

THE EFFECT OF MINERAL NUTRITION
ON THE GROWTH OF THREE ETHIOPIAN GRASS SPECIES

A Thesis

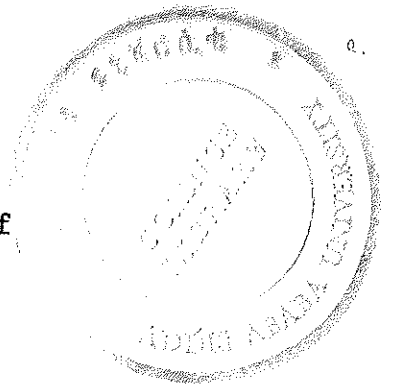
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In Partial Fulfilment
of the Requirements for the Degree of
Master of Science in Biology



by

✓ Saba Abera

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ABSTRACT

The effects of nutrient gradients on the growth and chemical compositions of three grass species (Andropogon abyssinicus R.Br. ex Fresen; Hyparrhenia pilgerana C.E. Hubbard and Pennisetum schimperii A. Rich) grown in pure and mixed stands were investigated to examine the response of the grass species to different concentrations of total nutrients and to detect any difference in the growth of the species in mixed relative to their growth in pure stand. The experiment was conducted under greenhouse conditions and the plants were supplied with a series of concentrations of the Long Ashton Nutrient Solution.

Plant height, tiller number, leaf area, leaf length and leaf width, total dry matter and nutrient concentrations in the tissue increased with increasing nutrient supplies for both pure and mixed stand experiments of all the three species. Root /Shoot ratio, on the other hand, decreased as nutrient supplies increased.

There was a significant difference in plant height, tiller number, dry matter, and internal tissue concentration of plants grown in pure and mixed stand. However, leaf area, leaf length, leaf width and root /shoot ratio did not show any

significant difference between the plants in pure and mixed stands. The most important effects of the addition of mineral nutrients were increased density of the shoots, growth, and general improvements in the vegetative vigor of the plants. The results of dry matter production and tiller number indicated that P.schimperi to be a poor competitor in mixed stands.

INTRODUCTION

Grass establishment occurs over a wide range of climatic conditions to form the grasslands that occupy about one fifth of the land surface of the globe (Mckell, 1972). Grasslands are important to man's economy by virtue of providing pastures for grazing animals. Thus man has always been interested in grasslands, and in their extent and management (Gould, 1968; Vos, 1969; Duffey et.al. 1974; Jung and Kocher, 1974). Since grazing is the imposition of a biotic factor upon vegetation the maintenance of grassland becomes an immediate ecological problem (Bor, 1973; Jewiss, 1966 and Baker, 1978).

Out of the 10,000 estimated grass species of the world only 40 are cultivated to any appreciable extent for pastures in both the tropical and temperate regions (Hartley & Williams, 1956; cited in Mckell,1972, Tothill,1978). Although forage crops, grasses in general, have not received the same attention as cereals during the early days, man through experience,has learned that under proper care and management, the feeding value of grasses justifies their consideration as crops in their own right (Dunham,1957). If farmed at its highest potential, grass yields more starch and protein equivalent per acre than any other crop (McIlroy 1972). If grassland agriculture is to be understood and exploited

to the full, it is essential at the outset to understand the potentialities of grasses, their place in the natural communities, their habit and physiology - in short their ecological and biological relationships (McIlroy, 1972).

Regulation of the mineral nutrition of plants is one of the most ancient and most accessible methods affecting the growth and yield of crops, and in the past many experiments have concentrated their efforts on the problems of plant nutrition (Willis, 1963; Hackett, 1965 and Langer, 1968). It is essential to know the response of plants to mineral elements since it is the major factor in determining their natural distribution and their ability to grow and survive in ecosystems that have been altered by man (Andrew and Johanson, 1978).

Many pastures that are either sown or native, occasionally by design but more often by accident or influence of environmental factors consist of several species. Because of this pasture - scientists over the years have shown a continuing interest in studying interactions among pasture species (Hall, 1978; Tothill, 1978). Competition, as one of the underlying principles in plant communities, has received great impetus from the valuable contributions of

people like Dewit (1960; cited in Hall, 1978), Harper (1961; cited in Hall, 1978) and Donald (1963; cited in Hall, 1978). Plants may compete with each other for space, moisture and nutrients (Daniel and Roberts, 1966).

Black (1966) indicated that few terms in ecology have been used with such a wide diversity of meaning as competition, while Williamson (1957) showed that different definitions were given to the term by various authors interested in the subject. Etymologically, the word competition means "seek together" (Hall, 1978). Clements (1907; cited in Hall, 1978) and Donald (1963; cited in Hall 1978) proposed a generally accepted definition of competition though not in congruity with the majority of plant scientists. According to Clements (1907: cited in Black 1966), "competition is a question of the reaction of a plant upon the physical factors which encompass it, and of the effects of these modified factors upon the adjacent plants". Black (1966) summarized the definition of competition, as proposed by Clements and compiled by Donald, as consisting of :-

- i. the modification of the environment by the presence of a plant and
- ii. the effect of these modifications upon surrounding plants.

Because of its wider application, the term competition in one usage may cover the relationship between the plant communities and the environmental factors that tend to limit their development and, in another, a detailed analysis of the interaction of individual plants with their microclimate and their effects on the neighbouring plants (Black, 1966).

It is also known that symbiotic phenomenon and any determinant influence of one plant on another like the secretion of toxic substances (allelopathy) have been included in the definitions of competition by some authors (Hall, 1978).

As pointed out earlier, nearly every author interested in the definition of competition has his own version, 4 but Silvertown (1987) grouped these definitions into two types :-

- i. those which define the interaction on the basis of its mechanism (eg. Grime, 1979) and
- ii. those which emphasize the outcome of the interaction between two competing species which must, for example, lead to a reduction in the survivorship, growth or reproduction of the competing individuals (Harper, 1977; Begon, Harper and Townsend, 1980)

Plants are conceived as competing for necessities that are in finite supplies (Trenbath, 1974). Those plants most competitive by virtue of being best adapted to the environment at a given time will thrive and spread at the expense of other plants (Daniel and Roberts, 1966; Harper, 1977; Grime, 1979).

A series of studies have been undertaken to evaluate the response of individual species to gradients of nutrient concentrations or other environmental factors. In contrast, there have been few studies of species in mixtures along nutrient gradients (Austin, 1982).

Parrish and Bazzaz (1982) have indicated the complexity of nutrient gradients, their indirect effects on plants. However, because plant species do show marked differences in physiological and ecological responses along nutrient gradients, Parrish & Bazzaz (1982) have emphasized the importance of such studies presumably because it can offer valuable insights into plant community organization and competitive relations.

Austin and Austin (1980) in various experimental works have studied the performance of several plant species in pure and in mixed stands under different levels of nutrients.

They suggested that such an experiment could provide a framework to the ecology of the plants by indicating those portions of a fertility gradient where particular species will be most productive and which species will achieve dominance in mixtures at different levels of fertility (Austin and Austin, 1980; Austin, 1980, Austin et al., 1985).

Because inherent differences between species can be more apparent under controlled environmental conditions, the present experiment was designed to explore the effect of nutrient gradients on the growth performances of three grass species grown in pure and in mixed stands.

Grasses belonging to the genera Panicum, Pennisetum, Andropogon, Themeda and Hyparrhenia provide the dominant grass cover in both East and Central Africa (Vos, 1969).

Although there are a large number of grass species in Ethiopia (Froman and Person, 1974), the North Western and Central highlands are predominantly covered by members of three grass genera; namely Andropogon, Hyparrhenia and Pennisetum (Zerihun, 1987).

Zerihun's (1985) study of the grassland communities on the central plateau of Ethiopia has shown that three grass species constitute the major cover of the plateau.

Hyparrhenia pilgerana and Andropogon abyssinicus prevail on protected sites whereas the grazed areas are characterized by preponderance of Pennisetum schimperii (Zerihun, 1985, 1986).

It is, therefore, needless to emphasize that livestock play a role on the local distribution of grasses by selectively grazing and browsing thus encouraging some grasses and eliminating others (McIlroy, 1972; Watkins and Clements, 1978; Vos, 1959; cited in Marten and Donker, 1968; Crawley, 1983).

Of the above three grass species, Andropogon abyssinicus and Hyparrhenia pilgerana are more palatable. The latter to a lesser degree because of its coarse and stemmy nature at maturity (Froman and Person, 1974), Pennisetum schimperii is not favored by grazing animals. The unpalatability nature of P. schimperii, is attributed to the very high fibre and silica content of the tissue (Evalson 1970; cited in Zerihun, 1985).

Zerihun (1985, 1986) showed that grazing by livestock brings about a shift in the composition of the species. Overgrazing induces the replacement or diminution of important species like Andropogon abyssinicus and Hyparrhenia pilgerana by the less favored species like Pennisetum schimperii on the central plateau of Ethiopia (Zerihun, 1985, 1986).

Under protected conditions Hyparrhenia pilgerana becomes eventually dominant over A. abyssinicus and this shift in dominance from A. abyssinicus to Hyparrhenia pilgerana is not highly desirable as far as palatability of the swards is concerned. It was, therefore, suggested that factors which could discourage the predominance of Hyparrhenia pilgerana over the more palatable ones should be introduced for optimal exploitation of pastures (Zerihun, 1985, 1986). Pennisetum schimperi which is the dominant species in most overgrazed sites, though not desired from the palatability point of view can give protective cover to the soil. The high rate of soil erosion on the central plateau of Ethiopia (McDougall et.al., 1975; Virgo & Munro, 1977) can be adduced to the loss of vegetation cover and overgrazing beyond Pennisetum schimperi dominance stage. There is no vestige of the original forest which once characterized the central plateau. The area now is covered by permanent or temporary croplands or grasslands.

Because grasses make less demand upon the habitat and because of the high productivity of the grassland vegetation, Zerihun (1986, 1988) propounds the vantage of maintaining the grassland so as to keep it in as productive a state as possible. Tothill (1978) in describing the ecology of a pasture, has mentioned the need for optimization of pasture

productivity, so as to have a sustained long term livestock production, and the simultaneous maintenance of landscape stability. It is also considered that these factors are crucial in the objectives of a pastoral system. Studies carried out on grasses are, therefore, not only of academic interest but also have their own agricultural and ecological value.

The two grass species (Andropogon abyssinicus and Hyparrhenia pilgerana) were taken as representatives of grasses in the protected areas and the third grass species (Pennisetum schimperi) in over grazed areas.

Composition of a grassland community can be rapidly and substantially modified mainly by grazing in that animals select plant parts and plant species in proportion to their relative abundance in pastures (Watkins and Clements, 1978; Crawley, 1983).

Another factor which can alter the composition of a grassland community is the addition of nutrients. Instances have been reported where the addition of complete fertilizer often leads to dominance by a single species and thus, resulting in the elimination of diversity. This is well illustrated by the work of Willis (1963) where the grasses Festuca rubra and Poa pratensis became dominant by the addition of complete

nutrients in dry dune pasture and *Agrostis stolonifera* in wet dune meadows.

Such studies may show the importance of relative level of nutrient concentration in determining the species composition of a particular area.

Plant species show marked differences in physiological and ecological responses along nutrient gradients. A regime which may promote optimum growth of one species may cause reduced growth as a result of toxicity or deficiency in another (Bannister, 1976).

Parrish and Bazzaz (1982) suggested that differences between species that appear on an artificially produced gradient strongly infer to differences in resources use at a given site in the field. The resource availability may be affected by neighbours. Harper (1964; cited in Hall; 1978) wrote "the essential qualities which determine the ecology of a species may only be detected by studying the reaction of its individuals to their neighbours and ... the behaviour of the species in isolation may be largely irrelevant to understanding their behaviour in the community". He added differences between species which are crucial in determining their success or failure when grown together may only be exposed and demonstrated when the species are grown together.

The purpose of the present work is, therefore, to examine in some detail the growth characteristic of the three grass species in mixed and pure stands and to determine if the growth functions of the species can bear some relations in the competitive ability of the grasses. Moreover, in this investigation it is hoped to elucidate the importance of the levels of the various nutrient gradients in controlling the vigor, distribution and relative abundance of the grass species.

This study, therefore, has two major objectives:-

- a. to analyse the growth of the grass species in pure stand at different concentrations of total nutrients
- b. to detect any differences in the growth of species in mixed stand at different nutrient concentrations relative to their growth in pure stand.

MATERIALS AND METHODS

I. Glasshouse Experiments

Scoriaceous sand was obtained and sieved to exclude the gravel fraction. It was then leached with tap water for 30 days.

The sand, about 500 gm and 750 gm was put in ceramic (clay) pots with perforated bases of average diameter 11 cm for the pure stand and 13 cm for the mixed stand experiments. The inside of the pots were lined with polyethylene to avoid contamination. The sand in the pots was further washed with distilled water for purification.

The seeds were collected from a natural population. Heads containing seeds of Andropogon abyssinicus were collected from a farm close to Menagesh forest in Wolmera and Hyparrhenia pilgerana near the tree line above Menagesha forest and those of Pennisetum schimperii from the lower edge of Chilimo forest Western Shewa.

Two series of experiments were carried out :-

- a) Experiments in pure stand :- Seeds from a single species were sown in a pot for each nutrient level and upon emergence the seedlings were thinned out to three per pot.

b) Experiments in which seeds of each species were planted randomly in one pot for each treatment. After germinated seedlings were removed so that three plants of each species remain in a pot, 9 plants all together.

Equal distance was maintained as much as possible between nearest neighbours either as pure or mixed stand of all three species.

Randomized complete block design with three replication per treatment was used in all the experiments. To minimize edge effects, seeds of the different species were sown in pots around the experimental pots.

The seedlings entered the experiments on the 15th day after sowing. The nutrient solution used in the study was the Long Ashton Nutrient Solution (Hewitt, 1966), an efficient solution containing Sodium for use in sand cultures. The environmental gradients was a series of concentrations of the Long Ashton Nutrient Solution ranging from 1/64 up to 8 times the recommended concentration, giving 10 levels. The particular treatment levels were chosen for convenience in dilution. Tap water was used as control. The basic chemical composition and the calculated nutrient composition of the basic culture solution and of extremes of nutrient series is shown in Table 1.

In the early stages of growth (the first 8 weeks), each pot received 100 ml of the appropriate nutrient solution and later 200 ml of the solution twice a week, since loss by evapotranspiration is likely to increase as biomass increases.

The pots were inspected and watered with distilled water either once or twice a day, depending on the humidity.

The experiment was run for five months and the plants were harvested on the 150th day after sowing. A second experiment was run using the same procedure for three months for the determination of dry matter production.

The following parameters were recorded in the course of the experiments:-

I. GROWTH PARAMETERS

The effects of nutrient gradients on plant height and tiller number were studied at ten days interval, and that of dry matter production at four weeks interval. Leaf area, leaf width and leaf length of the first experiment were recorded at 148th day after sowing.

i. Plant Height

Maximum height (stem + leaves) of individual plants was measured from the sand surface in the pot to the highest

point on the tallest leaf at ten day intervals from the 25th to 75th day after sowing. The mean height per plant was then recorded.

ii. Tiller Number

Tiller counts of individual plants were made at ten day intervals from 25th to 75th day after sowing. The mean tiller number per plant was then recorded.

iii. Leaf Area, Leaf Width and Leaf Length

The third leaf blades were removed from randomly selected plants in each pots and traces were made on a paper. The area was then estimated by planimetry of tracings. Leaf width and leaf length were estimated from the same tracings. These parameters were recorded at 148th day after sowing.

iv. Dry Matter and Root / Shoot Ratio

The plants were harvested at 4, 8 and 12 weeks after the start of the experiment. Whole plants were removed from each pot and the root system washed in tap water to remove sand. Plant parts were separated into shoot and root portions, dried over-night at 100 °C and weighed. The data were expressed as dry weight per plant part and Root /Shoot ratio.

II. Plant Tissue Analysis

The upper most leaf blades of each treatment were collected and composited into one sample.

The samples were transferred into an oven and dried at 70 ° c for 24 hours. The oven dried samples were ground in a mill to pass a 1 mm , sieve and kept in plastic containers until analysis.

The plant material was digested using the wet destruction method described in F.A.O. soils bulletin (1980) with slight modifications. 0.3g of the oven-dried plant material instead of 0.5g suggested in the F.A.O. bulletin, was introduced into a test-tube and digested with 4ml. conc. H_2SO_4 on a hot plate at 280 ° c. Small quantities of 30% H_2O_2 was added at intervals until the digest became clear. After cooling, the digests were diluted to 75 ml. with deionized water.

Determination of K, Ca and Mg

Aliquats of digests were diluted with 0.1% Lanthanum chloride and concentrations were determined by Atomic Absorption Spectrophotometer (Model Perkin Elmer 2380), using a mixed standard of K, Ca and Mg. Air - acetylene was used as a fuel.

Determination of P and N

Aliquates of the wet digest solutions were diluted with pure water and simultaneous determination of N and P were made with Continuous Flow Analysis (auto-analyser) using the standard methods of Chemlab. Instruments Ltd.1981.

Results

The raw data have been transformed into histograms and line graphs and these are shown in Figs. 1 to 16. Analysis of variance following Orloci and Kenekl (1985) was run in the Biology Dept. Flora Project Hewlett - Packard 150 pc. The results of the analysis are shown in table 1 - 12 in the appendix.

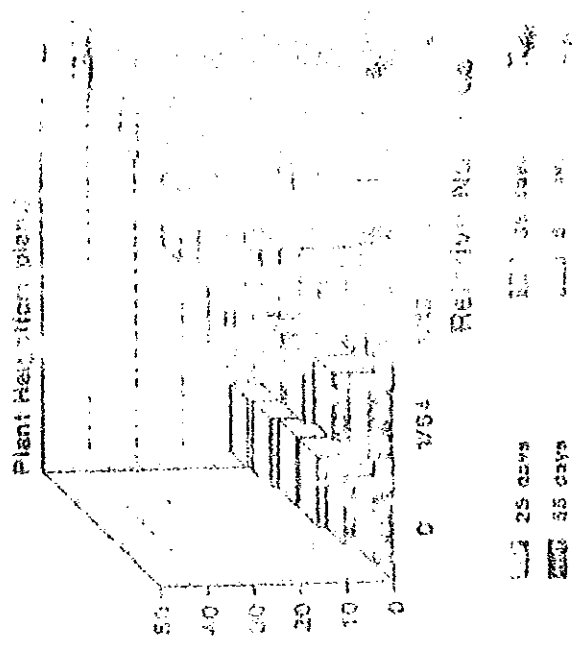
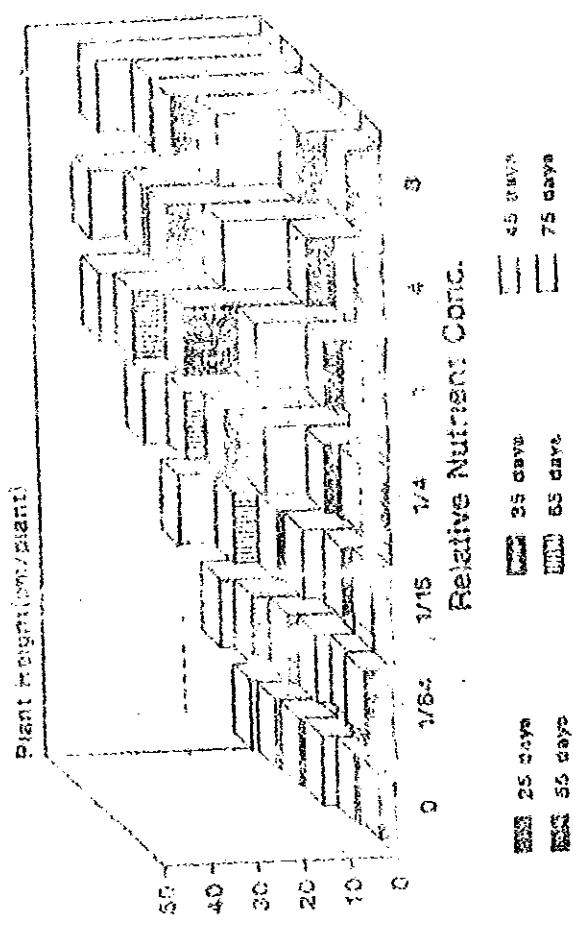


Fig. 1 Course of height growth of Andropogon abyssinicus during a) and b) monoculture experiment at different nutrient levels.

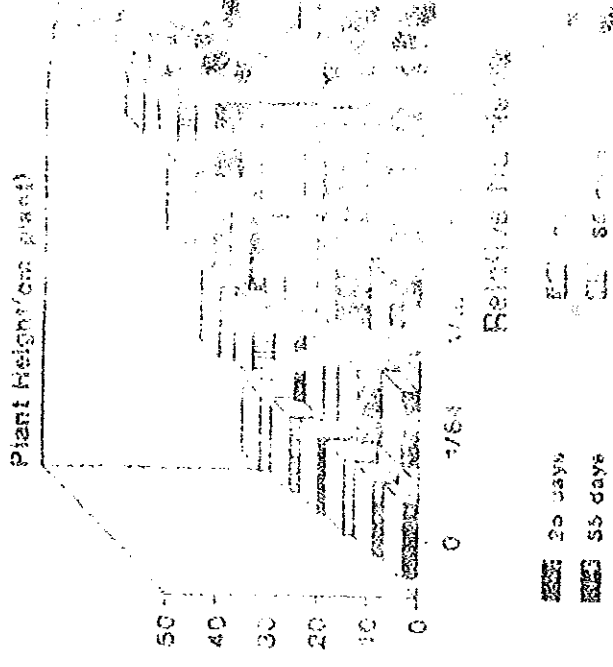
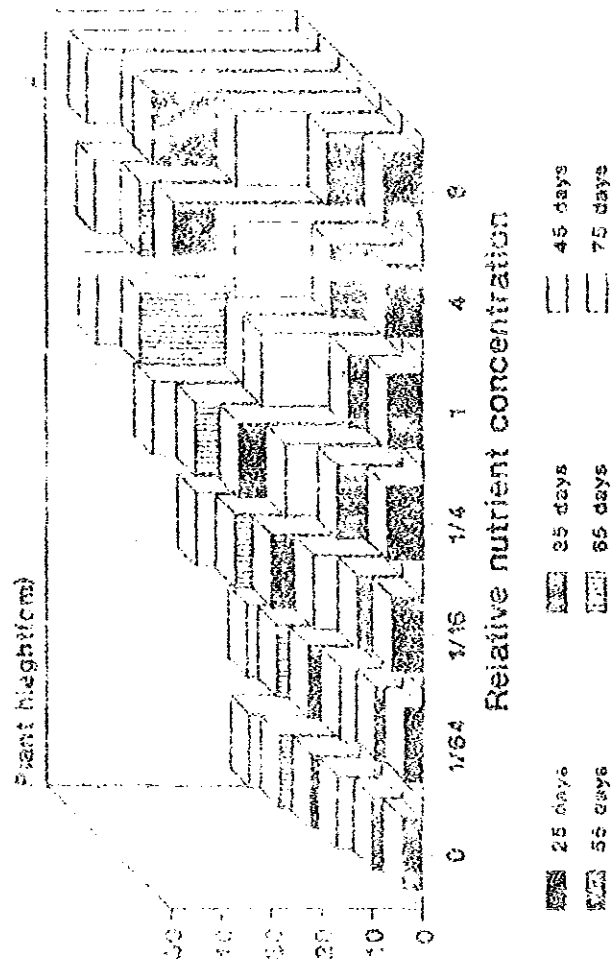


Fig. 2 Course of height growth of Hyparrhenia Sp. during a) mixture and b) monoculture experiment at different nutrient levels.

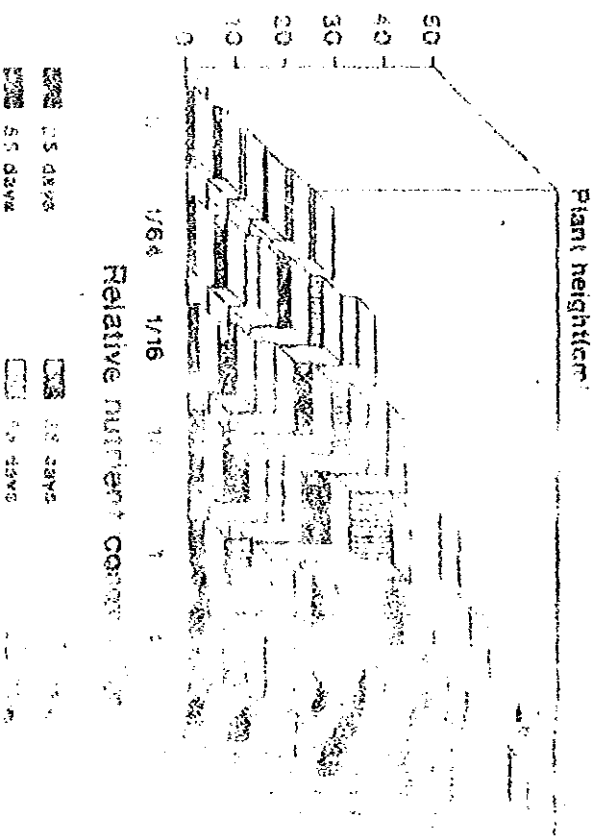
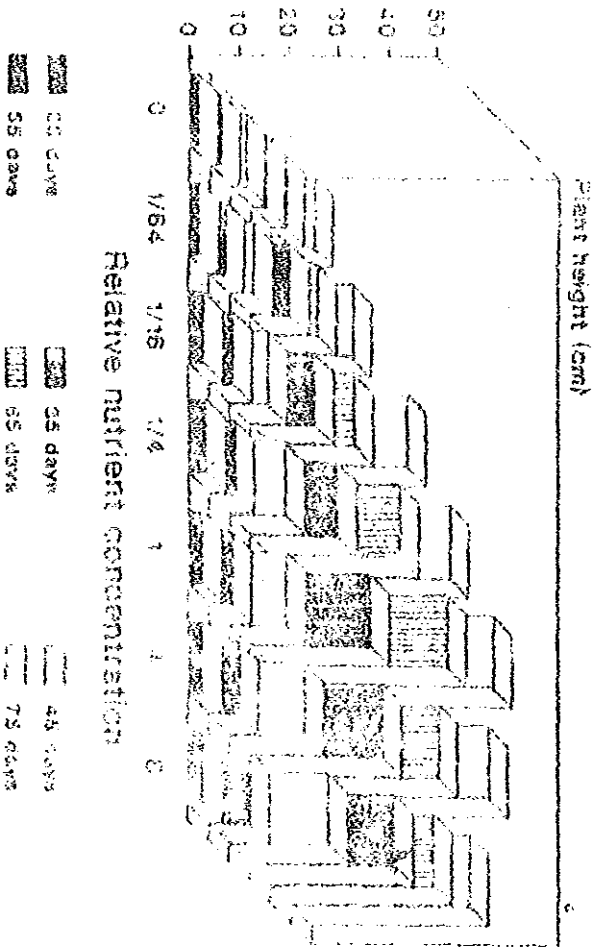


Fig. 3 Course of height growth of *Ipomoea pes-caprae* Schimper during a) Nitrate and b) phosphate experiment at different nutrient levels.

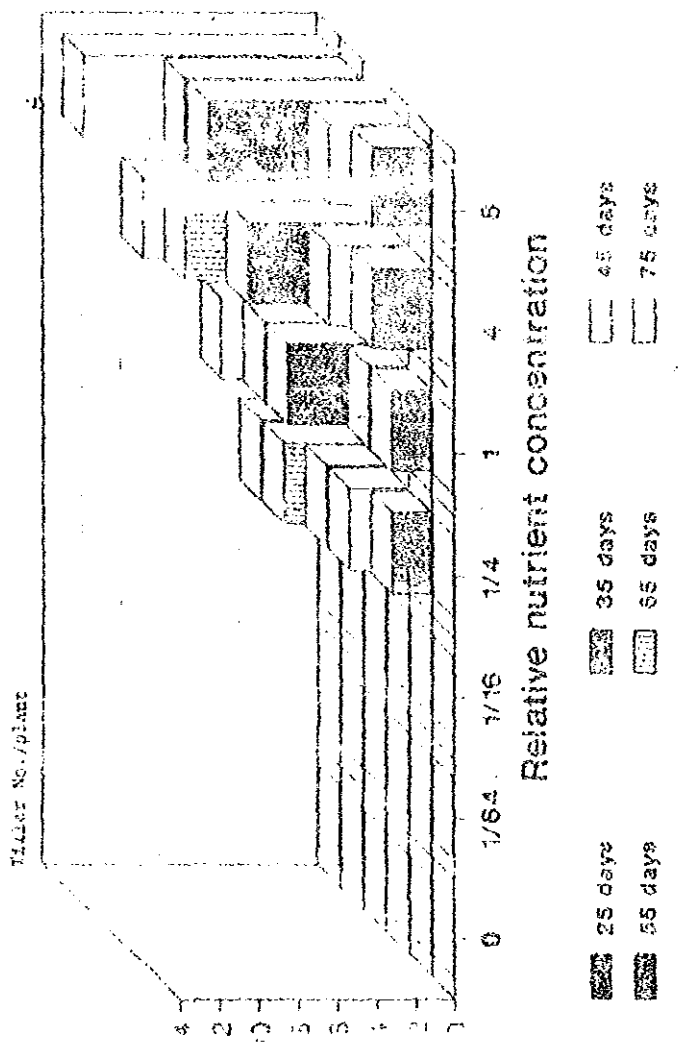
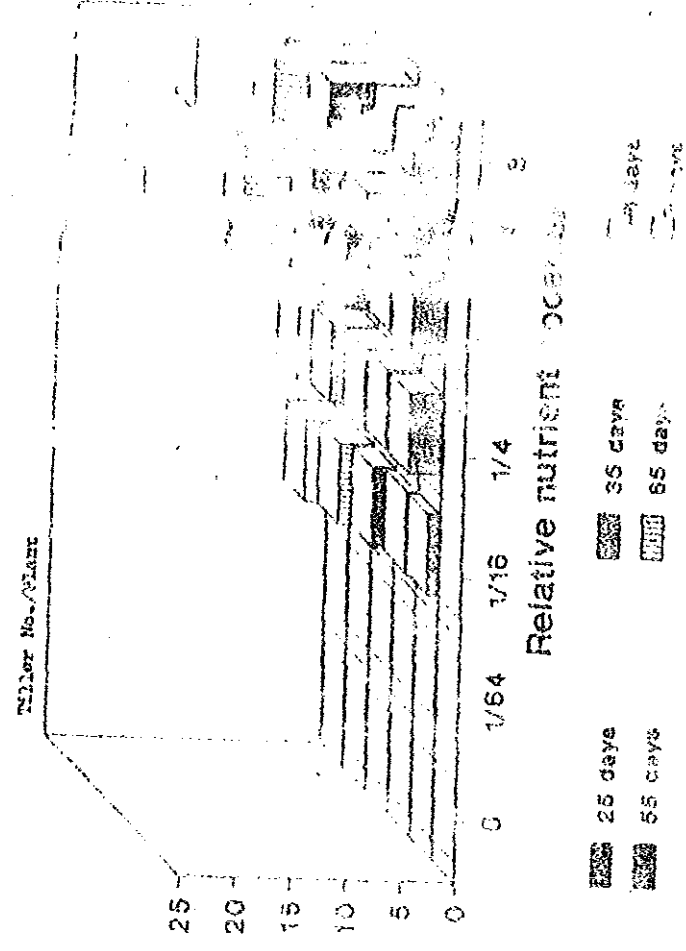


Fig. 4 The effect of nutrient gradient on tiller no. of *A. abyssinicus* a) mixture and b) monoculture experiments.

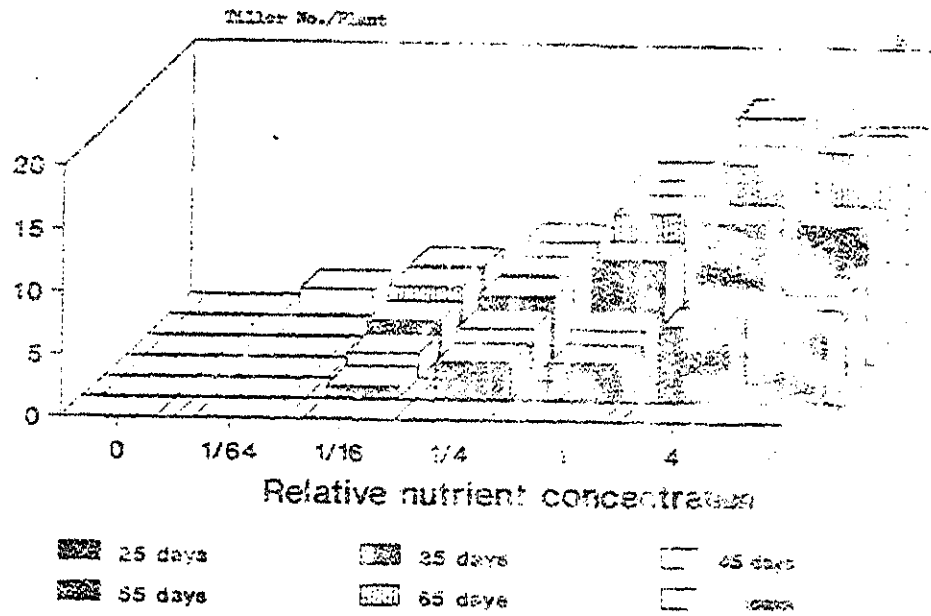
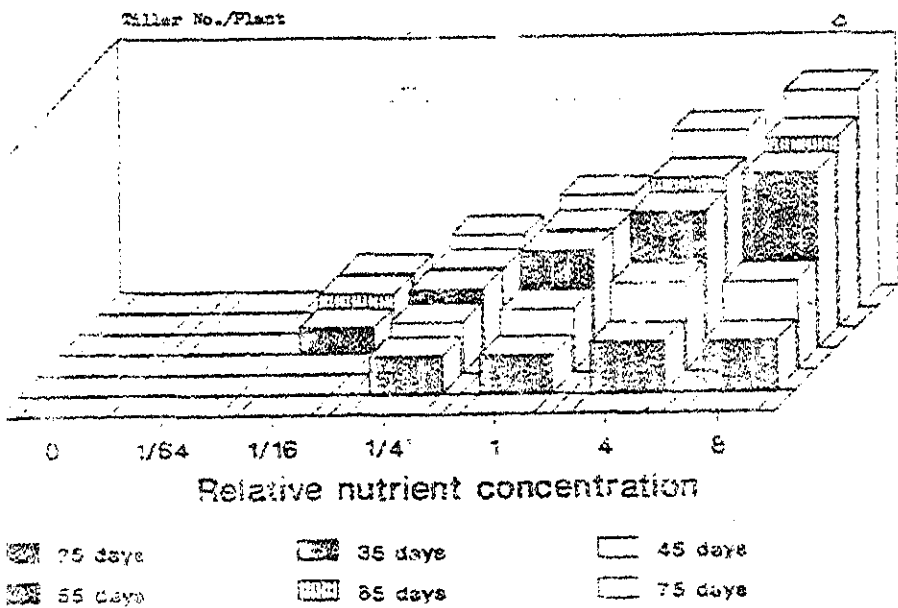


Fig. 5 The effect of nutrient conc. on tiller number of Hyparrhenia Sp. in a) Mixture and b) monoculture experiment.

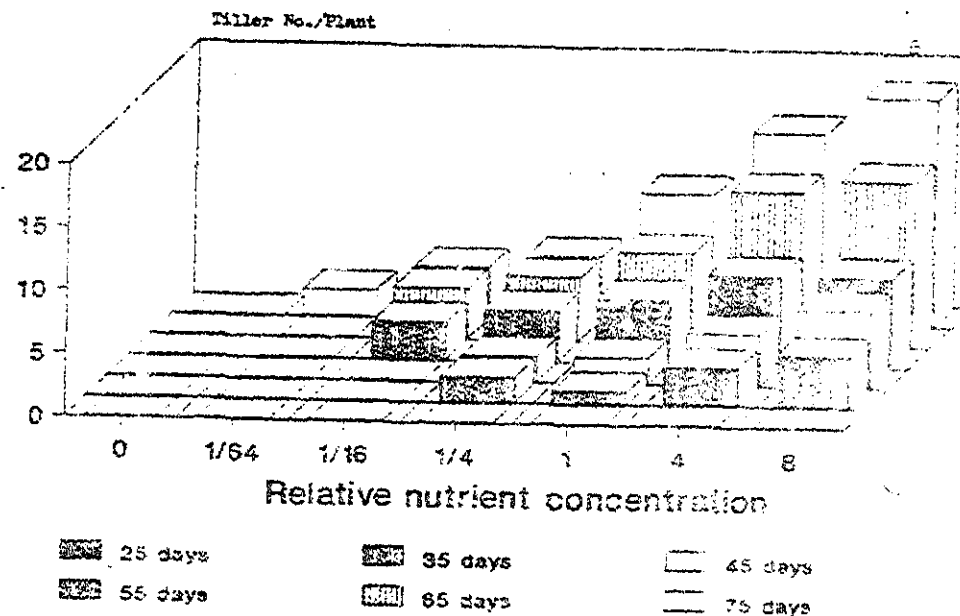
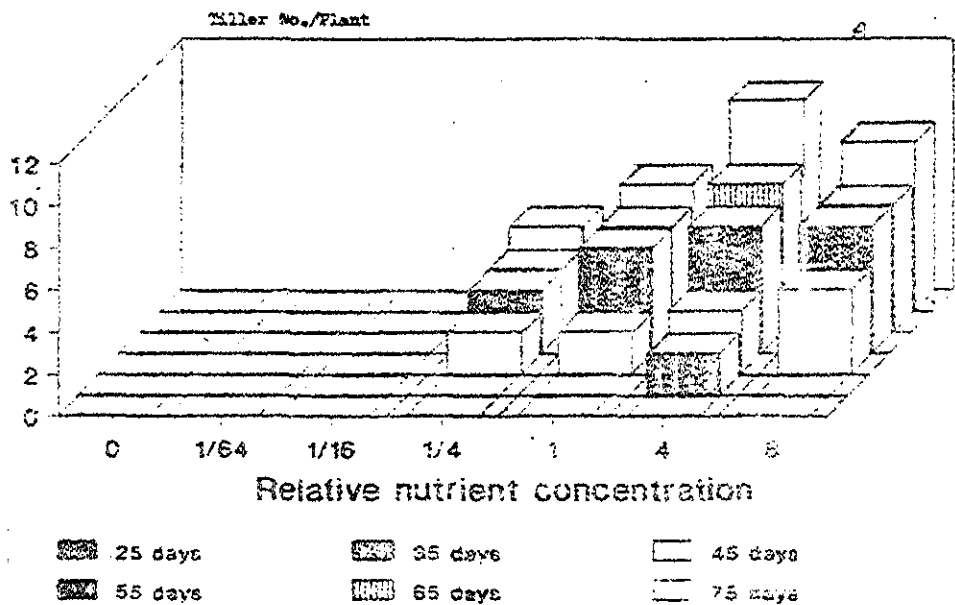


Fig. 6 The effect of nutrient gradient on tiller no. of Pennisetum Schimperi grown in a) mixture and b) monoculture.

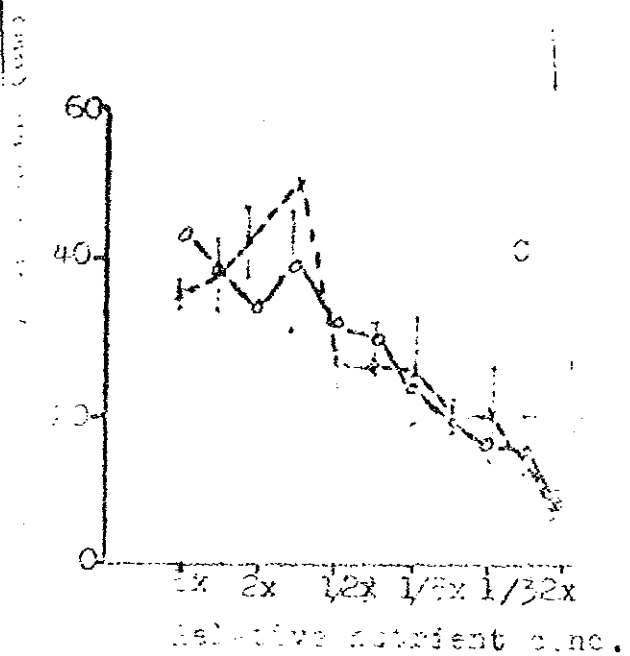
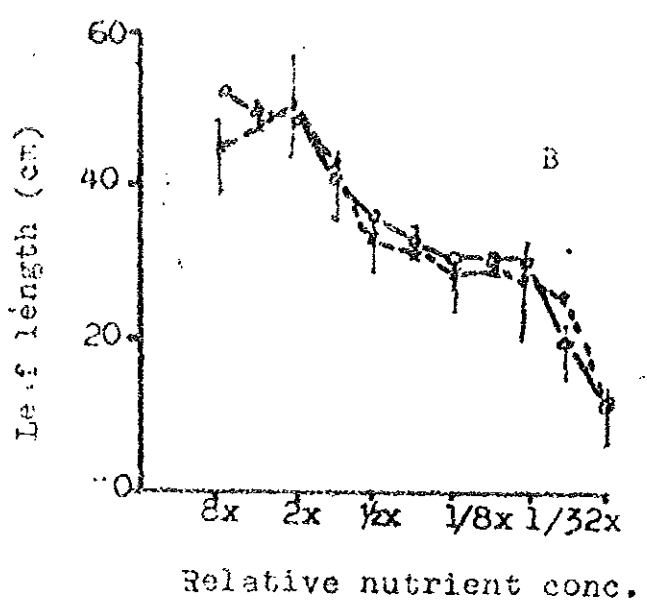
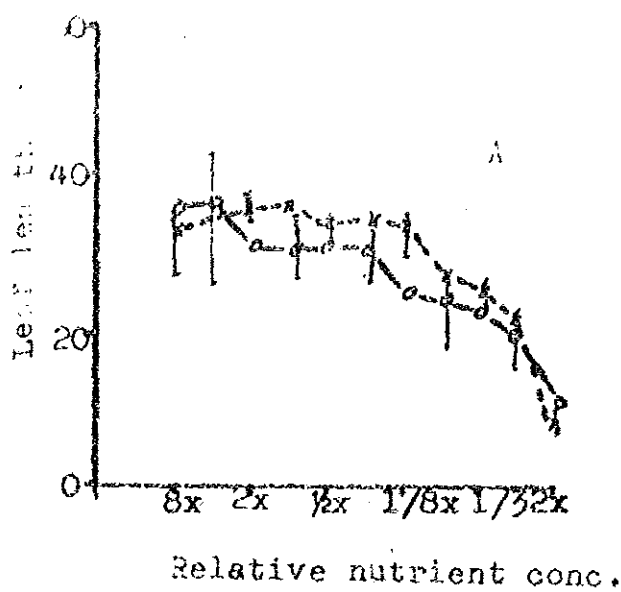


Fig. 8. Effect of nutrient conc. on leaf length of plants grown in constant (8x) and decreasing (1/2-1/32x) nutrient conc.
 a) *Andropogon furcatus*
 b) *Brachiaria pilgerana*
 c) *Leptochloa schimperii*

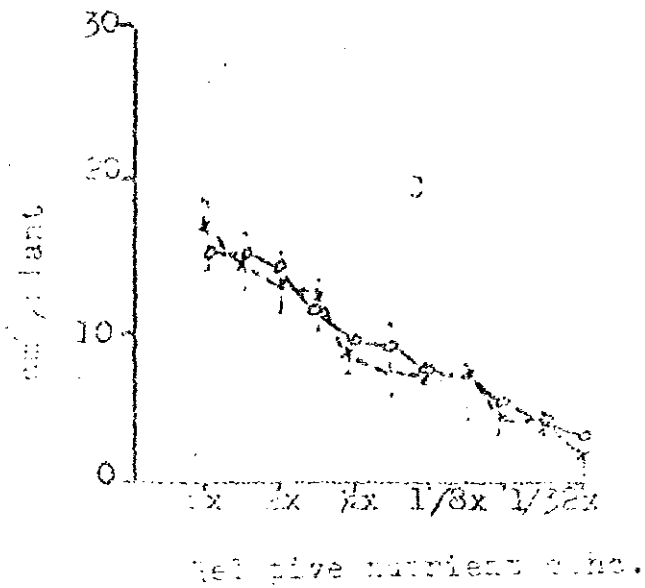
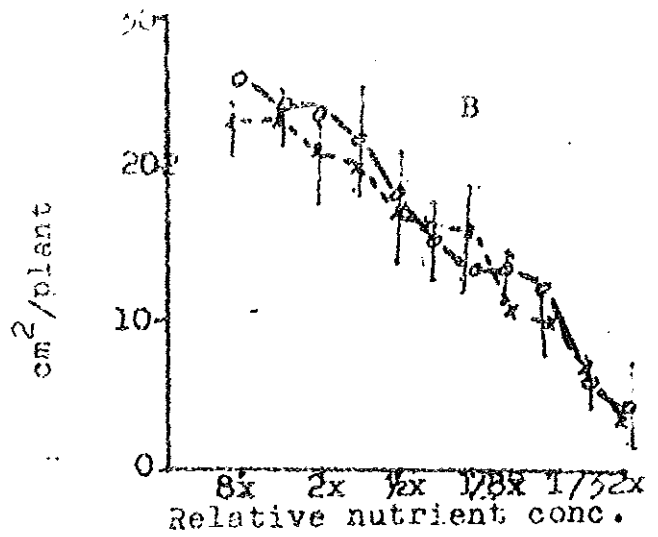
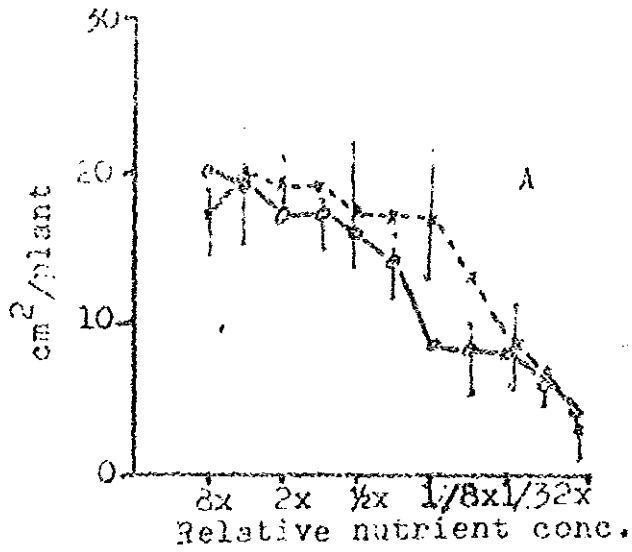


Fig. 7. The effect of nutrient deficit on leaf area of plants grown in controlled (x...x) and natural (o-o) conditions of *Hydrocotyle sphenoloba* L. (var. *Hydrocotyle sphenoloba* L.) and *Hydrocotyle sphenoloba* L. (var. *Hydrocotyle sphenoloba* L.)

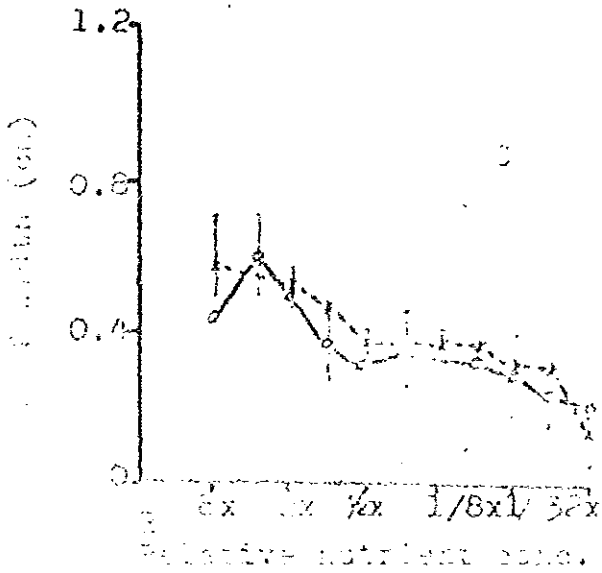
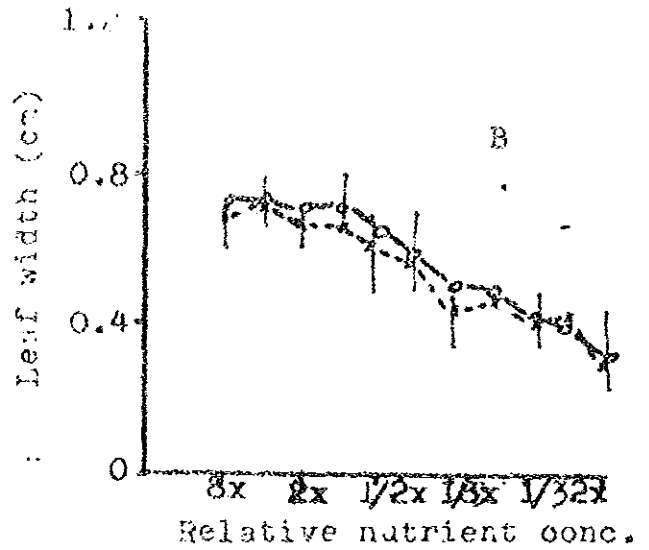
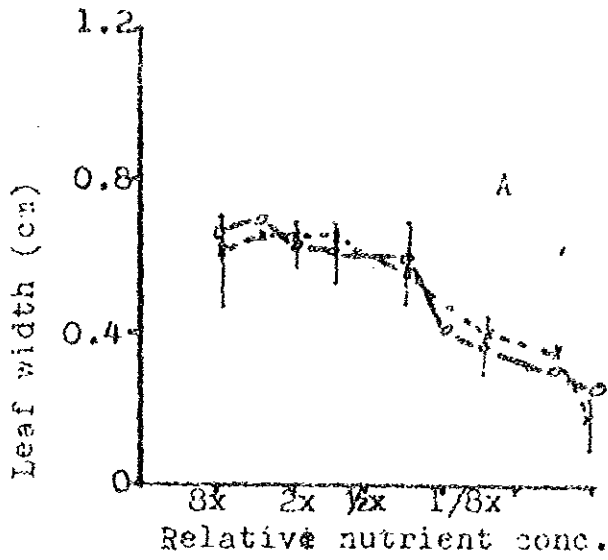


Fig. 9. Influence of relative nutrient concentration on leaf width of *Phaseolus vulgaris* L. (cv. 'Giant') under different nutrient conditions. The solid line with open circles represents the control (8x) and the dashed line with crosses represents the nutrient deficient condition (1/32x). Error bars represent standard error of the mean.

DRY-MATTER production

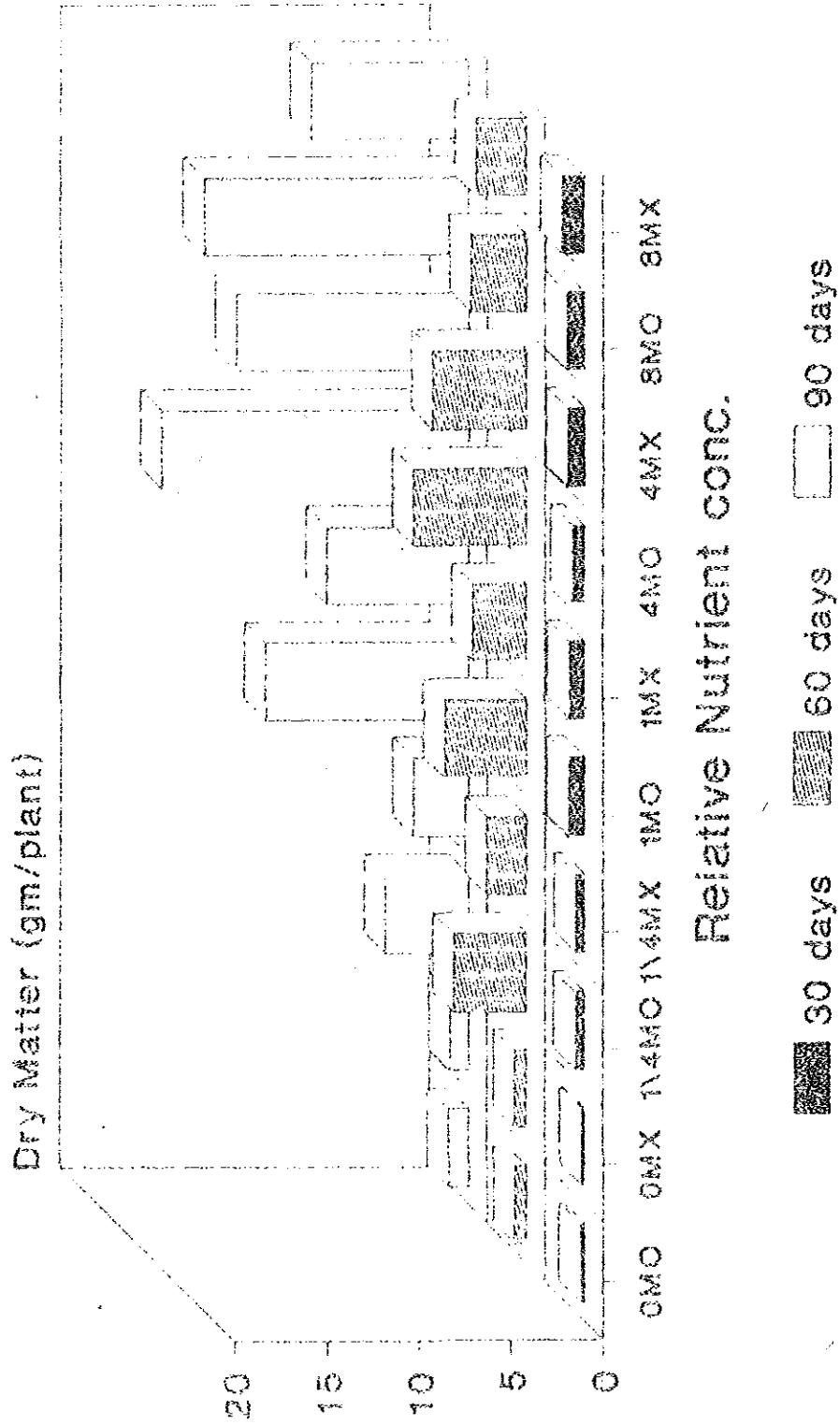


Fig- 10 The effect of nutrient gradient on the yield of *A. abyssinicus* grown in monoculture and mixture - (The subscript Mo, refers to the yield of plants at the particular nutrient level in pure stand and Mx refers to

affect the composition of the plant tissue (Raymond, 1969; Whitehead, 1966; cited in Duell & Trout, 1972, Viets, 1980. Donohue et. al. 1981 and Cherney and Robinson, 1985).

CONCLUSION

The results of studies of the effect of nutrient gradients on the three grass species in pure and mixed stands showed that growth in all cases was highly reduced by a shortage of nutrient supply. Plant height, tiller number, dry matter, and leaf area, length and width of all three species increased in response to increasing nutrient supply while the root/shoot ratio decreases with increased nutrient supply.

Among other characters dry weight and tiller number are the most informative for predicting establishment potential in the field (see also Tyler, Chorlton and Thomas, 1987). In the present study, with regards to dry weight and tiller number, P. schimperi was found to be a poor competitor, it failed to survive competition when introduced in mixed stand with A. abyssinicus and Hyparrhenia pilgerana. In the mixture experiment the species most benefited by the addition of nutrients were the two dominants, Andropogon and Hyparrhenia. In contrast, under the augmented nutrient regimes, P. schimperi was markedly depressed apparently because of the enhanced competitive pressure from the two luxuriantly growing dominants.

P. schimperi being tolerant to grazing (or less favoured by livestock) becomes dominant or replaces the less tolerant species, A. abyssinicus and Hyparrhenia pilgerana in over-grazed areas but fails to compete with them under conditions of less stress (see Zerihun, 1985, 1986).

Tropical grasses tend to be low in nutritive value (see Siewerdt & Holt, 1979) and even if a very small increase in efficiency could be obtained by nutrient application, the overall economic benefits might be considerable.

It is possible to suppress the less palatable grass, P. schimperi by application of fertilizer in pastures. The economic benefits must, however, be weighed and optimal concentration or rate of fertilizer application must be assessed for definite recommendations. To get the most return of such endeavour the time of harvest should be determined since Hyparrhenia pilgerana can lose its palatability at old age.

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Table A.1. Table of ANOVA for
Plant Height cm /plant

Species	Source of variation	SS	D.F.	M.S.	F	
ANDROPOGON	A	250.625	1	250.625	43.639	*
	B	27755.130	5	5551.025	966.540	*
	C	15870.410	10	15870.410	276.334	*
	AB	160.656	5	32.131	5.195	*
	AC	167.422	10	16.742	2.915	**
	BC	5396.250	50	107.925	18.792	*
	ABC	533.766	50	10.675	1.859	*
	Error	1516.203	264	5.743		
Total	51650.460	395				
HYPARRHENIA	Treatment					
	A	32.656	1	32.656	6.625	***
	B	32668.880	5	6533.775	1325.473	*
	C	19960.310	10	1996.031	404.924	*
	AB	188.156	5	37.631	7.634	*
	AC	434.891	10	43.489	8.822	*
	BC	5477.672	50	109.553	22.225	*
	ABC	378.453	50	7.569	1.535	N.S
Error	1301.359	264	4.926			
Total	60442.380	395				

Key A - Mixing
B - Time
C - Nutrient Levels

F* - Significant at 0.1% level of Probability
** - Significant at 0.5% level of Probability
*** - Significant at 2.5% level of Probability
N.S - Not Significant

Table of ANOVA for
Plant Height cm /plant

Species	Source of Variation	SS	D.F.	M.S.	F	
Pennisetum	Treatment					
	A	67.680	1	67.680	0.669	N.S
	B	36729.170	5	7345.835	72.642	*
	C	15496.730	10	1549.673	15.770	*
	AB	650.438	5	130.088	1.286	N.S
	AC	759.180	10	75.918	0.751	N.S
	BC	12660.810	50	253.216	2.504	*
	ABC	5011.438	50	100.229	0.991	N.S
	Error	26696.580	264	101.123		
Total	98522.020	395				

Key A - Mixing
B - Time
C - Nutrient Levels

F* - Significant at 0.1% level of Probability
** - Significant at 0.5% level of Probability
*** - Significant at 2.5% level of Probability
N.S - Not Significant

Table A.2

Table of ANOVA for
Tiller Number /Plant

Species	Source of Variation	SS	D.F.	M.S.	F
	Treatment				
ANDROPOGON	A	102.328	1	102.328	84.789 *
	B	1479.595	5	295.919	245.199 *
	C	2568.251	10	256.825	212.806 *
	AB	110.422	5	22.084	18.299 *
	AC	94.251	10	9.425	7.810 *
	BC	1317.977	50	26.360	21.842 *
	ABC	104.659	50	2.093	1.734 N.S
	Error	318.608	264	1.207	
	Total	6096.092	395		
	Treatment				
HYPPARRHENIA	A	25.104	1	25.104	12.805 *
	B	2351.369	5	470.274	239.873 *
	C	3880.709	10	388.071	197.944 *
	AB	18.951	5	3.790	1.933 N.S
	AC	77.073	10	7.707	3.931 *
	BC	1482.809	50	29.656	15.127 *
	ABC	83.173	50	1.663	0.848 N.S
	Error	517.575	264	1.961	
	Total	8436.762	395		

Key A - Mixing
 B - Time
 C - Nutrient Level

F* - Significant at 0.1% level
of Probability
N.S - Not Significant

Table A.2

Table of ANOVA for
Tiller Number /Plant

Species	Source of Variation	SS	D.F.	M.S.	F
	Treatment				
PENNSYLVANIA	A	240.319	1	240.319	116.097 *
	B	1455.648	5	291.130	140.644 *
	C	1648.977	10	164.898	79.662 *
	AB	146.585	5	29.317	14.163 *
	AC	125.574	10	12.557	6.066 *
	BC	958.786	50	19.176	9.264 *
	ABC	117.221	50	2.344	1.133 N.S
	Error	546.474	264	2.070	
	Total	5239.584	395		

Key A - Mixing
B - Time
C - Nutrient Level

F* - Significant at 0.1% level
of Probability
N.S - Not Significant

Table A.4 Table of ANOVA for
Leaf Length cm /Plant

Species	Source of Variation	SS	D.F. ,	M.S.	F	
	Treatment					
ANDROPOGON	A	103.355	1	103.355	7.219	N.S
	B	3799.957	10	379.996	26.541	*
	AB	248.219	10	24.822	1.734	N.S
	Error	629.953	44	14.317		
	Total	4781.485	65			
	Treatment					
HYPPARRHENIA	A	29.203	1	29.203	1.050	N.S
	B	8557.086	10	855.709	30.753	*
	AB	257.891	10	25.789	0.927	N.S
	Error	1224.305	44	27.825		
	Total	10068.480	65			
	Treatment					
PENNISETUM	A	0.672	1	0.672	0.029	N.S
	B	8255.668	10	825.567	35.269	*
	AB	413.984	10	41.398	1.769	N.S
	Error	1029.953	44	23.408		
	Total	9700.278	65			

Key - A - Mixing
 B - Nutrient Levels

F* - Significant at 0.1% level
 of probability
 N.S.- Not Significant

Table A.5

Table of ANOVA for
Leaf Width, cm /Plant

Species	Source of Variation	SS	D.F.	M.S.	F	
	Treatment					
ANDROPOGON	A	0.000	1	0.000	0.001	N.S
	B	1.505	10	0.150	30.097	*
	AB	0.113	10	0.011	2.267	N.S
	Error	0.220	44	0.005		
	Total	1.838	65			
	Treatment					
HYPARRHENIA	A	0.022	1	0.022	4.5	N.S
	B	1.231	10	0.123	25.394	*
	AB	0.015	10	0.001	0.306	N.S
	Error	0.213	44	0.005		
	Total	1.481	65			
	Treatment					
PENNISETUM	A	0.010	1	0.010	1.016	N.S
	B	0.687	10	0.069	7.194	*
	AB	0.150	10	0.015	1.575	N.S
	Error	0.420	44	0.010		
	Total	1.267	65			

Key - A - Mixing
b - Nutrient Level

F* - Significant at 0.1% level
of probability
N.S. - Not Significant

Table A.6

Table of ANOVA for
 Dry Matter Production, gm /Plant

Species	Source of Variation	SS	D.F.	M.S.	F
	Treatment				
ANDROPOGON	A	47.032	1	47.032	38.096 *
	B	2591.675	10	2591.167	209.928 *
	C	15.510	2	7.755	6.281 N.S
	AB	81.975	10	8.198	6.640 *
	AC	1.776	2	0.888	0.719 N.S
	BC	177.989	20	8.899	7.209 *
	ABC	12.479	20	0.624	0.505 N.S
	Error	162.961	132	1.235	
	Total	3091.396	197		
	Treatment				
HYPARRHENIA	A	9.689	1	9.689	15.828 *
	B	1252.837	10	125.284	204.653 *
	C	14.235	2	7.117	11.626 *
	AB	71.601	10	7.160	11.696 *
	AC	0.938	2	0.469	0.766 N.S
	BC	47.335	20	2.367	3.866 *
	ABC	8.898	20	0.445	0.727 N.S
	Error	80.807	132	0.612	
	Total	1486.341	197		

Key - A - Mixing
 b - Nutrient Level

F* - Significant at 0.1% level
 of probability
 N.S.- Not Significant

Table A.6 Table of ANOVA for
Dry Matter Production, gm /Plant

Species	Source of Variation	SS	D.F.	M.S.	F
	Treatment				
PERNNISEYON	A	42.173	1	42.173	270.998 *
	B	633.529	10	63.353	407.092 *
	C	3.643	2	1.821	11.704 *
	AB	244.281	10	22.428	144.118 *
	AC	0.642	2	0.321	2.063 N.S
	BC	19.518	20	0.976	6.271 *
	ABC	9.304	20	0.465	2.989 *
	Error	20.542	132	0.156	
	Total	953.633	197		

Key - A - Mixing
 B - Nutrient Levels
 C - Time

F* - Significant at 0.1% level
 of probability
 N.S.- Not Significant

Table A.7

Table of ANOVA for
Root / Shoot Ratio

Species	Source of Variation	SS	D.F.	M.S.	F	
	Treatment					
ANDROPOGON	A	0.112	1	0.112	0.857	N.S
	B	5.463	10	0.546	4.176	*
	AB	0.405	10	0.040	0.309	N.S
	Error	5.757	44	0.131		
	Total	11.736	65			
	Treatment					
HYPARRHENIA	A	0.086	1	0.086	0.560	N.S
	B	4.856	10	0.486	3.116	**
	AB	0.415	10	0.042	0.271	N.S
	Error	6.749	44	0.153		
	Total	12.106	65			
	Treatment					
PENNISETUM	A	0.001	1	0.001	0.013	N.S
	B	2.770	10	0.277	2.730	***
	AB	0.513	10	0.051	0.506	N.S
	Error	4.464	44	0.101		
	Total	7.748	65			

Key - A - Mixing
B - Nutrient Levels

F* - Significant at 0.1% level
of probability
** - Significant at 0.5% level
of probability
*** - Significant at 2.5% level
of probability

Table A.8 Table of ANOVA for Percentage
N Content of Leaves

Species	Source of Variation	SS	D.F.	M.S.	F
	Treatment				
ANDROPOGON	A	0.246	1	0.246	164.864 *
	B	16.487	9	1.832	1225.340 *
	AB	0.404	9	0.045	30.047 *
	Error	0.030	20	0.001	
	Total	17.167	39		
	Treatment				
HYPARRHENIA	A	0.161	1	0.161	77.739 *
	B	12.144	9	1.349	650.326 *
	AB	0.509	9	0.057	27.283 *
	Error	0.041	20	0.002	
	Total	12.856	39		
	Treatment				
PENNISETUM	A	0.104	1	0.104	20.182 *
	B	13.678	9	1.520	294.792 *
	AB	1.464	9	0.163	31.544 *
	Error	0.103	20	0.005	
	Total	15.349	39		

Key - A - Mixing
 B - Nutrient Levels

** - Significant at 0.1% level
 of probability

Table A.9 Table of ANOVA for Percentage
P Content of Leaves

Species	Source of Variation	SS	D.F.	M.S.	F
Treatment					
ANDROPOGON	A	0.016	1	0.016	416.153 *
	B	0.229	9	0.025	678.712 *
	AB	0.035	9	0.004	104.833 *
	Error	0.001	20	0.000	
	Total	0.281	39		
Treatment					
HYPARRHENIA	A	0.000	1	0.000	8.066 **
	B	0.022	9	0.002	64.318 *
	AB	0.005	9	0.001	16.210 *
	Error	0.001	20	0.000	
	Total	0.028	39		
Treatment					
PENNISETUM	A	0.005	1	0.005	264.155 *
	B	0.181	9	0.020	1148.405 *
	AB	0.026	9	0.003	164.777 *
	Error	0.000	20	0.000	
	Total	0.212	39		

Key - A - Mixing
 B - Nutrient Level

F* - Significant at 0.1% level of probability
 ** - Significant at 2.5% level of probability

Table A.10 Table of ANOVA for Percentage
K Content of Leaves

Species	Source of Variation	SS	D.F.	M.S.	F
Treatment					
ANDROPOGON	A	0.686	1	0.686	199.318 *
	B	7.083	9	0.787	228.508 *
	AB	0.782	9	0.087	25.218 *
	Error	0.069	20	0.003	
	Total	8.620	39		
Treatment					
HYPARBHENIA	A	0.021	1	0.21	17.588 *
	B	9.090	9	1.010	838.139 *
	AB	0.777	9	0.086	71.619 *
	Error	0.024	20	0.001	
	Total	9.912	39		
Treatment					
PERNISETUM	A	0.578	1	0.578	315.654 *
	B	22.298	9	2.478	1351.953 *
	AB	0.797	9	0.089	48.352 *
	Error	0.037	20	0.002	
	Total	23.711	39		

Key - A - Mixing
B - Nutrient Levels

** - Significant at 0.1% level
of probability

Table A.11 Table of ANOVA for Percentage
Ca Content of Leaves.

Species	Source of Variation	SS	D.F.	M.S.	F
Treatment					
ANDROPOGON	A	0.016	1	0.016	9.088 **
	B	0.710	9	0.079	45.947 *
	AB	0.188	9	0.021	12.148 *
	Error	0.034	20	0.002	
	Total	0.948	39		
Treatment					
HYPARRHENIA	A	0.192	1	0.192	88.909 *
	B	1.795	9	0.199	92.423 *
	AB	0.223	9	0.025	11.495 *
	Error	0.043	20	0.002	
	Total	2.253	39		
Treatment					
PENNISETUM	A	0.163	1	0.163	314.089 *
	B	0.939	9	0.104	201.501 *
	AB	0.153	9	0.017	32.903 *
	Error	0.010	20	0.001	
	Total	1.265	39		

Key - A - Mixing
 B - Nutrient Levels

F* - Significant at 0.1%
 level of probability
 ** - Significant at 1%
 level of probability

Table A.12

Table of ANOVA for Percentage
Ng Content of Leaves

Species	Source of Variation	SS	D.F.	M.S.	F
	Treatment				
ANDROPOGON	A	0.001	1	0.001	9.828 **
	B	0.082	9	0.009	140.066 *
	AB	0.009	9	0.001	14.800 *
	Error	0.001	20	0.000	
	Total	0.093	39		
	Treatment				
HYPARRHENIA	A	0.014	1	0.014	273.885 *
	B	0.338	9	0.038	751.233 *
	AB	0.011	9	0.001	25.142 *
	Error	0.001	20	0.000	
	Total	0.364	39		
	Treatment				
PENNISETUM	A	0.025	1	0.025	891.344 *
	B	0.156	9	0.017	628.931 *
	AB	0.023	9	0.003	93.863 *
	Error	0.001	20	0.000	
	Total	0.204	39		

Key - A - Mixing
B - Nutrient levels

F* - Significant at 0.1%
level of probability
** - Significant at 1%
level of probability

~~Declaration~~
Declaration

I, the undersigned, declare that this dissertation is my own work and that all sources of material used for the thesis have been correctly acknowledged.

Name: Safa

Signature: Safa

Date of submission

July 2, 1989

DRY MATTER Production

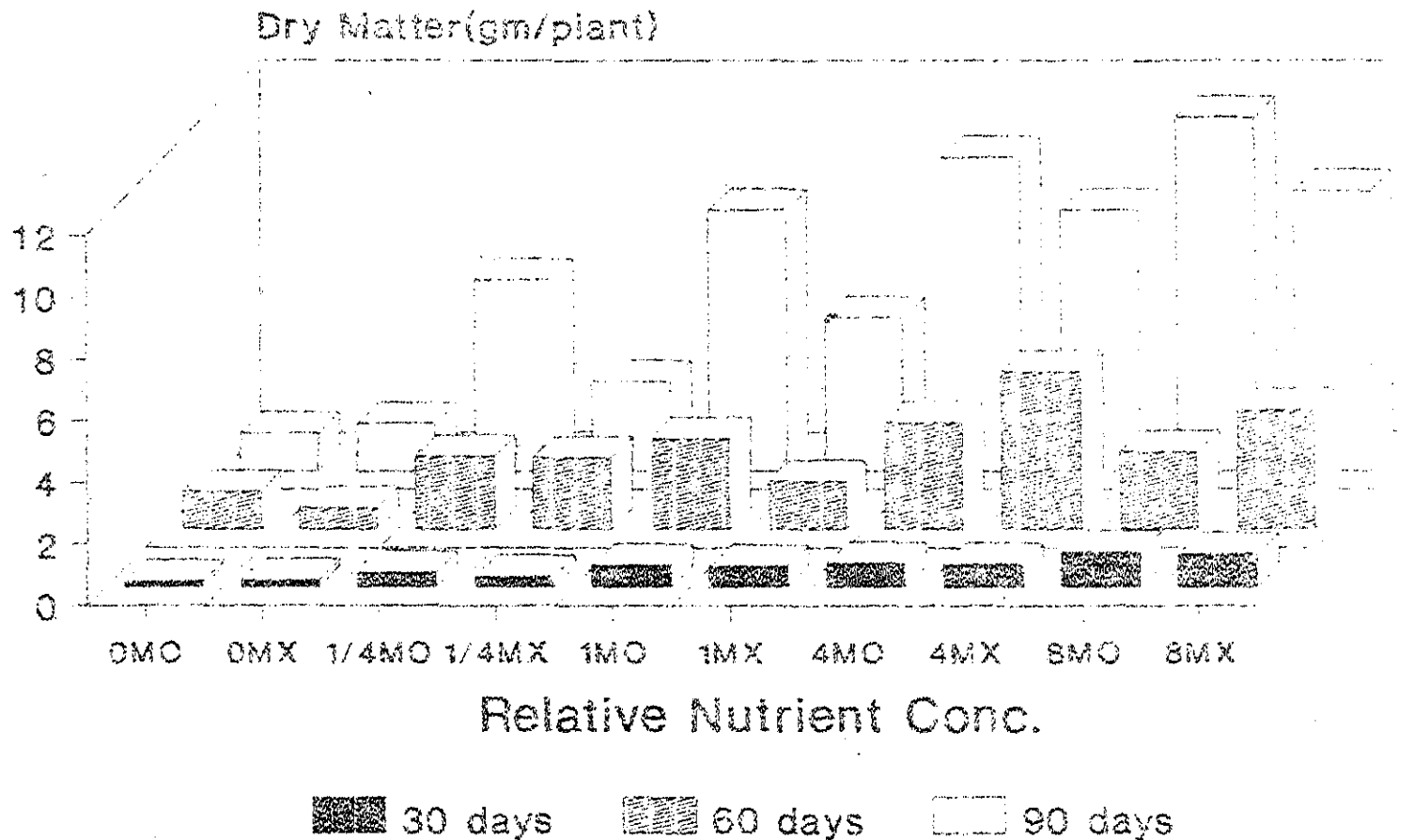


Fig- 11 The effect of nutrient gradient on the yield of Hyparrhenia SP. grown in monoculture and mixture. (The subscript Mo, refers to the yield of plants at the particular nutrient level in pure stand and Mx refers to the yield in mixed stand).

DRY MATTER Production

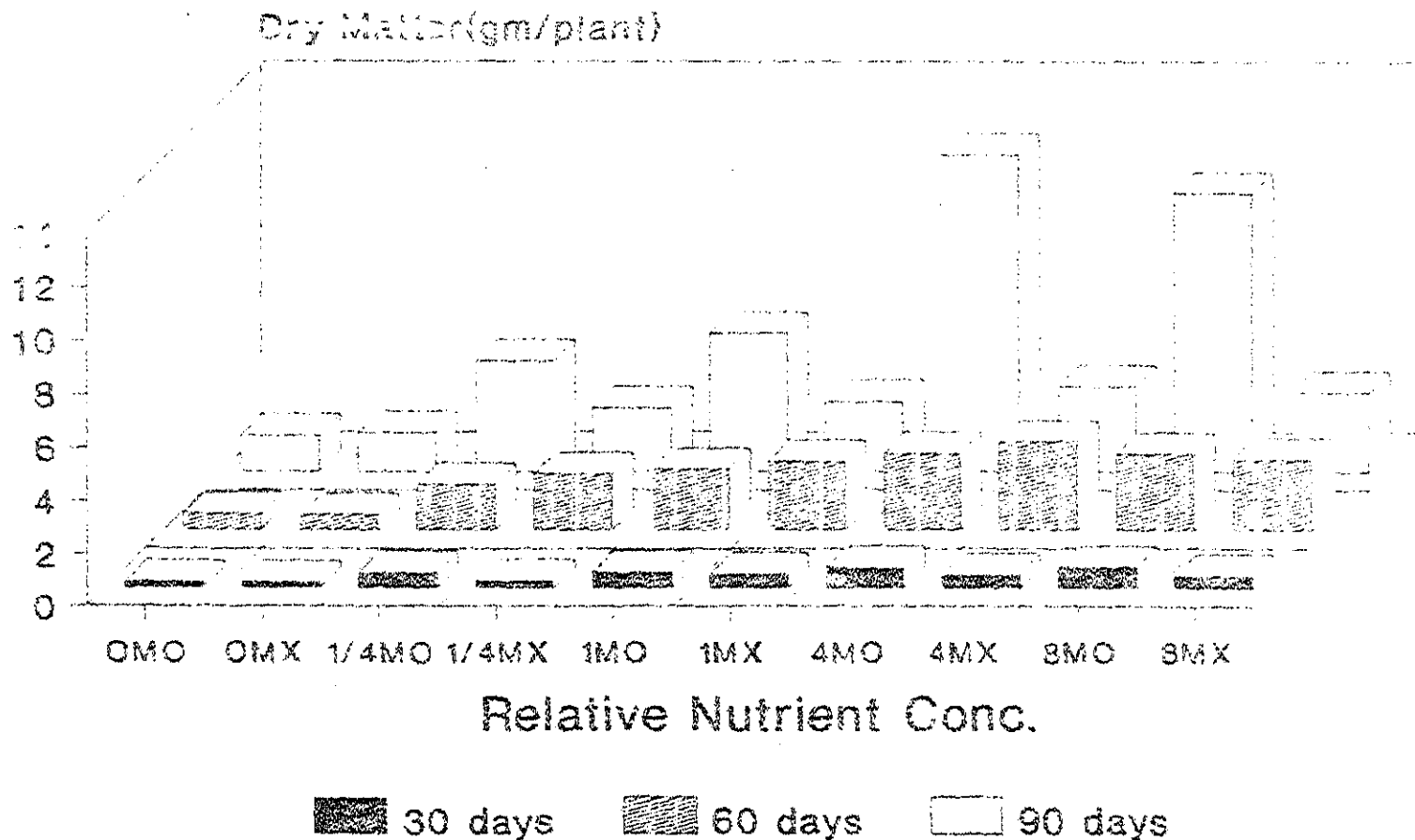


Fig- 12 The effect of nutrient gradient on the yield of *E. scolimperi* grown in monoculture and mixture. The subscript Mo. refers to the yield of plants at the particular nutrient level in pure stand and Mx refers to the yield in mixed stand).

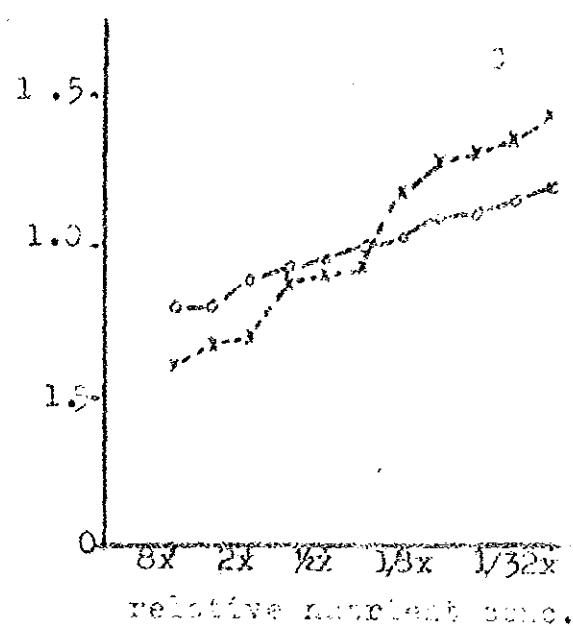
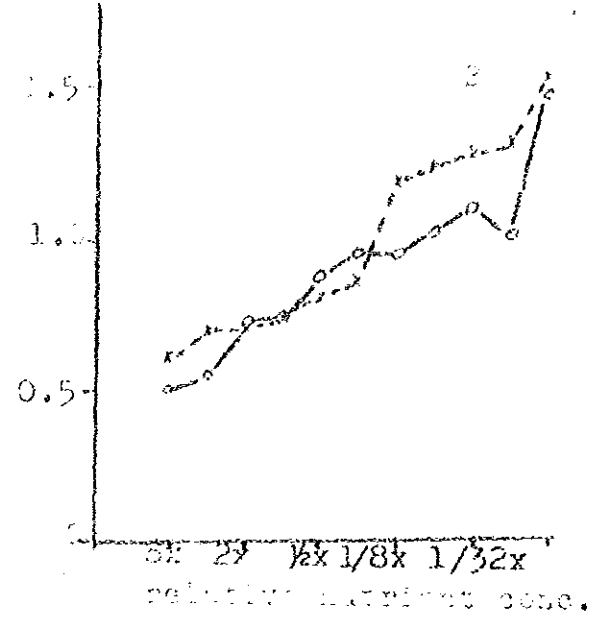
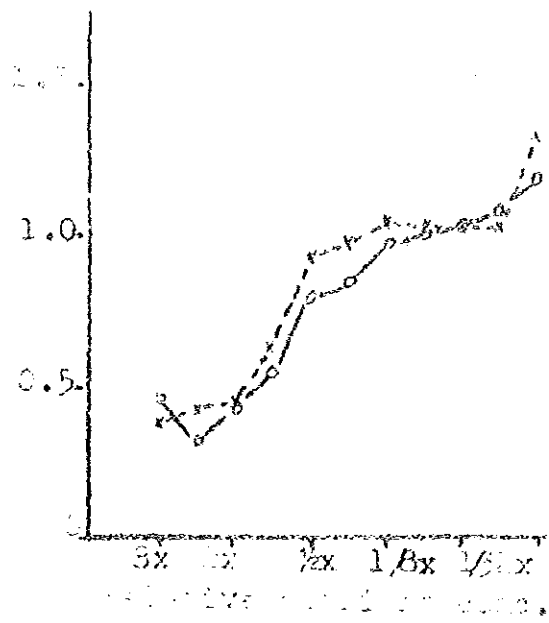
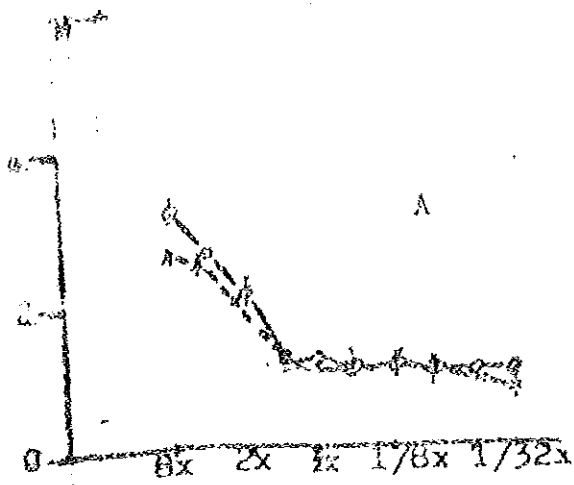
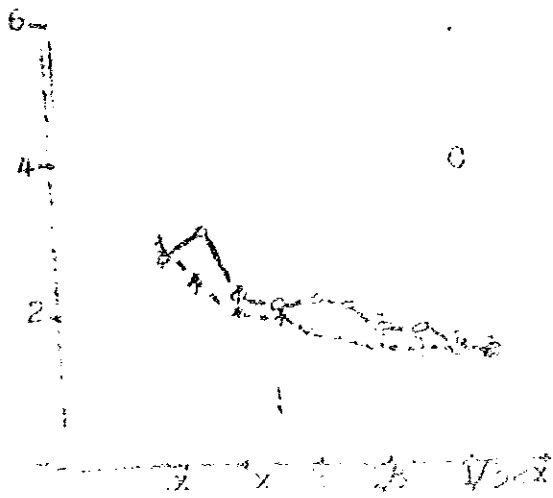
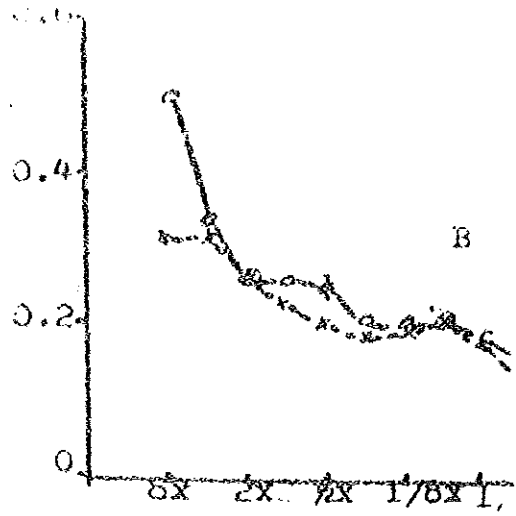


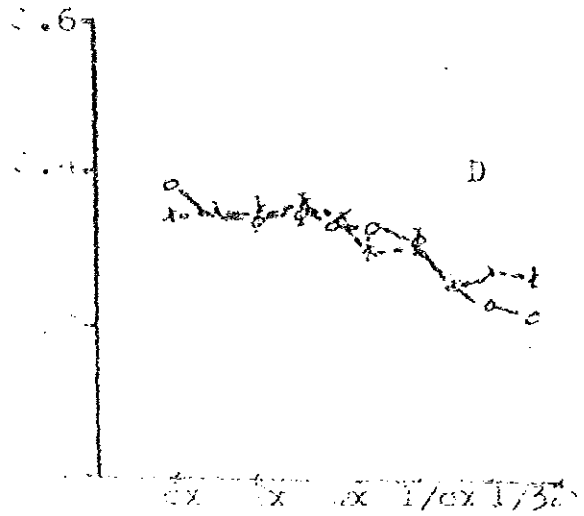
Fig. 1 The effect of nutrient incident on ratio of plants grown in monoculture (x...x) and mixture (o...o) of
 a) Agrostis physodes
 b) Hieracium pilosella
 c) Ranunculus scaberrimus



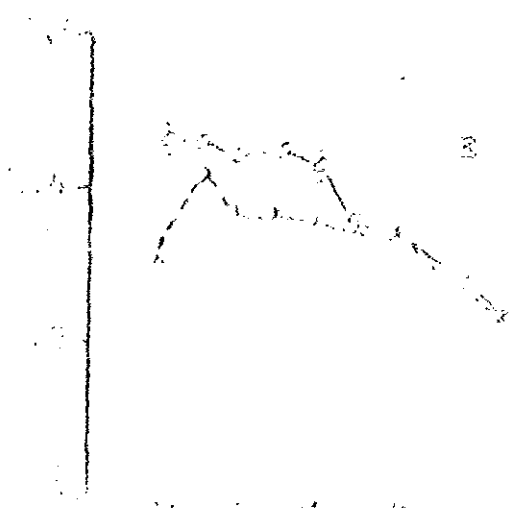
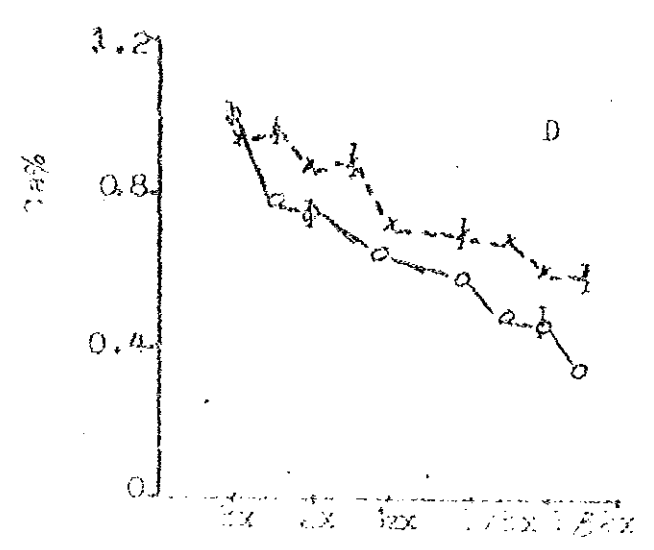
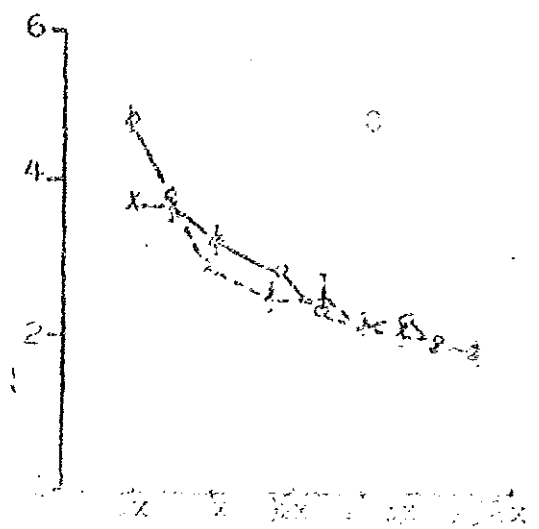
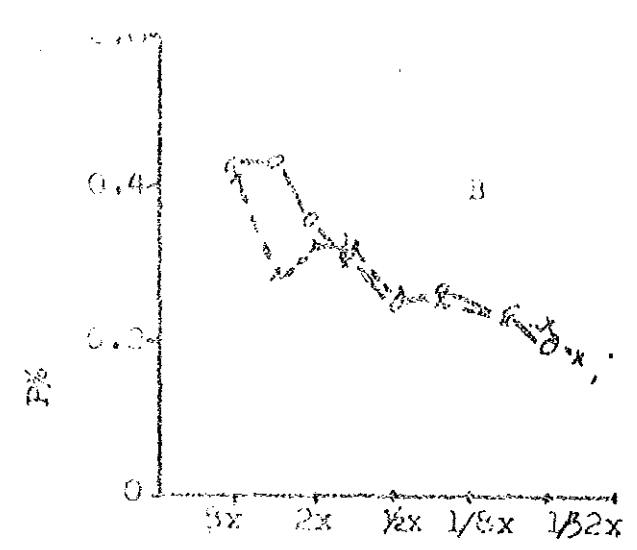
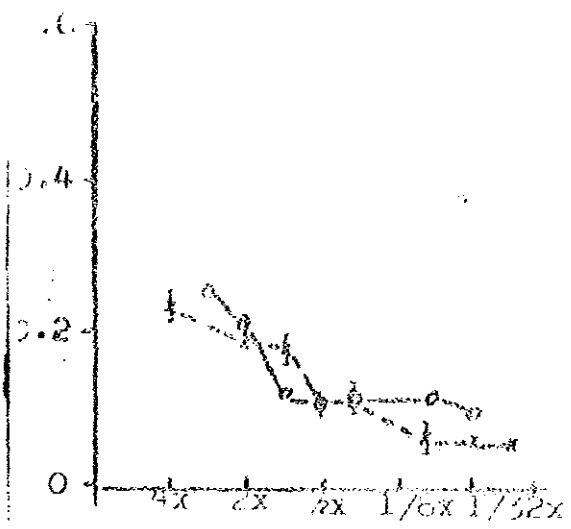
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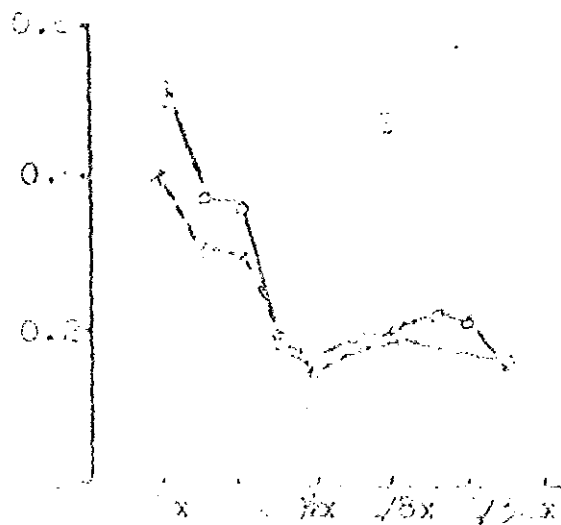
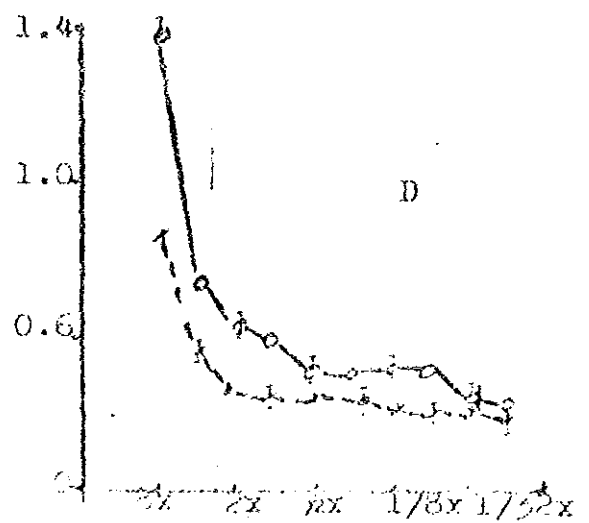
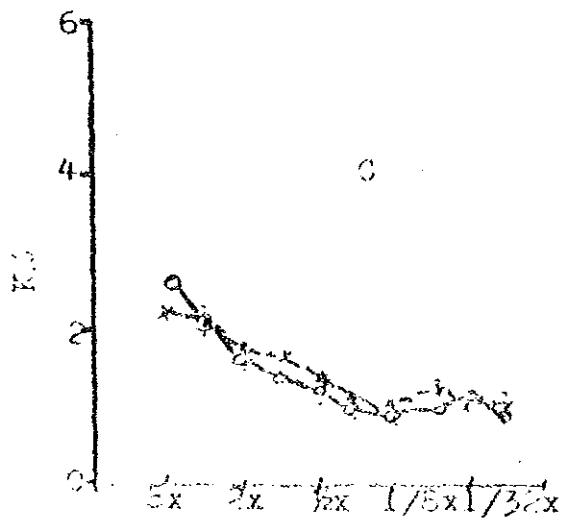
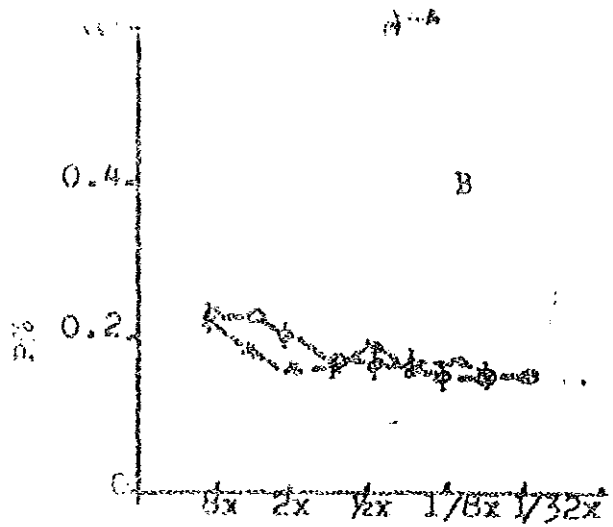
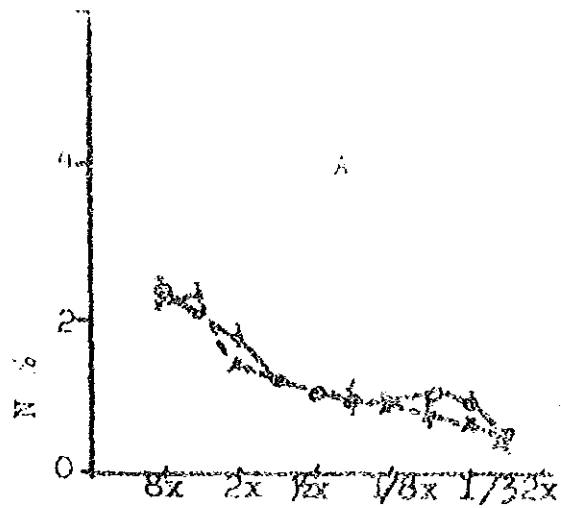
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DISCUSSION

Among other vegetative properties height has been considered important in competitive interactions between species in relation to environmental gradients (Dubbs, 1971; Shamsi and Whitehead, 1977; Grime, 1979).

In the present experiment analysis of variance showed that the effect of nutrient gradients on the height of all plants was statistically significant ($P < 0.001$). The plants also showed a significant difference in height with time (Figs. 1-3). The height of all species increased in response to increasing nutrient concentrations. Plants that were grown in lower concentration 1/32x, and 1/64x were greatly reduced in size and hardly branched.

The effect of mixing on height was more pronounced in A. abyssinicus and Hyparrhenia pilgerana than P. schimperii where there was not a significant difference in height between mixed and pure plants (Appendix Table 1). All species attained maximum height at the 2x and 4x nutrient level. The interaction between mixing and time and mixing and nutrient concentration was significant (0.1% level) only for Andropogon and Hyparrhenia while there was a significant interaction between nutrient

concentration & time for all species. The interaction between time, nutrient concentration and each parameter were significant only for Andropogon. These would imply that in Andropogon a difference in height attributable to mixing depends on the particular level of nutrients and days of measurement.

Tillering refers to branching at the base of the grass stem. Although the grass plant is an assemblage of shoots, the individual tiller has been considered by many investigators to be the growth unit of grasses (Bor, 1973). Productivity, in fact, depends to a greater extent on the ability of the plant to initiate tillers and on the later development of these shoots.

For many perennial grasses the tiller is important as the organ of perennation (Jewiss, 1966; Langer, 1979) and the ability to tiller rapidly is recognized as an important attribute of a pasture grass, eg. knight (1961).

In the present study analysis of variance showed a significant difference ($P < 0.001$) in the number of tillers produced in plants that were grown at the different nutrient levels in all three species. The effect of mixing and time on tillering was also statistically significant (Fig. 4-6, Appendix Table 2). The interaction between mixing and time was significant only in A. abyssinicus and P. schimperi. There were significant

interactions between mixing and nutrient concentration and between time & nutrient concentration in all species. The interaction between time, tiller number and nutrient concentration was not significant, implying that a difference in tillering attributable to mixing does not depend on the particular level of nutrients or on days of measurement.

Tiller production in both annual or perennial species has been shown to be strongly affected by the level of mineral supply (Laude, 1972). Mineral nutrition has a strong influence on the number of tillers produced, and it also determines the length of time over which new tillers appear.

For instance Langer (1966) and Willis (1965) reported that in both cereals and grasses at low level of nutrition, tillering stopped sooner and after fewer tillers had appeared than when nutrients were given at full strength. The present study is in agreement with the above findings. Not only were more tillers produced, but also the tillers were much bigger and more vigorous at the higher level of nutrition 2x, 4x and 8x. Tillering in the basic nutrient concentration (1x) was moderate but much better than in the lower concentration and the control (tap water) where tillering was uniformly poor. For all the species, either in pure or in mixed stands, tillering did not appear until the second time of measurement (35th day after sowing).

The difference between the plants in pure and mixed stands was not only in tiller number, but also in the appearance of new tillers. In the mixed stands tillering was not apparent in the lower concentrations. For example, tillering in A. abyssinicus started only during the fourth measurement time (55th day) at 1/8x nutrient level whereas in pure stands tillering started already in the second measurement time (35th day after sowing) at 1/16 x nutrient level (Fig.3). The effect of mixing is more pronounced in P. schimperi because tillering occurred at the 3rd measurement at 1/4x nutrient conc., while in pure stand it occurred at the lowest nutrient level (1/64x) (Fig. 6)

The effect of nutrient conc. on leaf area, leaf length and leaf width is highly significant ($P < 0.001$) for all plants (Figs.7-9, Appendix 3-5). Analysis of variance showed that the differences in leaf areas, leaf lengths and leaf widths of pure and mixed plants of all three species is not significant. The interaction between mixing and nutrient concentration is not significant either.

The highest mean leaf area (20.39 cm^2) in A. abyssinicus in pure stand experiment occurred at 4x nutrient level, while the mean control leaf area was only 2.28 cm^2 . In mixed stands, the peak leaf area at 8x nutrient level. Hyparrhenia in both mixed and pure stand showed a peak mean leaf area, 25.98 cm^2 and 22.59 cm^2 respectively at 8x nutrient level. P. schimperi also showed a trend similar to that of Hyparrhenia pilgerana.

A. abyssinicus had a leaf length of merely 7.70 cm in the control while the plant attained the highest leaf length (36cm) at 2x nutrient level. Hyparrhenia pilgerana attained its highest leaf length (50.30cm) at 2x nutrient level while the control was only 10 cm long. P. schimperii at 1x nutrient level was 45.76 cm long and the control only 7.03 cm long. Analysis of variance between plants in mixed and pure stand experiments did not show any significant difference. There was, however, a difference between the nutrient levels at which they attained a peak (Fig. 8).

Leaf width showed significant variation ($P < 0.001$) under the different treatments. A. abyssinicus in pure stand had maximum leaf width (0.66 cm) at nutrient levels, 1x, 2x and 4x, while the control was only 0.16 cm. wide. P. schimperii had the highest value, 0.56 cm, at 8x nutrient conc. and the control was 0.13 cm. wide. However, there was no significant difference between leaf widths of plants grown in pure and mixed stands.

In general, the increase in leaf area, leaf length and leaf width of all plants in response to increasing nutrient levels manifested the important role of nutrients in the overall growth performance of plants.

The effect of nutrient gradient on the total dry weight yield is shown in Fig.10-12. Increasing nutrient conc. increased dry

matter (DM) yields of all three species in both experiments for the 4th, 8th, and 12th week growth periods. There was a significant difference (0.1%) in yield between plants grown in pure and mixed stand experiments. There was a significant interaction between mixing and nutrient concentration and time and nutrient concentration, while the interaction between mixing and time was not significant. The interaction between time, nutrient concentration & mixing was significant only in P. schimperi indicating that a difference attributable to mixing in P. schimperi depends on the particular concentration of nutrients and days of measurement (Appendix Table 6). All species show the same general trend of response of increase in yield as nutrient level increases. However, the dry weight of A. abyssinicus and P. schimperi at the highest level, 8x, is less than that of 4x. In general, the plants receiving the basic nutrient solution to the higher levels showed good growth; those receiving lower nutrient conc. showed moderate to poor growth while the control produced by far the least growth. A clear and distinct difference in yield was observed at higher level of nutrition whereas in the lower concentrations there was no marked difference in yield between subsequent dilutions.

Improving plant performance by nutrient application is a long known fact and has been established by several investigators

(Jordan 1913; cited in Gilbert, 1950; Evans, 1960; Grundon, 1972; Jung and Kocher, 1974; Remison, 1978; Austin and Austin, 1980; White and Halvorson 1980; Halvorson and White 1981; Pemadasa, 1981).

The effect of excessive nutrient application in reducing plant performance has also been reported (Andrew and Johansen, 1978, Donohue et al., 1981; and Smith, Cornforth and Henderson, 1985). In the present study, of the three grass species Andropogon and Pennisetum in both pure and mixed stand experiments had their peak performed at the same nutrient level, 4x. Hyparrhenia showed a maximum yield at 8x along the nutrient conc. gradient.

So far little work has been done using mixed stands when compared to pure stands (Simmonds, 1962 : cited in England, 1968 ; Shontz and Shontz, 1972; Austine, 1982; Austine et. al; 1985). Although Pennisetum performed well in pure stands, it had a much lower yield in mixed stands compared with those of Andropogon and Hyparrhenia. It was almost 4x and 3x less than Andropogon: Hyparrhenia respectively at the 4x nutrient level where it attained maximum yield. The maximum yield observed for individual species in mixtures varies widely from 12.66 g for Andropogon to 3.19 g, for Pennisetum schimperi. In the mixed stand experiment, the results obtained, specially as regards to tiller number and dry matter production, suggestes that P. schimperi is a poor

competitor. Among other factors the relatively small seed weight (1000 grain wt = 0.56 g) of *P. schimperii* compared to 1.77 g & 1.66 g of *Andropogon* and *Hyparrhenia* respectively might be attributable to its poor competitive ability. It has been stated that in some instances the size of the seed may confer a particular competitive advantage (Risser, 1969). Evans and Young (1972) claimed that most perennial grasses are susceptible in the seedling stage to competition because of relatively low seedling vigor which is associated with seed size and weight. And it is stated that increased seedling vigor attributable to seed size and weight is a result of greater reserve materials in the endosperm (Mckell, 1972).

The improvement in vigor of the grasses to which increasing nutrients were added was reflected in increases in heights of the shoots, increased tillering and greatly enhanced dry weights. In general, the considerable increase of growth in grasses enriched with nutrients is a strong evidence of the importance of limiting effects of nutrient supply.

The effect of nutrient gradient on the root/ shoot ratio is shown in Fig. 13. Analysis of variance showed the difference in the root / shoot ratio of plants under the different treatments to be statistically significant (Appendix Table 7). However, the difference in the root / shoot ratio of all plants grown in

pure and mixed stand is small and does not reach the level of statistical significance (10% level). The interaction between mixing & nutrient concentration is not significant. In all species and for both pure and mixed stand experiments, the plants responded to each successive dilution by an increase in root / shoot ratio. (See also Vos, 1962; Viets, 1965; Shamsi and Whitehead, 1977; Black 1968: cited in Andrew and Johansen, 1978 and Austin *et. al.*, 1985).

Such an increase in Shoot /Root ratio (or a decrease in root/shoot ratio) at the higher level of nutrition is consistent with the hypothesis that at low nutrient concentration the ability to put more biomass into root production is an advantage whilst at high nutrient concentrations shoot biomass confers a competitive advantage (Austin, 1982).

A decrease in the dry weights of roots with increasing levels of nutrients had also been established by other investigators (Vose, 1962 ; Hackett, 1965 and Clement, Hopper and Jones, 1978). Although in the present study, the weights of roots were not reduced at the higher concentration of nutrients, examination of the root systems revealed differences resulting from the nutrient regimes. In general, roots receiving lower level of nutrition were more finely divided and had plenty of intertwined roots. In contrast, at the higher concentration the root systems were much thicker and sparse.

Competition between the root and shoot for minerals and photosynthesis has frequently been invoked to explain the changes in root to shoot ratio brought about by change in the environment (Troughton, 1967).

Meristems nearest to the source of supply of substance can have the greatest competitive ability for that substance. Accordingly, roots are the better competitors for minerals, while shoots the better competitors for photosynthates. This may explain why root growth is least affected by a shortage of minerals. The shoot meristems depended upon minerals translocated to the shoot and would therefore, increase in size or number in proportion to the nutrient supply. The accompanying decrease in root size is attributed to a limited supply of photosynthates (Humphries, 1958).

Plant analysis as a tool for assessing the nutritional status of plants has received much attention and many experiments have shown the relationship between mineral element content in leaves and in the growth or substrate. Motivation for determination of nutrient concentrations in leaves for diagnostic purposes arises from the assertion that there exists a relationship between nutrient supply and levels of elements and that increases or decreases in concentrations relate to higher or lower yields, respectively (Evenhuis and Waard, 1980 and Okaye, 1980).

Changes in mineral nutrition appear to be reflected in the concentrations of leaf nutrients which varies with the conditions of nutrient supply in the medium. This variation in tissue concentration in response to a change in the external supply had been reported by several investigators (Goodall and Gregory, 1947; Smith, 1962; Vose, 1962; Hojjati, Templeton and Taylor, 1977).

In the present study analysis of variance showed that there was a significant difference in the concentration of nutrients in the leaves of plants under the different treatments for both pure and mixed stand experiments (Appendix Table 8-12). Internal nutrient concentration rises in response to increasing nutrient supply (Figs.14-16). Similar results had been reported for Epilobium sp. and Lythrum sp. in the works of Shamsi and Whitehead (1977) where nutrient concentrations in leaf, stem and root were affected similarly by decreasing concentration of the solution. They had found a very high nutrient levels in the leaves of plants grown in the full strength culture solution than those grown in the series of dilutions.

For all elements analysed there was generally a rise in tissue concentration with increased levels of nutrient supply, though there were a certain anomalies where nutrient concentration in the leaves did not respond to increased nutrient supply. For

instance, in A. abyssinicus plants that were supplied with 1/8x nutrient level relatively showed higher; percentage Mg content (0.31%) in leaf tissue than plants given 1/4x which had 0.29 percentage Mg. Percentage P content in leaf tissue of Hyparrhenia pilgerana showed 0.18% in 1/2x the nutrient level while in the basic solution the percentage P content was 0.16%

Similarly in P. schimperi, plants grown in 1/4x nutrient level had high percentage of P content (0.27%) than those in 1/2x nutrient level which had 0.24% P content. These anomalies might be ascribed to small differences in nutrient level between subsequent dilutions.

Since the supply of nutrients from soils can be variable, it is not surprising to find differences in the amounts of various nutrients in plants in the field (Filter and Hay, 1981). The mineral nutrient requirement of all plants are not the same both qualitatively and quantitatively (Gerloff, 1963). Differences in the amounts of nutrients could also be observed under controlled conditions, and furthermore much uniformity and much diversity are known to exist in the nutrient needs of plants and their ability to get them (Viets, 1980). By the same token, in the present study contents of N, P, K, Ca, and Mg in leaf tissues do show variation among the three species. Asare (1974) had reported that in the pure stands Centrostima sp. had the highest N

content and Andropogon gavanus the lowest and he also found similar results in the mixed stands.

Leaves of all species generally showed a higher percent of K content at all levels of treatments even at lower concentrations, than the other elements. A relatively higher percentage of N and Ca content was obtained in leaves of A.abyssinicus than the other two species and a higher percentage of P and Mg content was also observed in Andropogon than Hyparrhenia, while the percentage of P and Mg content was highest in leaf tissue of P.schimperi.

The variation in the chemical composition of leaves between plants in pure and mixed stands was statistically significant. The interaction between mixing and nutrient concentration was significant which would imply that the difference in the internal tissue concentration of all plants under the different nutrient levels depends on whether the plants are grown in pure or mixed stands.

Although leaf nutrient concentration is controlled primarily by nutrient supply, there are many factors indirectly influencing the mineral element content of plants. The final manifestation is the resultant of all parameters influencing each other and the plant (Cottenie, 1980 and Okaye, 1980). Among these factors, maturity or physiological age of the plant, seasonal and climatic factors, soil parameters and plant species are known to