ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

# JOURNAL OF AGRONOMY

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Journal of Agronomy 4 (4): 323-328, 2005
ISSN 1812-5379


# The Effect of Cutting Height of *Senna singueana* (Del.) Lock. In Mixed Intercropping System on Foliage Biomass Production and Maize Yield in Morogoro, Tanzania

[1]J.B. Nduwayezu, [2]L.L.L. Lulandala, [2]S.A.O Chamshama and [2]A.G. Mugasha
[1]Botswana College of Agriculture, Department of Crop Science and Production,
Private Bag 0027 Gaborone, Botswana,
[2]Sokoine University of Agriculture, Faculty of Forestry and Nature Conservation,
Department of Forest Biology, P.O. Box 3010 Morogoro, Tanzania,

**Abstract:** A study was conducted during 1998-2001 at Kitete, Morogoro, Tanzania to determine the potential use of a commonly occurring shrub (*Senna singueana* (Del.) Lock.) in tropical Africa for soil fertility replenishment. *Senna singueana* (Senna), which is also locally known as Mhumba, was examined in mixed inter-cropping trial at four cutting heights (25, 50, 75 and 100 cm), measuring its foliage biomass production and maize yield. Senna was established using 3 months-old seedlings at 2.0 m inter-row and 0.9 m intra-row spacings. Staha maize variety was used as the test-crop. Foliar biomass, maize yield and N-partitioning between maize parts (grain, straws and cobs) were determined. Senna had the highest growth rate during 4-10 months after establishment. Foliage dry matter yield (fertilizer source) increased with cutting stubble height to 75 cm after which it declined. Cutting Senna plants at 75 cm height maximized both its potential for foliar biomass production (2.70 t $ha^{-1}$), prunings N contribution to the maize crop (59.5 kg N $ha^{-1}$), yields of maize grain (2.70 t $ha^{-1}$), straws (2.50 t $ha^{-1}$) and cobs (0.55 t $ha^{-1}$) and N-partitioning between maize grain (40.1 kg N $ha^{-1}$), straws (12.8 kg N $ha^{-1}$) and cobs (3.7 kg N $ha^{-1}$). It is concluded that Senna grows rapidly and recovers fast to coppice profusely following foliage harvesting. Pruning Senna plants at 75 cm height optimizes soil N availability and plant uptake and promotes healthy plant growth, maximizes biomass production and yield of associated maize crops. It is, however, suggested that future genetic improvement research should focus on evaluating various *Senna singueana* provenances with a view of identifying the strains that maximize its productivity.

**Key words:** Mixed intercropping, nitrogen, tree/shrub management, *Senna singueana*

## INTRODUCTION

Deficiency of essential plant nutrients as a result of lowered levels of Soil Organic Matter (SOM) is responsible for unsustainable food crop production, human health deterioration and escalating rate of environmental degradation in sub-Saharan Africa[1-3].

To reduce the current trend of land degradation and hunger there is a need for building up organic matter in the soil and increasing food supply on a sustainable basis through the adoption of suitable trees/shrub species for agroforestry practices. The suitable agroforestry species are those exhibiting fast growth, high foliage biomass production and the capacity to provide firewood of high calorific value and litter of high protein content[4,5]. Considerable evidence showed that trees or shrubs in agroforestry systems may have facilitative, complementary and competitive effects on associated crops. They can increase soil carbon (C) enrichment through root turnover[6], restore soil fauna involved in decomposition processes[7,8], ameliorate soil physical properties[9], improve the levels of SOM and essential nutrients[9-11] and increase the use of soil resources by the whole tree-crop association[6,8,9]. These tree-crop competitions may lead to the increased crop yield reductions and economic failure of the land-use system[12]. The appropriate agroforestry tree/shrub species management regimes, therefore, may not only minimize the tree-crop competition for available resources but they can also maximize both the potential of agroforestry trees and shrubs for biomass production[13-15], prunings nutrients contribution to the soil[3] and yield of associated crops[16].

While a lot of work has already been done on evaluating the suitability of exotic tree and shrub species for agroforestry[8-11,15,17,18], little information exists

**Corresponding Author:** Dr. J.B. Nduwayezu, Botswana College of Agriculture, Department of Crop Science and Production, Private Bag 0027 Gaborone, Botswana Tel: 267 3650100/0312 Fax: 267 3928753

on productivity (i.e. foliar and woody biomass) and management regimes (e.g. spacing, cutting height and pruning frequency) of indigenous species including *Senna singueana* (Del.) Lock. (Senna). Senna, is a lesser-known indigenous shrub which is widespread in tropical Africa[19] and commonly used by the smallholder Tanzanian farmers as a source of food (pods and leaves), fodder/forage (goats and bees), fertilizer (foliages), energy (firewood), medicine (leaves and roots used as remedy for venereal diseases, malaria, convulsion, epilepsy, coughs, yellow fever, intestinal worms, constipation, heartburn, stomachache, diarrhoea, dementia and wounds) and income generation (charcoal and spoons making). The major objective of this study, therefore, was to assess both the growth performance and the effect of different cutting heights of *Senna singueana* plants on the foliage biomass production potential and yield of the intercropped maize in mixed intercropping formation.

## MATERIALS AND METHODS

**Site description and materials:** The study was carried out in Morogoro, Tanzania on a site (Latitude 37°8'E; Longitude 6°30'S; Altitude 375 m.a.s.l) characterized by slightly acidic sandy clay loam soils containing moderate total N, available P and cation exchange capacity, bimodal rainfall pattern and miombo vegetation type. The seeds of Senna used in the production of tree seedlings/transplants for the mixed intercropping study, were collected during November 1997 from local trees within the study area (Kitete Village).

### Experimental procedures

**Experimental design, treatments, establishment and management:** The mixed intercropping experiment was established in April 1998, with healthy 3-month-old *Senna* transplants averaging 13 cm height in Randomized Completely Block Design of 4 cutting height treatments (25, 50, 75 and 100 cm above ground level) plus one no-tree control treatment and replicated 3 times. In this trial each treatment plot consisted of 4.0×8.9 m rectangle containing 5 tree rows and 5 tree columns of 0.9 and 2.0 m intra- and inter-row spacing. Lopping began at 1year-old and there were 3 loppings (i.e. 2 loppings at 3 and 6 weeks after maize planting during the long rain maize growing season and 1 pruning in May- a year after the second pruning). Three assessments were carried out on (i) initial height and collar-diameter growth (April, 1998-March, 1999), (ii) foliage biomass production, prunings N contribution to the soil, maize crop yield and N partitioning between different maize parts i.e. grain, cobs and straws (March-May, 1999). All assessments in each treatment plot were carried out in the middle 3 tree rows and 3 columns leaving one outer row and column on each side of the plot for controlling boundary effect. At each of the first two harvests the bulk of the foliage was mulched over the mixed intercropping spaces of the whole treatment plots making it a double foliage application. The samples for determination of initial N concentrations in *Senna* prunings were taken for laboratory analysis[20]. Foliage biomass yields were estimated by multiplying the total fresh weight per plot by the Dry Matter (DM) factor and the results extrapolated to per hectare yields. After drying in the field (common practice by the local farmers) the maize crop was harvested and its yield recorded. Nitrogen partitioning between different maize plant components was also determined[20].

**Statistical analysis:** Analysis of variance was conducted using the ANOVA procedure of MSTAT-C to determine the treatment effects on: (i) *Senna* foliage dry matter yield, (ii) prunings N contribution to the maize farm, (iii) maize biomass production by the various plant components (i.e. maize grain, cobs and straws) and (iv) N partitioning between different maize parts. The Duncan's Multiple Range Test (DMRT) was used to separate the differing treatment means.

## RESULTS

**The initial plant height growth performance under mixed planting system:** The results of *Senna* plants mean height growth (Fig. 1) indicate that, during the first 3 months of establishment, *Senna* plants grew slowly. Subsequently, the growth rate of *Senna* plants increased rapidly, reaching the highest level at 10 months. The 4-10 months period, therefore, represents the grand period of vegetative growth of this indigenous shrub species.

**Senna foliar biomass production, prunings N contribution, maize yield and N-partitioning between various plant components:** The foliage DM yields significantly ($p<0.05$) increased with increasing cutting stubble height to 75 cm (Table 1) after which it declined slightly. Cutting *Senna* plants at 75 cm above ground level also gave significantly ($p<0.05$) higher prunings N contribution (i.e. 3.63% mean N concentration in tissues of *Senna* prunings) to the maize crop, maize yield (Table 1) and N content in tissues of different maize plant components i.e. grain, straws and cobs (Table 2) than lower cutting heights and no-tree control treatment, respectively.

Table 1: Soil N supplementation through Senna foliage application, maize biomass production by the various plant components and overall total foliar dry matter yield under different cutting heights at Kitete, Morogoro, Tanzania

| Cutting height (cm) | Seuna prunings N added to the soil (kg N $ha^{-1}$) | Average maize yield (t $ha^{-1}$) Grain | Straws | Cobs | Foliagebiomassyield after maize harvesting (t $ha^{-1}$) |
|---|---|---|---|---|---|
| 25 | 25.3±4.2b | 2.01±0.2bc | 2.40±0.03a | 0.53±0.06a | 0.84 ±0.07b |
| 50 | 36.8±3.0b | 2.24±0.05ab | 2.48±0.1a | 0.48±0.03a | 2.00±0.13a |
| 75 | 59.5±7.0a | 2.70±0.2a | 2.50±0.05a | 0.55±0.1a | 2.70 ±0.13a |
| 100 | 54.1±5.7a | 1.74±0.3bc | 2.38±0.6a | 0.39±0.06a | 2.02±0.27a |
| Control | None | 1.46±0.3c | 2.11±0.08b | 0.32±0.1a | None |
| Prob.> F-ratio | p=0.006 | p=0.015 | p=0.016 | p=0.341 | p=0.0015 |

Means in the same column that are followed by the same letter a, b, c do not differ significantly (p=0.05) (DMRT)

Table 2: Nitrogen partitioning between different maize parts under different tree cutting height and no-tree control treatments in the *Senna singueana* mixed intercropping system at Kitete, Morogoro, Tanzania

| Cutting height (cm) | Average N-partitioning (kg N $ha^{-1}$) between the various maize plant components: Grain | Straw/Stover | Cobs |
|---|---|---|---|
| 25 | 18.9±1.7b | 9.40±0.98bc | 2.6±0.34ab |
| 50 | 24.5±0.32b | 10.80±0.53ab | 2.2 ±0.32ab |
| 75 | 40.1±3.8a | 12.80±0.81a | 3.7±1.0a |
| 100 | 21.6±3.6b | 10.30±1.5ab | 1.6±0.24b |
| Control | 8.1±1.6c | 6.80±0.35c | 0.9±0.21b |
| Prob. > F-ratio | p<0.001 | p=0.013 | p=0.034 |

Means in the same column that are followed by the same letter a, b, c, ab do not differ significantly (p=0.05) (DMRT)

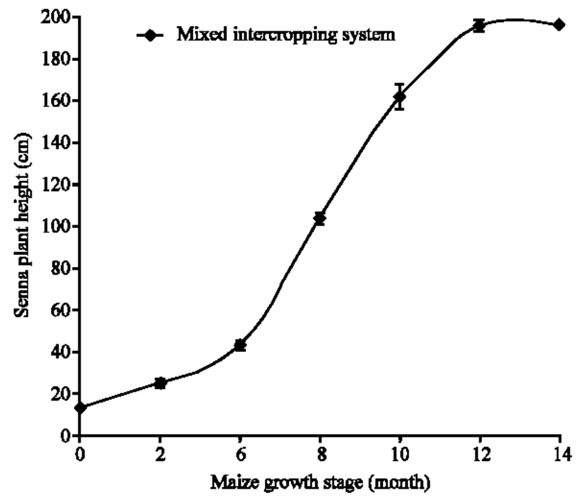


Fig. 1: Average heights of *Senna singueana* plant at different growth stages under mixed intercropping system at Kitete, Morogoro, Tanzania

## DISCUSSION

### Growth and strategic pruning of Senna plants for optimum biomass production and maize yield under mixed intercropping system

**Height growth of *Senna singueana* plants:** During the first 3 months after planting out in the field, the plants of *Senna* suffered shock resulting in slowed height growth (Fig. 1) and loss of leaves, which are essential for photosynthesis. The loss of leaves after planting out could, however, be a mechanism by which young *Senna* plants control or minimize plant water losses through the transpiration process, which is very crucial for root growth and development. This slow initial growth rate also earlier reported on other species[21] was, probably, due to the plants being adversely affected by the carbohydrate concentrations falling below certain threshold levels. The rapid increase in the rate of height growth after recovering from the transplanting shock, was probably a result of the high efficiency of the root system which was initially, observed to increase directly with the aerial plant growth before finally decreasing as the plant matured. The enhancement in the rate of recovery of plants following field transplanting shock thereby resulting in the development of fibrous root systems and higher root growth capacities had, similarly, been reported earlier for *Eucalyptus camaldulensis*[21]. The observed slightly higher height increment of *Senna* plants grown under mixed intercropping system as compared with those under the alley farming system[22] can probably be attributed to minimum inter-tree above and below ground competition as a result of wider spacing.

**Foliar biomass production and implications of the Senna prunings to the smallholder farmers:** The foliage biomass yields of *Senna* under mixed inter-cropping system increased with lopping height to 75 cm cutting height before declining at the higher cutting height (Table 1). The increasing ability of *Senna* plants to produce more biomass with the increasing cutting height can probably be attributed to the high efficiency of the plant root systems, which is in conformity with the results of *Eucalyptus camaldulensis*[21].

Although not counted, it was observed that cutting at 75 or 100 cm gave more buds and high number of coppice shoots per parent stump than cutting at lower heights (25 and 50 cm). This could also explain the higher biomass yields recorded under these treatments, especially at 75 cm cutting height treatment. The reduced dry matter yield recorded at 100 cm lopping height compared with the 75 cm cutting height treatment, however, can probably be attributed to the increased competition for nutrients, water and light between the coppice shoots of the same parent stump (i.e. higher number of smaller size coppices at 100 cm). Overall, these observations are in agreement with those reported in other studies suggesting that cutting trees and shrubs at various heights ensured vegetative growth, with greater shoot development and foliage yield being observed at higher cutting stubble height[17,18,23-25]. At stubble heights greater than 75 cm, however, the results have been variant and inconsistent.

The biomass dry matter yield of *Senna* (Table 1) obtained during the maize cropping season, however, is still low as compared with the biomass yields of other agroforestry species like *Leucaena leucocephala* (2.53 t $ha^{-1}$)[26], *Calliandra calothyrsus* (12.0 t $ha^{-1}$)[13] and *Sesbania sesban* accessions (25-42 t $ha^{-1}$)[27]. Possibly this can be related to differences in genetic composition, plant age, population density, pruning periods and frequency and differences in soil characteristics and ecological conditions.

The increased N contribution from *Senna* prunings (Table 1) as a result of increasing the cutting height may probably be attributed to the proportionately higher amounts of the incorporated N-source biomass at higher heights, which is in agreement with the results from other studies on different tree/shrub species[17,28-30]. Based on the conversion of biomass harvested from *Senna* intercropping system into commercial N containing fertilizer equivalent like urea (46% N), it can be noted that, in cash terms, application of *Senna* foliages is a saving for the smallholder farmers.

**Management of Senna plants for optimum maize production and maize parts N content:** Cutting *Senna* plants at 75 cm above ground level not only maximized foliar biomass production and N contribution (Table 1) but also optimized both the maize plant biomass yield (Table 1) and N content of the various maize plant components (i.e. grain, cob and straw) (Table 2). The higher maize yields obtained under plots with *Senna* plants as compared with yields from the sole maize cropping (controls) can probably be attributed to the increased nutrient availability, especially N, during the critical maize growth stages as a result of the decomposing and mineralizing *Senna* manures. The facilitative and complementary effects of agroforestry species on associated crops earlier reported by a number of researchers[7,11,31] can also explain the increased maize production under plots with *Senna* plants as compared with the no-tree controls. Enhanced performance and production of food crops as a result of growing them in association with trees and shrubs, which increase N availability for crop uptake, have, similarly, been reported for other agroforestry species[16,32,23].

The report by Sanchez and Palm[34] indicated that 100 kg N $ha^{-1}$ is required by maize crop so that an African farmer is able to produce 4 tons of maize grain per hectare. The maize grain yields (Table 1) obtained in the present study, therefore, are lower than expected probably attributable to the inadequate N supply caused by insufficient foliage biomass harvested from the *Senna* intercropping system and incorporated into the soil. The lowered maize grain yields caused by insufficient tree prunings applied to the maize farm were also observed in other studies at Sokoine University Farm, Morogoro, Tanzania, with *Sesbania sesban*[35]. The lower level of maize grain yield could also probably be due to the competitive effect (competition for nutrients, water and light) of *Senna* plants on associated maize crop as similarly observed elsewhere by some researchers[6]. Crop yield reductions attributable to tree-crop competition was also reported in studies on *Leucaena leucocephala*, *Flemingia congesta*, *Inga edulis*, *Cajanus cajan*, *Eucalyptus* species and other multipurpose tree and shrub species[12,36-39].

## CONCLUSIONS AND RECOMMENDATION

From these results, it is concluded that *Senna*, a lesser-known indigenous shrub, is found to grow rapidly and recover fast to coppice profusely following foliage pruning. Subjecting *Senna* plants at 75 cm cutting height not only optimizes soil N-nutrient availability and plant uptake but also promotes healthy plant growth to maximize both biomass production and yield of associated maize crops. The degree of maize yield enhancement and N content in tissues of different maize components (grain, straws and cobs) in mixed intercropping system are closely linked to the quantity of foliages harvested and amount of prunings N made available for uptake by maize plant roots. Being widespread in Africa, *Senna* shows a wide range of genetic variation. The knowledge about possible genetic improvements of this indigenous shrub has not, however, been assembled. Research is urgently required to evaluate various *Senna* provenances with a view of identifying the strains that maximize its productivity.

## ACKNOWLEDGMENTS

It is a pleasure to acknowledge and convey our sincere thanks to the Sokoine University of Agriculture for her facilities; the International Development Research Centre and African Academy of Sciences for their financial supports and the International Centre for Research in Agroforestry for scientific advice. The Kitete Village government, Mzee Musa Saburi, Kauta Mohamed and the late Mohamed Kayanda, supported the authors during data collection. We, therefore, acknowledge the collective and individual supports of these people most heartily.

## REFERENCES

1. Palm, C.A., R.J.K. Myers and S.M. Nandwa, 1997. Combined Use of Organic and Inorganic Nutrient Sources for Soil Fertility Maintenance and Replenishment. In: Replenishing Soil Fertility in Africa (Eds., Buresh, R.J., P.A. Sanchez and F. Calhoun). Soil Science Society of America (SSSA), Madison, Wisconsin, USA., pp: 251.
2. Quiñones, M.A., N.E. Borlaug and C.R. Dowswell, 1997. Fertilizer-Based Green Revolution for Africa. In: Replenishing Soil Fertility in Africa (Eds., Buresh, R.J., P.A. Sanchez and F. Calhoun). Soil Science Society of America (SSSA), Madison, Wisconsin, USA., pp: 251.
3. Sanchez, P.A., K.D. Shepherd, J.S. Meredith, M.P. Frank, R.J. Buresh, N.I. Anne-Marie, A.U. Mokwunye, F.R. Kwesiga, C.G. Ndiritu and P.L. Woomer, 1997. Soil Fertility Replenishment in Africa: An Investment in Natural Resource Capital. In: Replenishing Soil Fertility in Africa (Eds., Buresh, R.J., P.A. Sanchez and F. Calhoun). Soil Science Society of America (SSSA), Madison, Wisconsin, USA., pp: 251.
4. Subhash, N. and S. Nautiyal, 1990. Some fast growing short rotation fuel-wood species for Himachal Pradesh. Ind. Forest., 13: 300-306.
5. Negi, G.C.S., 1995. Phenology, leaf and twig growth pattern and leaf nitrogen dynamics of some multipurpose tree species of Himalaya: Implementation towards agro forestry practice. J. Sustainable Agric., 6: 43-60.
6. Schroth, G., 1999. A review of belowground interactions in agroforestry, focussing on mechanisms and management options. Agrofor. Syst., 43: 5-34.
7. Rhoades, C., 1995. Seasonal pattern of nitrogen mineralization and soil moisture beneath *Faidherbia albida* (syn. *Acacia albida*) in central Malawi. Agrofor. Syst., 29: 133-145.
8. Buresh, R.J., G. Tian, P.K.R. Nair and C.R. Latt, 1998. Soil improvement in sub-Saharan Africa. Agrofor. Syst., 38: 1-3, 51-76.
9. Aihou, K., N. Sanginga, B. Vanlauwe, O. Lyasse, J. Diels and R. Merckx, 1999. Alley cropping in the moist savanna of West Africa: I. Restoration and maintenance of soil fertility on terre de barre soils in Bénin Republic. Agrofor. Syst., 42: 213-227.
10. Mafra, A.L., A.A.W. Miklos, H.L. Vocurca, A.H. Harkaly and E. Mendoza, 1998. Biomass production and soil chemical attributes in an alley cropping system and under Brasilian cerrado vegetation. Revista Brasileira de Ciencia do Solo, 22: 43-48.
11. Jose, S., A.R. Gillespsi, J.R. Seifert, D.B. Mengel and P.E. Pope, 2000. Defining competition vectors in a temperate alley cropping system in the Midwestern USA.3. Competition for nitrogen and litter decomposition dynamics. Agrofor. Syst., 48: 61-77.
12. Young, A., 1997. Agroforestry for Soil Management. 2nd Edn., CAB International/International Centre for Research in Agroforestry, Nairobi, Kenya, pp: 320.
13. Morikawa, R.T., D.O. Lantagne, M.A. Gold, S.G. Krecik and J.M. Roshetko, 1995. Management of *Calliandra calothyrsus* for fodder production in Jamaica. Trop. Grasslands, 29: 236-240.
14. Abou-Deya, I.B. and M.Y. Draz, 1996. Oldman saltbush for forage and sand dune stabilization. Ann. Agric. Sci. Cairo, 41: 815-825.
15. Bodji, N.C., 1997. Effect of cutting height and frequency on survival and forage productivity of *Cajanus cajan* CIAT 18 700. Revue d' Elevage et de Medecine Veternaire des Pays Tropicaux , 50: 309-312.
16. Mugendi, D.N., 1997. Tree-biomass Decomposition, N Dynamics and Maize Growth under agroforestry Conditions in the Subhumid Highlands of Kenya. In: Abstracts of Ph.D, M.Sc, M. Phil and Diplome ingenieur Theses in Agroforestry, 1987-1998 (Eds., Temu, A.B., J. Kiio, M. Kimenye and E. Gimonde). ICRAF, Nairobi, Kenya, pp: 74.
17. Chourio, J., V. Colina, T. Clavero, R. Razz and C. Castro, 1997. Effect of defoliation on biomass production of *Clitoria ternatea* (L.) DNE. Cuban J. Agric. Sci., 31: 113-117.
18. Bouayad, A., A.E.I.K. Achhal and M. Fechtal, 1998. Estimation of biomass and essential oil production by *Artemissia herba-alba* Asso. In: Skoura pasturage (Ouarzazate Province). Anales de la Recherche Forestiere au Maroc, 31: 17-25.
19. Brenan, J.P.M., 1967. Leguminoseae, Sub-family Caesalpinioideae. In: Flora of Tropical East Africa (Eds. E. Milne-Readhead and R.M. Polhill) Royal Botanic Garden, Kew, Engalnd, pp: 230.
20. Anderson, J.M. and J.S.I. Ingram, 1993. Tropical Soil Biology and Fertility. A Handbook of Methods. 2nd Edn., C.A.B International. Wallingford. UK.

21. Chamshama, S.A.O., 1984. Establishment techniques for *Eucalyptus* species: Effects of Nursery Treatments, Site Preparation and Fertilization on Survival and Growth. Ph.D Thesis, University of Dar es Salaam, pp: 171.
22. Nduwayezu, J.B., 2001. *Senna singueana*: Yield, Decomposition and Nitrogen Mineralization. Ph.D Thesis, SUA, Tanzania, pp: 225.
23. Gaddanakeri, S.A., S.K. Gumaste and C.S. Hunshal, 1993. Effect of subabul (*Leucaena leucocephala*)-live bund on growth and yield of companion crop of sunflower (*Helianthus annuus*). Ind. J. Agron., 38: 598-602.
24. Saleem, M. and D.P. Singh, 1995. Response of coppicing *Albizia lebbek* at different heights on regeneration and subsequent biomass production. Ind. Forest., 121: 59-62.
25. Tarawali, G., P.A. Iji, P.C. Chionuma and U. Obot, 1996. Herbage yield and quality of *Gliricidia sepium* under different cutting heights and defoliation frequencies. Agrofor. Syst., 34: 315-326.
26. Carrete, C.F.O., V.J.A. Eguiarte and A.R. Sanchez, 1993. Comparison of four cutting heights in the production and quality of forage from the two varieties of *Leucaena*. Techrica Pecuaria en Mexico 31: 122-127.
27. Heering, J.H., 1995. The effect of cutting height and frequency on the forage, wood and seed production of six *Sesbania sesban* accessions: Productivity of *Sesbania sesban* accessions under irrigated conditions. Agrofor. Syst., 30: 341-350.
28. Bai, M.M., S. Lakshmi and G.R. Pillai, 1990. Cutting management of subahul. Agric. Res. J. Kerala, 28: 48-49.
29. Fransisco, G., L. Simon and M. Soca, 1998. Effect of three cutting heights on biomass yield from *Leucaena leucocephala* cv. CNIA-250. Pastos-y-Forrajes, 21: 337-343.
30. Muir, J.P., 1998. Effect of cutting height and frequency on *Leucaena leucocephala* forage and wood production. African J. Range Forage Sci., 15: 1-2, 7-10.
31. Gallardo, A. and J. Merino, 1999. Control of leaf litter decomposition rate in a Mediterranean shrubland as indicated by N, P and lignin concentrations. Pedobiologia, 43: 64-72.
32. Tiki, M.T., 1992. Effect of pruning frequency on the yield of maize/cowpea in a *Leucaena* alley cropping system. In: Abstracts of Ph.D, M.Sc, M. Phil and Diplome Ingenieur Theses in Agroforestry, 1987-1998 (Eds., Temu, A.B., J. Kiio, M. Kimenye and E. Gimonde). ICRAF, Nairobi, Kenya, pp: 74.
33. Haggar, J.P., E.V.J. Tanner, J.W. Beer and D.C.L. Kass, 1993. Nitrogen dynamics of tropical agroforestry and annual cropping systems. Soil Biol. Biochem., 25: 1363- 1378.
34. Sanchez, P.A. and C.A. Palm, 1996. Nutrient cycling and agroforestry in Africa. Unasylva, 47: 24-28.
35. Fasuluku, S.A.T., 1998. Effect of relay intercropping of *Sesbania sesban* on soil fertility improvement and maize and firewood production at Morogoro, Tanzania. M.Sc. Thesis, SUA., pp: 1.03
36. Daniel, J.N., C.K. Ong and M.S. Kumar, 1991. Growth and resource utilization of perennial pigeonpea (*Cajanus cajan* (L) Mill. sp.) at the tree-crop interface. Agrofor. Syst., 16: 177-192.
37. Ong, C.K., M.R. Rao and M. Mathuva, 1992. Trees and crops: Competition for resources above and below ground. Agrofor. Today, 4: 4-5.
38. Okorio, J., S. Byenkya, N. Wajja and D. Peden, 1994. Comparative performance of seventeen upperstorey tree species associated with crops in the highlands of Uganda. Agrofor. Syst., 26: 185-204.
39. Hocking, D., G. Sarwar and S.A. Yousuf, 1997. Trees on farms in Bangladesh. 4. Crp yields underneath traditionally managed mature trees. Agrofor. Sys., 35: 1-13.