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Evaluation of the Relative Efficacy of Alley Species with Respect to Hedge-row Persistence, Herbage Yield and Fuel Wood Production in Central Part of U.P., India

Umesh Dubey [a], U.K. Mishra [b], B. K. Tripathi [b], Dharmendra Kumar [c] and Yogesh Kumar [d*]

[a] Department of Agronomy, Janta Mahavidyalaya, Ajitmal, Auraiya (U.P), India.
[b] Department of Genetics and Plant Breeding, Janta Mahavidyalaya, Ajitmal, Auraiya (U.P), India.
[c] Department of Horticulture, Janta Mahavidyalaya, Ajitmal, Auraiya (U.P), India.
[d] Department of Soil and Water Conservation, Janta Mahavidyalaya, Ajitmal, Auraiya (U.P), India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Field experiments were conducted at Malgawan Research Farm, Janta Mahavidyalaya Ajitmal Auraiya during two consecutive kharif seasons of 2022 and 2023 to evaluate the relative efficacy of Alley species with respect to hedge-row persistence, herbage yield and fuel wood production. Out

**Corresponding author: E-mail: yogesh.iitkanpur@gamil.com;*

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of the two alley species tested viz*. Leucaena leucocephalla and Sesbania sesban* under Agro-forestry system, *L*. *Leucocephalla* for herbage production is good and it gives more herbage yield(119.59q/ha) than *S.sesbane* yielded 105.01q/ha, that fulfils fodder requirement and becomes best alternate of fodder during shortage of fodder. *S.sesban* for fuel wood production are recommended and yielded 42.55q/ha. It is higher than, *L*. *Leucocephalla*. Both the alley species be pruned prior to crop sowing in both the consecutive seasons and pruned material be added to the soil, increases soil fertility as well as organic carbon content in soil. Under P_0 (No Pruning), the establishment and persistency were better than both the pruning management and P_0 significantly increased the tree height 4.35meter than P_1 & P_2 1.91 &1.96 meter height respectively. The number of branches was significantly higher in *S.sesban* with no pruning (33.69) over both the pruning management P_1 & P_2 system in both seasons. The Relative growth rate kg/ha/day, fresh yield of pruning q/ha, dry matter yield of pruning q/ha, fuel wood production q/ha, leaf fodder production q/ha and N, P & K uptake q/ha were found more with *L*. *Leucocephalla* under treatment P_2(pruning during crop growth and foliage used as forage) than P_1 (pruning during crop growth and foliage added to soil) with N_2 level of fertilizer than N_0 & N_1 fertilizers level respectively in both years mean basis.

Keywords: Alley species; herbage yield and fuel wood & relative efficiency.

1. INTRODUCTION

India is an agricultural based country where over 70% of the population lives in villages, comprising 105 million farm families. According to ICAR's vision 2023, 97 m.ha. are under soil degradation. Nitrogen fixing trees (NFTs) and shrubs in agro-forestry systems are capable of fixing about 50–100 kg N/ha/year. Similarly, the area under forest which are the main source of timber and fuel wood dwindling around 17% of the country's land area against the national requirement of around 33% under forest cover (Bahuguna 1985) and Debroy1986 are however, of the opinion that the productive and effective forest area in the country is much less than the reported figure.

Unfortunately forage and fuel wood is however still considered as low priority products. Moreover, due to the increasing pressure on arable lands for growing food fibre and cash crop to meet the rising needs of human populations, there is no scope for diverting cultivated land for forage or fuel wood production. Alternatively forage and fuel resources have to be developed on marginal and sub marginal lands spreads over 175 m.ha. in arid and semi arid areas. These areas are characterised with erratic monsoon behaviour & soil fertility and moisture are the most important factors limiting crop production. Under these conditions, it is envisages growing of arable crops/grasses along with suitable tree species simultaneously on the same piece of land provides better land utilization and ensures stable production.

Of the different systems of Agro-forestry "Alley Cropping" (also called hedge row intercropping or avenue cropping) appears to be an appropriate agro- forestry system. The hedgerows are cut back at the planting of annual crops and periodically pruned during cropping to prevent shading and to reduce competition with the associated crops. The hedgerows can grow freely to cover the land when there are no crops (king et al 1984). Trees/shrubs used to form hedge rows should be multipurpose and nitrogen-fixing which could enrich the soil besides providing the pruning for forage green manures. The other desirable characteristics are easily established, wider adaptability, fast growth rate, coppicing habit, quick regeneration after pruning tolerance to disease and pests and aberrant weather conditions. Subabul (*Leucaena leucocephalla*) and Shevari (*S. sesbane)* are important multipurpose trees with wide adaptability and potentiality for utilization as alley component in alley cropping system. The regular pruning of hedge row is crucial to reduce competition between trees and crops for sunlight, water and nutrient frequently. The biomass incorporated pruned biomass from *L. leucocephalla* and *S. sesbane* into the soil acting as green manure, this enhances soil organic matter and nutrient content particularly nitrogen because *L. leucocephalla* and *S. sesbane* are leguminous trees capable of fixing of atmospheric nitrogen, which reduces the need for synthetic nitrogen contributed by these trees.

It is in this context that the present investigation entitled" Evaluation of the relative efficacy of alley species with respect to hedge- row

persistency, herbage yield and fuel wood production in Central U.P".

2. METHOD AND MATERIALS

2.1 Description of Study Area

The experiment was conducted during rainy season of 2022 and 2023 where annual crop was grown in association with *L*. *Leucocephalla* and *S*.*sesban* at Janta Mahavidyalaya Malgawan Agricultural research farm Ajitmal, Auraiya. The sub humid climate of the area features hot summer, dry winds and humid monsoon season with an average annual rainfall ranges 600-700 mm is usually received from July to Sept. with few showers during winters. The soil at the test site was sandy loam in texture, Ph 7.8, Electrical conductivity of 1.72 m.mhos and soil organic carbon of 0.32% with 180kg available N, 18.94kg available P_2O_5 and 255.43 kg/ha available K respectively.

2.2 Experimental Design and Treatment Arrangement

In this trial the treatment comprising 2 Alley species, three levels of pruning and three levels of fertility were tested in a split-plot design, keeping Alley species and pruning management in the main plot and fertilizer management in the subplot respectively. Treatment was comprised under

T_1- A_1 +P_0 +N_0 (No pruning and no application of nitrogen in A_1 *S*. *sesban*)
T_2-A_1+P_1 +N_1 (P_1- pruning during crop growth and foliage added to soil also fertilized with 45 kg/ha N in alley species *S*. *sesban*)
T_3- A_1+P_2+N_2 (P_2- pruning during crop growth and foliage added to soil also fertilized with 90 kg/ha N in alley species *S*. *sesban*)
T_4- A_2+P_0+N_0 (No pruning and no application of nitrogen in A_2 alley *L*. *Leucocephalla*)
T_5- A_2+P_1+N_1 (P_1- pruning during crop growth and foliage added to soil also fertilized with 45 kg/ha N in alley species *L*. *Leucocephalla* spp)
T6-A_2+P_2+N_2 (P_2- pruning during crop growth and foliage added to soil also fertilized with 90 kg/ha N in alley species *L*. *Leucocephalla*)

The experiments were tested in a single split plot design with a 9m×5m plot size and replicated thrice. The alley species sesbania and Leucaena were fertilized @ 20kgN +50 kg P_2O_5/ha and no fertilizer was applied to the alley spp. in the subsequent years of the experiment, The alley species seedlings were raised in a poly bag by sowing of two seed in each bag, after 60-65 days seedlings were used for transplanting. During 2nd and 3rd years of the investigation leaves of lopping of the alley spp. were used as a source of green manure for sorghum. The leaf mass was uniformly mixed into the soil at the time of final tillage operations, 15 days before the sowing of experimental crop. Sesbania and leucaena were established through planted in paired rows on either side of the plots in pits of 40×40×40 cm size maintaining an inter and intra row distance of 75 cm and 50 cm respectively. The crop and alley spp. are irrigated time to time when ever needed, weed management practices were adapted as one mechanical weeding and applied Atrazine @ 0.75 kg ai/ha in 600 litters of water as preemergence.

The Hedgerows of Alley species were pruned during July coinciding with the sowing of sorghum. Leaves are separated from the twigs and component wise weight recorded, the leaves were used for soil application or as forage as per the treatment. Sowing of fodder sorghum was done behind the plough 25cm row apart using a seed rate of 40 kg/ha respectively among the both alley species. Sorghum was fertilized at the rate of 40 kg P_2O_5 and 30kg K_2O/ha. Nitrogen as per treatment was applied in the form of Urea.

The observations were recorded of Alley species are germination count, plant height, Collar diameter of the main shoot, number of branches, RGR, Fresh yield of pruning's, Dry matter yield of pruning, Fuel wood and leaf fodder production. Seed production from Alley species and Uptake studies respectively.

3. RESULT AND DISCUSSION

The result of experiments have been obtained were considered of practical importance and therefore have been discussed in detail along with the repercussions of weather parameters on growth and development, green forage yield and quality of produce, uptake and production of nutrients for the tree crops *L*. *Leucocephalla* & *S*. *sesban*. Next to the genetic constitution environment is the foster factor, which decides the growth and development and failure and success of any crop under field conditions. As is apparent from the result, the weather conditions, on the whole proved quite conducive at the time

of seedling in both seasons by having sufficient relative humidity, bright sunshine, mean average temperature and evaporation during both the experimental seasons. The data indicates that the effect of seasons on alley species, comparatively favored by entire cropping seasons in the first season over the second season. Hence it may be asserted that the variations in yield data are not due to season but are due to the treatment effects.

Alley species study depicted in Tables (1 & 2) reveals that the variation in establishment and persistency (95.46%), tree height (3.14meter), RGR (33.91 kg/ha/day), Fresh yield of pruning (119.59q/ha.), leaf fodder production (68.89q/ha), dry leaf fodder production(17.22q/ha), seed production(11.85q/ha) and crude protein yield were recorded with alley species *L*. *Leucocephalla* trees and it is more than the *S*. *sesban* in both the seasons and also on a mean basis. The collar diameter of *S*. *sesban* trees (26.93cm) was significantly more than the *L*. *Leucocephalla* in both seasons and also on a mean basis. Similar results reported by (N.K. et al 2010).

S. *sesban* had a greater number of branches (32.85) than *L*. *Leucocephalla* in both years. In fact, the *L*. *Leucocephalla*, which is basically in the tree group attains more height and persistency while on the other hand, *S*. *sesban* a shrub attains less height, more number of branches and more collar diameter. The persistency is very high in *L*. *Leucocephalla* and *S*. *sesban* both (Table 1). Table 3 data reveals that the N, P & k content % and P, K uptake q/ha of s *S*. *sesban* trees were more than the *L*. *Leucocephalla* in both the years and on a mean basis. The protein content therefore was also more in *S*. *sesban*. The N uptake q/ha of *S*. *sesban* trees was more than the *L*. *Leucocephalla* on pooled basis. Here it may be argued that though the foliage production was more in Leucaena but the N content was so high in *S*. *sesban* that *L*. *Leucocephalla* could not supersede *S*. *sesban* in N uptake q/ha.

The light interception percent of sesbania trees was more than the percent light interception of *L*. *Leucocephalla* in both the years and also on a mean basis. It was all because of better canopy of *L*. *Leucocephalla* which does not allow the light to intercept on the ground. The reverse was true with *S*. *sesban* in light interception because of its poor canopy. Similar finding recorded by Bhatia et al. (2000)

3.1 Effect of Pruning Management

Under reference further reveals that the Sorghum crop with both the pruning management had significant variations with most of the characters mentioned earlier, while establishment and persistency due to pruning management were not well marked in both years. Under P_0 (No Pruning), the establishment and persistency were better than both the pruning management and P_0 significantly increased the tree height (4.35 m) & The number of branches (33.69) over both the pruning management system in both season. The variation in collar diameter due to pruning management was not well marked in both the years, however both the pruning mgt. Showed more diameter than treatment P_0 in both the years and pooled basis. Here, it may be inferred that under no pruning conditions, the trees will attain more height than the pruned trees. Further, the trees that have been without topped will gain more diameter than the trees where topping/pruning has not been done. As per fact, the seed production would also be higher under no pruning conditions.

Table 2 data reveals that the Relative growth rate (32.04 kg/ha/day), fresh yield of pruning (112.98 q/ha), dry matter yield of pruning (49.91 q/ha), fuel wood production (37.12 q/ha), leaf fodder production (51.08 q/ha) and N,P & K uptake (3.05,0.74 &1.70 q/ha) were found more with treatment P_2(pruning during crop and foliage used as forage) than P_1 (pruning during crop growth and foliage added to soil) in both the years and also on a mean basis. The seed (production 8.66q/ha) assessed under no pruning conditions was found more in second year than first year. The N, P & K contents were found more with P_0 (no pruning) than both the pruning mgt. in both the years and also on a mean basis. The variations in crude protein content due to *S*. *sesban* and *L*. *Leucocephalla* alley species were not well marked in both the season and also on a mean basis. The Alley species crude protein yield q/ha which was assessed under P_2 (Pruning during crop growth and foliage used as forage) was found more in second season than first year. The Pruning management enhanced soil fertility and organic carbon content, with specific regimes favouring growth and nutrient uptake. These findings offer sustainable solutions for fodder shortages and soil health also intensification of planting and contributes Biodiversity conservation and environmental benefits. Results are supported by Bathia et al. (2000) & Devi. S. et al. (2020).

Table 1. Establishment and Persistency, Tree height in meter and Collar Diameter in cm

Treatments	Establishment & Persistency %		Tree Height in meter		Collar Diameter in cm	
Alley species	**2021-22**	**2022-23**	**2021-22**	**2022-23**	**2021-22**	**2022-23**
Sesbania (A_1)	98.24	93.24	2.62	3.03	19.60	26.93
Leucaena (A_2)	98.80	95.46	2.85	3.14	12.69	21.62
Sem±	0.469	0.843	0.060	0.110	0.629	0.551
C.D. at 5%	NS	NS	0.190	NS	1.985	1.739
Pruning Management						
No Pruning(P_0)	98.61	94.86	4.35	5.61	14.83	24.21
Pruning (P_1)	98.33	93.31	1.91	1.82	16.33	25.59
Pruning (P_2)	98.61	93.89	1.96	1.83	17.28	23.03
Sem±	0.574	1.033	0.73	0.135	0.771	0.675
C.D.at 5%	NS	NS	0.233	0.428	NS	NS
N level Kg/ha						
0 (N_0)	97.64	92.92	2.76	2.94	16.48	23.76
45 kg (N_1)	98.75	95.00	2.72	3.15	15.98	24.06
90 kg (N_2)	99.17	95.14	2.73	3.16	15.99	25.01
Sem±	0.663	0.919	0.053	0.083	0.447	0.388
C.D.at 5%	NS	NS	NS	NS	NS	NS

Table 2. Relative growth rate, Fresh yield of pruning & Dry matter yield q/ha of pruning's, Fuel wood production, Leaf fodder production, Dry leaf fodder production and seed production of Alley species q/ha as influenced by treatments

Treatments	No. of branches/Tree	Crop growth rate (RGR)Kg/ha/Day	Fresh yield q/ha	Drymatter yield of prunning	Fuel wood production q/ ha	Leaf fodder production q/ha	Dry leaf fodder pro.q/ha	Seed production from alley spp.
Alley Species								
A_1	32.85	29.72	105.01	50.98	42.55	33.64	8.45	5.48
A_2	22.85	33.91	119.59	47.41	30.39	68.89	17.22	11.85
Sem±	0.67	-	-	-	-	-	-	-
C.D.at 5%	2.12	-	-	-	-	-	-	-
Pruning Management								
P_0	33.69	-	-	-	-	-	-	8.66
P_1	25.28	31.68	111.62	48.70	35.82	51.45	12.88	-
P_2	24.57	32.04	112.98	49.91	37.12	51.08	12.79	-
Sem±	0.82	-	-	-	-	-	-	-
C.D.at 5%	2.60	-	-	-	-	-	-	-
N level Kg/ha								
0 (N_1)	28.68	31.27	110.16	44.90	32.38	50.07	12.53	8.54
45 (N_2)	27.46	32.16	112.63	49.24	36.32	51.71	12.93	7.99
90 (N_3)	27.40	32.68	114.10	50.25	37.21	52.02	13.05	9.47
Sem±	0.66	-	-	-	-	-	-	-
C.D.at 5%	NS	-	-	-	-	-	-	-

Table 3. N, P& K Content, N, P & K Uptake and Green fodder yield q/ha of Sesbania and Leucaena as influenced by Various treatments

Treatments	Obtain Content from all pruned material of Alley Species			N, P & K uptake in q/ha			Green Forage yield in q/ha		LER	ATER q/ha/ day
Alley Species	**N Content**	**P Content**	**K Content**	**N**	**P**	**K**	**Intercrop**	**Sole crop**		
Sesbania (A_1)	2.88	1.18	2.08	3.02	1.23	2.19	33.64	71.79	1.23	0.61
Leucaena (A_2)	2.57	0.15	0.97	3.03	0.18	1.15	68.89	148.98	1.24	0.61
Pruning Management										
P_0	2.74	0.68	1.53	-	-	-	-	-	-	-
P_1	2.70	0.67	1.51	3.01	0.74	1.68	51.45	109.35	1.24	0.61
P_2	2.70	0.66	1.51	3.05	0.74	1.70	51.08	109.55	1.23	0.61
N level Kg/ha										
0 (N_1)	2.68	0.65	1.53	2.95	0.72	1.66	50.05	107.59	1.24	0.61
45 (N_2)	2.71	0.66	1.53	3.05	0.74	1.72	51.71	110.62	1.23	0.61
90 (N_3)	2.74	0.69	1.54	3.12	0.78	1.75	52.02	112.01	1.23	0.61

Table 4. Available N Kg/ha (0 – 22.5 cm) of Experimental field as influenced by different treatments

Treatments	After experiment during 2021 - 22	After Experiment during 2022-23	In Kg /ha during 2021 -22	In Kg/ha during 2022-23
Alley species				
Sesbania (A_1)	0.097	0.105	194	210
Leucaena (A_2)	0.093	0.106	186	212
Pruning Management				
P_0	0.087	0.096	174	192
P_1	0.095	0.102	190	204
P_2	0.092	0.096	184	192
N Level Kg/ha				
0 (N_1)	0.091	0.095	182	190
45 (N_2)	0.096	0.100	192	200
90 (N_3)	0.098	0.104	196	208

P_0 – No Pruning

P_1 – Pruning during Crop growth and foliage added to soil

P_3 – Pruning during crop growth and foliage used as for a

3.2 Effect of N

A look at data presented in Tables 1, 2 & 3 reveals that the variations in germination count, establishment and persistency, tree height (3.16 m), collar dia (25.01 cm), number of branches, relative growth rate (32.68 kg/ha/day),fresh yield of pruning's (114.10 q/ha), dry matter yield of pruning's (50.25 q/ha), fuel wood production (37.20 q/ha), green leaf fodder production (52.02 q/ha), dry leaf fodder production (13.05 q/ha) and seed production (9.47 q/ha) from alley species N,P and K content and its uptake qha^1, light interception, LER and ATER affected due to deferent N levels and under N_3 (90 kg/ha) treatment were recorded higher yield of all parameters in both the seasons. It is an established fact that N in general promotes the vegetative growth of the entire flora may be the herb, shrub and trees. This vegetative growth creates a proper sheet for photosynthetic activity of the plants which in turn, augments the entire process related to development, yield and quality. This is the reason that both the alley species viz. *L. Leucocephalla* and *S. sesban* were favoured by the N in their growth, yield and quality aspects. Similar findings recorded by Silva et al. (2015).

4. CONCLUSION

In the present situation of the country especially in central part of U.P. whereas population density increases day by day and cultivated area converted into rehabilitation area. As a result, forest area also decreases day by day. Under such condition to maintain food grain production without minimize the forest area, Agro-forestry is proved to be the best option for our present needs. The present study compares the performance of the two alley species i.e., *L. leucocephalla* and *S. sesban* in an Agro-forestry system in two consecutive kharif season, focusing on herbage production, *L. leucocephalla* yielded 119.59q/ha while *S. sesban excelled 105.01 q/ha*. Therefore, present study revealed that *L. leucocephalla* fulfils fodder requirement and becomes the best alternative of fodder during shortage of fodder and *S. sesban* fulfils the fuel wood requirement. Both the alley species be pruned prior to crop sowing and pruned material be added to the soil to enhance soil fertility and organic carbon content of soil that favour growth and nutrient uptake.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

AICRPDA. (1987). All India Coordinated Research Project for Dryland Agriculture, Main Center Rajkot, *Annual Report*, PP.SA-8.

AOAC. (1970). *Official Methods of Analysis*. Association of Official Analytical Chemists, Washington, D.C.

Atta-Krah, A. N. (1989). Availability and use of fodder shrubs and trees in tropical Africa. *Proc. Workshop on Shrubs and Tree Fodder for Animals*, IDRC-276e:140-162.

Bahuguna, S. (1985). My life my tree: Message on World Forest Day. *Patriot*, March 22.

Balasubramaniam, V., & Sekayannge, L. (1991). Effect of free legumes in hedgerows on soil fertility changes and crop performance in semi-arid highlands of Rawanda. *Biological Agriculture & Horticulture*, 8:17-32.

Beedy, T., Snapp, S., Akinnifesi, F., & Sileshi, G. (2010). Impact of *Gliricidia sepium* intercropping on soil organic matter fractions in a maize-based cropping system. *Agric. Ecosyst. Environ.*, 138:139-146.

Bhatia, K. S., & Kanaujia. (2000). Growth responses of pearl millet and barley to *Leucaena leucocephala*-based agroforestry system. *Indian Journal of Agroforestry*, 2:33-36.

Bhatt, R. K., Khan, T. A., Pathak, P. S., & Mishra, A. K. (2006). Sustainable forage production under silvipastoral systems in semi-arid conditions. *Indian Journal of Agroforestry*, 2:461-468.

Burman, D., & Gill, A. S. (2001). Alley cropping system for soil resource management. *Indian Grassland and Fodder Research Institute, Jhansi*. *Indian Journal of Agroforestry*, 3(2):108-119.

Burman, D., Adhikari, P. P., Hombegowda, H. C., Jakhan, P., & Madhu, M. (2017). Soil erosion control and carbon sequestration in shifting cultivated degraded highlands of eastern India. *Agroforestry System*, 91(4):757-771.

Burman, D., Adhikari, P.P., Hombegowda, H.C., Jakhan, P., & Madhu, M. (2018). Soil and onsite nutrient conservation potential of aromatic grasses at field scale under a shifting cultivated degraded catchment in Eastern Ghat, India. *International Journal of Sediment Research*, 33, 191–201.

Chaturvedi, O. P., & Jha, A. N. (1994). Production potential of *Leucaena leucocephala* and intercrops grown under different alley management systems in mid Indo-Gangetic plains. *Range Management & Agroforestry*, 15:93-103.

De Oliveira, V. R., Silva, P. S. L., Pontes, F. S. T., & Antonio. (2016). Growth of arboreal leguminous plants and maize yield in agroforestry systems. *Revista Árvore*, 40:679-688.

Devi, S., Bharadwaj, K.K., Dahiya, G., & Sharma, M.K. (2020). Assessment of yield and nutrient uptake of wheat in agri-silvi horticulture system under semi-arid region of Haryana. *Indian Journal of Ecology*, 47(3), 866–868.

Dubois, M., Gilles, K. A., Hamilton, J. K., Rebers, P. A., & Smith, F. (1986). Colorimetric method for determination of sugarcane-related substances. *Analytical Chemistry*, 28:350-356.

Faria Marmol, J. (1994). Evaluation of accessions of *Leucaena* in the very dry tropical forest of Zulia State, pp. 192-201.

Gill, A. S. (2002). *Leucaena* leaves as a source of manure. *L.R.R.*, 5:26.

Jakhar, P., Barman, D., & Madiganda, M. (2013). Alley cropping system for natural resource conservation in shifting cultivation degraded lands of Eastern Ghats. In *Natural Resource Conservation; Emerging Issues & Future Challenges* (pp. 851-855).

Jat, N. K., Pandey, A., & Dhar, S. (2010). Influence of *Sesbania* green manure with or without wheat residues and N fertilization on maize-wheat cropping system. *Indian Journal of Agronomy*, 55(4):253-258.

Krishna, B. E., & Allolli, T. B. (2005). Influence of cropping system and source of nutrients in *Leucaena*-based alley cropping system on yield and quality of tomato. *Karnataka Journal Agric. Sci.*, 18(2):464-468.

Martins, J. C. R., Freitas, A. D. S. D., & Menezes, R. S. C. (2015). Nitrogen symbiotically fixed by cowpea and *Gliricidia* in traditional and agroforestry systems under semi-arid conditions. *Pesquisa Agropecuaria Brasileira*, 50:178-184.

Moura-Silva, A.G., Aguiar, A.D.C.F., Jorge, N., Agostini-Costa, T.D.S., & Moura, E.G. (2017). Food quantity and quality of cassava acted by leguminous residues and inorganic nitrogen application in a soil of low natural fertility of the humid tropics. *Bragantia*, 76, 406–415.

Primo, D. C., Menezes, R. S. C., Sampaio, E. V. D. S. B., Garrido, M. D. S., & Souza, C. S. (2014). Recovery of N applied as 15N-manure or 15N *Gliricidia* biomass by maize, cotton, and cowpea. *Nutrition Cycle Agroecosystem*, 100:205-214.

Shukla, N. P., Rekib, A., & Burman, D. (2002). Productivity of *Sesbania* alley cropping system with sequentially cropped berseem and maize at different moisture regimes and fertilizers. *Tropical Agricultural Research and Extension*, 5(1-2).

Silva, A. R. D., Collier, L. S., Flores, R. A., Santos, V. M. D., & Barbosa, J. M. (2015). Productive yield of cowpea and maize in single crop and mixtures in an agroforestry system. *Am. Eur. J. Agric. Environ. Sci.*, 15:85-92.

Tangendjaja, B., Lowry, J. B., & Wills, R. H. B. (1986). Changes in mimosine, phenol, protein, and fibre content of *Leucaena leucocephala* leaf during growth and development. *Aust. J. Exp. Agric.*, 26:315-317.

Tudri, S., Ishi, Y., Numaguchi, H., & Pransanpainch, S. (2002). The effect of cutting interval on the growth of *Leucaena* and three associated grasses in Thailand. *Trop. Grassl.*, 36: 90-96.

Zaharah, A. R., Chintu, R., Ziana, Z. Z., Bah, A. R., & Rashidah Wak. (2008). Management of agroforestry systems for enhancing resource use efficiency and crop productivity. *Iana Vienna*, ISSN 1011-4289.

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