

Sorghum Yield Under the Canopies of *Faidherbia Albida* (Delile) *A.Chev* and *Cordia africana Lam* Parkland Trees in Fedis District, Eastern Ethiopia

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Abstract— Among several agroforestry practices in the east Hararghe of Ethiopia, Parkland agroforestry practices are common. However, the effect of tree species on the grain yield and above ground biomass of Sorghum has not scientifically quantified in the study area. Therefore, the study was conducted to investigating the effect of parkland trees on the grain yield and above ground biomass of Sorghum at Fedis District, Oromia, Ethiopia. Six isolated and nearly similar *F. albida* and *C. africana* trees of each species growing on similar site conditions were selected and the canopy coverage of each tree was divided into four radial transects. Three plots from the tree trunk were established for assessing the sorghum yields and above ground biomass. Sorghum yield and biomass samples from three horizontal distances: 2.5m, 5.0m and 25m were collected for analysis of Sorghum yield and biomass. The result revealed that sorghum grain yield were significantly ($p < 0.05$) higher under the tree canopies than open field that means its higher by 2089.51 and 1789.53 kg /ha under *F. albida* and *C. africana* respectively at the distance of 2.5m and these values decreased to 1459.40 and 1266.01 kg /ha under *F. albida* and *C. africana* respectively, at the distance of 25m. The mean biomass recorded at three different distances from the two tree trunks, were not differently significant statistically ($p > 0.05$). The research finding showed that trees have positive relation with grain yield and above ground biomass of sorghum. Hence, the growing of *Faidherbia albida* and *Cordia africana* trees on small holder farms improve crop productivity for improvement of this Parkland agroforestry system.

Keywords— Fedis District, Parkland Agroforestry, Canopy cover, sorghum yield, open field.

I. INTRODUCTION

Climate change, soil erosion, unsustainable farming practices, excessive tillage, overgrazing and deforestation including loss of biodiversity, have led to severe land degradation and desertification Leakey *et. al.* [8]. Poverty levels and population growth rates of Ethiopia (more than 3% per annum) are high, the later exceeding the annual food production growth rates which stand at 2% per annum. The majority of the population (85%) practice subsistence agriculture Hiernaux and Turner, [5] and the dominant land use system and the main provider of food, nutrition, income, and environmental services is the traditional parkland system (integrated crop-tree-livestock systems). Through either farmers managed natural regeneration of trees (FMNR) or active planting, a massive-scale adoption of trees on farmlands can play an important role to enhance tree diversity and cover- at landscape level. Then potentially contribute to enhancing food security of resource poor smallholders through the provision of ecosystem goods and service.

The definition of agroforestry used by ICRAF Leakey, [7] is: “a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits. In addition, parkland trees and shrubs provide firewood and construction materials, and a range of services such as shade for humans and animals, wind protection and aesthetic and spiritual value. Retaining of mature trees on the farmlands is a common practice in most African countries. Thirty-nine percent of African farmland is under 10% or greater tree cover, benefitting more than 100 million people Zomeret *al.*, [15]. Increased tree diversity at landscape level potentially contributes to enhancing food security of resource-poor smallholders through the provision of ecosystem goods and service. Therefore, the study was initiated the to investigate the effects of *F.albida* and *C.africana* trees on the grain yield and above ground biomass of Sorghum under and outside of the canopy to evaluate the grain yield of sorghum and above ground biomass under the canopies of trees species and compared to open field in Fedis district.

II. MATERIAL AND METHODS

2.1 Description of the Study Areas

The study was conducted in Fedis district of East Hararghe Zone, Oromia National Regional State; Ethiopia. It is located in the eastern part of the country at 550 km from Addis Ababa the capital city of Ethiopia and 24 km from Harar town in the southern direction (Figure 1). The geographical location of the district is 8° 22' 00" and 9° 14' 00" N and 42° 62' 00" and 42° 19' 00" E. The altitude of the area ranges from 500-2100 meter above sea level (FWANRDO, 2017/18).

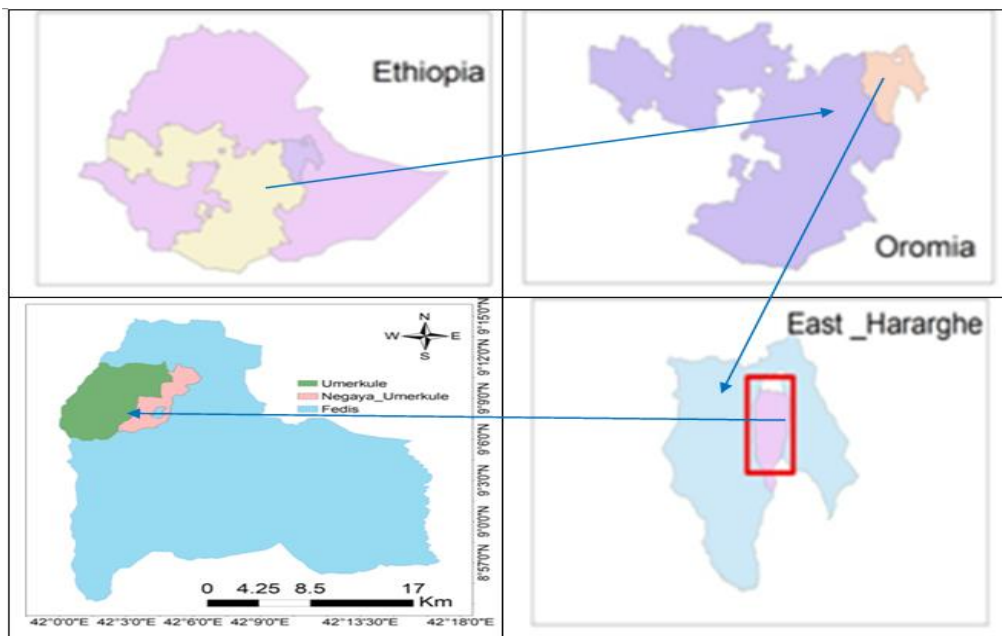


FIGURE 1: Location map of the study area

2.1.1 Climate and rain fall

According to FWANRDO (2017/18) report, the district has two basic agro-climatic conditions, namely Midland (39%), and lowland (61%). The district experience mean annual maximum and minimum rainfall, mean annual maximum and minimum temperature in the area were 850 to 650 mm, 30.4°C, and 10.0°C, respectively. Accordingly, the district has a bimodal rainfall distribution pattern with heavy rains from April to June and long and erratic rains from August to October.

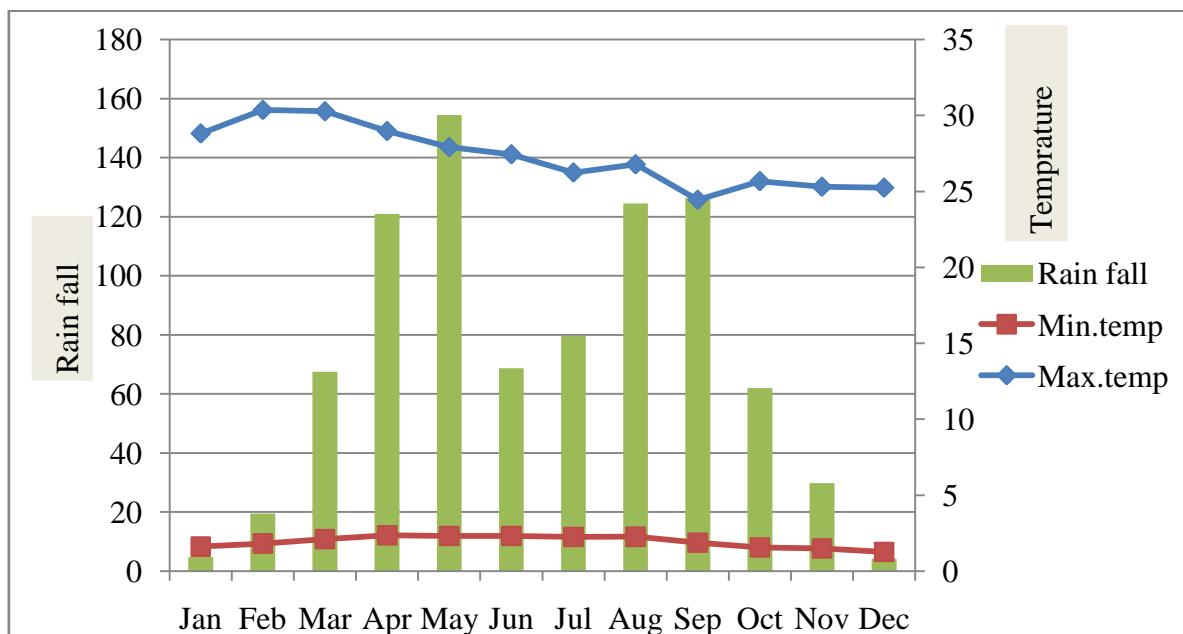


FIGURE 2: Rain fall and Temperature data of Fedis District, 2018 GC

2.1.2 Topography and land use

Topographic feature of the study area is 70% plain area, 28% plateau and 2% mountain or hill. Cultivable land/cropland (21.02%), pasture (2.80%), forest (11.2%), grass land (38.01%), communal land (10.5%) and remaining (14.04%) is considered as mountainous, valley and otherwise unusable (FWANRDO, 2017/18).

2.1.3 Soil and vegetation

The soil of the study area was dominantly sand clay loam soils (moderately fine texture). The area of the district covered by forest, bushes and shrubs is 42,954 ha (FWANRDO, 2011). Fedis district has few patches of natural vegetation cover and some of the area is occupied by plantation forests and farmers incorporating trees on farmlands, boundary plantings, trees in croplands and woodlots agroforestry etc. The most dominant tree species found in the area include; acacia species, *Croton macrostachyus*, *Cordia africana*, *Fedhrbia albida*, *Eucalyptus camaldulences*, and many others (FWANRDO, 2011).

2.1.4 Agricultural activities

Agriculture in the district is characterized by small-scale subsistence mixed farming-system with livestock production as an integral part. The livelihood of the Fedis district is highly associated with agricultural activities for the fulfillment of household needs. Farmers are growing trees and /or shrubs in the agricultural landscape and also crop production is a leading economic activity of the area. Crop production is mainly rain-fed, practically all annual crops produced by this way for household consumption. Cereal crops including maize (*Zea mays* L.), sorghum (*Sorghum bicolor*), and haricot beans (*Phaseolus vulgaris*) are grown on the study area. Haricot bean (*Phaseolus vulgaris*) is growing as an intercrop with maize and sorghum crops in the study area. A cash crop such as *Chat* (*Catha edulis*) is also grown predominantly in the study area. In addition to these different fruits, vegetables, cereal crops, and tuber crops are the most common agricultural products of the study area (FWANRDO, 2017/18).

2.1.5 Tree management practices

There are certain management techniques which are applied to trees in park land agroforestry systems in the study area by some farmers. According to their respond there are two types of pruning i.e. Removal of branches from the lower part of the tree crown which is known as side pruning and pruning of a tree branches near the stem. Side pruning is specially used for young trees, in order to improve their growth. As they said, at least two or three layers of the green branches of young trees should remain uncut. For mature trees they cut the branches near the stem for the reduction of shade for crops near the tree. Sometimes Farmer of the study area uses pollarding for fodder that is out of the reach of livestock. There are also some farmers who remove trees from their farm land completely in order to insure suitable for machine harvesting technique. In general their objectives of pruning are to reduce shading effect of the tree and early harvest of branch for fencing or fuel wood. They also said good time for pruning is towards the start of rain season for fencing their farm land when the work will not interfere with growing crops and when the workload in other agriculture tasks is not so heavy.

2.2 Sampling Design and Methods of Data Collection

2.2.1 Tree sample selection

The study was carried out on farmers' field in Fedis District, East Hararghe Zone of Oromia Regional State to compare the sorghum yield performance under traditionally retained parkland *F. albida* and *C. africana* trees against the open field outside the canopy cover. *F. albida* and *C. africana* trees being the most abundant scattered tree species on crop fields were selected for this study. The selected farm fields with this tree species are characterized by a gentle slope where sorghum and maize are staple food crops of the area. Relatively homogenous site conditions in terms of aspect and topography and growth of the trees were also considered in the selection of the trees of each species. Farmers of the study area rarely apply inorganic fertilizers to their farmlands. The farmers used manual land preparation methods like hand hoeing and oxen to cultivate the sampled farm fields. The sampled trees had also more or less similar management history. On the selected field, individual trees of *F. albida* and *C. africana* having approximately similar height, diameter at breast height (DBH), crown diameter and from uniform site condition were marked to make other soil forming factors nearly constant. Of all the marked trees, six individuals of *F. albida* and *C. africana* trees were systematically selected for this study, their DBH, height and crown diameter was measured by using caliper, hypsometer and meter tape, respectively. Each tree species was replicated six times. The dimension of each replication was almost uniform with the average DBH, height, and crown radius of 27.5 cm, 10.67 m and 4.65 m for *F. albida*, respectively. Similarly, for *C. africana* the average DBH, height and crown radius were 31.83 cm, 12 m and 5.49 m respectively.

2.2.2 Treatments and experimental design

There were two factors involved in this study: distance from the tree trunk and tree species were involved. The distance factor had three different treatment levels; at half of the canopy radius under the tree, canopy edge (radius of the canopy) and at three times canopy radius away from the trunk outside the canopy as control following the procedure by Jiregna *et al.*, (2005). The tree species factors involved two tree species; *F.albida* and *C. africana* trees that are traditionally grown commonly on croplands were selected independently in the study area. The design employed had 3*2 factorial arrangements of treatments in randomized complete block design (RCBD) replicated six times, totaling 3*2*6 =36 total sample units or sample size for sorghum yield were used in this study.

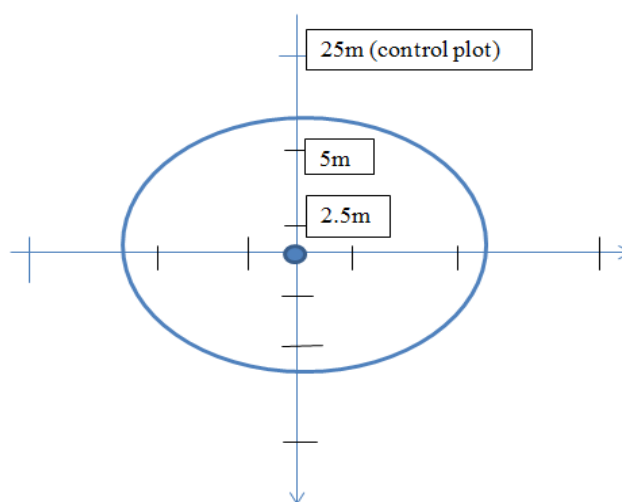


FIGURE 3: Experimental design of the sampling in the field work.

2.2.3 Grain yield data collection

Three plots of 1 m*1 m was laid at mid canopy radius, at edge canopy radius and open field in four compass directions (North, South, East and West) under selected trees on the existing sorghum farm field for assessing the sorghum yield on the farmer managed farm field. Sorghum was harvested from each plot. The harvested sorghum from the same radial distance was composited for each replication. The grain yield of sorghum was harvested and weighed after drying. Grain yield of sorghum were measured in each plots. Threshing of sorghum were done manually, cleaned and weighed and the grain yield obtained was reported as kg /ha.

2.2.4 Statistical Analysis

Randomized complete block design (RCBD) with two ways (ANOVA) were carried out to statistically compare the difference among treatments using SAS computer soft ware SAS Institute (1996). Statistical differences were tested using the least significant difference (at 0.05%).

III. RESULTS AND DISCUSSION

3.1 Grain yield and biomass

The analysis of variance of the study showed that the grain yields of sorghum and biomass were significantly different ($P < 0.05$) due to the effects of tree species and distance from the tree trunk. The grain yield of sorghum was decreased significantly and gradually as the distance from the trees trunk increased (table 1). The Highest values of sorghum grain yield were 2089.51 and 1789.53 kg ha⁻¹ under *F.albida* and *C. africana* trees respectively at the distance of 2.50 m away from the tree trunks and these values decreased to 1459.40 and 1266.01 kg ha⁻¹ under *F.albida* and *C. africana* respectively, at the distance of 25.0 m away from the tree trunks. The biomass also under both trees species were decreased as distance from the tree trunk increases (table 1). The increase in grain yield under the trees could be due to improvement of soil properties under the tree canopies than the open fields. Soils under tree canopies were better than the outside due to higher accumulation of soil organic matter, nutrient cycling and nitrogen fixation by tree species, especially *F.albida* and *C. africana*. Abebe [1] reported increased grain yield of sorghum and haricot bean under the canopy of *F.albida*, *C. africana* and *C. macrostachyus* trees as compared to the open cultivated land on Harergie high land.

TABLE 1

EFFECT OF TREE SPECIES AND DISTANCE FROM TREES ON GRAIN YIELD AND BIOMASS OF SORGHUM AT FEDIS DISTRICT

Distance (m)	<i>Faidherbia albida</i>		<i>Cordia africana</i>	
	Grain yield kg/ha	Biomass kg/ha	Grain yield kg/ha	Biomass kg/ha
2.5	2089.51 ^a	2860.00	1789.53 ^b	2360.00 ^a
5.0	1805.02 ^b	2831.50	1559.22 ^c	2245.30 ^a
25	1459.40 ^c	2808.61	1266.01 ^d	1837.20 ^b
CV	9.56	14.10	9.56	14.10
LSD (0.05)	109.31	NS	109.31	322.19

*Means with the same letter are not significantly different at ($P < 0.05$)

The combined analysis of variance of the study showed that grain yield of sorghum were significantly different ($p < 0.05$) due to distance from the tree trunk and tree species. Similarly there were a significant difference of overall means between the two tree species ($p < 0.05$). The Highest values of sorghum grain yield were 2022.17 kg/ha under *F. albida* and *C. africana* at distance of 2.50 m away from the tree trunks and these values decreased to 1354.40 kg/ha under *F. albida* and *C. africana* at the distance of 25.00 m away from the tree trunks. The finding indicated that, crop grown under the canopy of *F. albida* and *C. africana* obtained more advantage compared to the open field i.e. at distance 25.00 m from tree trunk. The mean variation at three distances might be come from modification of microclimate and soil physical and chemical properties by the trees species (Table 1).

Trees influence microclimate and soil property through organic matter accumulation and canopy produced shade which reduced evaporation from the soil surface and modifies air temperature extreme. Kho et al. [7] reported the same result and colleagues reported a 36% increase in dry matter production of pearl millet (*Pennisetum glaucum*) under tree canopies compared to open crop-only plots. This result suggested that the effect of *F. albida* on crop production is more pronounced in conditions of low soil fertility Sileshi [13] as nutrients are less limiting to crops at greater fertility levels. These yield increases under *F. albida* (often referred to as the 'albida effect') are attributed to the combined effects of improved soil fertility, soil water and microclimate. Trees can improve water holding capacity of soil, organic matter through addition of litter fall and root decay, reduce evaporation from the soil surface under the canopy, nutrient cycling and nitrogen fixation Buresh and Tian, [3]. These factors could boost grain yield and biomass production of sorghum under the canopy of the two species, since they advance contents of the indicated factors in the soil. Because of the fertility and moisture content under the canopies of both trees were better than that of out of canopy, the mean grain yield under the canopies were greater than the open cultivated land. Victor sh. [14] done research on yields of maize from plots under canopies of *F. albida* trees were significantly ($p < 0.05$) higher than those from plots outside the canopies.

TABLE 2

EFFECT OF *F. ALBIDA* AND *C. AFRICANA* TREES ON GRAIN YIELD AND BIOMASS OF SORGHUM

Effects		Grain yield and Biomass	
Distance (m)		Grain yield kg/ha	Biomass kg/ha
2.5		2022.17 ^a	3818.21
5.0		1659.59 ^b	3530.20
25		1354.40 ^c	3281.03
CV		10.39	8.93
LSD (0.05)		103.9	NS
Tree species			
<i>F. albida</i>		1803.33 ^a	3125.72 ^a
<i>C. africana</i>		1555.14 ^b	2679.19 ^b
LSD (0.05)		8.48	6.70
Distance x Tree species			
2.5 m	<i>F. albida</i>	2055.02	3928.20
	<i>C. africana</i>	1889.12	3618.12
5.0 m	<i>F. albida</i>	1810.40	3408.02
	<i>C. africana</i>	1508.22	3418.33
25 m	<i>F. albida</i>	1443.14	3328.67
	<i>C. africana</i>	1266.23	3218.44
LSD (0.05)		NS	NS

* Means with the same letter are not significantly different at ($P < 0.05$)

The mean under the two species was significant from each other; the mean under *F.albida* was greater than that of grown under *C. africana*, which could be as result of phonological characteristics of the tree species. *F.albida* shades its leaves during crop growing season, which allows more lights for photosynthesis reaction. Therefore, crops grown under *F.albida* gets more advantages compared to those crops grown under *C. africana*. The mean biomass recorded at three different distances from the two tree trunk, was not differently significant statistically ($p > 0.05$) (table 2). In general, the result of analysis indicated that, decreasing pattern of mean biomass as distance from tree trunk increases, for both *F. albida* and *C. africana*. The mean values of biomass under canopy was 3818.21 kg/ha and decreased to 3281.03 kg/ha in open field. There were significant variation of biomass between tree species ($p < 0.05$). The mean biomass obtained under *F. albida* was greater than that of mean biomass obtained under *C. africana* (3125.72 kg/ha and 2679.19 kg/ha respectively), which could be due to deference in the level of light incidence under the two trees and variation in soil fertility emanating from organic litter decomposition and subsequent nutrient release under the canopies of the species. The case of variation among distance from tree trunk was alike to that of the grain yield stated above i.e. fertility gradient cause for biomass difference was created by the role played by *F. albida* and *C. africana* on the soil under its canopy. Trees affect soil properties through several pathways Buresh and Tian [3]; Rhoades, [11]. Thus, higher biomass obtained under the canopy of *F. albida* and *C. africana* as compared to on field one.

IV. CONCLUSIONS AND RECOMMENDATIONS

The study has been done on the effect of *F. albida* and *C. africana* on yield and biomass of sorghum grown under canopies of both trees in Fedis District, East Hararghe, Oromia. As a result of significant difference in nutrient available between under canopy and open plot grain yield was greater under the canopy. According to combined analysis both trees showed significant effect on grain yield and biomass of sorghum grown under canopies compared to that grown out of canopies of both trees. The higher mean of grain yield and biomass were observed under canopies than that grown on open field, which could be as result of additional nutrients, through litter fall, root turnover and exudates, and n-fixation. Parkland agroforestry system is very important in soil fertility management especially for poor farmers in order to boost their productivity.

Retaining these tree species and in particularly *F. albida* on farms in the study area is of paramount importance for soil fertility enhancement so as to improve food security of small farming households. Based on the findings the following recommendations are forwarded. (1). Further research should be required on *F. albida* and *C. africana* trees on appropriate component management practices and the number of trees retaining per hectare associated crop productivity. (2) .In addition to their role in maintaining soil fertility, these two species provides various products and services to the farmers. Thus, the continued use of these species in the agricultural setting of Fedis district and other areas in the eastern Hararghe area to maintaining soil fertility and provide services to the farmers.(3) .The result of grain yield and biomass of sorghum reported in this study was from under farmer's management practice. So, further study is needed under controlled experiment in association with these trees.

ACKNOWLEDGEMENTS

The authors are thankful to the staff of Agroforestry Research Team of Fadis Agriculture Research Center for data collection and for provision of the necessary facilities for research work and Oromia Agricultural Research Institution for its financial support.

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