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Optimization of plant density of Akashmoni (*Acacia auriculiformis*) for production of fuel wood in the bunds of crop land

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Abstract: The experiment was carried out at the Field Laboratory of the Department of Agroforestry, Bangladesh Agricultural University, Mymensingh during the period from September, 2010 to August, 2011 to determine the optimum planting density of *Acacia auriculiformis* for maximization of fuel wood production in the crop field. *Acacia auriculiformis* seedlings were planted following Randomized Complete Block Design (RCBD) with four replications maintaining four different spacing viz., 0.5m, 0.75m, 1m and 1.25m, which were the treatments of this study. Data were collected at every three months interval i.e., 90, 180, 270, and 360 DAP. Growth parameters i.e., plant height, stem base diameter, number of primary and secondary branches and length of primary branches were significantly influenced by different spacing. During initial stage of establishment plant height of seedlings in all treatments were almost significantly similar but after six months i.e., 180 DAP plant height gradually decreased with increasing spacing of plantation. Reverse relationship was found between height and diameter growth of the plants. After six months of plantation, number of primary branch per plant gradually decreased and number of secondary branch per plant gradually increased with increasing planting density. Length of primary branch of Akashmoni was gradually increased with increasing spacing of plantation in every interval of data collection i.e, 90, 180, 270 and 360 DAP. After one year, longest (1.28 m) primary branch was in 1.25m distant plants and shortest (0.64 m) was in 0.5 m distant plant. The amount of phyllode, branch, stem and root per plant was gradually decreased with decreasing planting spacing. Total biomass yield was highest (6.45 kg/plant) in widely planted trees and lowest (3.51 kg/plant) in closely planted trees. Highest amount of weight or moisture lost from wide (1.25 m) spacing or sparsely planted trees and gradually decreased with decreasing spacing. Total yield was higher in plantation of 0.75m spacing which is statistically similar with 0.5m spacing and these were significantly greater than the total yield produced in other spacing (1m and 1.25m). Though total yield almost similar in 0.5m and 0.75m spacing but 0.75m spacing would be better option for getting more PAR interception as well as to minimize competition between tree and crops for growth resources (light, water and nutrients).
Key words: *Acacia auriculiformis,* planting density, fuel wood, cropland Agroforetry, field bunds.

Introduction

Cropland Agroforestry is not a traditional practices except in a few places of north-western part of Bangladesh where tree species like date palm (*Phoenix sylvestris*), babla (*Acacia nilotica*), khoir (*A. catechu*) and palmyra palm (*Borassus flabellifer*) grow naturally on agricultural lands in the higher parts of the Ganges floodplain and are intentionally retained and maintained by the farmers for different household utilities and products and also for earning money (Abedin and Quddus, 1991). A case study on cropland agroforestry found that 46 percent of farmers generated cash income from felling trees and met expenses for purchase of land, bullocks and inputs for crops, supplemented expenses of marriage, household expenditure, and loan repayment (Chowdhury and Mahat, 1993). Recently few non-governmental organization (NGOs) and government organizations (GOs) initiated cropland agroforestry and encouraged farmers to adopt it.
As a result, farmers in various parts of the country started planting trees on cropland. Cropland agroforestry includes trees like species of *Eucalyptus, Acacia nilotica, A. albida, A. auriculiformis, Swietenia macrophylla, Dalbergia sissoo, Samanea saman, Artocarpus heterophyllus,* etc. planted along with various annual crops like paddy, wheat, and cereals and other cash crops in farmers' lands. Trees are simultaneously planted in rows sparsely in crop field and/or along the alies (bunds). However, farmers are biased toward agricultural crops. These trees provide food, timber, fuel, fodder, construction materials, raw materials for forest-based small-scale enterprises and other cottage industries and in some cases, enrich soil with essential nutrients. The best product having commercial value from cropland trees can be poles and pulpwood as these trees are mostly short- rotation species.

To maintain the environmental equilibrium and rate of socio-economic development at least 25% area of a country should be covered with forest. In Bangladesh the total forest area covers about 17% of the land area (BBS, 2010) but the actual tree covered area is estimated at around 9.4% which is decreasing at an alarming rate (Hossain and Bari, 1996). Due to continuous transformation of forest land to agricultural land, aquaculture, homestead and other purposes about 8000 ha of forest land is decreasing per year (FAO, 1981). Another 99,000 ha of reserved forest lands were encroached or subjected to shifting cultivation. Village forest, mainly covered by homesteads accounts only 0.27 million ha. Out of 64 districts, as estimated, 28 districts have no public forest land (Islam, 1991). So, the effective area of forest (9.4%) in Bangladesh is neither in a position to fulfill the requirements of the people's demand for fuel, fodder and timber nor to stabilize the climatic condition. On the other hand, in Bangladesh the demand of food crops increasing rapidly due to ever increasing population. The country has only 8.29 million hectares of arable land to feed 142.3 million people (BBS, 2010). The population will be doubled in the last 30 years; while the country has only a land area of 14.39 million hectares. But due to over growing population per capita land area is decreasing at an alarming rate of 0.005 ha/cap/year since 1989 (Hossain and Bari, 1996). This put heavy pressure on land for human habitation and crop production.
However, the fertility of our land is decreasing rapidly due to intensive cropping and use of high input technologies. Under this alarming condition it is necessary to find out a suitable alternative to overcome this situation. Since, there is neither scope for expanding forest area nor sole crop areas. So, efficient land utilization will be necessary. This must be achieved primarily by increasing production of

fast growing nitrogen fixing tree species on the cropfield bunds. Nitrogen fixing trees have great potential in improving soil fertility, soil conservation and rehabilitant degraded wasteland. Proper management of nitrogen fixing plants will also provided fodder and fuel wood and hence reduces the pressure on forest.

Acacia auriculiformis (Akashmoni) is a fast growing middle sized nitrogen fixing tree. It is an Australian native species. Forest Department established plantation of Akashmoni during 1980 to 1990 in Bangladesh. Akashmoni is ideal for fire wood and charcoal making and also suitable for furniture making as it has attractive figure and finishes well. It has proved to be a good pulp wood. This will be a suitable species for planting as shelter belt in the beach and sea front areas. It has the ability to establish and grow well in very poor soil, even in saline and seasonally water logged soils. This is a vigorous nitrogen fixing tree species. Nitrogen fixing tree have special advantages over other tree species. Biological nitrogen fixation by the legume is important in relation to global environment. As a legume tree, Akashmoni has the ability to fix atmospheric nitrogen and through which wood quality improvement. It increases the soil fertility through increasing the organic matter status of soil. (Tangania and Subba Rao 1975) reported that symbiotic nitrogen fixation by *Rhizobium* meets the N requirement of the crop and leaves provide 40-108 kg N ha^{-1} to the soil. Therefore, it is high time for systematic depth research for the production of fuel wood. The present research work was undertaken to determine the optimum planting density of Akashmoni for maximization of fuel wood production in the crop field.

Materials and Methods

Experimental site: The experiment was carried out at the Field Laboratory of the Department of Agroforestry, Bangladesh Agricultural University, Mymensingh during the period from September, 2010 to August, 2011. The experimental site was located at 24.75°N latitude and 90.5E longitude at the mean elevation of 18m above the sea level (FAO, 1988). The climatic condition of the experimental site is sub-tropical and characterized by high temperature and heavy rainfall during kharif season (April to September) and scanty rainfall associated with moderately low temperature during the Rabi season (October to March). The overall relative humidity remains high almost all over the year except the winter.

Planting material: The planting material of the study was the seedling of Akashmoni (*Acacia auriculiformis*). The seedling of this species was planted in the border or ails or field bunds of rice field. The seedlings were collected from ‘Liton Nursery’. Polybag seedlings were collected and heights of the seedlings on an average were 1.5 feet. The seedlings were erect, free from disease infection and insect infestation.

Experimental design and layout: All planting materials were planted surrounding the rice field following Randomized Complete Block Design (RCBD) with 4 (four) replications. Total 100 meters of field boundary/ bunds/ ail were planted with *Acacia auriculiformis* seedling. 100 m field bund evenly divided as 4 (four) blocks and each block is treated as replication. In each replication total four different treatments were randomly distributed. Different spacing of plantation of *Acacia auriculiformis* was the treatments of this study. Total four different spacing were selected for the plantation of *Acacia auriculiformis* seedlings. These four different spacing was the treatments of this study and the different spacing was (i) Treatment 1 (T_1) = plant to plant distance 50 cm or 0.5 m. (ii) Treatment 2 (T_2) = plant to plant distance 75 cm or 0.75 m. (iii) Treatment 3 (T_3) = plant to plant distance 100 cm or 1 m. and (iv) Treatment 4 (T_4) = plant to plant distance 125 cm or 1.25 m. Number of planted seedling in each treatment = length of Bund ÷ spacing × replication. For example, in case of 50 cm spacing, total number seedling = 6.25 m ÷ 0.5 m × 4 = 50. Total number of seedlings which were planted in different treatments or spacing is shown in Table 1. In total 128 seedlings of *Acacia auriculiformis* were planted for this experiment.

Table 1. Number of seedlings in different spacing

Spacing/Treatments	Number of seedling planted
T_1 = 50 cm spacing	50
T_2 = 75 cm spacing	33
T_3 = 100 cm spacing	25
T_4 = 125 cm spacing	20
Total	**128**

Seedling transplantation: Total 128 seedlings of *Acacia auriculiformis* were transplanted in the field bunds of rice field. Before plantation a 1′×1′×1′ size pit was prepare for each seedling during the last week of July, 2010. After pit preparation well decomposed cowdung was mixed thoroughly and opened few days for sun dry. Then the pits ready for seedling transplantation and all seedlings are transplanted during the 15 September, 2010. After removing polybag of from soil ball was placed the centre of the pit and then pit was compactly fill up with soil. Necessary intercultural operations like gap filling, weeding, watering, fertilizing etc. were done when it was required. The growth of all seedlings of *Acacia auriculiformis* were observed for data regeneration.

Data collection: Related data were recorded from the different treatment of this study. The growth parameters of *Acacia auriculiformis* seedlings viz., Plant height (m), Stem base diameter (cm), Number of primary branches, number of secondary branches, length of primary branches, biomass yield of individual trees (kg), dry weight of biomass (kg) etc. were recorded. These parameters were observed after three months intervals upto one years from transplantation i.e., 90, 180, 270 and 360 days after planting (DAP). Biomas included phyllode, branches, main stem, and root of the tree. Estimating method of these parameters is as follows:

Plant height (cm): Plant height of all trees from different treatments was estimated in each period of data collection. It was measured in meter (m) from the ground level to the tip of main shoot.

Stem base diameter: Stem base also estimated from all trees different treatments during every time of data collection. It was measured in centimeter (cm) from six inch above the ground level.

Number of primary branch plant^{-1}: It was determine by counting the effective branch originating from main stem from selected plants. Length primary branches also measured in each data collecting period from branch base to tip in centimeter (cm).

Number of secondary branch plant^{-1}: It was also determine by counting the branches which arises from main the primary branch. It was counted from all primary bracnches of in each tree.

Biomass estimation: Biomass means the mass of both above and below ground parts of the tree. In this study biomass was estimated by weight basis (kg/plant) from the sample plants of *Acacia auriculiformis* after year of DAP. Total four plans per treatment i.e., each from per replication was uprooted and estimated separately. Weight of phyllode, branches, main stem and root were estimated and total of all these treated weight of whole plants.

Dry weight estimation: Dry weight of phyllode, branches, main stem and root was measured after complete drying the samples in the oven at 80°C. Representative part of the sample was drying in the oven and converted it per plant. Weight loss of different parts of study species during drying were measured using the equation, % weight loss = {(Fresh weight – dry weight) $\div$ fresh weight} × 100.

Total fresh and dry yield: Total fresh and dry yield of all *Acacia auriculiformis* trees was estimate from each treatment after one year of plantation. Total fresh yield one tree multiplied by number of trees in each treatment considered as total fresh yield of the treatment. From this total fresh yield dry yield was estimate by reducing average percent weight loss of each treatment.

Statistical analysis: The recorded data were compiled and analysed by RCBD design to find out the statistical significance of the experimental results. The means for all recorded data were calculated and the analyses of variance for all the characters were performed. The mean differences were evaluated by Duncan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984) and also by Least Significant Difference (LSD) test.

Results and Discussion

Growth parameters of *Acacia auriculiformis* at different spacing: Plant height, stem base diameter, number of primary and secondary branches and length of primary branches are the growth parameters which were observed for determining the effect of spacing or planting density for more fuel wood production by *Acacia auriculiformis.* Effect of planting density on the above parameters of this species is presented below:

Table 2. Effect of planting density on the growth parameters of *Acacia auriculiformis* at different DAP

Treatments/ Density	Plant height (m)				Stem base diameter (cm)				No. of primary branches				No. of seconadry branches				Average length of primary branches (m)			
	90 DAP	180 DAP	270 DAP	360 DAP	90 DAP	180 DAP	270 DAP	360 DAP	90 DAP	180 DAP	270 DAP	360 DAP	90 DAP	180 DAP	270 DAP	360 DAP	90 DAP	180 DAP	270 DAP	360 DAP
T1	1.20a	2.31a	2.82a	3.66a	5.12c	7.14d	9.23d	11.18d	3a	5a	8a	14a	6a	12d	15d	22d	0.21d	0.35d	0.53d	0.64d
T2	1.18a	2.22b	2.52b	3.23b	5.66b	8.41c	10.55c	13.68c	2b	4b	7b	12b	6a	15c	20c	26c	0.35c	0.41c	0.67c	0.85c
T3	1.17a	2.19b	2.41c	3.02c	5.75b	9.72b	12.18b	14.13b	2b	3c	6c	11c	6a	18b	22b	28b	0.45b	0.67b	0.89b	1.04b
T4	1.16a	1.81c	2.23d	2.77d	6.12a	10.46a	13.92a	16.26a	2b	3d	5d	7d	4b	19a	24a	30a	0.52a	0.78a	1.13a	1.28a

Means in column followed by the same letter are significantly different by DMRT at $p \leq 0.05$; T_1 = 50 cm, T_2 = 75 cm, T_3 = 100 cm and T_4 = 125 cm; DAP = Days after planting

Plant height: Plant height of *Acacia auriculiformis* seedlings were observed at every three months interval i.e., 90, 180, 270, 1nd 360 DAP (Table 2). It was found that during initial stage of establishment plant height of seedlings in all treatments were almost significantly similar but after six months i.e., 180 DAP plant height gradually decreased with increasing spacing of plantation. After one year of plantation highest plant height (3.66 m) was found in the 0.5 m spacing and lowest (2.77 m) was 1.25 m spacing. In all the period of data recoding plant height was highest in T_1 density i.e. dense spacing plant height was higher than sparse spacing. This may be due to the apical dominance of height growth. Apical dominance means maristematic tissue of shoot tip was rapidly divide and elongate which results higher plant height compare to lateral expansion or diameter growth. According to Hillman (1994) dense spacing encouraged higher apical dominance resulting taller plant under dense spacing. Besides the legume plant has a general tendency to grow taller in dense population or closer spacing, Shannan *et al.* (1971) observed this phenomenn in soybean. High population density enables plants longer and narrow canopy (Saxena, 1984).

Stem base diameter: Diameter growth results from dividation and elongation of stem lateral meristem. Diameter growth of *Acacia auriculiformis* trees was significantly influenced by different plant spacing (Table 2). Reverse relationship was found between height and diameter growth from this study. In this study it was found that stem base was higher in widely transplanted *Acacia auriculiformis* trees compare to closely planted plants. Stem base diameter of 1.25 m spacing planted trees during 90, 180, 270 and 360 DAP were 6.12, 10.46, 13.92 and 16.26 cm, respectively (Table 2). These were the highest stem diameter which was gradually decreased following a similar trend with decreasing spacing of plantation. Lowest stem diameter was found at each period of data collection in closely (0.5 m) planted seedlings which were 5.12, 7.14, 9.23 and 11.18 cm, respectively, during 90, 180, 270 and 360 DAP. The may be due to more activation lateral maristematic tissue of stem. It was observed by Hillman (1994) that 'lateral meristem of stem was more active in case of wide distantly planted trees compare to close plantation'. Similar results were reported by Hong (1989) during study on soybean and he observed that stem diameter increased with increasing plant density.

Number of branch/plant: Number of branch/plant of *acacia auriculiformis* was significantly influenced by plant density (Table 2). It was recorded from this study both primary and secondary branch initiation from stem largely depends on planting density. Upto 90 DAP, variation was not remarkable but after six months i.e., 180 DAP it was remarkable and it was observed that 'number of primary branches were highest in closely planted trees and number secondary branches were highest in widely planted trees. After six months, number of primary branch per plant gradually decreased and number of secondary branch per plant gradually increased with increasing planting density'. Number of both branches was also increasing with increasing age of trees in all density of plantation. Highest (14) number of primary branch was in 0.5 m distant plants and lowest (7) in 1.25 m distant plants after 1 year of plantation. Highest (30) number of secondary branch was in 1.25 m distant plants and lowest (22) in 0.5 m distant plants after 1 year of plantation. Though the number of primary branch was lower in widely distant plants but these were more vigorous and long compare to closely distant plants. Due to vigorousness primary branches arises from widely distant plant produce more secondary branches compare to closely planted trees. The reason of this phenomenon may be apical dominance in densely plantation which enhances production of branches from every internode of stem but due to severe competition for light, moisture and nutrients the branches were less vigorous compare to wide distant plantation. This phenomenon supported by Hillman (1994) in his apical dominance study and Najafi *et al.* (1997) in their study on soybean.

Length of primary branch: Length of primary branch of Akashmoni tree was effectively influenced by plantation density. It was gradually increased in increasing spacing of plantation in every period of data collection i.e, 90, 180, 270 and 360 DAP (Table 2). Obviously length of primary branches will increase with increasing age upto a certain period. After one year, longest (1.28 m) primary branch was in 1.25 distant plant and shortest (0.64 m) was in 0.5 m distant plant. The reason of this may be availability of growth resources (Light, water and nutrients) in widely distant plantation compare to closer one.

Effect of planting density on biomass yield per plant of *Acacia auriculiformis*: Biomass yield means yield of both above and below ground parts of any plants. In this study biomass yield of *Acacia auriculiformis* was greatly influenced by plantation density (Table 3). After one year of *Acacia auriculiformis* plantation, it was found that above ground parts i.e., phyllode, branch, stem etc. and below ground parts (root) produced higher biomass in widely planted trees individually. Highest amount of phyllode, branch, stem and root per plant were 1.02, 1.65, 2.23 and 1.55 kg, respectively, in widely (1.25 m) planted trees. The amount of these parameters gradually decreased with decreasing planting spacing. Lowest amount of phyllode, branch, stem and root per plant were 0.45, 0.94, 1.25 and 0.87 kg, respectively, in closely (0.5 m) planted trees. Considering these entire parameters (phyllode, branch, stem and root) total biomass yield also highest (6.45 kg/plant) in widely planted trees and lowest (3.51 kg/plant) in closely planted trees. Widely planted trees enjoy more space which encourages wide spread shoot and root development. Wide spacing also ensures more interception of PAR (Photosynthetically Active Radiation) which results more assimilates by photosynthesis. More assimilates required for producing more biomass in the plants considering all parameters (Leaf, stem, branch, root, flower, fruit etc., (Dwivedi 1992).

Table 3. Effect of Density on the biomass yield of *Acacia auriculiformis* after 1 year

Treatments / Density	Biomas yield (kg/plant)				
	Phyllode	Branch	Main stem	Root	Total
T1	0.45c	0.94c	1.25d	0.87d	3.51d
T2	0.84b	1.45b	1.76c	1.29c	5.34c
T3	0.85b	1.51b	1.85c	1.32b	5.53b
T4	1.02a	1.65a	2.23a	1.55a	6.45a

Means in column followed by the same letter are significantly different by DMRT at $p \leq 0.05$; T1 = 50 cm, T2 = 75 cm, T3 = 100 cm and T4 = 125 cm

Effect of planting density on weight loss during drying of biomass: Moisture content within the plants depends upon different factors viz. moisture availability in the soil, rainfall, plant morphology, air temperature and humidity, sunshine etc. In this study it was observed that plant density also significantly influenced the moisture availability within the different plant parts (Table 4). During drying of different parts of *Acacia auriculiformis* was loss different amount of weight as moisture or water. Irrespective of all parameters highest amount of weight or moisture lost in wide (1.25 m) spacing or sparsely planted *Acacia auriculiformis* trees and gradually decreased with decreasing spacing distance. Highest 55, 41, 39 and 37% weight or moisture was lost in 1.25 m spacing and lowest 36, 26, 23 and 20% lost 0.5m spacing by phyllode, branch, main stem and root, respectively. Average weight lost during drying by different parts of *Acacia auriculiformis* trees in T1, T2, T3 and T4 treatments was 26.25, 32.25, 36.25 and 43%, respectively (Table 4). From these results it is clear that moisture content by different parts of *Acacia* *auriculiformis* was higher in sparsely planted trees. Wide spacing ensure more water absorption by exploring more area, this may be one reason for more moisture content in wide spacing plants. Trung and Yoshida (1985) found increased dry matter production with increasing plant density of pea. More water lost by phyllode followed by branch, stem and root in all treatments of this study. It may be due to more compactness and fiber content by different plant parts as order of root > stem >branch >phyllode. This phenomenon also support by Sheldrake and Narayanan (1979) by their observation in different parts of pigeonpea.

Table 4. Effect of density on the weight lossing during drying of *Acacia auriculiformis* biomass

Treatments/ Density	Weight loss during drying (%)				
	Phyllode	Branch	Main stem	Root	Average
T1	36c	26d	23d	20c	26.25d
T2	41b	34c	29c	25bc	32.25c
T3	45ab	39b	33b	28b	36.25b
T4	55a	41a	39a	37a	43a

Means in column followed by the same letter are significantly different by DMRT at $p \leq 0.05$; T1 = 50 cm, T2 = 75 cm, T3 = 100 cm and T4 = 125 cm

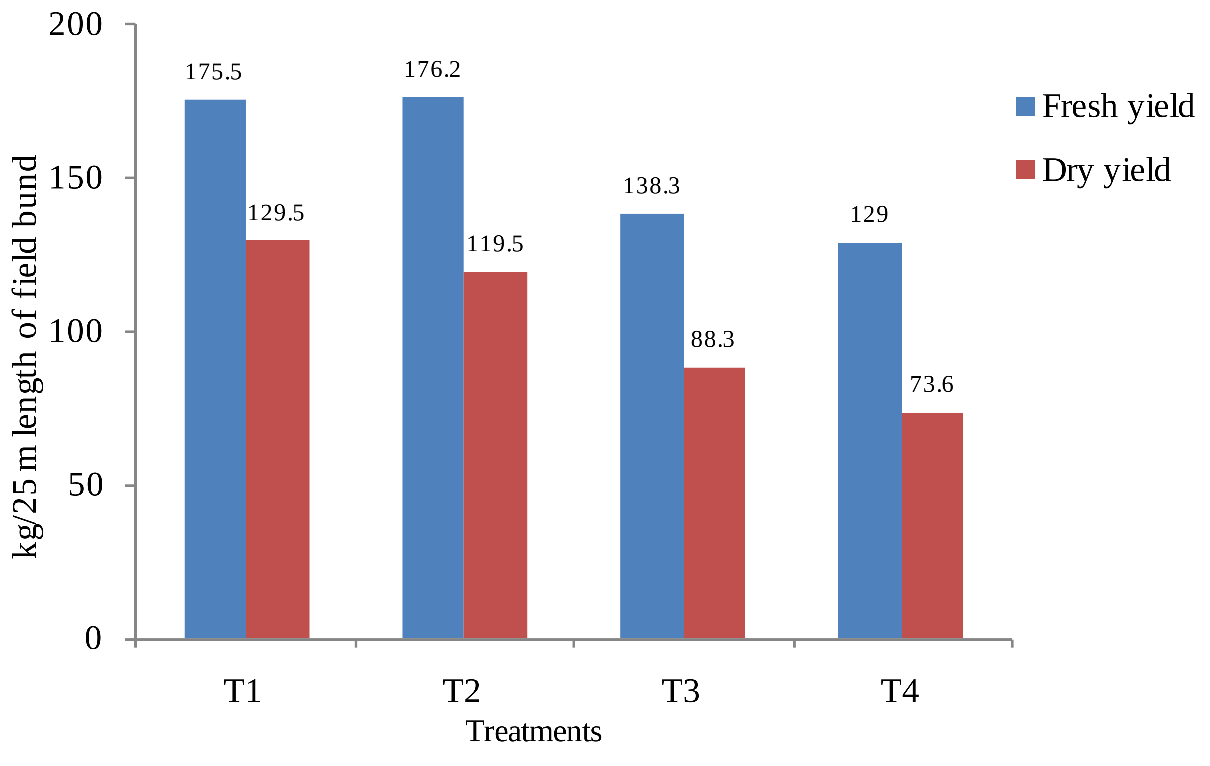

Fig. 1. Total fresh and dry yield of *Acacia auriculiformis* at different spacing on 25m field bund

Total fresh and dry yield of *Acacia auriculiformis* at different spacing: Total yield means yield from 25m long field bund in all treatments. Total 50, 33, 25 and 20 seedling were planted in 0.5m, 0.75m, 1m and 1.25 m spacing of each 25m long field bund plantation of this study (Table 1). Total fresh and dry yield of *Acacia auriculiformis* was significantly similar in 0.5 and 0.75 m distantly planted trees. Highest fresh yield (176.2 kg/ 25m length of field bund) was obtained from 0.75m distant plant of *Acacia auriculiformis* followed by 0.5m, 1m and 1.25m distant plant and yield was 175.5, 138.3 and 129 kg/ 25m length of field bund, respectively (Fig. 1). Almost similarly highest dry yield (129.5 kg/ 25m length of field bund) was obtained from 0.5m distant plant of *Acacia auriculiformis* followed by 0.75m, 1m and 1.25m distant plant and yield was 119.5, 88.3 and 73.6 kg/ 25m length of field bund, respectively. From this result it is clear that total yield was higher in 0.75m spacing maintaining plantation which is statistically similar with 0.5m spacing. Though total yield almost similar in 0.5m and 0.75m spacing but 0.75m spacing would be better option for getting more PAR interception as well as to minimize competition between tree and crops.

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