intervals resulted in 6, 3, and 2 harvests respectively. Dry matter yields of regrowth were obtained at each harvest, while stubble and roots were obtained at the final harvest only.

Maximum dry matter yields in all defoliation treatments and in non-defoliated control plants were obtained at 3 μMP. Total dry matter production decreased with lowered cutting height, the lowest top and root yields being consistently obtained at all solution P concentrations and all cutting intervals in the 2.5 cm cutting height and complete defoliation treatments. The effects of cutting height were particularly marked at the 7-day cutting interval. Best growth of defoliated plants was achieved with a cutting interval of 21 days and a cutting height of 7.5 or 12.5 cm.

Mean rate of P absorption were depressed by the most severe defoliation treatments, viz. 2.5 cm cutting height and the complete defoliation treatments. Death of some plants occurred in these treatments.

The P concentrations in the regrowth and whole tops of defoliated plants were always higher than those in the tops of non-defoliated control plants. Al-through P concentrations in the regrowth and whole tops increased with lowered cutting height following a single defoliation, subsequent defoliations decreased P concentration in the regrowth, particularly at the lower cutting heights.

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Critical P concentrations, derived from relationships between plant growth and tissue P concentrations were higher in defoliated than in control plants. The critical P concentration increased with lowered cutting height following a single defoliation, but decreased with lowered cutting height following a series of defoliations. The critical P concentration also decreased with increased cutting interval in all cutting height treatments.

INTRODUCTION

Legume species have played a key role in low cost pasture improvement programs in Australia both in circumstances where they are sown directly for animal production or as a pasture ley in a cropping rotation (Williams and Andrew, 1970). Among all important factors affecting legume growth phosphorus (P) has been recognized as a major limiting nutrient in most tropical soils suitable for improved pasture production in Austratia and in many countries in the tropics.

Many experiments aimed at evaluating the responses of pasture legume species to P have been conducted using pots of soil in the glasshouse or small plots in the field. However, information on comparative performance of some tropical pasture legume species growing under constantly maintained solution P concentrations has been reported recently by Chantkam (1978). In fact, pasture species under field or sward conditions were not subjected only to the effect of mineral nutrient elements but also subjected to other factors such as soil moisture, defoliation and so on. Therefore, the present experiment was carried out to investigate the effect of several defoliation regimes on growth and tissue P concentration of common centro grown in flowing solution culture at eight constant P concentrations.

MATERIALS AND METHODS

This experiment was conducted in eight flowing solution culture units which have been described briefly by Edwards and Asher (1974) and Asher and Edwards (1978). Within each unit solution P concentration was randomly assigned and four methods of defoliation x three cutting intervals x three replicalions were employed using a randomized block design. P treatments were imposed 13 days after pregerminated seeds were transferred into the flowing culture units which contained basal nutrients only. The composition of the basal nutrient solution used was described by Chantkam (1978). This nutrient solution in each unit was replaced every week to ensure that the concentration of all basal nutrients was maintained within acceptable limits throughout the experiments.

Potassium dihydrogen phosphate was used as a source of P. The nutrient solution in each unit was sampled and analysed daily for P throughout the experiment using the methods of Jintakanon *et al.* (1975) and Truog and Meyer (1929). P concentration was maintained constantly by continuous slow addition of P at a rate estimated to be equal to the rate at which plants taking up P from the solution. The mean P concentrations maintained are as follws (μM): 0.06, 0.24, 0.7, 3, 9, 26, 87 and 264.

The solution pH was maintained

at 6.0 by means of automatic pH control system using either 0.1 M KOH or 0.1 M HCl in the tritrant reservoir, depending upon the direction of drift. The temperature of the solution in each unit was maintained at 25.0°C.

Defoliation treatments were initiated 29 days after the imposition of P treatments. At this time. plants were cut down to stubble heights of 2.5, 7.5 and 12.5 cm, while in a fourth treatment all leaves were removed from the plants. Cutting intervals of 7, 14 and 21 days were imposed on plants in each of the four defoliation treatments over the 42 days experimental period which followed the initial defoliation. These cutting intervals resulted in 6, 3 and 2 harvests respectively. Dry matter yields of regrowth were obtained at eaeh harvest, while stubbles and roots were obtained at the final harvest only. Plant tissues were determined by using the method of O' Neill ahd Webb (1970).

RESULTS

Dry Matter Yields

Maximum dry matter yields of stubble, regrowth, whole tops and roots in all defoliation treatments and in non-defoliated control plants were obtained at 3 μMP (Figure 1). Total dry matter production decreased with lowered cutting

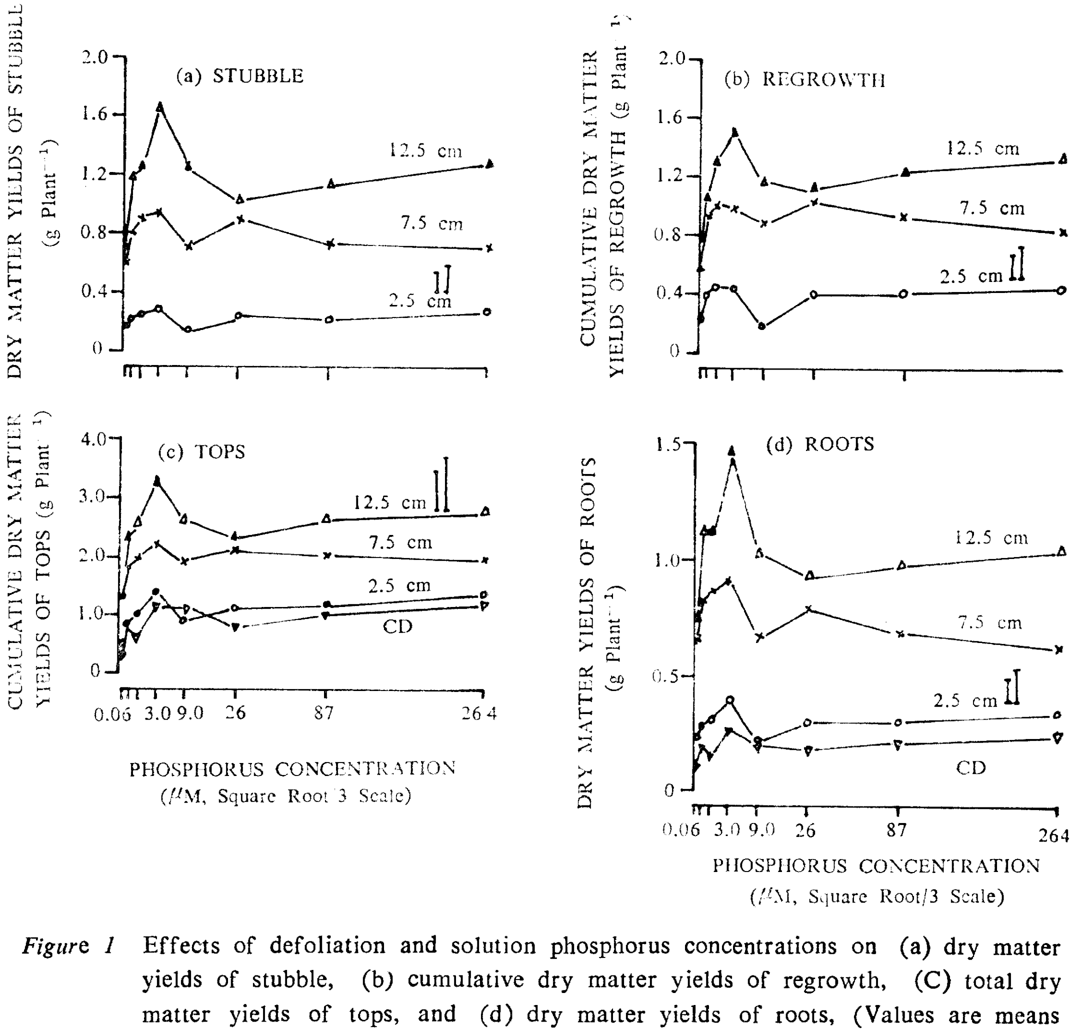

Figure 1 Effects of defoliation and solution phosphorus concentrations on (a) dry matter yields of stubble, (b) cumulative dry matter yields of regrowth, (C) total dry matter yields of tops, and (d) dry matter yields of roots, (Values are means across cutting intervals.)

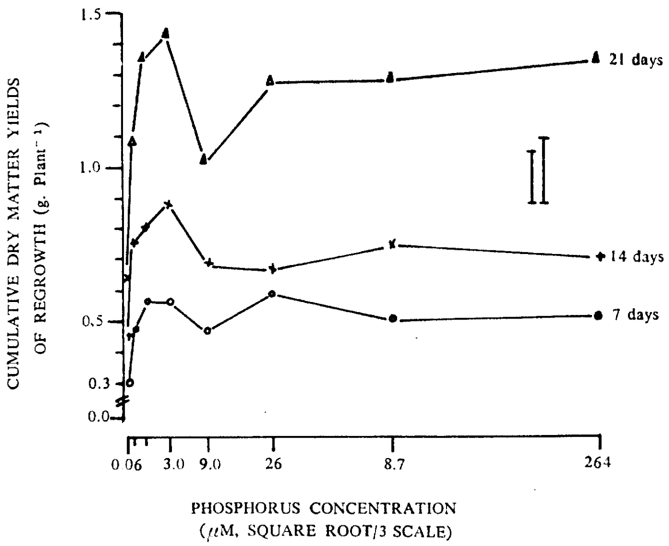

Figure 2 Effects of cutting interval and solution phosphorus concentration on cumulative dry matter yields of regrowth. (Values are means across defoliation treatments).

height, the lowest yields of tops and roots being consistently obtained in the 2.5 cm cutting height and the complete defoliation treatments at all solution P concentrations.

Decreasing the cutting interval from 21 to 14 days generally had a much larger effect on the cumulative yields of regrowth than a further reduction in cutting interval from 14 to 7 days (Fugure 2). However, the effect of cutting interval on regrowth was minimal at the most limiting solution P concentration and increased rapidly up to about 3 μMP. Thereafter, there was little change. Under more frequent cutting the plants reached maximum yield of regrowth at a lower solution P concentration (0.7 μM) than under less frequent cutting (14 and 21 day intervals) which required a solution P concentration of 3 μM.

Dry matter yields of whole tops and roots significantly decreased with decreased cutting height at all cutting intervals (Figure 3). On an absolute basis this decrease was more marked at the 7-day than at the 14-day and 21-day intervals. Best growth of defoliated plants was achieved with a cutting interval of 21-days and a cutting heights of 7.5 or 12.5 cm.

Plant P Concentrations

The P concentretions in the regrowth and whole tops of defoliated plants were always higher than those in the tops of non-defoliated control plants (Table 1). The concentrations of P in the regrowth decreased with decreased cutting height and with increased cutting interval. These decreases were greater at the 7-day interval. On the other hand, the decreases in P concentrations with increasing cutting interval were greater in the plants with higher cutting heights.

Decreasing the cutting height decreased the P concentrations in the whole tops at all cutting intervals. The

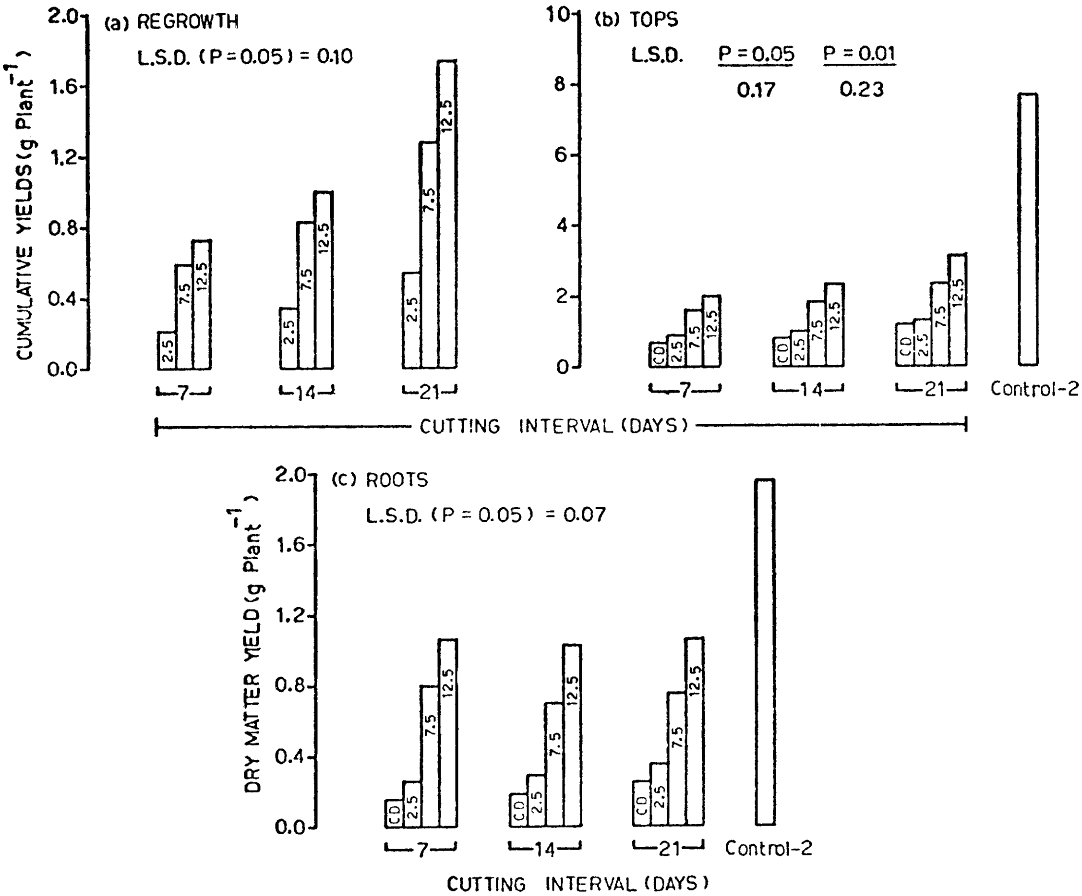

Figure 3 Effects of defoliation and cutting interval on (a) cumulative dry matter yields of regrowth, (b) total dry matter yields of tops, and (c) dry matter yields of roots of centro (Values are means across solution phosphorus concentrations; 2.5, 7.5, 12.5, and CD indicate the cutting height treatments at 2.5 cm, 7.5 cm, 12,5 cm and complete defoliation respectively. Control ♯2 plant was harvested at 84 days from transplanting and its value was excluded from statistical analysis),

decrease was greater at the 7-day than at the 14-day and 21-day intervals. The decrease in the concentrations of P in tops with increasing cutting interval was greatest in plants cut at a height of 12.5 cm.

The concentrations of P in roots decreased with decreased cutting height only at the 7-day and 14-day intervals. The P concentrations in roots of plants cut down to 2.5 cm stubble height increased with increasing cutting interval. This trend was not evident in plants cut at 7.5 and 12.5 cm heights, nor in the completely defoliated plants.

There was a greatest reduction in the P concentration of the regrowth with decreased cutting height at 0.6 μMp (Table 2). The concentration of P in tops were more strongly reduced by decreasing the cutting height at the lower than at the higher solution P concentrations.

Great decreases in the concentrations of P in the regrowth through increasing the cutting interval were most pronounced

Table 1 Effects of defoliation and cutting interval on tissue P concentrations (% dry weight) of centro (Values are means across solution P concentrations).

Defoliation treatments	Cutting interval (days)			L.S.D.	
	7	14	21	P = 0.05	0.01
	(a) Cumulative regrowth				
12.5 cm	0.68	0.60	0.50	0.020	0.030
7.5 cm	0.67	0.59	0.51		
2.5 cm	0.59	0.54	0.47		
CD	–	–	–		
	(b) Whole tops				
12.5 cm	0.48	0.47	0.41	0.020	0.030
7.5 cm	0.47	0.45	0.44		
2.5 cm	0.41	0.42	0.39		
CD	0.37	0.39	0.36		
	(c) Roots				
12.5 cm	0.36	0.34	0.34	0.034	–
7.5 cm	0.32	0.29	0.32		
2.5 cm	0.30	0.31	0.36		
CD	0.26	0.26	0.25		

Non-defoliated control plant : Tops = 0.28 %P
Roots = 0.27 %P

at 0.06 and 0.24 μMP (Table 3). A similar interaction between these two variables was also found on the P concentrations in the tops.

Critical P Concentrations

The critical P concentrations presented in Table 4 and Table 5 were derived from the relationships between dry matter yields of cumulative regrowth, whole tops, regrowth following each successive defoliation and their P concentrations. The results showed that the critical P concentrations in the regrowth and tops generally decreased with decreased cutting height at all cutting intervals (Table 4) This decrease. was greatest when the cutting height was lowered from 7.5 to 2.5 cm at the 7-day interval. The critical P concentration in tops of non-defoliated control plants (0.27 % P) was very much lower than that of defoliated plants at all cutting intervals. Increasing the cutting interval generally decreased the critical P concentrations in both the regrowth and whole tops of all defoliated plants. However, the regrowth exhibited greater decreases in the critical P concentrations with lengthened cutting interval than did the whole plant tops.

The critical P concentrations in the first regrowth following initial defoliation were little affected by cutting height at any cutting interval with the exception of the increase at a cutting height of 2.5 cm when the cutting interval was 7 days (Table 5). Thereafter, the critical concentrations in the regrowth of each successive defoliation generally

Table 2 Effects of defoliation and solution P concentration on tissue P concentrations (% dry weight) of centro (Values are means across cutting intervals).

Defoliation treatments	Solution P concentration (μM)								L.S.D.	
	0.06	0.24	0.7	3	9	26	87	264	P = 0 05	0.01
(a) Cumulative regrowth										
12.5 cm	0.48	0.57	0.60	0.59	0.62	0.61	0.64	0.64	0.40	–
7.5 cm	0.45	0.60	0.59	0.65	0.58	0.62	0.64	0.61		
2.5 cm	0.40	0.50	0.54	0.57	0.55	0.57	0.57	0.58		
CD	–	–	–	–	–	–	–	–		
(b) Whole tops										
12.5 cm	0.33	0.45	0.50	0.48	0.44	0.45	0.49	0.51	0.04	–
7.5 cm	0.33	0.46	0.48	0.49	0.43	0.47	0.49	0.48		
2.5 cm	0-25	0.37	0.43	0.44	0.39	0.44	0.44	0.46		
CD	0.22	0.34	0.39	0.38	0.38	0.41	0.45	0.44		
(c) Roots										
12.5 cm	0.20	0.29	0.34	0.31	0.35	0.31	0.43	0.50	NS	
7.5 cm	0.19	0.28	0.28	0.32	0.29	0.30	0.40	0.40		
2.5 cm	0.17	0.28	0.32	0.31	0.34	0.33	0.42	0.43		
CD	0.13	0.21	0-23	0.24	0.27	0.25	0.35	0.37		

Table 3 Effects of cutting interval and solution P concentration on tissue P concentrations (% dry weight) of centro (Values are means across defoliation treatments)

Cutting interval (days)	Solution P concentration (μM)								L.S.D.	
	0.06	0.24	0.7	3	9	26	87	264	P = 0.05	0.01
(a) Cumulative regrowth										
7	0.53	0.67	0.62	0.68	0.65	0.69	0.67	0.66	0.04	0.05
14	0.44	0.53	0.61	0.60	0.56	0.62	0.62	0.65		
21	0.35	0.48	0.50	0.53	0.53	0.50	0.55	0.52		
(b) Whole tops										
7	0.31	0.44	0.44	0,46	0.41	0.45	0.47	0.47	0.03	–
14	0.29	0'40	0.48	0.45	0.42	0.47	0.47	0.50		
21	0.26	0.38	0.42	0.43	0.40	0.41	0.45	0.44		
(c) Roots										
7	0.18	0.29	0.26	0.30	0.30	0.29	0.44	0.43	NS	
14	0.16	0.23	0.31	0.28	0.32	0.30	0.37	0.44		
21	0.18	0.28	0.30	0.32	0.32	0.30	0.43	0.41		

Table 4 Effects of cutting height and cutting interval on the critical P concentrations (% dry weight) in the cumulative regrowth and whole tops of centro.

Cutting Intervals (days)	Cumulative regrowth			Whole tops		
	12.5 cm	7.5 cm	2.5 cm	12.5 cm	7.5 cm	2.5 cm
7	0.65	0.63	0.57	0.46	0.45	0.38
14	0.58	0 53	0.51	0.46	0.43	0.40
21	0.48	0.47	0.45	0.40	0.38	0.36

Table 5 Effects of cutting height on the time course of the critical P concentrations (% dry weight) in each successive regrowth of centro.

Cutting interval (days)	Cutting height (cm)	Critical P concentration (% dry weight)					
		Defoliation					
		1	2	3	4	5	6
7	12.5 cm	0.64	0.83	0.75	0.71	0.72	0.60
	7.5 cm	0.61	0.84	0.74	0.70	0.74	0.59
	2.5 cm	0.73	0.77	0.66	0.62	0.64	0.47
14	12.5 cm	0.59	0.85	0.55	–	–	–
	7.5 cm	0.55	0.84	0.48	–	–	–
	2.5 cm	0.57	0.68	0.46	–	–	–
21	12.5 cm	0.53	0.46	–	–	–	–
	7.5 cm	0.53	0.44	–	–	–	–
	2.5 cm	0.52	0.43	–	–	–	–

decreased with lowered cutting height. These critical concentrations became similar when the cutting interval was lengthened to 21 days. Apart from the first defoliation after initial cutting the critical concentrations in the regrowth of each successive defoliation generally decreased with lowered cutting height. There were differences in the critical concentrations of the regrowth within each cutting height and cutting interval. Increasing the cutting interval greatly decreased the critical concentrations in the regrowth of plants in all cutting height treatments.

Mean Rate of P Absorption

Mean rates of P absorption per unit dry weight of roots were calculated from the equation used by Loneragan and Asher (1967). Mean rates of P absorption were depressed by the most severe defoliation treatments, viz. 2.5 cm cutting height and the complete defoliation treatments. The rates of ab sorption increased from 9.5 to 14.6 μmol P g^{-1} dry roots day^{-1} as the cutting interval increased from 7 to 21 days. Increasing the solution P concentration from 0.06 to 0.7 μM significanty increased the mean rate of absorption from

7.7 to 14. 4 μmol P g^{-1} dry roots day^{-1}. Maximum rate of absorption of 15 μmol Pg^{-1} dry roots day^{-1} occurred at 87 μMP. In general, there was little effect of solution P concentration ranging from 0.7 to 87 μM on mean rate of P absorption. However, a significant decline in the mean rate of absorption occurred at 264 μMP.

DISCUSSION

The response of centro plants to external solution P concentration in the present experiment was little affected by defoliation, although there were significant interactions between defoliation and solution P concentration on the dry matter yields. Thus, defoliated plants required 3 μMP as did non-defoliated control plants for maximum yield of tops and roots. However, these results did not agree with those obtained from the still solution culture experiments in which the centro plants were subjected to the continuously depleting solution P concentrations and a single defoliation (Chantkam, 1978). He found that centro plants cut at 2.5 cm stubble height reached a maximum yield of tops at 12,800 μMP while the control plants and plants in the 7.5 and 12.5 cm cutting height treatments reached the maximum yields at 3,200 μMP. Therefore, different P supply systems used in these studies have undoubtedly caused differences in the responses of both the defoliated and non-defoliated control plants to external solution P concentrations between the two experiments. Much lower solution P concentrations required for maximum growth of defoliated plants in flowing solution culture than in the still solution culture systems is parallelled by effects on growth responses of the non-defoliated control plants. The results from the present experiment suggest that the solution P concentration required for maximum yields of centro in flowing culture was not very sensitive to the effect of cutting height and cutting interval when compared to the still solution culture experiments. The contrasting conditions of nutrient supply in the two solution culture systems discussed have analogies in soil systems. Soils with low nutrient "potential" and a high "capacity", P in this case, to resist changes in that potential (Schofield, 1955) are analogous in nutrient supply to the flowing culture system. Soils with a high initial potential but a low capacity are analogous to the standard solution culture system(Loneragan, 1968). Therefore, plant species may be expected to show as wide a variation in sensitive to deficiency when grown on soils as they do in solution cultures of contrasting nutrient supply.

It has been shown that defoliation reduces plant growth of some tropical pasture species (Jones, 1967; 1974a; 1974 b; Thomas, 1976 a; 1976 b). Increasing the cutting interval generally increased the dry matter yields of most pasture plants. The results from this experiment also reveal that dry matter yields of centro decreased with decreasing cutting height and increased with increasing cutting interval. The lowest total dry matter yields were observed in the 2.5 cm cutting height and the complete defoliation treatments when defoliated every 7 days. The reduction in yield of plants in these severe defoliation treatments is attributed to the lack of photosynthetic area of the stubble to meet the demands of the plants for regrowth.

The reduction in tissue P concentration in the regrowth portion and whole tops of plants in the most severe defoliation treatments(Table 1) was associated with a lower proportion of younger tissues to older tissues comprising the whole tops of plants in these two treatments. The lower concentrations of P in the regrowth under less frequent defoliations were due to the more older tissues than those under more frequent defoliations. The decline in P concentration in tops of Townsville stylo with age has also been documented (Jones, 1968; Moody and Edwards, 1978).

A very similar pattern of defoliations was observed on the critical P concentrations as did the actual mean P con centrations. However, the critical con centrations obtained in the present experiment were higher than those obtained from the still solution culture experiment (Chantkam, 1978; Spear *et al.*, 1979). Following the first defoliatton the effect of cutting height on the critical concentrations was reversed at all successive defoliations and cutting intervals (Table 5). This indicated that several defoliations can alter the effect of cutting height on the critical P concentrations in the regrowth portion of centro grown in constant solution P concentrations.

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