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PERFORMANCE OF CEREAL CROPS UNDER CLONAL EUCALYPTUS BASED SILVOARABLE SYSTEM IN SALINE CONDITION

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SUMMARY

Eucalyptus, a member of family Myrtaceae and it is one of the most prime species in agroforestry and clonal planting material for more returns in short rotation most popular in farmers due to its fast growth. It can adapt a varied range of edaphic and climatic and its cultivation is considered an eco-friendly approach to cope up with the salinization. In Haryana, agroforestry practices vary according to the agro-climatic zones and socio-economic status of the farmers, tree diversity, existing cropping pattern and availability of irrigation water. The present investigation was carried out at the Forestry Research Farm during the *rabi season* of 2019-20 at CCS Haryana Agricultural University, Hisar to found effect of different spacing of clonal Eucalyptus plantation on the performance of wheat and barley crops in saline condition in Semi-arid environment. Therefore, field crops namely wheat *(Triticum aestivum)* HD- 2967and Barley (*Hordeum vulgare)* BH-393 were sown under clonal eucalyptus 4m x 2m and 5m x 2m spacing and in open (devoid of trees) following randomized block design with seven replication during rabi season. Growth, yield attributes and yield were recorded at harvest. The maximum plant height (71.58 cm) of wheat was recorded under 5m x 2m spacing as compared to in 4m x 2m spacing. The other parameters viz, no. of effective tillers /m^2, days taken to maturity (no.), number of grains/spike, test weight (g) showed similar pattern under 5m x 2m spacing in the study. Among different spacing , the maximum grain yield (3.01 t/ha) and straw yield (3.94 t/ha) was recorded in spacing 5m x 2m .The plant height (84.59cm) of barley was found higher under 5m x 2m spacing. Similarly, other parameters viz, no. of effective tillers / m^2, days taken to maturity (no.), test weight (g), and grain yield in barley were found higher under 5m x 2m spacing as compared to 4x2m spacing. The crop indicates that 5m x 2m spacing is more appropriate spacing of clonal Eucalyptus plantation from productivity and practically fruitful aspect.

Key words: Growth,intercropping, rabi *season*, spacing, cereals crops and yield

Eucalyptus tereticornis commonly known as 'red gum' is native of Australia and Papua New Guinea. It belongs to family Myrtaceae and one of the most widely cultivated forest trees. It is one of the commercial important exotic forest resources of the country and highly demanded in plywood and veneer industries. It is widely popular because of its fast growth, straightness with clear bole, short rotation and good coppicing ability. In fact, this species is grown in varieties of site situations for production of pulp and paper as well as rayon. About one million hectares of eucalyptus plantations are managed by forest departments and forest development corporations in India. *Eucalyptus tereticornis* and *E. camaldulensis* are the major species grown in arid regions of the country. They are essentially Austro-Malayan trees with a natural latitudinal range extending from 7′N to 43′39′′ S. It flourishes from coastal areas to areas situated at an altitude of 2000 m, tropical to warm temperate climate and rainfall ranges of 400-4000 mm. As a short rotation and fast growing nature, this species is widely preferred by farmers, where there is a great demand from pulp and paper industries as well as local market for pole. Significant improvements in quality of produce and reductions in per unit production costs have also been possible with the use of true to type, uniform and genetically improved clonal planting stock of Eucalyptus. The demand of wood from forest or commercial plantation for timber, fuel wood, pulp and paper production is

increasing year after year. Among many, Eucalyptus is widely planted in farm forestry system in the form of block plantations, boundary plantations, strip plantations and agroforestry systems throughout the world more particularly in India to provide wood products especially in the region of scarcity. 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. In our country Eucalyptus is one of the most prime species in agroforestry and farmers are mostly diverting towards clonal planting material for more returns in short rotation. Eucalyptus clones have revolutionized the productivity and profitability of the plantations in many states of our country 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). 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. Saline and alkaline soils are of widespread occurrence in arid and semi-arid regions, which need to be revegetated profitably. It can adapt a varied range of edaphic and climatic conditions and its cultivation is considered an eco-friendly approach to cope up with the salinization of lands. In Haryana, agroforestry practices vary according to the agro-climatic zones and socio-economic status of the farmers, tree diversity, existing cropping pattern and availability of irrigation water. Eucalyptus has enormous social, economic, and ecological contributions in way of positive impacts if it is planted on the right sites with good management planning and proper tending operations. This helps to provide wood for energy, construction, income and farm implements as well as enhance their environmental roles. Under current demand and market conditions, planting Eucalyptus provides a far better return on investment than alternative land uses (crop production and animal keeping) for the smallholder tree cultivators. It has a great role in minimizing the supply and demand gap of wood products and conserving soil and water as well as providing a greener landscape. Thus contributing significantly to the conservation of biodiversity-rich natural forests. Eucalyptus helps households to become wood self-sufficient and provides considerable cash income. Most of the studies ranked Eucalyptus as the second major source of rural household income Moreover, the selection of more valuable clone to the local community, proper land use planning, extension support, and economic profitability assessment need to be considered for Eucalyptus plantations. In northern India farmers are cultivating different cereal crops under different spacing's of eucalyptus but the information on cultivation of cereal crops under clonal eucalyptus based plantation is lacking. Although the growing of inter crops with trees was started about a decade or so ago, no effort has been made so far to evaluate the effect of different spacing of clonal eucalyptus plantation on the performance and production of wheat and barley 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. Plantation of clonal eucalyptus is one of the best options to increase the tree cover outside the forest. The need of growing tree with agriculture crop 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. Growing of tree is a popular tool to modify the microclimate under field conditions. Trees mainly modify radiations, relative humidity, carbon dioxide concentration, wind velocity and soil environment to crop (Dhillon *et al*., 2016). Growing of wheat and barley crops under clonal eucalyptus an industrial plant will not only meet human being feed demand, but will also increase its availability during lean periods. Therefore, there is a great need to identify suitable cereal 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 grains. Cereals like barley and wheat

have been an integral part of the human diet for thousands of years. Both crops belong to the grass family that includes many others like rice, corn and sugarcane. The grains of wheat and barley are actually caryopsis or fruits of the grass. Each grain comprises of endosperm, outer bran and an inner germ. When wheat is consumed as whole grains, they are a rich source of important nutrients such as folate, copper, phosphorus, manganese, selenium, niacin, thiamine, calcium and vitamin B6. On the other hand, Barley is full of antioxidants, vitamins and minerals. The consumption of whole grain barley can provide a burst of fibre and other nutrients like niacin, chromium, phosphorous, magnesium, copper, selenium, manganese and vitamin B1. These are two of the most easily domesticated crops of all times. Barley and wheat are nutritive similar crops cultivated majorly for drink, food and animal feed production. Identification of the best cereal crops under different spacing of clonal eucalyptus plantation to maximize the grain yield is important so that it can contribute to fulfilling the food demand. Wheat (*Triticum aestivum*) HD- 2967 and Barley (*Hordeum vulgare*) BH-393 are two important quick-growing, cereal crops of *rabi* season which is an integral part of traditional system.

MATERIALS AND METHODS

The present investigation was carried out at the Forestry Research Farm during the *rabi season* of 2020-21 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 environment 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 × 2 m) 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. Tree height and diameter at breast height (DBH) were measured randomly using measuring tape (cm) respectively. Therefore two cereal crops wheat (*Triticum aestivum*) variety HD-2967and Barley *(Hordeum vulgare*) variety BH-393 were sown under clonal eucalyptus 4m x 2m and 5m x 2m spacing and in open (devoid of trees) during *Rabi* season in already established two years eucalyptus plantation. The standard package of practices developed by CCS Haryana Agricultural University, Hisar was followed to cultivate cereal crops to found effect of different spacing of clonal eucalyptus plantation on the performance of wheat and barley crops in saline condition in Semi-arid environment.

RESULTS AND DISCUSSION

Edhaphic Properties of experimental soil

The site is situated in the semi-arid region of North-Western India characterized by 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. Edhaphic properties presented in Table 1 which revealed that the soil was saline, low in organic carbon and available nitrogen, medium in available P and K.

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 *rabi* crop. The higher nutrient status near the tree might be due to the addition of large quantity of leaf litter. The higher decomposition of leaf litter favours the higher nutrient status of the soil. Similar findings were also observed by (Singh and Sharma, 2007). Increase in soil carbon through plantations may also act as an important carbon sink. The higher available nutrient content in agroforestry system over the agriculture system may be attributed to litter fall addition from trees as well as addition of root residues of crops

TABLE 1
Edhaphic properties of experimental field (0-15 cm)
Eucalyptus tereticornis based plantation

Tree spacing (m)	pH	$EC_{1:2}$ (dS/m)	OC (%)	Available nutrients (kg/ha)		
				N	P	K
4x2	8.2	1.1	0.36	116.5	11.2	258.4
5x2	8.2	1.2	0.34	114.8	11.1	256.3

TABLE 2
Growth performance and yield of wheat under different spacing's of clonal Eucalyptus tereticornis plantation

Tree spacing (m)	Plant height (cm)	Effective tiller/m^2 (no.)	Maturity days (no.)	Grains/ spike (no.)	Test wt. (gm)	Grain yield (t/ha)	Straw yield (t/ha)	B:C ratio
4 x 2	62.27	171.69	150.52	19.78	23.59	2.22	2.95	0.70
5 x 2	71.58	184.67	146.84	23.87	26.58	2.44	3.19	0.77
Control	85.75	287.61	140.27	35.12	38.58	4.22	5.42	1.33
Mean	73.20	214.66	145.88	26.26	29.58	2.96	3.85	-
C. D. (P=0.05)	7.73	9.83	3.73	2.15	1.78	0.14	0.23	-

TABLE 3
Growth performance and yield of barley under different spacing's of clonal Eucalyptus tereticornis plantation

Tree spacing (m)	Plant height (cm)	Effective tiller/m^2 (no.)	Maturity days (no.)	Grains/ spike (no.)	Test wt. (gm)	Grain yield (t/ha)	Straw yield (t/ha)	B:C ratio
4 m x 2 m	75.34	231.54	131.52	35.48	27.54	2.28	2.95	0.68
5 m x 2 m	84.59	274.94	128.32	39.54	29.89	2.69	3.34	0.80
Control	105.61	325.81	124.67	47.53	38.42	4.15	5.45	1.25
Mean	88.51	277.43	128.17	40.85	31.95	3.04	3.91	-
C. D. (P=0.05)	8.42	16.40	1.77	2.35	0.95	0.22	0.27	-

and trees. These findings were supported by (Gupta and Sharma, 2009). On account of recycling of organic matter, higher organic carbon and available N, P and K contents were observed in the soil under intercropped eucalyptus plantations than at a site without trees and the contents varied depending upon the inter-crops. The impact of agroforestry systems on soil fertility in terms of higher organic matter content, total nitrogen, available phosphorus and potash in the top soil has been reported by (Uthappa *et al*., 2015 and Ramesh *et al*., 2023) Increase in tree litter and nutrients increases with increasing plantation age (Bargali, 1992).Eucalyptus plantation can ameliorate salinity and sodicity of soil by improving decreasing soil EC and pH. The results also revealed that the soil chemical properties under 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 clonal eucalyptus based plantation. The reduction of soil pH and EC closer to tree can be attributed to accumulation and subsequent decomposition of organic matter which releases organic acids.

Growth attainment of clonal eucalyptus trees during study period

Data presented in the Fig. 1 revealed that 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 5 m x 2 m spacing. In the study, the maximum plant height and girth at breast height of (9.2 m) and GBH (25.7cm) was found under 5×2m 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 and Yadav *et.al*.,2022) 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 4x2m 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 dbh 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 x 2m spacing.

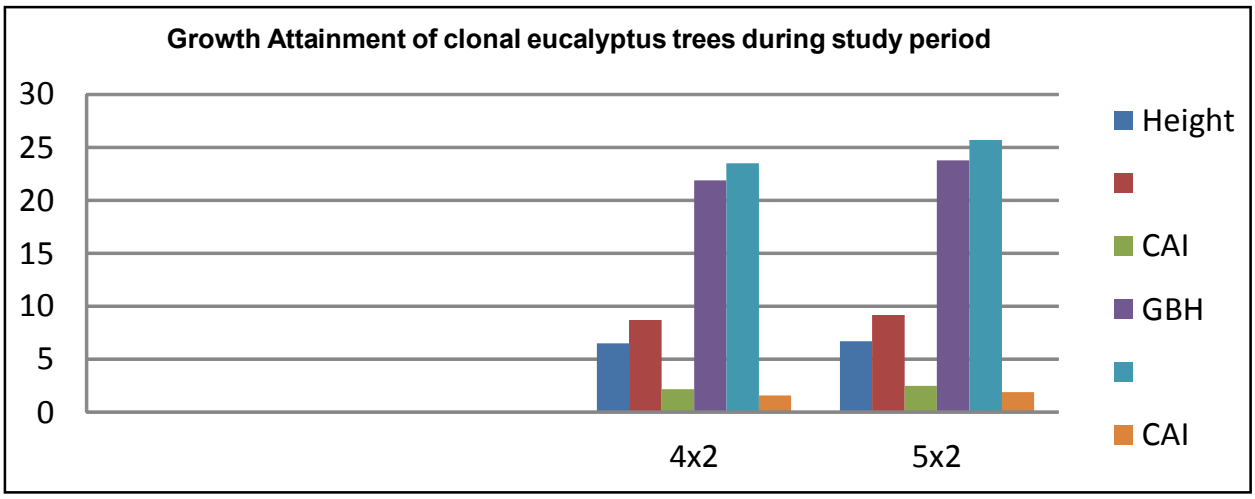

Fig. 1. Growth Attainment of clonal eucalyptus trees during study period.

Growth performance and yield of cereal crops under different spacing's of *Eucalyptus tereticornis* plantation

Cereal crop wheat (HD-2967) was sown under different spacing's of clonal Eucalyptus plantation and in open (devoid of trees). Growth, yield attributes and yield were recorded at harvest. In addition, B: C ratio was also analyzed. An appraisal of the data presented in Table 2 revealed that the plant height of wheat varied significantly under different spacings of clonal eucalyptus i.e. 4mx2m and 5m x2m . Significantly higher plant height, effective tillers (no.), grains /spike (no.), test weight and grain yield in wheat were observed under 5m x 2m spacing as compared to 4m x 2m spacing. The maximum plant height (71.58 cm) of wheat was recorded under 5m x 2m spacing as compared to (62.27 cm) in 4m x 2m spacing. The reduction in plant height under different spacings may be due to the increase in competition for light/moisture, presence of eucalyptus leaf litter mulch and modification of micro-environment The findings of present study are in agreement with the results of (Kaur *et al.,* 2010**)** who reported that plant height of wheat was significantly more in sole crop than the inter-cropping with poplar. These results also supported by (Kumari *et al*., 2022) that all growth parameters were found highest under 5mx2m spacing of eucalyptus based agri-silviculture system as compare to 4m x 2m spacing and control (devoid of tree).This might be due to the difference in the light intercepted by the sole wheat crop and poplar-inter cropped plots less in the months of December to February, but it increased considerably after mid of March. Therefore, reduced light intensity in poplar based agroforestry system decreased the photosynthetic efficiency of crops resulting in poor growth performance. Poor performance of wheat crop was caused by decreased photosynthetic efficiency as a result of reduced light intensity in poplar based agroforestry system (Rani *et al*., 2011; Chauhan *et al*. 2012). The other parameters viz, no. of effective tillers /$m^{2,}$ days taken to maturity (no.), number of grains/ spike, test weight (g) showed similar pattern under different treatments in the study. The grain yield varied from 4.22 t/ha (control) to 2.22/ha (4m x 2m) spacing with the general mean of 2.96 t/ha. Among different spacings, the maximum grain yield (2.44 t/ha) and straw yield (3.19 t/ha) was recorded in spacing 5m x 2m . There was significant reduction in the grain yield of wheat under different spacings of eucalyptus over control (devoid of trees). The per cent grain yield reduction under 4m x 2m and 5m x 2m spacing was 47.39 and 42.18 %, respectively over control. This may be due to more vigour growth of eucalyptus plants and obviously more competition for moisture, nutrients and solar radiation between the annual crops and eucalyptus plants. (Chauhan *et al.,* 2010; Verma *et al.,* 2013) also reported similar results i.e., more grains ear and total yield in open than under poplar during their study in different parts of Punjab. The crop yield declined with increase in age of eucalyptus trees. The increase in age of eucalyptus is associated with root and canopy development, this cause intense competition for light/nutrient/water, and thus, reduced the yield of the cereal crops with increase in age of eucalyptus plantation. The benefit cost ratio (B:C ratio) varied from 0.70 (4m x 2m) to 1.33 (control).

Cereal crop barley (BH-393) was also sown during *Rabi* season under clonal eucalyptus

plantation, planted at different spacings (4m x 2m and 5m x 2m) and in open (devoid of trees). Growth, yield attributes and yield were recorded at harvest. The plant height of barley varied significantly under different spacings Table 3**.** Significantly higher plant height, effective tillers/m^2 (no.), grains /spike (no), test weight, grain yield and straw yield in barley were observed under 5m x 2m spacing as compared to 4m x 2m spacing. The maximum plant height of barley (105.61 cm) was recorded in control as compared to different spacing of eucalyptus *i.e*. 4m x 2m and 5m x 2m. (Kumar *et al.,* 2013) also found that less height of wheat under Eucalyptus plantation due to reduced light intensity under Eucalyptus. The other parameters viz., no. of effective tillers /m^2, days taken to maturity (no.), number of grains/spike, test weight (g) showed similar pattern under different treatments in the study. The grain yield varied from 2.28 t/ha (4m x 2m) to 4.15 t/ha (control) with the general mean of 3.04 t/ha. Among different spacings, the maximum grain yield (2.69 t/ha) and straw yield (3.34 t/ha) were recorded in 5m x 2m spacing. There was significant reduction in the grain yield of barley under different spacings of eucalyptus over control (devoid of trees). The per cent grain yield reduction under 4m x 2m and 5m x 2m spacing was 45.06 and 35.18 %, respectively over control. It may be due to more vigour growth of eucalyptus plants and obviously more competition for moisture, nutrients and solar radiation between the annual crops and eucalyptus plants. The yield of barley was highly affected under the inter spaces of eucalyptus clone. Above results supported by (Khan *et al.,* 2008; Kumar *et al.,* 2013) also observed lesser number of tillers under agroforestry system than sole cropping. As per the above finding (Kumar *et al.,* 2013) conducted a field experiment on wheat and mustard under *Eucalyptus teriticornis* and found that grain yield of both crops is decreased significantly as compared to sole cropping. The reduction (63.2%) was less in wheat. (Sarvade *et al.*, 2014) found that highest grain yield (36.0q / ha) was under open farming system. The reduction in grain yield was 16-62% under agroforestry system as compared to sole crop.

CONCLUSION

Two cereal crops wheat (HD-2967) and barley (BH-393) was sown under different spacing of two-year clonal eucalyptus plantation. The soil status of experimental site was saline, low in organic carbon and available nitrogen, medium in available P and K. 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 5m x 2m spacing. Both cereal crops wheat (HD-2967) and barley (BH-393) were sown in 4×2m and 5×2m spacing under clonal eucalyptus to evaluate effect of different spacings of clonal eucalyptus plantation on the performance of wheat and barley in saline condition in semi-arid environment during *rabi* season. The results revealed that all growth parameters were found highest under 5m x 2m spacing as compare to 4m x 2m spacing of clonal eucalyptus plantation and control (devoid of tree). Among different spacings, the maximum grain yield of wheat (2.44 t/ha) and barley (2.69 t/ha) were recorded under 5m x 2m spacing and similar trend were also recorded in the straw yield of wheat (3.19 t/ha) and barley (3.34 t/ha) Maximum grain yield of 2.44 t/h and 2.69 t/ha were recorded from wheat and barley under 5m x 2m spacing during *rabi* season. Similar trend was also recorded in the straw yield of wheat (3.19 t/ha) and barley (3.34 t/ha). Eucalyptus 5m x 2m spacing system exhibited highest B: C ratio wheat (0.77) and barley (0.80), as compared to 4m x 2m spacing of clonal eucalyptus plantation. Among both crops overall maximum grain yield reduction was recorded from wheat 47.39 % which was affected adversely under 4m x 2m spacing. It concluded that eucalyptus spacing 5m x 2m is more practically fruitful as compared to 4m x 2m spacing. The large spacing between rows favours the higher yield of annual crops. The wider spacing 5m x 2m performed better and more profitable as compared to 4m x 2m spacing.

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