PERSISTENCE OF TROPICAL LEGUMES ON PENINSULAR FLORIDA FLATWOODS (SPODOSOLS) AT TWO STOCKING RATES

W. D. PITMAN[1], C. G. CHAMBLISS[2], AND A. E. KRETSCHMER, JR.[3]

[1]University of Florida, Agricultural Research Centre, Ona, Florida, USA 33865.
[2]University of Florida, Agronomy Department, Gainesville, Florida, USA 32611,
[3]University of Florida, Agricultural Research Centre, Ft. Pierce, Florida, USA 33454.

ABSTRACT

*Persistence has been a major limitation to the use of tropical legumes in peninsular Florida. Hundreds of tropical legume accessions have been screened at Ft. Pierce, Florida over the past 20 years, and out of this group, a range of germplasm with adaption to the peninsular Florida climate has been identified. Persistence of 50 accessions from this program was evaluated on a seasonally-waterlogged flatwoods (Spodosol) site near Ona, Florida. Legume entries were sown in rows, and Pensacola bahiagrass (*Paspalum notatum*) seed was broadcast at the time legumes were sown. Two stocking rates were imposed after the establishment year.*

Three accessions in addition to the presently available cultivar Desmodium heterocarpon *cv. Florida were identified as being potentially adapted to continuous grazing in bahiagrass pastures in peninsular Florida. These accessions,* Vigna parkeri *cv. Shaw,* Desmodium barbatum, *and* Alysicarpus vaginalis, *were low-growing, seed-producing, perennial plants. Most accessions failed to persist at either stocking rate.* Macroptilium atropurpureum *cv. Sirato persisted better at the low stocking rate than at the high stocking rate, while the reverse was true for* D. barbatum *and* A. vaginalis.

INTRODUCTION

Several tropical pasture legumes have demonstrated adaption to the peninsular Florida climate by their persistence in observation plantings and plot studies at Ft. Pierce, Florida (Kretschmer 1967). Mixtures of some tropical legumes with grasses have been successfully maintained in plots under cutting for several years (Kretschmer 1968; Kretschmer 1972; and Kretschmer *et al.* 1979). In spite of the promising results from over 25 years of evaluation, the use of tropical legumes and the appropriate management to optimize their contribution can be found on only a small proportion of peninsular Florida flatwoods (Spodosol) pastures. The lack of widespread commercial acceptance of tropical legumes is at least partially due to their failure to perform, or even to persist, as well under commercial grazing as they have done under clipping treatments.

Performance of tropical legumes under clipping has been superior to their performance under grazing at locations in Australia (Whiteman 1969) and in Africa (Thomas 1976). However, the opposite situation has been found on acid, infertile savannas of South America (Thomas and de Andrade 1984), presumably due to low acceptability of the legumes to grazing livestock. Thomas (1976) concluded that legumes ultimately intended for grazing should be subjected to grazing in the early stages of evaluation.

Efforts to subject a number of tropical legume accessions to grazing defoliation and grass competition early in evaluation procedures in peninsular Florida have yielded erratic results as illustrated by Pitman and Kretschmer (1984). Although extreme grazing pressure on an individual accession could cause elimination of an adapted, highly palatable entry, accessions which have persisted to some degree as individual rows in grass pastures (Pitman and Kretschmer 1984) have subsequently been found to persist in small broadcast-sown pastures with grass competition and grazing defoliation (Pitman 1986 and Pitman *et al.* 1986).

Recent evaluations have identified a few grazing tolerant species from the group of legumes demonstrating general adaptation to the peninsular Florida climate and soils (Pitman and Kretschmer 1984). The most persistent of these legumes have limitations restricting large-scale grazing evaluation. Limited seed production due to late flowering in peninsular Florida is a problem with *Vigna parkeri* cv. Shaw. Erratic stand establishment and poor seedling vigor under moisture stress have limited use of *Desmodium heterocarpon* cv. Florida. While the limitations of these legumes merit further attention, additional legume accessions which have shown promise have become available for evaluation under defoliation treatments.

The low inherent soil fertility and generally low quality of forage grasses in summer in peninsular Florida necessitate continued efforts to identify and develop summer legumes which can persist in perennial grass pastures and contribute nitrogen to the soil and dietary protein to grazing cattle. A diverse group of tropical legume species was evaluated for persistence as single row entries in bahiagrass pastures under 2 stocking rates.

MATERIALS AND METHODS

Fifty tropical legume accessions representing 33 species and 17 genera (Table 1) were planted on a Spodosol site classified as Immokalee fine sand (sandy, siliceous, hyperthermic Arenic Haplaquod) near Ona, Florida (27° 26′ N latitude, 82° 55′ W longitude). Accessions were planted in a randomized complete block design with a total of 8 blocks. Each entry was sown as a single row 15m long in rows spaced 3 m apart. All accessions except Shaw creeping vigna, *Alysicarpus vaginalis*, and *Lotononis bainesii* were sown during July 2-7, 1983. Due to limited seed supplies, the above 3 accessions were established in peat cups and transplanted to the field in late July. All accessions except *L. bainesii* were inoculated with commercial cowpea *Rhizobium* at planting. *L. bainesii* seed was inoculated with a specific inoculant. Immediately before sowing the legumes, the 2-ha area was sown to Pensacola bahiagrass (*Paspalum notatum*) at 20 kg/ha on a clean-tilled seedbed.

Fertilization consisted of 22 kg P/ha and 83 kg K/ha in March of each year after establishment. Grazing was not imposed during the establishment year. In 1984 and 1985 the area was subjected to continuous grazing by crossbred yearling steers from April until mid September. Four blocks were subjected to a high stocking rate utilizing put-and-take stocking to maintain approximately a 15 cm stubble height. The other 4 blocks were subjected to a stocking rate of one-half the number of cattle used for the high stocking rate treatment. Stocking rates ranged from 4 to 6 head/ha on the heavily stocked treatment and from 1 to 3 head/ha on the lightly stocked treatment. In 1986, all blocks were grazed in common, with short, infrequent periods of grazing at a high stocking rate (50 head/ha) to remove grass competition and allow only limited grazing of legume regrowth. This grazing strategy was used to permit growth and observation of all persisting accessions.

Plant growth, and response to defoliation and pests, were monitored weekly throughout the 1983, 1984, and 1985 growing seasons. Ratings of plant persistence were made periodically during the 4 growing seasons from 1983 to 1986 using a scale of zero for no plants present, to 9 for a stand of legume throughout the original row.

RESULTS

Establishment and initial growth

Approximately 3 months after sowing, an overall mean rating of 4.7 indicated that the average legume stand across all accessions was approximately 50%. Only 2 accessions completely failed to establish. Both *Stylosanthes humilis* and the *Arachis* sp. failed to germinate due to poor seed quality. A dense sward of common bermudagrass (*Cynodon dactylon*) and sedges (*Cyperaceae* spp.) with scattered bahiagrass and vasey grass (*Paspalum urvillei*) established during the summer period.

TABLE 1

Persistence ratings[1] of tropical legumes planted at Ona, Florida in July 1983 (mean of 2 stocking rates)

Legume	Accession no.[2]	Date				
		Sept. 1983	Apr. 1984	Sept. 1984	Sept. 1985	July 1986
Aeschynomene americana	1725	2.1	0.0	0.4	0.0	0.0
Aeschynomene americana	1726	5.3	0.0	0.5	0.0	0.0
Aeschynomene fluminensis	2854	6.8	1.0	0.5	0.0	0.0
Aeschynomene histrix	2891	1.6	0.0	0.0	0.0	0.0
Aeschynomene sensitiva	2035	4.3	1.9	1.0	0.0	0.0
Aeschynomene villosa	2331	1.0	0.0	0.0	0.0	0.0
Aeschynomene villosa	2927	3.1	0.0	0.9	0.0	0.0
Alysicarpus vaginalis	3240	8.9	1.9	3.0	1.5	0.5
Arachis sp.	2273	0.0	0.0	0.0	0.0	0.0
Calopogonium mucunoides	5916	6.1	0.0	0.0	0.0	0.0
Centrosema pascuorum	1940	4.5	0.0	0.6	0.0	0.0
Centrosema pubescens	1687	6.1	1.0	0.6	0.0	0.0
Centrosema virginianum	1526	6.0	0.8	1.0	0.0	0.0
Centrosema virginianum	1935	4.8	1.0	1.3	0.0	0.0
Codariocalyx gyroides	1799	5.9	1.0	0.6	0.0	0.3
Desmanthus virgatus	474	5.1	0.4	0.1	0.0	0.0
Desmanthus virgatus	1857	4.9	0.1	0.0	0.0	0.0
Desmodium barbatum	1737	6.1	2.4	2.8	0.0	0.0
Desmodium barbatum	1923	7.4	5.6	6.3	3.0	0.8
Desmodium heterocarpon cv. Florida	588	8.5	6.1	5.6	1.9	1.0
Desmodium intortum	1022	0.5	0.0	0.0	0.0	0.0
Desmodium ovalifolium	1699	7.8	1.9	3.8	0.3	0.0
Desmodium uncinatum	1021	4.8	0.6	0.3	0.0	0.0
Galactia striata	3138	3.8	1.8	0.0	0.0	0.0
Galactia striata	3139	4.1	0.8	0.1	0.0	0.0
Galactia striata	3140	3.4	0.5	0.1	0.0	0.0
Lablab purpureus	1859	2.3	0.0	0.0	0.0	0.0
Lotononis bainesii	405	5.8	5.9	0.3	0.0	0.0
Macroptilium atropurpureum cv. Siratro	483	7.5	6.5	7.3	2.6	1.9
Macroptilium atropurpureum	3146	5.8	3.9	4.5	0.9	0.1
Macroptilium atropurpureum	3426	3.6	0.4	1.5	0.0	0.0
Neonotonia wightii	383	5.9	0.1	0.9	0.0	0.0
Neonotonia wightii	558	5.5	1.1	0.9	0.0	0.0
Neonotonia wightii	585	5.3	0.5	0.5	0.0	0.0
Stylosanthes guianensis	1414	2.1	0.0	0.1	0.0	0.0
Stylosanthes guianensis	1415	1.4	0.0	0.0	0.0	0.0
Stylosanthes guianensis	1756	1.9	0.0	0.0	0.0	0.0
Stylosanthes guianensis	7814	6.0	0.0	0.3	0.0	0.0
Stylosanthes guianensis	8201	5.4	0.0	0.0	0.0	0.0
Stylosanthes guianensis	8202	7.3	0.0	0.4	0.0	0.0
Stylosanthes guianensis	8203	7.5	0.4	0.6	0.0	0.0
Stylosanthes hamata	1233	4.8	0.0	0.0	0.0	0.0
Stylosanthes humilis	371	0.0	0.0	0.0	0.0	0.0
Stylosanthes tuberculata	2354	1.5	0.4	0.0	0.0	0.0
Teramnus labialis	1841	5.3	0.1	0.3	0.0	0.0
Teramnus labialis	1848	6.5	0.9	0.4	0.0	0.1
Vigna adenantha	1806	7.1	6.0	5.8	0.0	0.0
Vigna luteola	2127	6.5	0.8	3.4	0.5	0.0
Vigna parkeri cv. Shaw	2977	3.8	4.0	6.8	5.6	2.6
Zornia latifolia	2046	2.3	0.0	0.0	0.0	0.0
SE[3]		0.08	0.07	0.05	0.04	0.03

[1]Visual rating scale ranging from 0 for no surviving plants to 9 for a complete stand.
[2]Identification number of the University of Florida, Agricultural Research Center, Ft. Pierce, Florida.
[3]SE = Standard Error of the mean.

An average rating of 1.2 across all accessions in April 1984 illustrates the decline in legume stands during the first winter period. Environmental conditions during this period included a dense grass sward, predation of some accessions by wildlife, and intermittent frost. Aggressive growth of bermudagrass and bahiagrass occurred prior to the April 1984 rating, while growth of even the highest-rated legumes was still minimal following the last winter frost in early March.

Deer (*Odocoileus virginianus*) selectively grazed *Aeschynomene sensitiva* down to a stem diameter of about 6 mm during the autumn of 1983 and defoliated the other *Aeschynomene* accessions to a lesser extent, except for *A. histrix* which was not grazed. Both deer and rabbits (*Sylvilagus* sp.) utilized *Desmanthus virgatus* heavily resulting in loss of most of the original stand prior to the first frost of the 1983-84 winter.

From December 25, 1983 until March 2, 1984 frost occurred on 6 occasions with minimum air temperatures ranging from 0°C to −5°C. Between these frost events, weekly maximum temperatures were > 20°C, and several accessions initiated new growth after each frost. Plants present in April 1984 occurred as regrowth from perennating plants, with no new seedlings observed by this date. Thus, 31 of the 50 accessions had some perennating plants.

Effect of stocking rate

General responses

During the first 2 months of grazing in 1984, legume stand ratings increased under both stocking rates (Table 2). Development of new seedlings of several accessions was noted during this time. Other than this short-term legume stand increase, a drastic decrease in legume stand ratings over time is apparent under both stocking rates after June 1984 (Table 2). Most accessions failed to persist regardless of stocking rate. Fifteen accessions were no longer present by the end of the first grazing period (September 1984), 42 accessions were not in evidence by the end of the second year's grazing period (September 1985), and plants of only 8 accessions were found in July 1986 under a grazing scheme used to reduce grass competition and provide as much opportunity for legume growth as possible.

TABLE 2

Mean persistence ratings[1] of 50 tropical legume accessions at 2 stocking rates

Stocking rate	Sept. 1983[2]	Apr. 1984[2]	June 1984	Sept. 1984	Sept. 1985	July 1986
Low	4.1	0.9	1.3	1.2	0.4	0.1
High	5.2	1.5	1.8	1.4	0.3	0.2
Probability—stocking rate	—	—	0.01	0.08	0.46	0.64
Probability—interaction[3]	—	—	0.94	0.01	0.02	0.01

[1]Visual rating scale ranging from 0 for no surviving plants to 9 for a complete stand.
[2]Stocking rate treatments had not been imposed at these dates.
[3]Stocking rate-by-legume accession interaction.

Stocking rate

Stocking rate had a statistically significant ($P < 0.01$) effect on legume stand rating in June 1984 following the initial grazing period (Table 2). The magnitude of difference in stand ratings between blocks assigned to the 2 grazing treatments in April 1984 immediately before grazing treatments were imposed was similar to the difference in June (Table 2). A correlation of 0.82 was obtained between ratings for the 2 dates, April 1984 and June 1984, indicating that 67% of the variation among accessions in June 1984 could be accredited to the stands present in April 1984.

The main effect of stocking rate on legume stands was not significant ($P > 0.05$) at the end of the grazing periods in 1984, 1985, nor at the 1986 evaluation date (Table 2). An accession-by-stocking rate interaction (Table 2) was obtained at these 3 dates. Evaluation of the simple effects of stocking rate revealed that even though the main effect was not significant, some accessions were affected by stocking rate. Of the 35 accession with some plants persisting at the end of the 1984 grazing period, 6 accessions persisted to a greater ($P < 0.10$) extent under the high stocking rate and the other 29 accessions showed no response to stocking rate (Table 3). At the end of the

1985 grazing period, *A. vaginalis* survived to a greater (P < 0.05) extent under the high stocking rate. At the final rating July 1986, *Desmodium barbatum* had produced a greater (P < 0.05) stand on the area previously subjected to the high stocking rate, while the stand of *Macroptilium atropurpureum* cv. Siratro was greater (P < 0.10) at the low stocking rate. Shaw creeping vigna stands were not significantly different (P > 0.10) at the 2 stocking rates; however, stands of Shaw under the high stocking rate declined only 1.0 rating unit after September 1984 while stands at the low stocking rate declined 7.2 rating units. The only persistent accession which appeared to actually be unaffected by stocking rate was Florida carpon desmodium.

TABLE 3

Persistence ratings[1] at each stocking rate (SR) of legume accessions which had some plants surviving after the first grazing period

Legume accession	Stand Rating					
	Sept. 1984		Sept. 1985		July 1986	
	Low SR	High SR	Low SR	High SR	Low SR	High SR
A. americana 1725	0.0 h[2]	0.8 gh	0.0 d	0.0 d	0.0 d	0.0 c
A. americana 1726	0.0 h	1.0 fgh	0.0 d	0.0 d	0.0 d	0.0 c
A. flumenensis 2854	0.8 gh	0.3 gh	0.0 d	0.0 d	0.0 d	0.0 c
A. sensitiva 2035	1.3 fgh	0.8 gh	0.0 d	0.0 d	0.0 d	0.0 c
A. villosa 2927	0.3 h	+ 1.5 efgh	0.0 d	0.0 d	0.0 d	0.0 c
A. vaginalis 3240	1.8 efg	+ 4.3 bc	0.0 d	* 3.0 b	0.0 d	1.0 bc
C. pascuorum 1940	0.3 h	1.0 fgh	0.0 d	0.0 d	0.0 d	0.0 c
C. pubescens 1687	0.3 h	1.0 fgh	0.0 d	0.0 d	0.0 d	0.0 c
C. virginianum 1526	0.0 h	* 2.0 efgh	0.0 d	0.0 d	0.0 d	0.0 c
C. virginianum 1935	0.3 h	+ 2.3 defg	0.0 d	0.0 d	0.0 d	0.0 c
C. gyroides 1799	0.5 gh	0.8 gh	0.0 d	0.0 d	0.0 d	0.5 bc
D. virgatus 474	0.0 h	0.3 gh	0.0 d	0.0 d	0.0 d	0.0 c
D. barbatum 1737	2.5 def	3.0 cdef	0.0 d	0.0 d	0.0 d	0.0 c
D. barbutum 1923	6.0 c	6.5 a	3.3 b	2.8 b	0.0 d	* 1.5 b
D. heterocarpon 588	5.8 c	5.5 ab	1.5 c	2.3 bc	1.0 c	1.0 bc
D. ovalifolium 1699	3.0 de	4.5 bc	0.0 d	0.5 d	0.0 d	0.0 c
D. uncinatum 1021	0.0 h	0.5 gh	0.0 d	0.0 d	0.0 d	0.0 c
G. striata 3139	0.3 h	0.0 h	0.0 d	0.0 d	0.0 d	0.0 c
G. striata 3140	0.0 h	0.3 gh	0.0 d	0.0 d	0.0 d	0.0 c
L. bainesii 405	0.3 h	0.3 gh	0.0 d	0.0 d	0.0 d	0.0 c
M. atropurpureum 483	7.8 b	6.8 a	4.0 b	1.3 cd	3.5 a	+ 0.3 c
M. atropurpureum 3146	5.0 c	4.0 bcd	1.5 c	0.3 d	0.3 d	0.0 c
M. atropurpureum 3426	1.8 efg	1.3 efgh	0.0 d	0.0 d	0.0 d	0.0 c
N. wightii 383	1.0 gh	0.8 gh	0.0 d	0.0 d	0.0 d	0.0 c
N. wightii 558	0.3 h	+ 1.5 efgh	0.0 d	0.0 d	0.0 d	0.0 c
N. wightii 585	0.0 h	* 1.0 fgh	0.0 d	0.0 d	0.0 d	0.0 c
S. guianensis 1414	0.3 h	0.0 h	0.0 d	0.0 d	0.0 d	0.0 c
S. guianensis 7814	0.3 h	0.3 gh	0.0 d	0.0 d	0.0 d	0.0 c
S. guianensis 8202	0.5 gh	0.3 gh	0.0 d	0.0 d	0.0 d	0.0 c
S. guianensis 8203	0.0 h	1.3 efgh	0.0 d	0.0 d	0.0 d	0.0 c
T. labialis 1841	0.3 h	0.3 gh	0.0 d	0.0 d	0.0 d	0.0 c
T. labialis 1848	0.0 h	0.8 gh	0.0 d	0.0 d	0.0 d	0.3 c
V. adenantha 1806	6.0 c	5.5 ab	0.0 d	0.0 d	0.0 d	0.0 c
V. luteola 2127	3.5 d	3.3 cde	0.8 cd	0.3 d	0.0 d	0.0 c
V. parkeri 2977	9.0 a	4.5 bc	6.8 a	4.5 a	1.8 b	3.5 a

[1] Visual rating scale ranging from 0 for no surviving plants to 9 for a complete stand.
[2] Means within each column not followed by a common letter differ at the 0.05 level of probability according to Duncan's Multiple Range Test.
+ Denotes significance (P < 0.10) between stocking rates.
* Denotes significance (P < 0.05) between stocking rates.

Legume acccessions

Survival of individual accessions within each stocking rate treatment in 1984, 1985, and 1986 are also shown in Table 3. The stand of Shaw creeping vigna was greater (P < 0.05) than that of any other accession in 4 of the 6 analyses (2 stocking rates each during 3 years). Shaw was the superior accession at the low stocking rate in 1984 and 1985 and at the high stocking rate in 1985 and 1986. Although Siratro persisted to a greater extent than did Shaw at the high stocking rate in 1984, this relationship had been reversed by 1985, and by 1986 the stand of Siratro was not significantly greater than zero at the high stocking rate. At the low stocking rate in 1984 and 1985, the Siratro stand was surpassed ($P < 0.05$) only by that of Shaw. By 1986, Siratro was the most persistent entry at the low stocking rate. In 1985, one-third of the original *A. vaginalis* stand remained under the high stocking rate, but this accession failed to persist at all under the low stocking treatment. Only 4 accessions received stand ratings significantly greater ($P < 0.05$) than zero in July 1986. Shaw creeping vigna did so at both stocking rates. Siratro and Florida carpon desmodium did only at the low stocking rate, even though the numerical ratings of Florida carpon desmodium at the two stocking rates were identical. *D. barbatum* 1923 persisted only at the high stocking rate.

DISCUSSION

Observations from frequent monitoring of these plantings suggest some precautions in interpretation of the results. Grazing pressure by cattle was generally similar among legume accessions with respect to grazing stubble height. Thus, low-growing accessions were defoliated to lesser proportions than upright and climbing, viney accessions. This situation is to be anticipated for palatable legumes in continuously grazed bahiagrass pastures in Florida. Due to wildlife grazing, *D. virgatus* and *A. sensitiva* received heavier grazing pressure than the other accessions. Despite heavy grazing pressure and an upright growth habit, *A. sensitiva* persisted through 2 growing seasons suggesting some promise. *D. virgatus* has also persisted in nearby observation plots where defoliation was less severe. *Vigna adenantha* has persisted in adjacent areas for several years, although it failed to persist in this evaluation. Periods of deferment from grazing during the growing season and especially each autumn prior to frost appear to be important to long-term stand survival of the viney, trailing *V. adenantha.*

This study indicates both the limited range of tropical legume germplasm with potential for long-term pasture stands at Ona, Florida and the differences to be anticipated due to grazing management. Four accessions persisted well enough to indicate that they have potential value for continuously-grazed bahiagrass pastures in peninsular Florida flatwoods. These 4 accessions, Shaw creeping vigna, Florida carpon desmodium, *D. barbatum* 1923, and *A. vaginalis*, are low growing, seed producing perennial legumes. Species with these growth characteristics are more likely to provide sustainable legume components to bahiagrass pastures under the pasture management conditions currently typical of Florida grasslands than are the upright or climbing legumes. The use of rotational grazing, extended periods of deferment from grazing, or comparatively light stocking rates would probably result in extended survival and production from some of the viney legumes such as Siratro and *V. adenantha.*

The experimental area was subjected to periodic grazing for a 2-year period after data collection ceased. Only Shaw creeping vigna has remained to an appreciable extent, with this legume having spread over an average of 45 m^2 per replication on the 6 replications which survived the initial year.

In addition to identifying legume accessions with potential value for peninsular Florida pastures, germplasm tolerant of adverse environmental factors under pasture conditions was identified. Thirty-one accessions survived winter frosts as perennial plants during the first year. Thirty-five accessions survived the short periods of waterlogged soils during 2 summer rainfall seasons. These accessions could be of value in other environments where tolerance to either frost or waterlogging is required, especially where grass competition is less severe.

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NUTRIENT STRUCTURE AND DYNAMICS IN A TEMPERATE GRASSLAND COMMUNITY OF WESTERN HIMALAYA (GARHWAL), INDIA

ARUN K. AGRAWAL

Department of Botany, Government Post Graduate College, Kotdwara (Garhwal) 246 149, India.

SUMMARY

The purpose of this study was to ascertain the nutrient levels in the pasture components, and to estimate annual uptake, release and retention of nitrogen, phosphorus and potassium in a temperate grassland community of Western Himalaya (Garhwal) from June 1983 to June 1984. The surface soil (30 cm) contains larger quantities of nutrients than were held by the plant biomass. The quantity of N, P and K, taken up annually by plants was about 19.8, 3.7 and 28.8 kg/ha, respectively. Of this, about 10.2, 1.5 and 6.3 kg/ha respectively are released and about 9.6, 2.2 and 22.5 kg/ha are retained in the vegetative compartments.

INTRODUCTION

The mineral component of an ecosystem operates in a dynamic state through a series of inputs and outputs of the essential elements. Plants and soil are the sub-systems of this dynamic system and serve as storage compartments, while the atmosphere can be considered as an open reservoir. Fluxes of nutrients from plants are continuously transferred to soil via litter formation. The latter contains the basis of essential elements for the plants in an ecosystem (Billore and Mall 1976). The mobility of elements through the plant/soil/atmosphere continum constitutes nutrient cycling. Patterns of biological circulation of nutrients differ from polar to tropical latitudes (Rodin and Bazilevich 1967).