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NUTRIENT CONTENT AND PERFORMANCE OF THE HERBACEOUS LEGUME *TEPHROSIA BRACTEOLATA* IN RELATION TO THE GRASS *ANDROPOGON TECTORUM* IN BOTH NATURAL HABITAT AND POT CULTURE IN SOUTHWESTERN NIGERIA

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Abstract: Tephrosia bracteolata, an annual herbaceous legume (sub-family PapilionIodeae), occurs extensively in the savanna zone of West Africa. It is palatable to livestock. Its accumulation of nitrogen, phosphorus and potassium over a growing season (in natural habitat in Southwestern Nigeria) was measured and compared with that of *Andropogon tectorum,* another palatable grass in the same habitat. Crude protein concentration in *Tephrosia* throughout the growing season is enough to meet the recommended livestock requirements, whereas the concentration in *Andropogon* meets this requirement only when the grass is young. *Tephrosia* and *Andropogon* were positively associated in natural habitat. Competition between *Tephrosia* and *Andropogon* in pot culture was investigated. Both species showed a decrease in yield with increasing density, a pattern also shown for number of tillers of *Andropogon* and girths and heights of both plants at maturity. In the mixture the yield per plant of *Andropogon* was higher than in its monoculture.

Résumé: Tephrosia bracteolata, une papilioncée herbacée annuelle (sub. famille Papilioniodeae) se trouve extensivement dans la zone de savane de l' Afrique occidentale. Elle est mangée par le bétail. Les accumulations d'azote, de phosphore et de potassium durant une saison de croissance (dans des conditions naturelles au Sud-Ouest du Nigeria) ont été mesurées et comparées avec celle de *Andropogon tectorum,* une autre herbe palatable du meme habitat. La concentration brute de protéine dans *Tephrosia* tout au long de la saison de croissance est suffisante pour les besoins du bétail, alors que ces besoins ne sont satisfaits chez *Andropogon* que lorsque l'herbe est jeune. *Tephrosia* et *Andropogon* sont positivement associés dans le milieu naturel. Leur compétition a été testée en culture sur pot. Les deux espèces montrent une diminution de rendement lorsque la densité augmente, ce qui est le cas aussi pour de nombreux talles d'*Andropogon* et pour les circonférences et les hauteurs des deux plantes à maturité. En mélange les rendements par plant d'*Andropogon* sont superieurs qu'en monoculture.

Resumo: A *Tephrosia bracteolata*, uma leguminosa herbácea (sub-familia das Papilionoideae), ocorre extensivamente na savana africana da costa ocidental. É palatàvel pelos rebanhos. A sua acumulação em azoto, fósforo e potássio ao longo de uma estação de crescimento (no seu habitat natural no Sudoeste da Nigéria) foi medida e comparada com outra gramínea palatàvel, a *Andropogon tectorum,* no mesmo habitat. Ao longo da estação de crescimento, a concentração de proteína bruta na *Tephrosia* é suficiente para satisfazer as exigências recomendadas para o gado, enquanto que aquela concentração no *Andropogon* só o satisfaz enquanto a erva está jovem. A *Tephrosia* e a *Andropogon* encontravam-se positivamente associadas no habitat natural. A competição entre a *Tephrosia* e a *Andropogon* na cultura em vaso foi devidamente investigada. As duas espécies mostraram um decréscimo no rendimento com um aumento de densidade, um padrão igualmente evidenciado por um certo número de rebentos de *Andropogon*, diâmetros e alturas de ambas as espécies na maturidade. Em mistura, o rendimento por planta da *Andropogon é maior do que em cultura extreme.*

Key Words: Tephrosia, Legume, *Andropogon*, grass, growth, nutrient accumulation, natural habitat, competition.

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INTRODUCTION

Over 70% of the land area of West Africa is savanna, most of it open, unmanaged rangeland. The livestock carrying capacity of these rangelands is low because of the usually low nutritive herbaceous fodder. Grasses, the main herbaceous cover, have enough crude protein for animal maintenance only at the beginning of growth after which the crude protein concentration rapidly declines (Haggar 1970; Isichei 1983). This is usually accounted for by nitrogen-poor soils and high rate of carbohydrate accumulation by the grasses. In addition, the grasses dry out and become coarse and unpalatable in the dry season (Coppock *et al.*1986) further accentuating the animal nutrition problem.

It has often been suggested that to tackle this dual problem of low protein fodder during most of the growing season and near total absence of it in the dry season, the palatable herbaceous legumes may be used. Those legumes that are perennial, nodulated (and probably nitrogen fixing) and palatable are most highly recommended for overcoming the dry season fodder shortage (Mohamed Saleem & von Kaufman 1986). Early efforts aimed at solving this problem have been made by the use of both introduced and indigenous perennial herbaceous legumes notably *Stylosanthes* and *Alysicarpus* species (Foster 1961). Of late most efforts have been concentrated on *Stylosanthes* species and the indigenous ones have been ignored. Trials with *Stylosanthes* have so far been on a limited scale, but Agishi & De Leeuw (1986) and Mohamed Saleem *et al.* (1986) have observed that they compete poorly with native grasses and are prone to anthracnose (fungal disease) attack. Ideally, native perennial legumes, especially those that remain green during the dry season should be used, but enough effort has not been made towards their utilization even though the potential exists.

In this study we report on some aspects of the ecology of a herbaceous legume that is well accepted by livestock. The legume *Tephrosia bracteotata** (subfamily Papilionoideae), an annual, is one of the several *Tephrosia* species reported by De Leeuw (1979) to be favoured by livestock in northern Nigeria.

The nitrogen fixing ability of *T. bracteolata - Rhizobium* association has been reported by Sanogho *et al.* (1980).There are twenty-two species in the genus *Tephrosia* in West Africa, all of them herbaceous with a distribution ranging from the wet forest to the semi-arid areas (Hutchinson & Dalziel 1953).

In this report we discuss the environmental conditions under which *Tephrosia* occurs in a dry forest/savanna area in southwestern Nigeria. Its performance (cover and yield), nutritive value in terms of its nitrogen, phosphorus and potassium accumulation in relation to *Andropogon tectorum* (southern Gamba grass) and its performance in competition with the same grass in pot culture are also discussed.

A. tectorum and *T. bracteolata* apart from growing together in the habitat studied have almost synchronous phenologies. They disperse their seeds in December/January and at the beginning of the rainy season in March and seeds of *Tephrosia* germinate and *Andropogon* rhizomes start sprouting. *Tephrosia* flowers, fruits and sets seeds between September and December, while *Andropogon* does so mostly in November and December.

* Nomenclature is after Hutchinson and Dalziel (1953).

A. tectorum is a well known forage grass while *Tephrosia* is not so well known, but is well utilized wherever it occurs because of high palatability to livestock. Mohamed Saleem & von Kaufman (1986) noted that *Stylosanthes* species perform better if protected from strong competition by perennial grasses. If *Tephrosia* is going to be used in range improvement its performance in competition with the dominant grasses needs to be assessed. This we attempt here in pot culture by varying the frequencies of the two species at various densities.

THE STUDY AREA

The field study was carried out at the foot of a 410 m high inselberg situated at the Obafemi Awolowo University Campus (formerly University of Ife) (7° 32′ N, 4° 31′ E), south western Nigeria. Most of south western Nigeria is situated in the ecological zone described by White (1983) as "Guinea-Congolian forests, drier types", and parts of this region form the transition zone between forest and savanna. The Ife area is mainly dry forest but the shallow soil associated with the inselberg slopes has resulted in savanna-type vegetation (see Adejuwon 1971) with a herbaceous layer in which *Andropogon tectorum* is abundant.

The Obafemi Awolowo University campus and the area around it are underlain by Pre-Cambrian basement complex rocks. The soil is of ferruginous formation characterized by deep and intensely weathered pedon with few weatherable material remaining except inselbergs (Symth & Montgomery 1962). The soils of the region are usually acidic, contain about 9% clay which to a greater extent is kaolinite and to a lesser extent, other finer clays hence they have low cation exchange capacity, low water holding capacity and low buffer capacity (Agboola 1980; Ayodele 1986).

The Ife area usually has an eight month wet season (March-October) and a four month dry season (November-February). A rainfall total of 1950- mm was recorded in 1985, the year of the present study. Mean monthly maximum temperature for that year was 31°C and the mean monthly minimum 21°C. Relative humidity in the wet season was between 80 and 95% at 10.00 hours and between 70 and 80% in the dry season (all figures from Anon. 1986).

MATERIALS AND METHODS

Tephrosia *in relation to other herbaceous plants*

Two plots measuring 25 × 25 m each, here called plot A and plot B, were carved out of a grassland at the base of an inselberg. In May (early growing season) 1985, five line transects were randomly laid in each plot. Herbaceous cover was estimated in each plot by systematically dropping a metal pin along each transect. Hits of basal and aerial parts of (i) *Tephrosia* (ii) grass and (iii) other broad-leaved herbs were recorded at twenty points along each transect and used to estimate aerial and basal covers for the three classes of herbs. Vertical stratification in the vegetation was taken into consideration when measuring cover. It was thus possible to have more than one hit at a measuring point depending on the number of strata touched by the measuring pin (Greig-Smith 1983).

Herbaceous yield estimates were made by placing a 50 cm x 50 cm quadrat at every fifth metre point along each line transect and clipping all herbaceous plants rooted within the quadrat at soil level. Cover and yield estimates were repeated as described above mid-way into the growing season

(August) and towards the end of the growing season in October, care being taken not to clip material from the same spot twice within the year.

Clipped material from each sampling was taken immediately to the nearby laboratory and sorted into *Tephrosia,* grasses and other forbs. The sorted plants were dried to constant weight at 80°C in an oven.

From each collection for yield estimation and after weighing *Tephrosia* and *Andropogon* subsamples were bulked separately and their leaves were analysed for total nitrogen, total phosphorus and potassium (Tel & Rao 1982).

Having observed that *Tephrosia* grew abundantly in proximity with *Andropogon* in the study plots, a test for association was carried out using x^2 to test for significant departure from randomness. Samples for the test were collected by randomly placing fifty 50 cm X 50 cm quadrats in each of the two plots and recording the presence or absence of either or both of *Andropogon* and *Tephrosia.* A 2 X 2 contingency table showing the number of quadrats containing one, both or neither of the two species was set up for each plot. The x^2 values were set follwing Whittaker (1975) and Greig-Smith (1983).

Soil samples were collected from both plots in June 1985. At every metre point of the randomly laid transects for herbaceous sampling in May, soil samples were collected with a bucket auger from the 0 - 15 cm depth. The soild samples were air-dried, stones and gravel removed and samples for each plot bulked. Sub-samples were taken from each bulk for analysis of organic carbon (Walkley-Black titrometric method), total nitrogen (Kjeldahl method), exchangeable potassium (flame photometry), available phosphorus (Bray 1 method) and textural composition (hydrometer method). The pH of each soil sample was also determined, in 0.01 m $CaCl_2$.

Except otherwise stated, analysis of variance was used to test for significant differences.

Tephrosia *in competition with* A. tectorum

Tephrosia germinated best after soaking in concentrated sulphuric acid for 20 minutes. *Andropogon* sprouts from underground rhizomes at the beginning of the growing season especially after annual dry season fires. These sprouts were used for the present experiment as all attempts to germinate the seeds failed.

The pot experiment was carried out in a screenhouse with a roof made from transparent plastic sheets and a wall of wire mesh. The plants were grown in five litre capacity buckets each with a top diameter of 20 cm and a depth of 16 cm. Each bucket was 80 per cent filled with well homogenized soil collected from the site where *Andropogon* and *Tephrosia* grew together. The soil was wetted initially for one week to allow germination of any seeds that might be present.

The two species were each grown alone (monoculture) at four densities of 1, 2, 4, and 10 plants per pot and in equiproportion mixutres (1:1) at three total densities of 2, 4 and 10 plants per pot follwing De Wit (1960). The basis for these densities was the estimated space each plant would occupy were it growing in a normal field situation. Each density was replicated three times so a toatl of thirty-three buckets was used in the experiment. The experiment ran for six months, from May to November 1985, a period which corresponds with the phenological cycle of the two species.

Andropogon sprouts were planted first to enable them to develop roots. Two weeks later the required numbers of one-week old(from first day of planting) *Tephrosia* seedlings were transplanted into the pots. Each pot was wetted every other day with distilled water until harvest. Maximum yield per plant of each of the two species was the main variable measured. The plants were harvested as soon as signs of flowering appeared. The shoots were harvested by clipping them at soil level taking care to avoid loss of material. The roots were harvested by thoroughly wetting the soils and running in water under pressure into the buckets until all soil was flushed out. The plant materials were dried at 80° C to constant weight and weighed. In addition to yield, heights of the two plants at each density were measured. Girth of *Tephrosia* plants at base and number of tillers produced by *Andropogon* were also measured. The following parameters were calculated from the yield data (see de Wit & Van den Bergh 1965);

(i) Relative yield, which is the mean yield of a species in a mixture divided by its mean yield in monoculture at any particular density.
(ii) Relative yield total, the sum of the relative yields of the two species.

Differences in yield values between treatments were assessed by analysis of variance.

RESULTS AND DISCUSSIONS

Tephrosia *in natural habitat*

The soil of plot B is slightly more acidic with a mean pH of 4.30 as compared to 4.49 for plot A. These pH values are significantly different ($p<0.05$, t-test). Soil organic carbon concentration averaged 3.10% in plot A and 3.06% for B. Mean percentage total nitrogen in plot A was significantly higher than in plot B. Plot A had far more Bray 1 phosphorus than B while soil exchangeable potassium level in the two plots is nearly equal (Table 1).

TABLE 1. Soil properties of two plots at the base of an inselberg in south western Nigeria used for the study of the ecology of *Tephrosia bracteolata*. Values shown are mean ± 95% confidence interval of analytical replicates of bulked 25 subsamples from each plot.

Soil Attribute	Plot A	Plot B
pH (0.01M $CaCl_2$)	4.49±0.14	4.30±0.16*
Organic Carbon (%) (Walkley-Black)	3.16±0.19	3.06±0.19
Total Nitrogen (%)	0.35±0.03	0.28±0.09*
Phosphorus (ppm) (Bray 1)	19.75±1.53	10.00±1.30***
Exchangeable Potassium (me/100g)	0.49±0.03	0.45±0.02
Sand (%)	84.98±1.59	84.48±1.84
Clay (%)	7.23±1.11	8.68±1.84
Silt (%)	7.79±2.23	6.84±1.08
Textural class	Loamy sand	Loamy sand

*, *** Statistically significant difference between plots at $p < 0.05$ and $p < 0.001$, respectively.

The pH and nutrient concentrations of the soils in the plots are well within the range reported for south western Nigeria by Agboola (1980). Organic carbon concentration, percentage total nitrogen, exchangeable potassium and Bray 1 phosphorus values are higher than earlier mean values but well within the ranges of each of these attributes reported by Ayodele (1986), the present study area being wetter than Ayodele's study area. The textural composition is also close to what Ayodele reported.

There is difference in species composition between the two plots. Plot A has a total of twenty-one speices (10 monocots and 11 dicots), all of them being herbaceous.

Consistently higher mean cover and yield values for *Tephrosia* were obtained in plot B than in plot A (see Figs. 1 & 2) but the yield values are not significantly different because of wide variations in sampling unit values. But the yield of other herbaceous plants is much higher in plot A than in B suggesting that competition with grasses is an important factor determining the growth and abundance of *Tephrosia*. *Andropogon* has the same pattern of occurence as *Tephrosia* in that there was more of it in plot B where there are not many other grass species, then in plot A ($p<0.05$, t-test).

Nutrient concentration while not being the sole determinant of forage quality is a major factor affecting it. *Tephrosia* has significantly higher concentration of nitrogen and phosphorus than *Andropogon* in both plots and at the three sampling periods (Fig. 3). It is only at the beginning of growth (early rainy season) that *Andropogon* meets the 8.6% crude protein (% N x6.25) concentration requirement for the maintenance of livestock (National Research Council 1976), whereas the crude protein concentration in *Tephrosia* meets this requirement all through the year. The concentration of potassium is, however, higher in *Andropogon* than in *Tephrosia*.

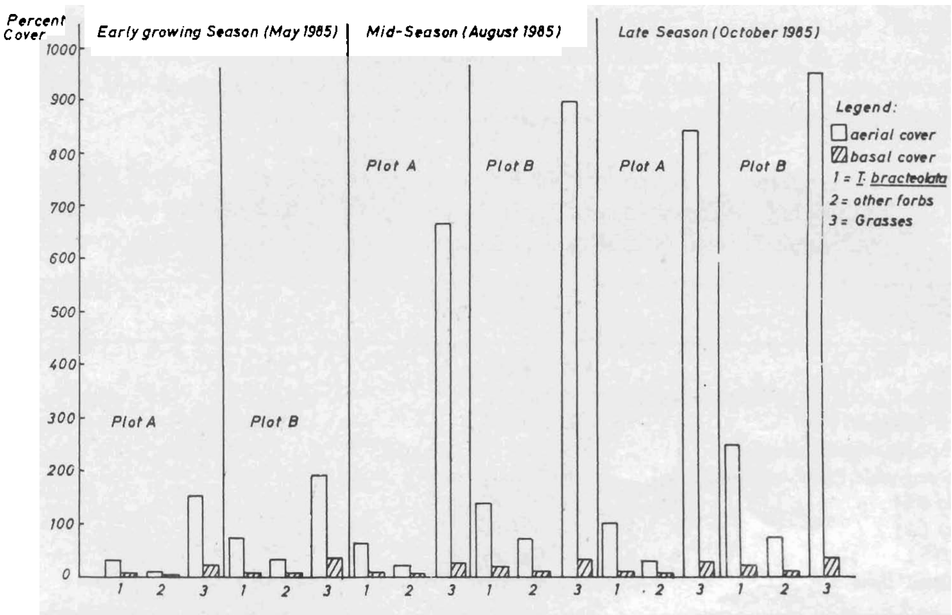

FIG 1. Percentage mean aerial and basal cover of *Tephrosia bracteolata* in relation to other herbs in two study plots at the base of an inselberg in southwestern Nigeria, at three sampling periods during the 1985 growing season.

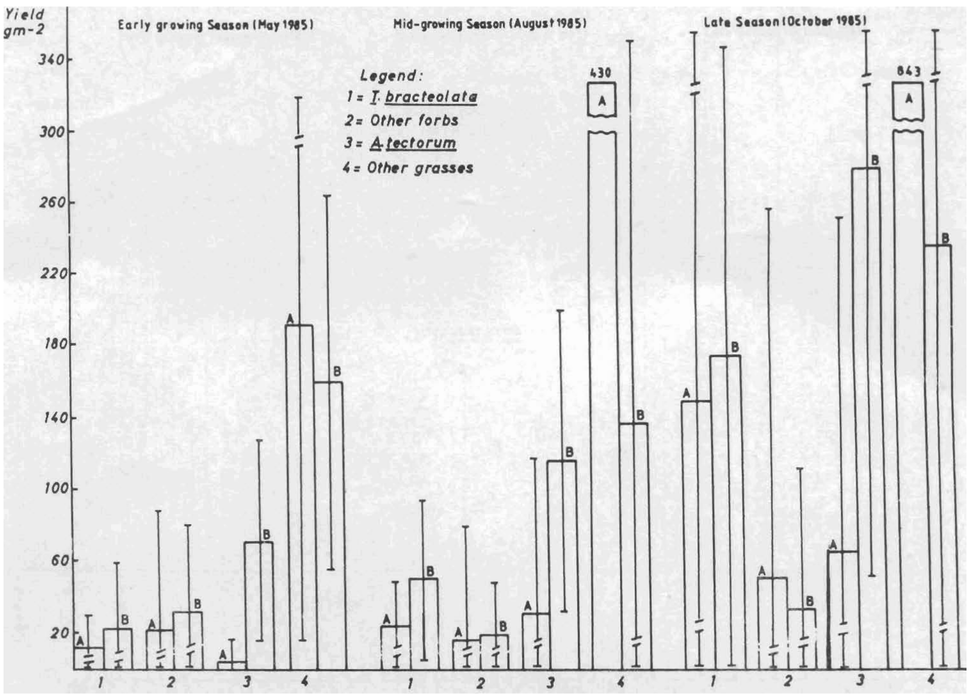

FIG. 2. Mean yield of *Tephrosia bracteolata* in relation to other herbs in two study plots, A and B, at the base of an inselberg in southwestern Nigeria, at three sampling periods during the growing season 1985. Vertical bars are 95% confidence interval.

The trends in the concentration of the nutrient elements in the leaves of the two species in the two plots do not in some cases relate to what was obtained in the soil. There is no significant difference in leaf nitrogen concentration between the two plots as there was in the soil. The same is applicable to phosphorus. But when nitrogen concentration in *Andropogon* alone is considered, plot A leaves have a significantly higher concentration ($P<0.05$). *Tephrosia* which bore root nodules was not entirely dependent on soil nitrogen to the same extent as *Andropogon*. Therefore, it must have accounted for the non-significance of the difference between the plots by counter balancing the trend shown by *Andropogon*. In fact *Tephrosia* had higher concentration in plot B (the plot with less soil nitrogen) than in A during August and October. It is however, important to note that the relationship between nutrient levels in the plant leaves as compared to what is available in the soil is non-static and subject to temporal variations.

The difference in the concentration of phosphorus in leaves of the two plants are not as wide as observed for soil available P. Plants growing in plot A, however, showed consistently higher accumulation than those in B. Concentration of potassium in *Tephrosia* and *Andropogon* was higher in plot A than in plot B. This is consistent with the trend observed for soil exchangeable potassium in the two plots.

There is significant positive association between *Tephrosia* and *A. tectorum* in both plots A and B ($P<0.5$) with respective x^2 values of 8.26 and 9.44. Ezedinma *et al.* (1979) reported association between some grass species and herbaceous legumes in the humid savanna zone of

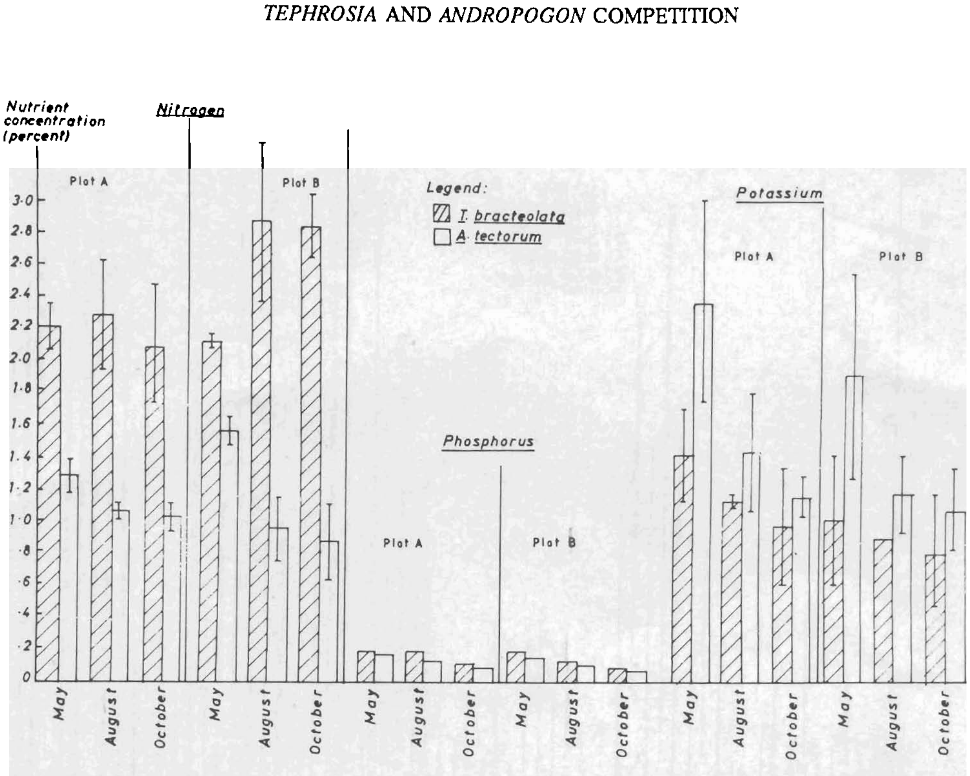

FIG. 3. Percentage total nitrogen, phosphorus and potassium in *Tephrosia bracteolata* and *Andropogon tectorum* leaves from two study plots, A and B, at the base of an inselberg, southwestern Nigeria in May, August and October, 1985. Vertical bars represent 95% confidence interval.

eastern Nigeria. They found *Andropogon, Hyparrhenia* and *Pennisetum* genera associated with legumes but not *Imperata* and *Loudetia.* Positive association may indicate that the associated species do not overlap in their demand for the same resources, due probably to differences in growth rhythm (Bebawi & Naylor 1981). Association may also result if both or one of the associated species has the ability to supplement the environmental resource the two speices would have competed for. Since nodulated *Tephrosia* is knwon to supplement nitrogen, association between it and grasses is possible.

Tephrosia *in connection with* Andropogon

Performance in relation to density in monoculture and mixture.

The mean girth per plant of *Tephrosia* was higher in mixture than in monoculture ($p<0.05$, Fig. 4a). Girth decreased with increasing density and the differences among the densities are significant ($p<0.001$).

The number of tillers produced by *A. tectorum* also decreased with increasing density ($p<0.05$). Tiller numbers are significantly higher in mixed stands of *A. tectorum* than in monoculutre ($p<0.05$). Tiller numbers are particularly high in mixtures at densities of 2 and 4 plants per pot.

Plant height in both species decreased with increasing density. The effect of density on height was statistically significant in *Tephrosia* but not in *Andropogon* (see Fig. 4b) and plants grown in monoculture were more affected. Plant height of both species was greater in mixtures than in the corresponding monoculture.

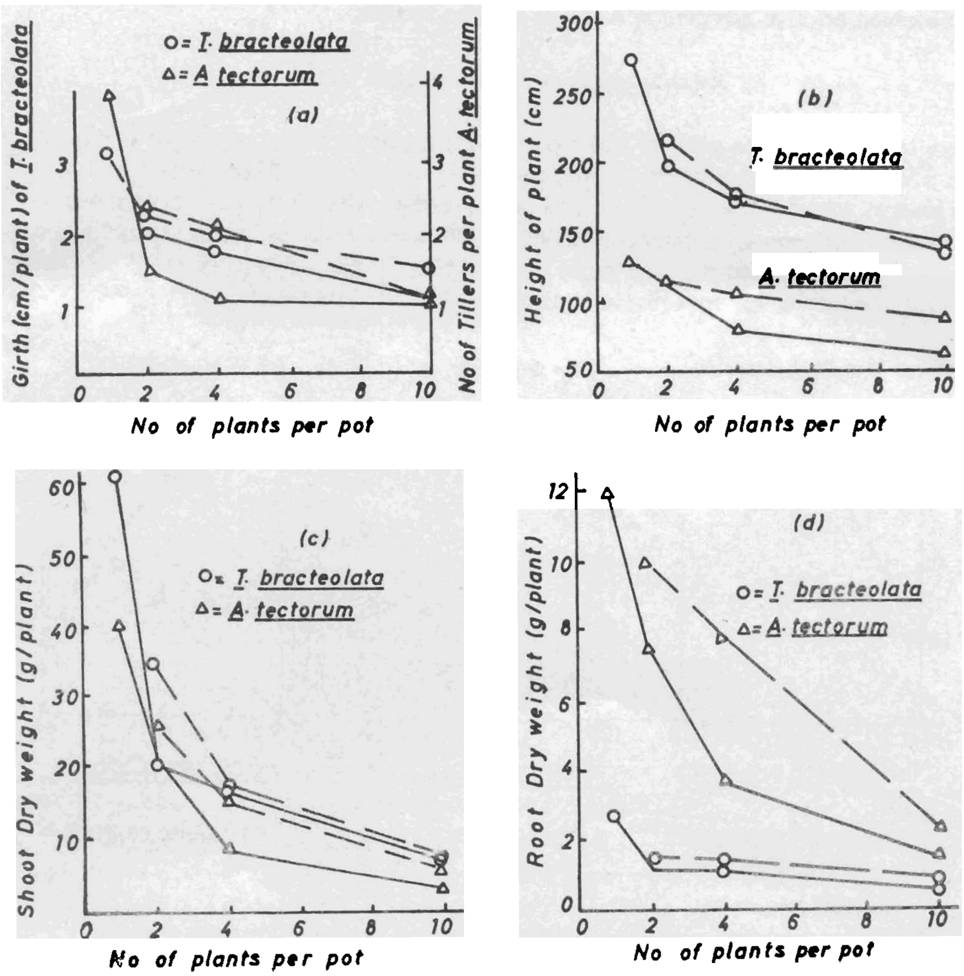

FIG. 4. Effect of density on aspects of growth at maturity on *Tephrosia bracteolata* and *Andropogon tectorum* when grown alone and in mixture of both plants in pot culture: (a) Stem girth of *Tephrosia* and tiller number of *Andropogon*; (b) Height: (c) Shoot dry weight; and (d) Root dry weight.

Shoot dry weight decreased with increasing density. In both species the yield per plant was higher in mixtures than in the corresponding monocultures (Fig. 4c). The root dry weight also decreased with increasing density (Fig. 4d). This effect of density on root weight was significant for *Andropogon* ($p<0.001$) but not for *Tephrosia*. *Andropogon* also had significantly higher root yield in mixtures than in monoculture ($p<0.001$). Further, there is significant interaction ($p<0.01$) between monoculture/mixture yield and density in *Andropogon*.

As expected, the performance (height, girth or number of tillers, and yield) of both species decreased with increasing density. Better performance of both species in mixtures than their monocultures suggests that intraspecific competition within each species was more intense than interspecific competition between them. Enhanced performance of mixtures is in line with the earlier observed positive association between the two species.

Relative yields and relative yield totals

Generally, the yields per plant in both species was higher in mixtures than in monocultures (Fig. 5). The monoculture yield of *Andropogon* was higher than that of *Tephrosia* at low density, but the reverse was the case at medium and high densities. There may have been a restriction in root growth especially for a monocotyledonous plant whose roots are usually spreading on the soil surface. And root competition is more important in affecting yield (Wilson 1988). At low monoculture density where root restriction is minimal total yield was higher.

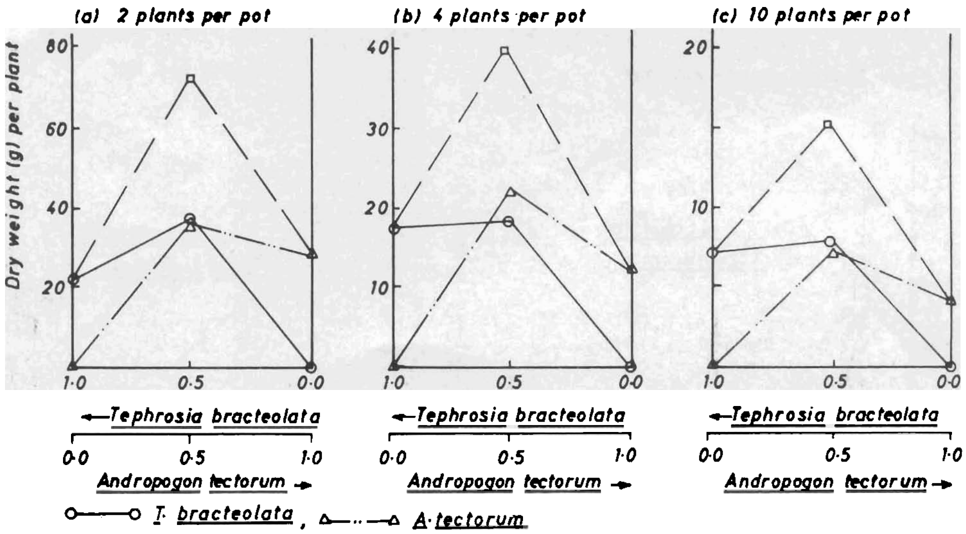

FIG. 5. Replacement series graphs showing the relationships between the dry matter production of I. *bracteolata* and *A. tectorum* in monocultures and mixtures at three different densities in pot culture.

TABLE 2. Mean total yield (g dry weight per plant) of *Tephrosia bracteolata* and *Andropogon tectorum* in monoculture and mixture in pot culture, southwestern Nigeria.

No. of plants per pot	Monoculture		Mixture		Relative yield		Relative Yield total
	Tephrosia	*Andropogon*	*Tephrosia*	*Andropogon*	*Tephrosia*	*Andropogon*	
1	64.76	52.36	–	–	–	–	–
2	21.57	28.63	36.70	36.27	1.70	1.27	2.97
4	17.77	12.07	18.65	22.69	1.05	1.88	2.93
10	7.24	4.24	7.94	7.46	1.10	1.76	2.28

For each of the mixture densities, the sum of the relative yield of the two species was consistently greater than unity (Table 2), suggesting that the species use at least partially different resources (Wilson 1988).

The results obtained in the present experiment could only serve as a guide to future experiments that might fully elucidate the conditions under which *Tephrosia* grows. Since for example, it is an annual, its survival and therefore a measure of its competitive ability could, in addition to yield, be seed production. Since range improvement is the final goal of the study the competition experiment will be best carried out under field range conditions with herbivores as an added factor. All these imply long-term experimentation.

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