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GROWTH PERFORMANCE OF FODDER CROPS UNDER *EUCALYPTUS* BASED SILVIPASTURE SYSTEM IN SEMI-ARID REGION OF INDIA

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SUMMARY

There is a large gap between the demand and supply of green fodder during lean period. A study was conducted at Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana to assess the productivity of fodder crops (berseem and oat) under a eucalyptus-based silvipasture system. The present study was carried out a 2.8-year-old plantation of *Eucalyptus tereticornis* planted at a spacing of 7m×3m and during the winter season (*Rabi*) different, fodder crops, *viz*. oat (*Avena sativa*) cv. OS-6 and berseem (*Trifolium alexandrinum*) cv. Mescavi, were sown under eucalyptus plantation and control with four replications. The results revealed that the maximum numbers of plants per m^2 (420.3) at 20 DAS, plant height (42.7 cm) at 120 DAS, fresh matter (1428.5 g), dry matter (191.4 g) at 150 DAS and green fodder yield (45.2 t/ha) of berseem was recorded in control (sole crop) than under eucalyptus plantation. Similarly, in oat maximum numbers of plants per meter row length (72.3) at 20 DAS, maximum plant height (135.2 cm), maximum fresh matter (3250.8 g), dry matter (412.3 g) at harvest and maximum green fodder yield (31.1 t/ha) was recoded in control (sole crop) than in eucalyptus based cropping system. The maximum gross return (Rs. 240056.2/ha) and net return (Rs. 102799.8/ha) were obtained from eucalyptus + berseem silvipasture system while the maximum benefit-to-cost ratio (BC ratio) was obtained under eucalyptus + oat system (1.75) closely followed by eucalyptus + berseem system (1.74).

Keywords : Eucalyptus, oat, berseem, B:C ratio, silvipasture

India is home to approximately 17.4% of the world's human population and 10.7% of cattle (more than 510 million head), putting enormous strain on land, water, and other resources. India, with the most cattle and the second-largest human population, requires a well-thought-out strategy to meet the country's ever-increasing demand for food, feed, and fodder in sufficient quality and quantity.

Livestock productivity in India is generally 20 to 60 % lower than the global average. The primary issues are found a lack of feed and fodder, which is followed by health, breeding and reproduction, and management. Small ruminants are generally reared in nomadic (30%) and sedentary (70%) systems, with around 80% of livestock being with marginal, small, and medium-sized farmers in rainfed situations. To keep an animal healthy and productive, it needs a well-balanced diet, which can be provided by a variety of protein-rich leguminous plants grown on the farm (Raju, 2013). Silvi-pasture is being used on a large scale because it combines concerns about production, resource conservation, and profitability. The process of integrating trees, forage, and the grazing of domesticated animals in a mutually beneficial fashion is known as "silvipastoral farming." It is one of several types of agroforestry that employs the concept of managed grazing. Due to the simultaneous production of tree crops, forage, and livestock on a well-managed silvi-pastoral farm, it can boost overall productivity and long-term revenue while also providing environmental benefits such as carbon sequestration. Herbaceous plants (mainly grasses and legumes), the forage component (fodder trees), and the domesticated animals that survive on the vegetation are all part of the biodynamic system. These systems offer an ecologically viable and sound approach. Tree pruning and lopping are also utilized as top feeds. By establishing adequate silvi-pasture models, it was possible to raise land productivity from 0.5–1.5 t/ha/year to > 15 t/ha/yr (Ramteke *et al.,* 2021). The increased forage supply provided by such systems is projected to lessen grazing pressure, resulting in significant environmental benefits.

Growing fodder crops under eucalyptus an industrial plant will not only meet animal feed demand, but will also increase its availability during lean periods. Therefore, there is a great need to identify suitable fodder crops that can grow well along with tree plantations with limited solar energy available underneath the trees (Ranjan *et al*., 2016). During the lean period, there is a large gap between the demand and supply of green fodder. Identification of the best crop under eucalyptus-based silvi-pasture system to maximise the fodder yield is important so that it can contribute to fulfilling the fodder demand. Cowpea (*Vigna unguiculata),* commonly known as Lobia in Hindi, is an important quick-growing, leguminous and rainy season fodder crop, which is an integral part of traditional cropping systems in the semi-arid regions of the tropics. It has the ability to tolerate drought and fix atmospheric nitrogen, which allows it to grow and improve poor soils (Nguyen *et al*., 2019). Oat is also an important winter season crop widely grown for green fodder because of its luxuriant growth, good palatability, and highly nutritious nature (Godara *et al*., 2012). Therefore, present study was planned to assess the productive yield of cowpea and oat in the eucalyptus-based silvipasture system.

MATERIALS AND METHODS

The present study was conducted at the Research farm of Forestry Department, CCSHAU, Hisar, Haryana in the semi-arid region of north-western India, which is located at 29° 09' N latitude and 75° 43' E longitude at an elevation of 215.2 m above mean sea level. The climate is subtropical-monsoonal, with an annual rainfall of 350–400 mm, 70% of which occurs between July and September. The soil is non-saline, with low levels of organic carbon and available nitrogen, medium levels of available P, and high levels of accessible potassium. Soil pH (7.9), EC (0.78 dS/m), organic carbon (0.42%), available nutrients N (140 kg/ha), P (12 kg/ha), and K (284 kg/ha) were all assessed prior to the experiment.

The present study was conducted in a 2.8-year-old plantation of *Eucalyptus tereticornis* planted at a spacing of 7x3 m and the experiment was laid out in a randomised block design with four replications. During the winter (*Rabi*) season, fodder crops i.e. oat (*Avena sativa*) cv. OS-6 and berseem (*Trifolium alexandrinum*) cv. Mescavi were sown under 7x3 m planted eucalyptus-and also sown in open (without trees) formed as control. Berseem was sown during the first fortnight of October, 2017 through the broadcast method with a seed rate of 19.76 kg/ha and the recommended dose of fertilisers (24.7 kg N and 69.16 kg P_2O_5) of the university were applied in this experiment. The whole amount of N and P was applied at the time of sowing and eight irrigation were applied during the crop growing period of Berseem. Oats was sown in the first week of November, 2017 at a row-to-row distance of 25 cm with a seed rate of 86.45 kg/ha and the recommended dose of fertiliser (79.40 kg N). Half of the nitrogen was applied at the time of sowing, and the remaining was applied as urea top-dressing at the first irrigation. During the oats' growing season, three irrigation were applied. Data on yield and its attributes of fodder crops was recorded from both the eucalyptus-based silvipasture system and control.

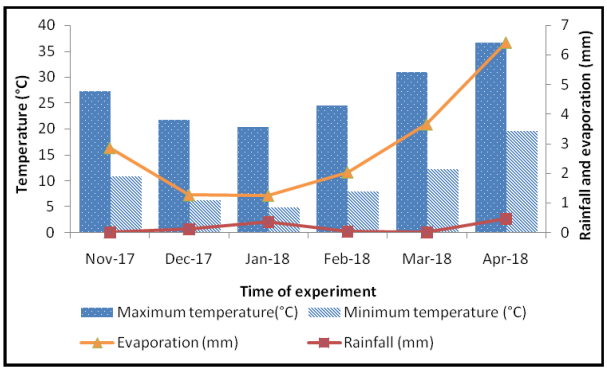

Fig. 1. Monthly weather data of experimental site from November, 2017 to April, 2018.

On the basis of market rates of inputs and outputs, rental value of land, total cost of cultivation, and gross revenue from both systems (eucalyptus-based silvipasture and control) were determined. The net return and the B:C ratio was computed using the total cost of cultivation as well as the total income from both systems. The data was statistically analyzed using the Paired t-test in Statistical Analysis Software.

RESULTS AND DISCUSSION

Effect of eucalyptus on the performance of berseem crop

Number of plants/m²

It is apparent from Table 1 that the numbers of plants/ m² at 20 DAS were significantly higher (420.3/m²) in control (devoid of tree) than eucalyptus based silvipasture system (355.2). The reduction in number of plants/ m² at 20 DAS in berseem was 15.49 per cent under eucalyptus over control. The reductions in crop growth have been acknowledged by several

research workers when eucalyptus and arable crops are grown together. The water uptake of eucalyptus is very high due to the way this tree enables them to compete with crops associated with their vicinity (Akhter *et al.,* 2005). The rooting pattern of eucalyptus consists of deep and lateral roots so as to utilize more resources such as soil moisture and nutrients (Akinnifesi *et al.,* 2004; Kidanu *et al.,* 2005). On the other hand, the water uptake of berseem is also high; therefore, the competition between tree and crop for soil moisture and nutrients were high, which ultimately reduced the numbers of plants in berseem under eucalypt plantation as compared to control. The availability of low solar radiation was also an important factor in hindering the germination of crops. The present findings are in close proximity to the results of Nandal and Hooda (2005).

TABLE 1
Number of plants/m^2 in berseem at 20 DAS under eucalyptus plantation and control

Treatment	Plants (m^{-2})
With eucalyptus#	355.2
Control (Devoid of trees)	420.3
t-value	6.21*

*Significant at 0.05 per cent level of P, # eucalyptus planted at a spacing of 7x3 m

Plant height (cm)

Plant height increased with successive stages of crop growth (Fig. 2). The results clearly indicate that Berseem showed significantly less plant height under eucalypt plantation in comparison to control (without trees) from 30 to 150 DAS. The maximum plant height (42.7 cm) of berseem was found at 120 DAS under control (sole berseem) and a minimum of 15.3 cm was observed under eucalypt plantation at 30 DAS. While the maximum reduction in plant height was recorded at 16.39, 19.51, 20.89, 17.33, and 18.53%, respectively, at different stages of growth (30, 60, 90, 120 and 150 DAS) under eucalyptus over control. These results are in close proximity with the findings of Ratan and Singh (2015), who reported that berseem at each cut in control, attained significantly more plant height than under eucalyptus plantation. Under control, the plant height of berseem was 40.1 (Ist cut), 39.1 (2nd cut) and 41.0 (3rd cut) cm, however, under eucalyptus, it was found to be minimum (23.4, 33.2 and 25.8 cm). The lower plant height of berseem under the eucalyptus-based

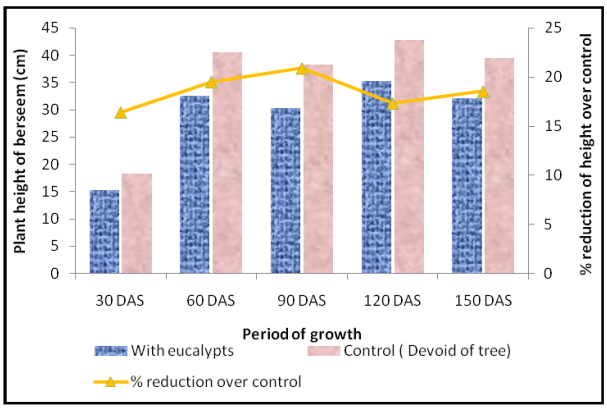

Fig. 2. Plant height (cm) at 30 days interval in berseem under eucalyptus plantation and control.

silvipasture system than under control might be due to the low availability of sunlight and more competition between tree and crop for moisture and nutrients.

Berseem intercropped with eucalyptus accumulated lowest fresh and dry matter at various stages of growth however; it attained maximum dry matter under control (Fig. 3 & 4).

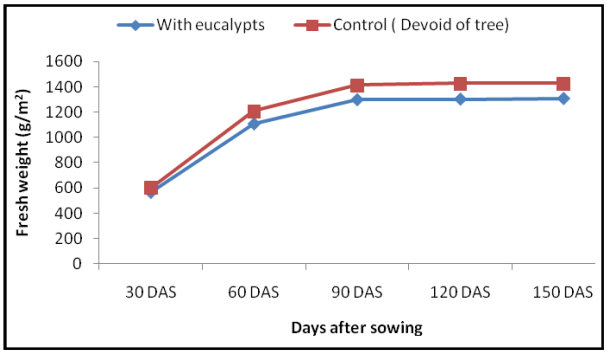

Fig. 3. Fresh matter accumulation (g/m2) at 30 days interval in berseem under eucalyptus plantation and control.

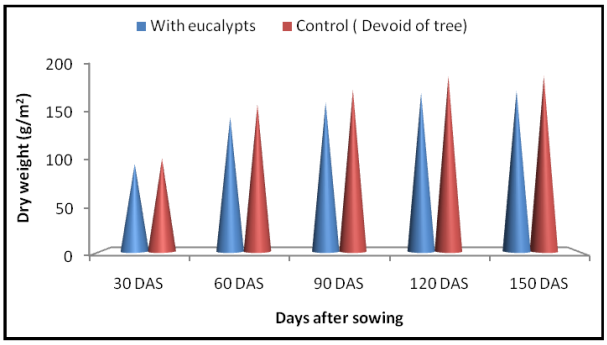

Fig. 4. Dry matter accumulation (g/m2) at 30 days interval in berseem under eucalyptus plantation and control.

Berseem grown in interspaces of eucalyptus based silvipasture system showed a maximum reduction in fresh and dry weight 5.63, 8.17, 7.87, 8.41, 8.25% and 5.82, 8.55, 7.88, 9.62 and 8.41% at 30,60,90,120 and 150 DAS, respectively over control.

Similar findings have also been reported by Prasad *et al*. (2010) in eucalyptus based agroforestry system.

Green fodder yield (t/ha)

The green fodder yield of berseem was higher (45.2 t/ha) in control (sole crop) than in the eucalyptus (41.5 t/ha). The per cent reduction in green fodder yield of berseem under eucalyptus was 8.19% over control (Table 2). The reduction in green fodder yield of berseem under eucalyptus may be due to low availability of light and more competition for moisture and nutrients. These results are in broad agreement with the findings of Ratan and Singh (2015). They discovered that when berseem was intercropped with eucalyptus, the stem was thinner than when it was not. As a result, the reduction in green fodder yield was significantly higher under the eucalyptus than control.

TABLE 2
Green fodder yield of berseem under eucalyptus plantation and control

Treatment	Green fodder yield (t/ha)
With eucalyptus#	41.5
Control (Devoid of trees)	45.2
t-value	4.95*

*Significant at 0.05 per cent level of P, # eucalyptus planted at a spacing of 7×3 m

Effect of eucalyptus on the performance of oat crop: Number of plants per meter row length at 20 DAS:

Oat grown in interspaces of eucalyptus plantations exhibited a lower number of plants per meter row length (62.1) than control (72.3) at 20 DAS (Table 3). The per cent reduction in the number of plants per meter row length at 20 DAS in oats was 14.11 under the eucalyptus over control (devoid of trees). The germination depends on the availability of soil moisture and solar radiation. However, under eucalyptus the quantum of available soil moisture content was found to be minimum, which inhibited the germination of oats. These results are in close proximity to the findings of Nandal and Hooda (2005).

Plant height (cm)

The results showed that plant height increased with successive stages of crop growth; however, the maximum rate of increase in height was recorded between 30 and 60 DAS in oat under both the systems (Fig. 5). The results show that from 30 DAS to harvest, less plant height was recorded in oats under the eucalyptus plantation compared to the control (devoid of tree).

TABLE 3
Number of plants per meter row length in oat at 20 DAS under eucalyptus plantation and control

Treatment	Plants/mrl
With eucalyptus#	62.1
Control (Devoid of trees)	72.3
t-value	4.78*

*Significant at 0.05 per cent level of P, # eucalyptus planted at a spacing of 7×3 m.

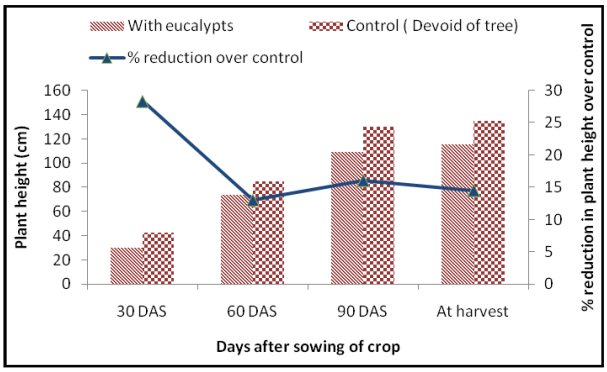

Fig. 5. Plant height (cm) at 30 days interval in oat under eucalyptus plantation and control.

Maximum plant height at harvest of oat was found 135.2 cm under control (sole oat). While the maximum reduction in plant height was 28.37, 13.01, 16.05, and 14.50% at 30, 60, 90, and harvest, respectively, under the eucalyptus plantation over control. The low interception of radiation under eucalyptus plantation may adversely affected the photosynthetic efficiency of oats, resulted in poor growth. These results are in support with the findings of Ranjan *et al.* (2016).

Fresh and dry matter accumulation (g/m^2) at different time intervals in oat

The maximum increase in fresh and dry matter accumulation was observed between 30 to 60 DAS of crop (Fig. 6 &7). Thereafter, it increased with slow rate till harvest. Oat intercropped with eucalyptus showed lowest fresh and dry matter accumulation at various stages of growth. The maximum fresh and dry matter was found under control during the year

of experimentation. Oat grown in interspaces of eucalyptus plantation showed a maximum reduction in fresh and dry weight of 3.34, 9.01, 8.55 and 11.68% and 5.49, 7.23, 1.65 and 10.89% at 30, 60, 90 DAS and at harvest, respectively over control (devoid of tree).

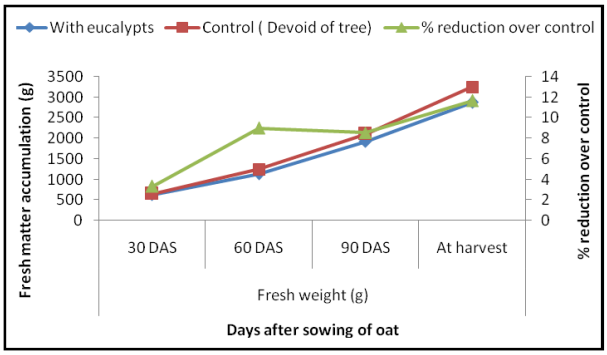

Fig. 6. Fresh matter accumulations (g/m^2) at 30 days interval in oat under eucalyptus plantation and control.

The lower fresh and dry matter accumulation of oat under eucalyptus-based silvipasture system might be due to availability of low sunlight and more competition for moisture and nutrients between annual and perennial components than in control.

Bhati *et al.* 2004 revealed the similar result of reduction in the yield of fodder crops under the canopy of different agroforestry trees of arid regions of Rajasthan. Ranjan *et al.* (2016), Ratan *et al.* (2015), Prasad *et al.* (2010), Chesney *et al.* (2010) also reported the corroborative results showing the reduction in grain yield of cowpea due to higher shade under *Eucalyptus tereticornis* based agroforestry system over open condition. Similar results were found by Alebachew *et al.* (2015). They reported that poor performance of maize sown adjacent to eucalypts plantation was due to competition for growth resources between eucalypts and adjacent crops.

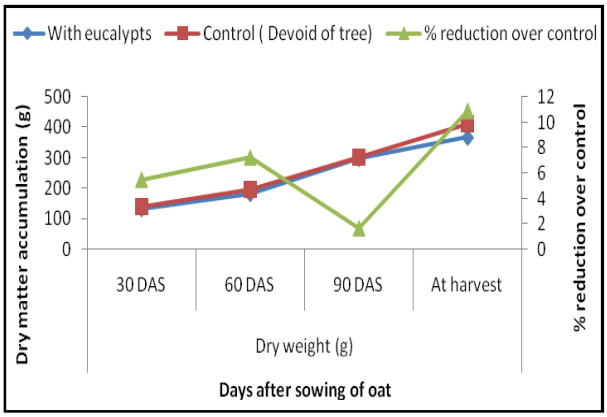

Fig. 7. Dry matter accumulation (g/m2) at 30 days interval in oat under eucalyptus plantation and control.

Green fodder yield (t/ha)

The green fodder yield of oat was higher (31.1 t/ha) in control (sole oat) than in the eucalyptus-based silvipasture system (28.1 t/ha). The per cent decrease in green fodder yield of oats under eucalyptus plantation was 9.32% over control (Table 4). Under a eucalyptus plantation, the light interception was minimal, which led to low photosynthetic activity. Therefore, the reduction in green fodder yield under the eucalyptus was higher.

TABLE 4
Green fodder yield of oat under eucalyptus plantation and control

Treatment	Green fodder yield (t/ha)
With eucalyptus#	28.2
Control (Devoid of trees)	31.1
t-value	3.88*

*Significant at 0.05 per cent level of P, # eucalyptus planted at a spacing of 7×3 m

Economic analysis of the eucalyptus based silvipasture system

Total cost of cultivation (Rs./ha) was found higher (Table 5) in berseem under the eucalyptus-based system, *i.e.,* eucalyptus + berseem (Rs. 137256.4). Similarly, the maximum gross return was obtained from eucalyptus + berseem, *i.e.,* Rs. 240056.2, followed by eucalyptus + oat (Rs. 216680.1). The maximum net return of Rs. 102799.8 was observed under the eucalyptus + berseem cropping system, followed by the eucalyptus + oat system (Rs. 93231.6). The maximum benefit-to-cost ratio (B:C ratio) was obtained under the eucalyptus + oat system, *i.e.*, 1.75, followed by the eucalyptus + berseem system (1.74), sole berseem (1.30) and sole oat (1.14). The highest net return observed under the eucalyptus + berseem system may be due to the multiple sales of green fodder and an additional return from sales of tree components.

The results are in corroboration with that of Banerjee *et al.* (2011), who reported that the net return under an agroforestry system was higher as compared to sole cropping. Dhillon *et al.* (2018) also reported that a higher gross return under a eucalyptus-based agroforestry system than sole cropping of barley.

CONCLUSION

The results revealed that the maximum net returns of Rs. 102799.8 were fetched under eucalyptus + berseem cropping system followed by eucalyptus +

TABLE 5
Economics of eucalyptus based silvipasture system and control (sole crop)

Name of crops	Cost of cultivation (Rs./ha)		Gross return (Rs./ha)		Net return (Rs./ha)		Cost/benefit Ratio	
	Agroforestry	Sole crop	Agroforestry	Sole crop	Agroforestry	Sole crop	Agroforestry	Sole crop
Berseem	137256.4	57079.6	240056.2	74539.6	102799.8	17460.0	1.74	1.30
Oat	123448.5	43271.7	216680.1	49755.6	93231.6	6483.9	1.75	1.14

oat system (Rs. 93231.6). While the eucalyptus + oat system exhibited highest B:C ratio (1.75), which is followed by the eucalyptus + berseem system (1.74), sole berseem (1.30) and sole oat (1.14), showing that eucalyptus based silvipasture system is more cost-effective than solitary cropping. It can be concluded that eucalyptus + oat system is more beneficial as compared to eucalyptus + berseem system and sole cropping.

REFERENCES

Akhter, J., K. Mahmood, M.A. Tasneem, K.A. Malik, M.H. Naqvi, F. Hussain, and R. Serraj, 2005 : Water-use efficiency and carbon isotope discrimination of *Acacia ampliceps* and *Eucalyptus camaldulensis* at different soil moisture regimes under semi-arid conditions. *Biologiaplantarum*, **49**(2): 269-272.

Akinnifesi, F.K., E.C. Rowe, S.J. Livesley, F. Kwesiga, B. Vanlauwe and J.C. Alegre, 2004 : Tree root architecture. Below-ground interactions in tropical agroecosystems: concepts and models with multiple plant components. (Eds M van Noordwijk, G Cadisch, C Ong) pp: 61-81.

Banerjee, H. and P. K. Dhara, 2011 : Evaluation of different agri-horti-silvicultural models for rainfed uplands in West Bengal. *Progressive Agriculture*, **11**(1): 143-148.

Bhati, T. K., J. C. Tewari and S. S. Rathore, 2004 : Productive dynamics of integrated farming systems in western Rajasthan, *Diversification of Arid Farming Systems*: 23-30.

Chesney, P.E., L.A. Simpson, R.N. Cumberbatch, O. Homenauth and F. Benjamin, 2010 : Cowpea yield performance in an alley cropping practice on an acid infertile soil at Ebini, Guyana. *The Open Agriculture Journal*, **4**(Special Issue# 001): 80-84.

Dhillon, R.S., S.B. Chavan, K.S. Bangarwa, K.K. Bharadwaj, S. Kumari and C. Sirohi, 2018 : Eucalyptus-based agroforestry system under semi-arid condition in North-Western India: An economic analysis. *Indian Journal of Ecology*, **45**(3): 470-474.

Eskandari, H. and A. Ghanbari, 2010 : Environmental resource consumption in wheat and bean intercropping: Comparison of nutrient uptake and light interception. *Notulae Scientia Biologicae*, **2**(3): 100-103.

Godara, A. S., U. S. Gupta and Ravindra Singh, 2012 : Effect of integrated nutrient management on herbage, dry fodder yield and quality of oat (*Avena sativa* L.). *Forage Research*, **38**(1):59-61.

Kidanu, S., T. Mamo and L. Stoosnijder, 2005 : Biomass production of Eucalyptus boundary and their effect on crop productivity on Ethiopian highland Vertisols. *Agroforestry Systems*, **63**: 281-290.

Nandal, D.P.S. and M.S. Hooda, 2005 : Production potential of some agricultural crops under different spacings of poplar. *Indian Journal of Agroforestry*, **7**(1): 16-20.

Nguyen Ngoc Vu, R. K. Arya and R. Panchta, 2019 : Studies on genetic parameters, correlation and path coefficient analysis in cowpea, *Range Management and Agroforestry,* **40**: 49-58.

Nguyen Ngoc Vu, R. K. Arya, R. Panchta and S. K. Pahuja, 2016 : Studies on meteroglyph analysis in cowpea [*Vigna unguiculata* (L.) Walp], *Forage Research*, **41**: 255-258.

Prasad, J. V. N. S., G.R. Korwar, K.V. Rao, U.K. Mandal, C.A.R. Rao, G.R. Rao, Y.S. Ramakrishna, B. Venkates warlu, S.N. Rao, H.D. Kulkarni and M.R. Rao, 2010 : Tree row spacing affected agronomic and economic performance of Eucalyptus-based agroforestry in Andhra Pradesh, Southern India. *Agroforestry Systems,* **78**: 253-267.

Raju, S.S. 2013 : Assessment of feed resources and its impact on livestock output in India. Agricultural Situation in India. **69**(12): 5-11.

Ramteke, R., O. P. Mishra, D. Nishima Singh, R. Pathak, M. S. Parmar and D. K. Barwa, 2021 : Revisiting Livestock Feeding and Fodder: Silvipastoral Farm.

Ranjan, R.K., H. Kumar and R. Umrao, 2016 : Efficacy of oat, berseem and lucerne under subabul (*Leucaena leucocephala*) and poplar (*Populus deltoides*) based silvopastoral system, *The Bioscan*, **11**(4): 2371-2374.

Ratan, N. and U.N. Singh, 2015 : Production potential of berseem in eucalyptus based agrisilvicultural system in Bundelkhand Region (U.P.) India. *Flora and Fauna,* **21**(1): 100-102.

Stevens, E. J., K. W. Armstrong, H. J. Bezar, W. B. Griffin and J. G. Hampton, 2004 : Fodder oats an overview. *Fodder oats: a world overview*, (33), 11-18.

Vijaya kumar E., K. Thangaraj, T. Kalaimagal, C. Vanniarajan, N. Senthil and P. Jeya kumar, 2020 : Multivariate analysis of 102 Indian cowpea (*Vigna unguiculata* (L.)Walp.) germplasm, *Electronic Journal of Plant Breeding*, **11**(1):176-183.

Welch, R.W., 1995 : The Oat Crop: Production and Utilization. ed. Chapman and Hall, UK. 584pp.