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PRODUCTION PROSPECTIVE OF FODDER CROPS IN SALINE SOILS UNDER *EUCALYPTUS TERETICORNIS* BASED AGRISILVICULTURE SYSTEM IN SEMI-ARID REGION

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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 Sorghum (*Sorghum bicolor*) HJ 541 and Cowpea (*Vigna unguiculata*) HC 46 under a eucalyptus-based agrisilviculture system. The present study was carried out a 2.0-year-old plantation of *Eucalyptus tereticornis* planted at different 4m × 2m and 5m × 2m spacing during the summer season (*kharif*) with different, fodder crops, *viz*. Sorghum (Sorghum bicolor) and Cowpea (*Vigna unguiculata*), were sown under eucalyptus plantation and control (devoid of tree) with seven replications. The results revealed that height of Sorghum (192.56 cm) and Cowpea plant (82.65) cm were higher under 5 m × 2m spacing as compared 4m × 2m spacing. Similarly the other parameters in both the crops such as leaf area of sorghum and cowpea (2088.64 & 1754.64 cm^2/plant), Plant Stem diameter (11.54 and 7.15 mm) and Fresh fodder yield (32.72 and 14.11 t/ha) were also higher under 5m × 2m spacing at harvest. The benefit cost ratio of this experiment was calculated. Among both the crop maximum value of benefit-to-cost ratio (BC ratio) (0.84) and (0.40) under 5m × 2m spacing in the sorghum and cowpea as compared to (0.73) and (0.36) 4m × 2m spacing. The crop indicates that 5m × 2m spacing is more appropriate spacing of Eucalyptus based Agrisilviculture system from efficiency and profitability point of view.

Key words : Eucalyptus, sorghum, cowpea, B:C ratio, Agrisilviculture

In India, Agriculture and Forestry have co-existed for many years in close proximity. Farmers from time immemorial have been growing useful tree species with agricultural crops, and fodder crops which used to supply food, fodder, fuel and small timber for himself and his livestock. Agroforestry systems of land use are not new to our rich heritage. It is an integrated approach to land use that is characterized by deliberate maintenance of trees and other woody perennials in fields and pastures. The idea behind planting fodder crops as an intercrop with tree is to obtain biomass production before these plants attain full growth, and later to obtain fodder or green manure material by frequent cutting and create thicker vegetation for better soil and water conservation. This system offers a good scope for more efficient use of land, water, other natural and human resources which has both productive and protective potential so can play an important role in enhancing the productivity of our land to meet the demands of the human and livestock (Pandey *et al*., 2018). The concept of Agrisilviculture system is combination of perennial tree and agricultural crops, could profitably be adopted in both arable and non-arable marginal and sub-marginal lands. Rapid population increase and consequent increase in the requirement for different kinds of paper products and the emphasis on paper as an environmentally friendly packaging material have led to increased demand for wood. The imbalance between the supply and demand for forest products is growing. Many pulp mills are finding it difficult to source wood from natural forests and find land where they can establish plantations (Puri and Nair, 2004). The majority of the mills are entering into contracts with local communities in the name of joint venture schemes for producing wood (Saxena, 1995). The yields

obtained from on-farm plantations of exotic species have often been many times greater than those from natural forests. The acreage under eucalyptus has increased rapidly in Haryana during the last decade due to the assured market, high returns from trees and supportive government policies. Tree growing has become a profitable land use with the establishment of company/farmer relationships, trading of wood in the open market, competition among paper mills to meet their wood requirements and development of wood markets. Tree crop integration results into many types of interactions for solar radiations, soil moisture and plant nutrients, there by changing microclimate, which affect the productivity of component crop. The farmers adopt only those agroforestry systems, which do not adversely affect their agricultural crops for food security. However, accommodation of trees on hectare basis in the farm land without unduly affecting crops under reduced light condition of the agroforestry system still remains to be inconclusive. A fundamental understanding of stand growth and the factors that influence it are vital for achieving and sustaining high rates of production. Agroforestry is one of the best options to increase the tree cover outside the forest. The need of agroforestry has been necessitated in many parts of the country, which face several agricultural and ecological problems, predominant of which are soil degradation, large scale deforestation, increasing population pressure of human beings and livestock, and decreasing land: man ratio. Agroforestry is a popular tool to modify the microclimatic under field conditions. Trees mainly modify radiations, relative humidity, carbon dioxide concentration, wind velocity and soil environment to crop (Dhillon *et al*., 2016). *Eucalyptus tereticornis* commonly known as 'red gum' is native of Australia and Papua New Guinea. It is one of the most widely planted exotic species that has been extended to other parts of the globe. It has been promoted in many tropical countries owing to its fast growth rate, adaptability to wider climatic and edaphic conditions and multiple uses (Evans, 1992). Eucalyptus clones have revolutionized the productivity and profitability of the plantations in many states of our country (Lal, 2005) and most popular choice to be planted along the edges or bunds of agricultural fields, and appears to be well incorporated and accepted in agroforestry in India (Tejwani, 1994). Saline and alkaline soils are of widespread occurrence in arid and semi-arid regions of northern India, which need to be revegetated profitably. In northern India farmers are cultivating different agricultural crops under different spacing's of eucalyptus but the information on cultivation of agricultural crops under eucalyptus based Agrisilvicultural system is lacking. Although the growing of intercrops with trees was started about a decade or so ago, no effort has been made so far to analyze the effect of different spacing of eucalyptus plantation on the productivity of fodder crops. These systems utilize the soil from its best capability and generate higher biomass from the same piece of land without any loss of fertility. 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 agri-silviculture 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. It has the ability to tolerate drought and fix atmospheric nitrogen, which allows it to grow and improve poor soils (Nguyen *et al*., 2019). Sorghum is also an important *kharif* season crop widely grown for green fodder because of its luxuriant growth, good palatability, and highly nutritious nature. In terms of quality, it contains 8-10% crude protein, 60-65%, NDF, 37-42% ADF, 32% cellulose and 21-23% hemi-cellulose when harvested at 50% flowering stage (Sunil Kumar *et al.,* 2012). Beside this, sorghum is also a moderately salt tolerant crop (Devi *et al.,* 2018). The eucalypts based agroforestry system favour the growing of various crops due to sparse canopy and interception of light. Keeping these in view therefore, present study was specifically planned to assess the production prospective of fodder crops in saline soils under Eucalyptus-based Agrisilviculture system in Semi-arid region.

MATERIALS AND METHODS

Site description

The study was carried out at CCS Haryana Agricultural University, Hisar, Haryana (India) at 29°

10 N 'latitude and 75° 43 E longitude at an elevation of 215 m above mean sea level. The site is situated in the semi-arid region of North-Western India. The climate is subtropical -monsoonic with an average annual rainfall of 350-400 mm, 70-80 per cent of which occurs during July to September. The summer months are very hot with maximum temperature ranging from 40 to 45°C in May and June whereas, December and January are the coldest months. The soil was saline, low in organic carbon and available nitrogen, medium in available P and K Eucalyptus (clone P-23) was planted in two spacing of (4m × 2m) and (5m × 2m) following randomized block design with six replication by digging out pits of 30 cm filled with 3:1 potting mixture of (soil: FYM) during July, 2018. The experiments were regularly monitored for replacement planting, irrigation and protective measures. Intercropping of sorghum Variety HJ 541 and cowpea (HC46) during *Kharif* under two spacing of Eucalyptus and also compared with control(devoid of tree). The standard package of practices developed by CCS Haryana Agricultural University, Hisar was followed to cultivate fodder crops.

RESULTS AND DISCUSSION

Growth performance of eucalyptus trees

Data presented in the Table1. revealed that at the time of sowing *kharif* crop , the plant height and girth at breast height varied from 6.5 to 6.7 m and 21.9 to 23.8 cm under 4m × 2m and 5m × 2m m spacing, and at the harvest time of *Rabi* crops, the plant height and girth at breast height varied from 8.7 to 9.2 m and 23.5 to 25.7 cm, respectively. Maximum current annual increment (CAI) for plant height (2.5 m) and girth at breast height (1.9 cm) in eucalyptus was recorded under 5m × 2m m spacing. In the study, the maximum plant height and girth at breast height of (9.2 m) and GBH (25.7 cm) was found under 5m × 2m spacing. Silva (1999) on Eucalyptus also observed that wider spacing performed better for higher growth and higher yield of agricultural crops over other spacings. Prasad et al (2010) reported the spacing of eucalyptus significantly influence the growth parameter of trees in terms of height, dbh and biomass. This may be due to more competition of eucalyptus plants for sunlight and different growth resources. Similar findings have been highlighted by (Ajit *et al.,* 2011; Chauhan *et al.,* 2011). In Eucalyptus based systems, major impact of tree spacing on eucalyptus growth has been observed under 4.2 m

TABLE 1
Growth performance of *Eucalyptus teriticornis* under different spacing's in the Agri-silviculture syste

Tree spacing (m)	Height (m)		CAI	GBH (cm)		CAI
	July, 2020	April, 2021		July, 2020	April, 2021	
4 x 2	6.5	8.7	2.2	21.9	23.5	1.6
5 x 2	6.7	9.2	2.5	23.8	25.7	1.9

spacing that the growth in the way of Plant Height and GBH exhibited lowest. This may be presence of saline soil in the experimental area hampered the growth of eucalyptus seedlings in early years of plantation. In the study (Fig. 1) all growth parameters showed that with the advancement of age, a gradual increase in height and GBH was observed and also with the increasing space in between tree rows, tree height increases with maximum height (9.2 m) is attained in 5m × 2m spacing.

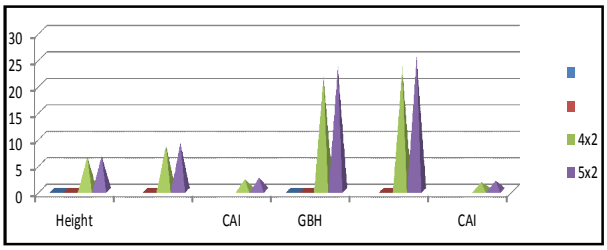

Fig. 1. Growth performance of Eucalyptus in reference to plant height, GBH (girth at breast height) and CAI (current annual increment).

Soil fertility of the field

Edhaphic properties presented in Table 2 and Fig. 2. likewise (pH 8.2), (EC 1.2), (OC 0.36%) and available nutrients(N 116.5, P 11.2 & K 258.4kg /ha)that revealed soil was saline, low in organic carbon and available nitrogen, medium in available P and K). The major climatic constraints were low and uneven rainfall distribution, late monsoon onset and prolonged dry spells during crop growing season. Positive effect of eucalyptus like increased organic matter content from leaf litter decomposition might have resulted in improvement in soil water holding capacity, porosity, texture, essential nutrient and yield improvement of *kharif* crop. Eucalyptus plantation results in improvement in soil nutrient (N, P, K, and organic matter) as compared to natural soil (Jan et al., 1996). Eucalyptus plantation can ameliorate salinity and sodicity of soil by improving decreasing soil EC, pH and SAR (Nasim *et al.,* 2007). The results also revealed that the soil chemical properties under

TABLE 2
Soil chemical properties of the experimental field (0-15 cm) *Eucalyptus tereticornis* based Agrisilviculture system

Tree spacing (m)	pH	EC1:2 (dS/m)	OC (%)	Available nutrients (kg/ha)		
				N	P	K
4 x 2	8.2	1.1	0.36	116.5	11.2	258.4
5 x 2	8.2	1.2	0.34	114.8	11.1	256.3

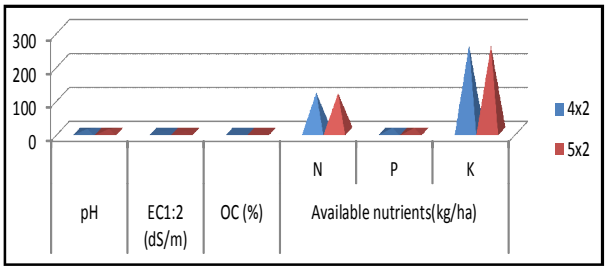

Fig. 2. Soil chemical properties of the experimental field

different agri-silvihorticulture system were considerable changed. The soil pH and EC were decreased whereas, the soil organic carbon and available N, P and K at 0-15 cm soil depths were slightly increased under different spacing of eucalyptus based agroforestry systems.

Growth performance of fodder crops at harvest

The field crops viz. sorghum (HJ 541) *Sorghum bicolor* and Cowpea (HC 46) *Vigna unguiculata,* were sown for fodder during *Kharif* season of 2019-2020 under eucalyptus plantation planted at 4mx2 and 5mx2m spacing's and in control (devoid of trees). Growth parameters of both the crop *viz*. Plant height (cm), leaf area (cm^2), stem diameter (mm) and fresh fodder yield t/ha were recorded at the time of harvest The data presented in Table 3 and 4 revealed that plant height of sorghum and cowpea at harvest stage increased with increases in the space of tree line however, maximum rate of increase in height was recorded under 5x2m spacing of eucalypts system as well as in control. The results clearly indicate that both the crop showed significantly lesser under 4mx2m spacing of eucalyptus system. Among both the spacing the maximum plant height of sorghum (192.56 cm) and cowpea (82.65 cm) was found under 5mx2m spacing at harvest. Similar pattern were also found in stem diameter in the both the crop. There was a significant reduction in the green fodder yield of sorghum and cowpea under different spacings of eucalyptus over control (devoid of trees). The green fodder yield of sorghum varied from 28.68 (4m × 2m) to 40.64 (control) t/ha with the general mean of 34.01t/ha. The per cent fodder yield of sorghum reduction under 4m × 2m and 5m × 2m spacing was 29.43 and 19.49 %, respectively over control. These results supported by Kumar and Nandal (2004) reported that the eucalypt tree belt had more adverse effect on wheat than did the poplar tree belt. The performance of wheat was very poor under eucalyptus plantation. However, fodder crop cowpea had a lower plant height (71.23cm) under 4mx2m spacing, which was comparable to (82.65cm) under 5mx2m spacing and in control (101.25cm). There was a significant reduction in the green fodder yield of cowpea under different spacings of eucalyptus over control (devoid of trees). The green fodder yield varied from 12.54 (4mx2m) to 18.56 (control) t/ha with the general mean of 15.07 t/ha. The percent fodder yield reduction in cowpea crop under 4m x 2m and 5m x 2m spacing was 32.44 and 23.97, respectively over control. The cultivation of cowpea under spacing 4m x 2m is not profitable due to dense shade of trees during the summer season, as indicated by more than 32.44 % reduction in fodder yield. Kotowskil *et al*. (2000) reported that light availability and intensity had a large effect than water level on biomass production of most plant species Among both fodder crops maximum reduction percent (32.44) was found in the green fodder yield of cowpea under 4x2m spacing of eucalyptus over control (devoid of trees). Overall reduction in fodder yield of crops in agroforestry systems as compared to control due to competition for utilization of growth resources adversely affected the fodder yield (cowpea and sorghum) under different tree species. Bhati et al. (2004) found a comparable finding of cowpea and other fodder crops yielding beneath the cover of diverse agroforestry trees in Rajasthan's desert regions. Ranjan *et al.* (2016), Ratan *et al*. (2015), Prasad *et al*. (2010), and Chesney *et al*. (2010) also reported corroborative data revealing a loss in cowpea grain output due to increasing shade under *Eucalyptus tereticornis* based agroforestry system compared to open condition but this reduction will be supplemented by multipurpose benefits of wood production from trees and other indirect benefits like carbon sequestration and mitigation of climate change. Kaushik, N. and Kumar, V. 2003. Fodder production potential of some fodder crops associated with top feed tree species under rainfed condition. 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. Similar

TABLE 3
Effect of different spacing of *Eucalyptus tereticornis* based Agrisilviculture system on growth and yield of Sorghum (*Sorghum bicolor*) crop during ***kharif*** season

Tree spacing (m)	Plant height (cm)	Leaf area (cm^2)/plant	Stem diameter (mm)	Fresh fodder yield (t/ha)	B : C ratio
4 x 2	171.58	1976.21	10.45	28.68	0.73
5 x 2	192.56	2088.64	11.54	32.72	0.84
Control	255.63	2378.54	14.82	40.64	1.04
Mean	206.59	2147.80	12.72	34.01	-
C.D. at 5%	11.30	72.73	0.54	2.42	-

TABLE 4
Effect of different spacing of *Eucalyptus tereticornis* based Agri-silviculture system on growth and yield of Cowpea (*Vigna unguiculata*) crop during ***kharif*** season

Tree spacing (m)	Plant height (cm)	Leaf area (cm^2)/plant	Stem diameter (mm)	Fresh yield (t/ha)	B : C ratio
4x2	71.23	1624.56	6.56	12.54	0.36
5x2	82.65	1754.64	7.15	14.11	0.40
Control	101.25	2465.34	9.73	18.56	0.53
Mean	85.04	1948.18	7.81	15.07	-
C.D. at 5%	7.49	39.58	0.54	1.12	-

results were found by Alebachew *et al*. (2015). They reported that poor performance of maize sown adjacent to eucalyptus plantation was due to competition for growth resources between eucalyptus and adjacent crops. Among both the crop higher value of benefit-cost ratio (0.84) and (0.40) under 5x2m spacing in sorghum and cowpea as compared to (0.73)and (0.36) under 4x2m spacing. The crop indicates that 5x2m spacing is more appropriate spacing of eucalyptus based agroforestry system from efficiency and profitability point of view.

CONCLUSION

At the time of crops harvest, the plant height and girth at breast height varied from 8.7 to 9.2 m and 23.5 to 25.7 cm, respectively. Maximum current annual increment (CAI) for plant height (2.5 m) and girth at breast height (1.9 cm) in eucalyptus was recorded under 5 m × 2 m spacing. The fodder crops Sorghum (*Sorghum bicolor*) HJ 541 and Cowpea (*Vigna unguiculata*) HC 46 were raised in two spacing 4m × 2m, and 5m × 2m during *Kharif* seasons in saline soils in semi-arid region under eucalyptus-based agrisilviculture system to assess the productivity of fodder crops. The results revealed that all growth parameters were found highest under 5m × 2m spacing of eucalyptus based agri-silviculture system as compare to 4m x 2m spacing and control (devoid of tree) Maximum green fodder yield of 32.72 and 14.11 t/ha were recorded from sorghum and cowpea under 5m × 2m spacing during *kharif* season. Eucalyptus 5m × 2m spacing system exhibited highest B:C ratio (0.84), as compare to spacing 4m × 2m eucalyptus based agri-silviculture system. Maximum fodder yield reduction was recorded from cowpea 32.43% which was affected adversely under 4m × 2m spacing. It concluded that eucalyptus spacing 5m × 2m is more beneficial as compared to 4m × 2m spacing.

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