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Wheat Yields Under the Canopies of *Faidherbiaalbida* (Delile) A. Chev and *Acacia tortilis* (Forssk.) Hayenin Park Land Agroforestry System in Central Rift Valley, Ethiopia

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Abstract: The study was conducted to evaluate the effect of Faidherbiaalbida and Acatiatortilis on the grain yield and above ground biomass of wheat. Parkland agroforestry system is, type of agroforestry where trees are deliberately retained on the crop land to improve soil fertility. Farm land of the study area is characterized by parkland agroforestry system. Farmers have different idea about the trees retained on their farm, some of them think that, these trees can help us for farm tools and fencing material while; others retained trees on the crop land for the purpose of fertility substitution. Therefore, the study was conducted to identify the effect of both trees on wheat growth. The study was conducted in central rift valley of Ethiopia, Oromia regional state, East shoa, at Langano and Tukakebeles in farm fields of Bora District where, both trees aretraditionally retained on the farm. At each site, four *F. albida* and four *A.tortilis* trees were purposively selected and wheat sample collected from four directions at three distances (1.35, 3.35 and 26.35 m) from tree trunk for both gain yield and above ground bio mass. Collected data was analyzed by two way ANOVA and mean separation with LSD (%). The Highest values of wheat grain yield were 73.33 and 68.85 kg ha-1 under *F. albida* and *A.tortilis* respectively at the distance of 1.35 m away from the6yuh tree trunks at Tuka location and these values decreased to 55.36 and 67.36 kg ha-1 under *F. albida and A.tortilis* respectively, at the distance of 26.35 m away from the tree trunks. The mean biomass recorded at three different distances from the two tree trunks, were not differently significant statistically ($p > 0.05$). In general, the result of analysis indicated that, decreasing pattern of mean biomass as distance from tree trunk increases, for both *Faidherbiaalbida* and *Acacia tortilis*. The research finding showed that trees have positive relation with grain yield and above ground biomass of wheat. So, farmer's knowledge improvement and further research regarding tree age class should be conducted for improvement of this agroforestry system.

Keywords: Parkland Agroforestry, Canopy Position, Wheat Performance

1. 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 Zomer*et 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

2. Material and Methods

2.1. Description of the Study Area

2.1.1. Location

The study site is located in Dugdadistrict, East Shewa Zone, Oromia Regional State in Central Rift Valley of Ethiopia in geographical location between 8° 6'30"N - 8° 25'30 N" and 38°45'0" E - 39°4'0" E and 110 km south east of, Addis Ababa, capital city of Ethiopia. The altitude of this district ranges from 1600 to 2020 meters above sea level. The administrative center of Bora District is Alemtena.

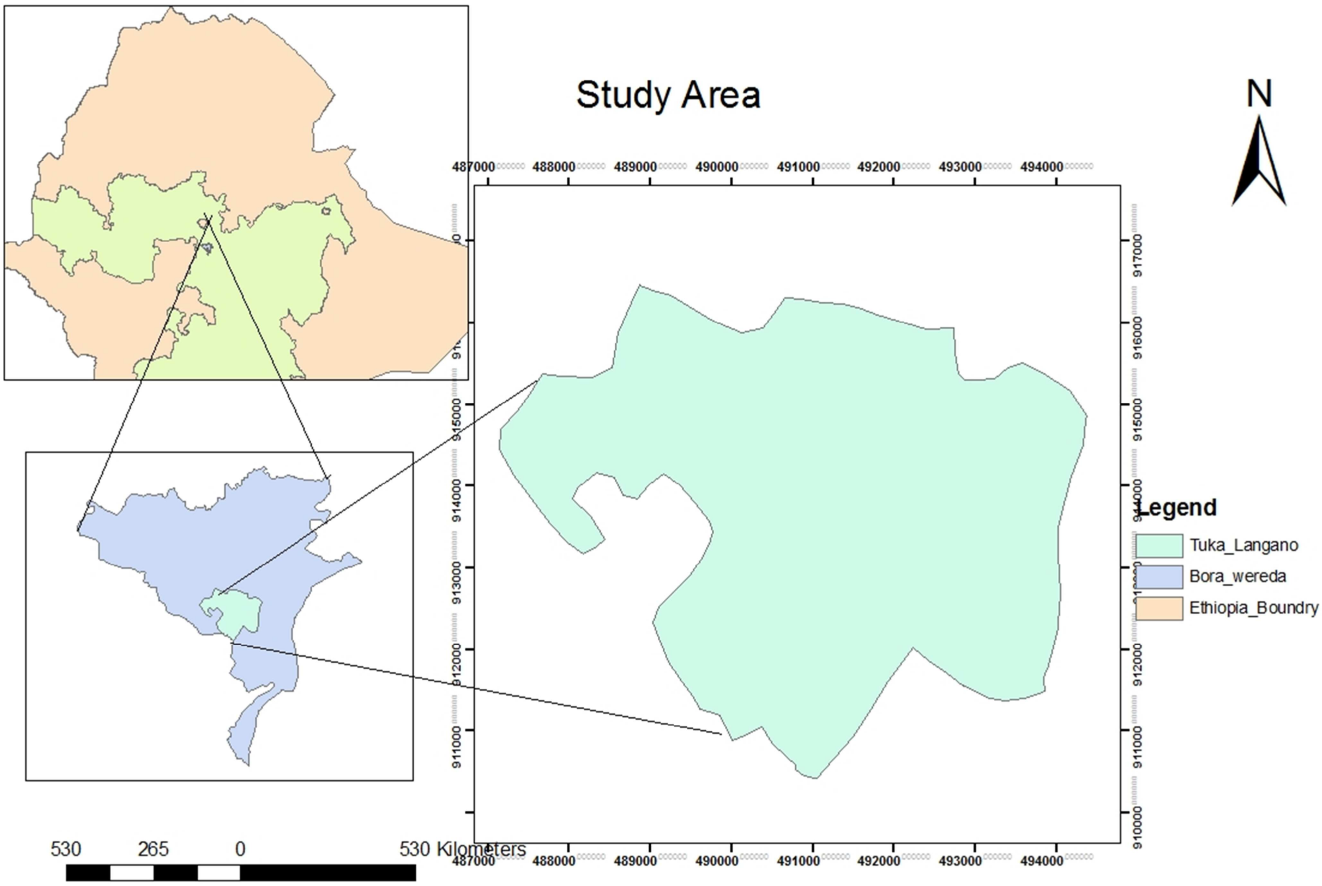

Figure 1. *Location map of the study area (Google Earth).*

2.1.2. Climate

The area falls within the semi-arid climatic zone, and according to the agro climatic zonation in Ethiopia, it is classified as "Dry WeynaDega". The mean annual rainfall, mean annual maximum and minimum temperature of the area over the past 20 years were 724.62 mm, 27.71 °C, and 14.25 °C, respectively.

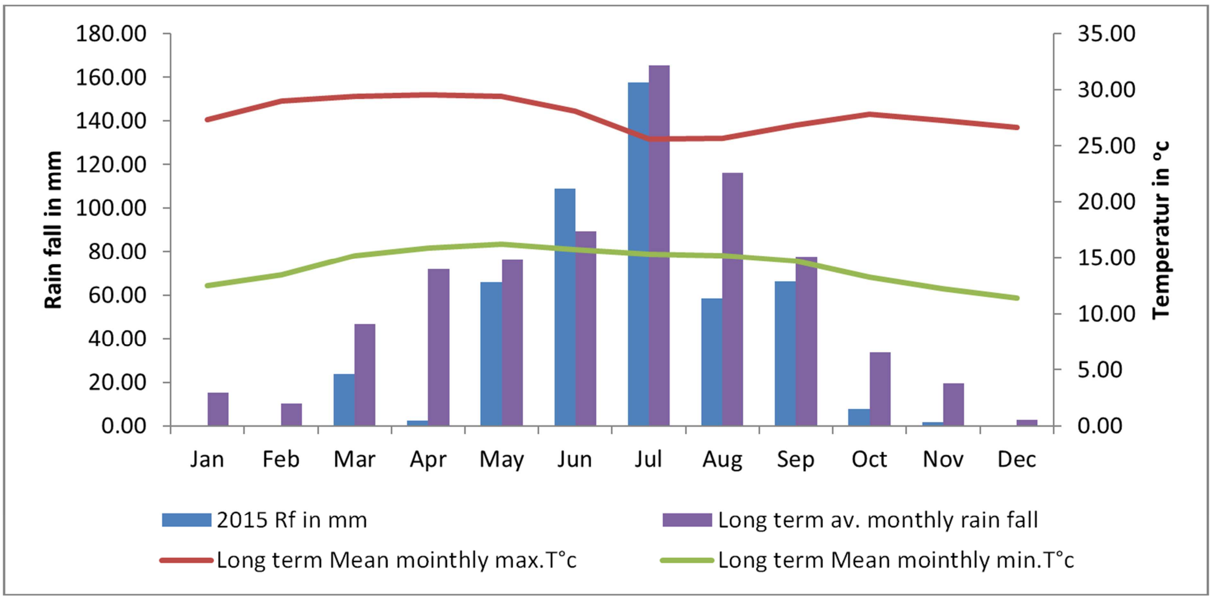

Figure 2. *(1994-2015) average monthly Rf in mm, 2015 Rf in mm and average monthly max. and min. Temperature in ° C (Zuway metrology station).*

2.1.3. Geology and Soil of the Study Area

The study site is situated in Ethiopia's rift valley where the geology is dominated by basalt, ignimbrite, lava, volcanic ash, pumice, reverie and lacustrine alluvium that gives rise to pale color, coarse textured and freely drained light soils. The soil was developed from lake deposits inter-bedded with pumice and classified as Andosols Makin *et al.* [9].

2.1.4. Land Use

Agricultural practices are mix of farming with rain-fed cultivation (mainly of Wheat) and cattle rearing for subsistence. A survey of the land in this district showed that 36.9% is arable or cultivable, 8.7% pasture, 9.6% forest, 0.4% swampy and the remaining 44.3% is considered degraded or otherwise unusable for crop production. Cultivated land is mostly located in the valley floor and major field crops are teff, barley, maize, lentils, horse beans, chickpeas and field peas. Most important vegetables that grown under irrigation were include haricot beans, tomato, onion and cabbage Moti Jaleta, [10]. Fruits and vegetables are important cash crops in the area. Due to the erratic nature of rainfall and poor fertility of the soils, agricultural production is very low Eshete, [4]. According to the District Agricultural Office, livestock including, cow, sheep, goat, horse, mule, donkey, and chicken are important in the agricultural production system as they provide expensive and easily accessible inputs required for crop production and power for ploughing and threshing. The crop production around the study site is rain-fed agriculture with dominant crops being wheat, Haricot bean, and *teff*. Agricultural practices such as fertilization, cow ploughing, and pesticide and herbicide application are common around the study site. The use of multi-purpose agroforestry park lands, for different purpose is also a common practice.

2.1.5. Tree Management Practice in the Study Area

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 steam 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 Data Collection

2.2.1. Selection of Agroforestry Trees and Treatment

Faidherbia albida and *Acacia tortilis* trees that are traditionally grown on croplands were selected independently for the study. Four scattered trees of *F.albida* and four *A.tortilis* growing on similar site condition at Tuka i.e. eight (8) trees at one location and total of sixteen (16) at both location were selected. Each trees replicated four times at both location. The selection of trees for each species was based on the similarity of their canopy cover, diameter, height, and age. The diameter at breast height of *Faidherbia albida* and *Acacia tortilis* was taken by measuring with caliper from two directions and its average was used as tree diameter. Average diameter of eight *Faidherbia albida* and *Acacia tortilis* was 43.31 cm and 47.71 cm respectively. Since canopy area is not perfect circle, the four direction radius from the tree trunks depending on the shape of canopy was measured and the average of the four radiuses $(r_1+r_2+r_3+r_4/4)$ was taken to calculate canopy area (appendix table 26). Relatively homogenous site conditions in terms of slope, aspect and topography and growth and vigor of the trees were also considered in the selection of the trees of each species. As indicated in Figure 3. the canopies coverage of each of 4 trees was divided into two radial transects and three plots (0.7 m x 0.7 m), two under the canopy with distance of 1.35 m, 3.35 m and one out of the canopy 26.35m from tree trunk as control for each radial was established Belay, [2]. Total sample size is number of treatments (3)* number of replicates (4)* tree species (2) * location (2). In this case radial distance from the tree trunks considered as treatment with three levels i.e. 1.35 m, 3.35 m and 26.35 m while as location and tree species taken as factors. Area around the tree trunks with 26.35 m radius is blocks.

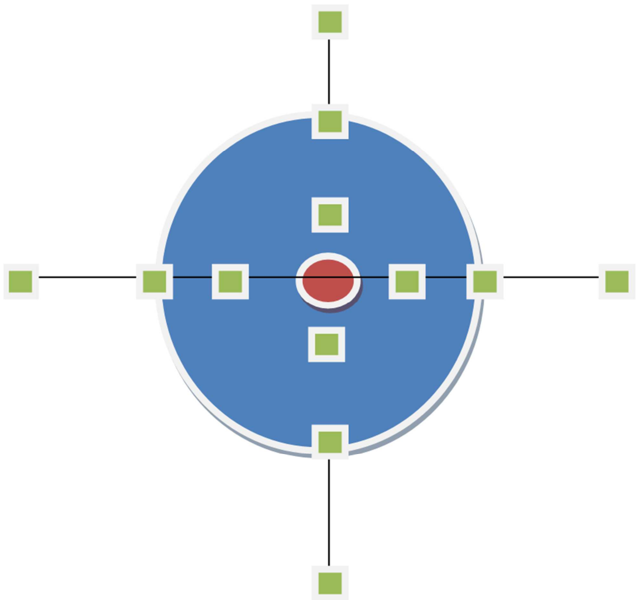

Figure 3. *Data collection design.*

1. Circle represents canopy of the tree and center is single tree trunk.
2. Plot on equal distance from the tree, considered as one treatment
3. Soil sample at 0-20 cm depth was taken from each plot for both chemical and physical analysis

2.2.2. Wheat Grain and Biomass Yield

Wheat variety used in the studied area was *Pica flora* with spacing between rows 20 cm and average yield of 3 t ha^{-}. Three plots of 0.7 m * 0.7 m at the distance of 1.35 m, 3.35 m, and 26.35 m from the tree trunk were established for determination of wheat grain and biomass yields on the farmer's managed croplands. Wheat crop planted at each plot with uniformly application of 100 kg DAP ha^{-} based on spacing and population used by farmers at the time of planting were harvested at ground base and weighted for its biological yield using digital balance. Then finally straw and grain yield were separated and weighted for its yield and biomass data at the time of harvest.

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%).

3. Results and Discussion

Grain yield and biomass

The analysis of variance of the study showed that the grain yields of wheat 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 wheat decreased significantly and gradually as the distance from the trees trunk increased (table 1). The Highest values of wheat grain yield were 73.33 and 68.85 kg ha-1 under *F. albida* and *A.tortilis* respectively at the distance of 1.35 m away from the tree trunks at Tuka location and these values decreased to 55.36 and 67.36 kg ha-1 under *F. albida and A.tortilis* respectively, at the distance of 26.35 m away from the tree trunks. The same is true for biomass under both trees and at both location i.e. it 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 A.tortilis.* Abebe [1] reported increased grain yield of sorghum and haricot bean under the canopy of *F.albida*, *Cordiaafricana*and *C. macrostachyus* trees as compared to the open cultivated land on Harergie high lands.

Table 1. *Effect of selected trees on grain yield and biomass of wheat at Tuka and Langano.*

Tree species	Radius	Tuka			Langano
		Grain yield kg/ha	Biomass kg/ha	Grain yield kg/ha	Biomass
Faidherbia	1.35	1047.54^{a}	2860.00^{a}	920.9^{a}	3200.9^{a}
	3.35	833.36^{b}	2831.50^{a}	805.00^{ab}	2845.10^{ab}
	26.35	790.89^{b}	2808.60^{a}	591.70^{b}	2291.00^{b}
	CV%	8.57	13.10	28.21	16.87
	LSD%	122.08	593.67	377.05	749.81

Tree species	Radius	Tuka			Langano
		Grain yield kg/ha	Biomass kg/ha	Grain yield kg/ha	Biomass
	1.35	983.61 ^{a}	2604.40 ^{a}	571.25^{a}	2135.60^{a}
Tortilis	3.35	891.57^{a}	2522.70^{b}	524.64^{a}	1837.20^{a}
	26.35	962.36 ^{a}	2320.90^{b}	397.82^{a}	1483.50^{a}
	CV%	10.49	7.70	25.32	22.42
	LSD%	171.74	330.86	220.72	705.39

The combined analysis of variance of the study showed, that grain yield of Wheat were significantly different (p <0.05, appendix table 1) due to distance from the tree trunk). Similarly there were a significant difference of overall means between the two locations (p<0.05). The Highest values of wheat grain yield were 1258.33kg/ha under *Faidherbia albida* and *Acacia tortilis* at distance of 1.35 m away from the tree trunks and these values decreased to 979.57kg/ha under *Faidherbia albida* and *Acacia tortilis* at the distance of 26.35 m away from the tree trunks. Although there were no statistically significant differences between means at distance 3.35 m and 26.35 m, the average of grain yield recorded at distance 3.35 m was greater than that recorded at 26.35 m (1097.35kg/ha and 979.57 kg/ha respectively). The finding indicated that, crop grown under the canopy of *Faidherbia albida* and *Acacia* tortilis obtained more advantage compared to the open field i.e. at distance 26.35 m from tree trunks. 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.

In the same study, Kho et al. [7] 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 faidherbia (often referred to as the 'albida effect') are attributed to the combined effects of improved soil fertility, soil water and microclimate. It is well-known that Soils rich in biota and organic matter are the foundation of increased crop productivity.

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 wheat 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. In another study Abebe, [1] reported increased grain yield of sorghum and haricot bean under the canopy of *F. albida*, *Cordiaafricana* and *C. macrostachyus* trees as compared to the open cultivated land in Harergie high-lands. Likewise, Victor sh. [14] done research in all the four regions, yields of maize from plots under canopies of *Faidherbia trees* were significantly (p < 0.05) higher than those from plots outside the canopies.

Table 2. *Effect of Faidherbiaalbida and Acacia tortilis, distance and locations on wheat yields.*

Items		Wheat Grain yield (kg/ha)	Wheat Biomass yield (kg/ha)
	1.35 m	1258.33^{a}	3818.22
Distance from tree base	3.35 m	1097.35^{b}	3530.20
	26.35 m	979.57^{b}	3281.30
Tree species	F.albida	1187.96	4008.90^{a}
	A.tortilis	1035.54	3077.60^{b}
Location	Tuka	1311.74^{a}	3797.20^{a}
	Langano	911.75^{b}	3289.30^{b}
CV (%)		20.09	14.66
LSD (5%)		160.18	3281.30

However the mean under the two species was not significant statistically from each other, the mean under *Faidherbia albida* was greater than that of grown under *Acacia tortilis*, which could be as result of phenological characteristics of the species. *Faidherbia albida* shades its leaves during crop growing season, which allows more lights for photosynthesis reaction. Therefore, crops grown under *Faidherbia albida* gets more advantages compared to those crops grown under *Acacia tortilis*.

The mean biomass recorded at three different distances from the two tree trunk, was not differently significant statistically (p >0.05, appendix Table 2). In general, the result of analysis indicated that, decreasing pattern of mean biomass as distance from tree trunk increases, for both *Faidherbia albida* and *Acacia tortilis* (table 2). The mean values of biomass under canopy was 3818.22kg/ha and decreased to 3281.30 kg/ha in open land. There was significant variation of biomass yield between tree species (p<0.05, appendix table 2). The mean biomass obtained under *Faidherbia albida* was greater than that of mean biomass obtained under *Acacia tortilis* (4008.9 kg/ha and 3077.6 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 *Faidherbia albida* and *Acacia tortilis* on the soil under its canopy.

Trees affect soil properties through several pathways Buresh and Tian [3]; Rhoades, [11]. Trees alter inputs to the soil system by increasing capture of wet fall and by adding to soil nitrogen via N_2 fixation. They affect the morphology and chemical conditions of the soil as a result of the characteristics of above and belowground litter inputs. The chemical and physical nature of leaf, bark, branch and roots alter decomposition and nutrient availability via controls on soil water and the soil fauna involved in litter breakdown. Extensive lateral root systems scavenge soil nutrients and redistribute them beneath tree canopies. In general, trees represent both conduits through which nutrients cycle and sites for the accumulation of nutrients within a landscape Rhoades, [11]. Thus, higher biomass obtained under the canopy of *Faidherbia albida* & *Acacia tortilis* as compared to on field one

4. Conclusions and Recommendations

The study has been done on the effect of *Faidherbia albida* and *Acacia tortilis* on yield and biomass of wheat grown under canopies of both trees in Bora district Central Rift-valley, at Tuka and Langano kebeles. 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 wheat grown under canopies compared to that grown out of canopies of both trees at Langano and Tuka. The higher mean of grain yield and biomass were observed under canopies at both location rather than that grown on open land, which could be as result of additional nutrients, through litter fall, root turnover and exudates, and n-fixation.. In general park land agroforestry system is very important in soil fertility management especially for poor farmers in order to boost their productivity. The research induces the following recommendations; (1) Farmers knowledge improvement about importance of *F. albida* and *A.tortilis* for soil fertility management and improving crop productivity because, most farmers clear the trees from their farm completely rather than using another technology like appropriate pruning. (2) Farther research on *F.albida* and *A.tortilis* regarding with their age class, should be done because, very old and large canopy of these trees increases only biomass but reduce yields of wheat grown under it as it was informed from district expert and field visit. (3) Another study on confirmation and validation is important to substantiate the findings of the current study and providing the findings to the police maker in order to enhance parkland agroforestry system

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