



Effect of *Croton macrostachyus* trees on yield of maize (*Zea mays*) and wheat (*Triticum aestivum*) crops in parkland agroforestry in central-Ethiopia

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ABSTRACT: The study was conducted to investigate the effect of scattered *Croton macrostachyus* trees on yield of maize and wheat crops in Miserak Azernat District, Silte Zone, Central-Ethiopia during 2023–2024 cropping season with an objective to evaluate the yield and yield components of maize and wheat grown under and outside the canopy of the *Croton macrostachyus* trees. For the experiment on the crops, two factors were used: crops (maize and wheat) and three radial distances at 1.5m, 3.5m, and 25m as a control away from the tree, with four times each crop in the RCBD replicated and a total of 24 samples used. Three radial distances of 1.5m, 3.5m, and 25m as a control away from the tree in Randomized Complete Block Design replicated eight times. The result revealed that yield and yield components of wheat and maize were higher under and near the tree canopy than far from the canopy. Wheat yields increased significantly at 1.5m with 22%, and maize yields were highest at 1.5m with 14.6% increments, compared to 25m way from tree trunk. The study showed that wheat is more compatible crop under tree canopy of *Croton macrostachyus*, compared to maize. The study concluded that integrating *Croton macrostachyus* trees with the suitable crop combinations could enhance crop yields. The research recommends further study on tree pollarding and other management practices, and litter quality.

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1. INTRODUCTION

1.1 Background

Agroforestry is a form of sustainable land use system that integrates trees with crops or animal husbandry to initiate an agro-ecological succession (FAO, 2013). Due to its economic, social, and environmental benefits (Abrha, 2016), agroforestry is widely promoted throughout the world and is an instrument for diversifying and enhancing production (Mbow *et al.*, 2014). Mixing trees with annual crops also helps farmers overcome crop failure due to climate change (Linger, 2014) and land degradation (Leakey, 2020).

It provides assets and income from carbon, wood energy, improved soil fertility, and enhanced local climate conditions; it provides ecosystem services and reduces human impacts on natural forests (Haile *et al.*, 2000). Agroforestry trees could bring about changes in soil, microclimate, crop yield, and other components of the system through the recycling of mineral elements, environmental changes, and composition (Manjur *et al.*, 2014). One of the reasons for practicing

agroforestry is for domestication of soil improving trees for enhancing soil productivity through a combination of selected trees and food crops on the same farm field (Kassa *et al.*, 2010).

Integrating cash crops in an agroforestry system (Aschalew, 2018) additionally gives an opportunity for better utilization of land, maintaining the health of tropical soils in terms of biological, chemical, and physical property. This could be through root activities, nutrient cycling, and numerous additional external factors reducing nutrient losses from erosion and leaching (Arevalo *et al.*, 2015). Depending on the socioeconomic and biophysical circumstances, smallholder farmers in Ethiopia employ a variety of agroforestry practices (Jamala *et al.*, 2013; Abrham *et al.*, 2016; Iiyama *et al.*, 2017). These include scattered trees on farmland or parkland agroforestry, coffee shade trees, homegardens, woodlots, boundary planting (windbreaks), and silvopastures (Zebene, 2007).

Scattered trees on the farmland or parkland agroforestry is one of the agroforestry practices, and grown trees on farmlands characterize a large part of the Ethiopian agricultural landscape, and it is the most dominant agroforestry practice in the country (Kindeya, 2004). Moreover, scattered trees on croplands are needed to solve problems like deforestation, unsustainable cropping practices, loss of biodiversity, increased risk of climate change, rising

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hunger, poverty, and malnutrition. Soil fertility has declined over a period of time due to high rates of soil erosion, the removal of crop residues for fuel and animal feed, rapid population growth, deforestation, inappropriate land use systems, and continuous cultivation of the land without sufficient management (Lal, 2001).

Yield improvement and enhancement of soil fertility can be obtained under scattered tree canopies. Decomposition and nutrient release, addition of litter, pumping of nutrients from deeper soil layers, and protection from nutrient loss are some of the vital processes that have a significant contribution to sustainable farm production (Sarvade *et al.*, 2014). Sorghum grain yields under the *Cordia africana* tree canopy increased by 14% compared to those grown on farmlands without trees in Burkina Faso (Boffa, 2000). According to Kho *et al.* (2001), in N'Dounga, Niger, *F. albida* improved soil physical and chemical properties through improving the microclimate of the system and increasing nutrient availability.

Planting or retaining scattered *Croton macrostachyus*, *Cordia africana*, *Olea africana*, *Acacia* spp., *Faidhrebia albida*, and *Psidium guajava* trees in the farmlands and homesteads is common practice in the southeastern Ethiopian highlands. Thus, investigation of the contribution of existing native multipurpose tree species on soil fertility via comparing soil properties beneath individual trees with treeless areas of the same soil conditions is crucial to sustaining the system in the area. Farmers in the Silte Zone of southern Ethiopia, in particular, have been maintaining and managing various tree species on croplands for various purposes, such as firewood, soil fertility improvement, fodder, timber, shade, and others, but little is known about why those particular tree species are planted or retained in the crop.

In the study area, the integration with soil fertility, the distinction between productivity under canopy and out of canopy from the *Croton macrostachyus* tree trunk and the crops (maize and wheat) their production are still unclear. Also, one of the major challenges in parkland agro-forestry practice, particularly *Croton macrostachyus* trees with cereal crops in the current study area, is for formulating appropriate tree-crop interaction due to competition between tree and crop components.

Therefore, in the study area, many farmers grow different types of cereal crops, such as maize, wheat, teff, sorghum, and barely beneath the canopies of *Croton macrostachyus*, for resource conservation and poverty alleviation. However, the effect of existing on-farm *Croton macrostachyus* trees on crop yield in the study site where cereal crops like, wheat and maize

are commonly intercropped with them has not been adequately investigated, and differences in performance of yield and yield components, and compatibility among cereal crops with respect to the distance from the *Croton macrostachyus* tree trunk have not been well considered. Therefore the current study was carried out to investigate the effect of the *Croton macrostachyus* trees on yield of maize and wheat crops in Parkland Agroforestry in Miserak Azernat district, Silte Zone, Central Ethiopia with the following objectives:

- To evaluate the performance of yield and yield components of maize and wheat grown under and outside the canopy of the *Croton macrostachyus* tree.
- To determine the computability difference between the two cereal crops (maize and wheat) with respect to the distance from the *Croton macrostachyus* tree trunk.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

2.1.1 Geographical Location

Miserak Azerenete district is one of the districts in Silte Zone Central Ethiopia, which are about 225 km and 45 km far from Addis Ababa and Hossena. Attitudinally, the District varies from 1850m to 2780m above sea level. Its geographic location is between 7°41' to 8°56' N and 37°57' to 38°6' E. The district is bordered by Alicho Weriro district in the north, Hadiya Zone in the south, Huleberag district in the east, and Gurage Zone and Mirabe Azernate district in the west (WADO, 2022).

2.1.2 Soil type

Distribution of dominant soil types across the district: hablic Nitisols 3039 ha (18%), hablic Luvisols 6944 ha (41%), vertic Luvisols 4116 ha (24%), total Luvisols 11060 ha (66%), lictic leptosols 1922 ha (11%), hablic leptosols 330 ha (1%), and hablic regosols 438 ha (2.5%) (Eyasu, 2016). The soils of study area are fertile soils characterized by a clay rich subsurface layer making them highly suitable for agriculture. These soils have high nutrient content, and good drainage of these soils make them suitable for a wide range of agriculture, from grains to orchards.

2.1.3 Climate and Relief

The district is predominantly Weyna Dega (mid-altitude) in terms of agro-climatic conditions. The annual average temperature of the area ranges from 13°C to 25°C (WADO, 2022). The rainfall pattern of the district is generally bimodal; the minor rainy season (Belg) starts in February and ends in April, while the main rainy season (Meher) begins around

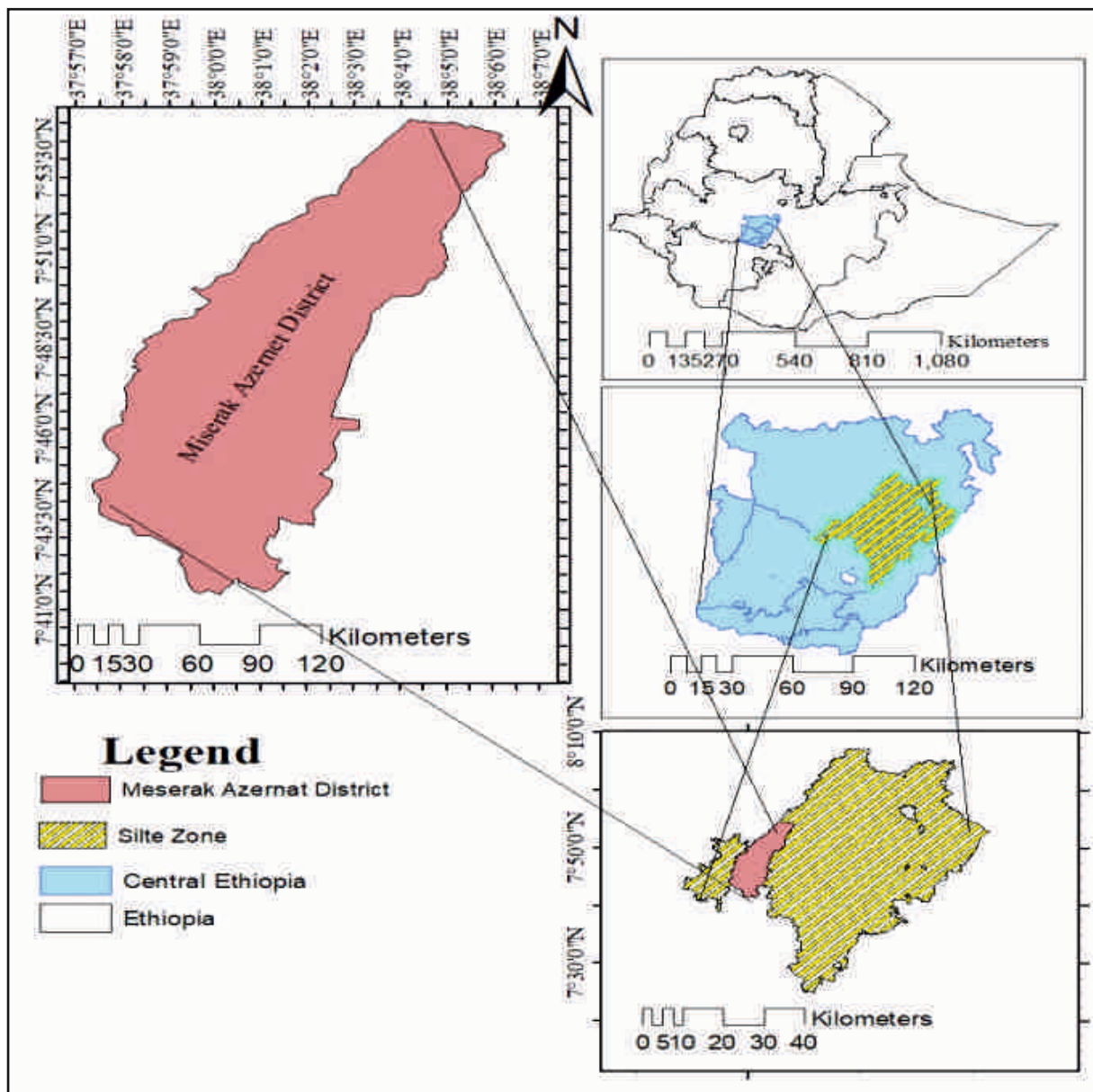


Figure 1: Map of the study area

June and stops in September. Its annual rainfall ranges from 875 to 1213 mm, with high variability.

Major agro-ecological zones in the Misrak Azernet district are the tepid sub-humid mid-highlands (11,416 ha) and the cool sub-humid mid-highlands (5372 ha). Geomorphic units and their extent in the district of Misrak Azernet: highlands with moderate to high relief hills (8333 ha), minor river gorges and ravines (7453 ha), degraded extinct central volcanoes, caldera remnants, and associated forms of high to mountainous relief (1003 ha) (Eyasu, 2016).

2.1.4 Population

The total population of the district is 84,878, of which 43,154 are males and 41,724 are females (CSA, 2007). It has seventeen rural and one urban kebeles. The number of agricultural households in the district is

estimated at 15,812, with 11,824 male-headed and 3,988 female-headed households (WADO, 2022). The average family size is estimated to be 6 and 4 per household in rural and urban areas, respectively.

2.1.5 Land use/ Land cover

Land use and land cover types in the district are rain-fed cultivation (9498 ha), dense forest (3520 ha), settlement, and homegarden (4407 ha), and communal grazing area (1679 ha) (Eyasu, 2016).

2.1.6 Vegetation

The total land area coverage of the district is 19404 ha. Currently, forestland of the district is 4701 ha of the total land area such as natural forest (1890) ha, community forest is (790) ha and private forest land is (1140) ha. The common tree in the area include, *Croton macrostachyus*, *Cordia africana*, *Hagenia*

abyssinica, *Podocarpus falcatus*, *Ficus sur*, *Milletia ferruginea*, *Prunus africana*, *Juniperus procera*, *Erythrina abyssinica*, *Eucalyptus* and *Gravillea robusta* which are grown as parkland, boundaries, live fences and woodlots (WADO, 2022). The dominant and important scattered trees on farm land in the district are *Coroton macrostachy*, *Cordia africana*, *F. albida*, *Hagenia abyssinica* and *Erythrina abyssinica*.

2.1.7 Agricultural activities

Agriculture is the dominant economic activity in the district. The livelihood of the people in the district depends mainly on mixed agriculture (crop-livestock production). The main annual crops are maize (*Zea mays*), wheat (*Triticum aestivum*), teff (*Eragrostis tef*), barley (*Hordeum vulgare*), beans (*Phaseolus vulgaris*), peas (*Pisum sativum*), potatoes (*Solanum tuberosum*), cabbage (*Brassica oleraceavar*) and carrots. The main perennial and widely used for income-generated crops in the district are enset (*Ensete ventricosum*), coffee, chat, avocados, casmir and timber trees. Enset (*Ensete ventricosum*) is the main perennial crop in Miserak Azernat district, a source of food all year round. According to the Miserak Azernet Agricultural office Report (2022), the dominant annual crops in the district that are intercropped with *Coroton macrostachy* trees are maize (*Zea mays*), wheat (*Triticum aestivum*), teff (*Eragrostis tef*), barely (*Hordeum vulgare*).

A typical cereal crop wheat (*Triticum aestivum*), maize (*Zea mays*), and teff (*Eragrostis tef*) production practice in the study area commenced for maize (*Zea mays*) in March and for teff in April to June. However, production practice for wheat (*Triticum aestivum*) begins after rain softens the soil, and fields can be ploughed multiple times (an average of three times). Sowing occurred around the end of March for maize (*Zea mays*) and between late June and early July for teff (*Eragrostis tef*) and wheat (*Triticum aestivum*). Manual row seeding was used for maize (*Zea mays*), wheat (*Triticum aestivum*), and teff (*Eragrostis tef*) (WADO, 2022).

2.2. Experimental Design and Sampling Strategies

2.2.1 Selection of *Croton macrostachyus* trees for crop study.

Croton macrostachyus trees being the most abundant scattered tree species on crop fields were selected for this study. The selected farmlands with *Croton macrostachyus* tree is characterized as a slightly gentle slope where maize and wheat are staple food crops of the area. 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 (i.e., eight of the selected trees were those that did not receive or

experience pollarding or lopping for at least 2–3 years to investigate the performance of the test crops under shaded conditions). On the selected field, *Croton macrostachyus* trees having approximately similar height, diameter at breast height (DBH), crown diameter and from approximately uniform site condition were marked. Of all the marked trees, eight *Croton macrostachyus* trees were randomly selected for this study.

For this study, tree diameter at breast height was measured with a caliper. The canopy's width and length were measured with measuring tape by stretching it from a point judged to be directly below the edge of the canopy to the tree trunk. A compass and meter tape was used to determine the sampling direction and radial distance (1.5m, 3.5m, and 25 m) along the sample transects. GPS was used to identify the exact location of the trees. Data were collected from four directions (east, west, north, and south), and the average of the four directions per radial distance was used in data analysis. The dimension of replication was almost uniform with for *Croton macrostachyus* the average DBH, height and crown radius were 69.25cm, 18.125m & 5.4875m respectively (Table 1).

2.2.2 Sowing of crops (maize and wheat) and data collection

The study site, the test crops were selected based on their coverage and contribution to food security in the country and the same to study area. The selected test crops are those that are widely grown in the study area in combination with *Croton macrostachyus* tree.

Tree–crop combination of two experiments was four *Croton macrostachyus* trees+ wheat and four *Croton macrostachyus* trees + maize and totally eight mature trees were considered for the experiments and eight controls outside canopy of each matured tree

Each experiment comprised of three treatments (distance) from the tree trunk, including 1.5m, 3.5m, and 25m (control). The effects of *Croton macrostachyus* tree on each test crop were evaluated by measuring their yield and yield components at three points along radial distances namely, 1.5m, 3.5m, and 25 m (control) from the tree trunk.

To cultivate the sample farm areas, the farmers manually prepared the land using tools like hand hoes and oxen. Typical selected crop Maize (*Zea mays*), and wheat (*Triticum aestivum*) production practices in the study area were ploughed for maize in March, and for wheat, production practices were ploughed after rain softened the soil, and fields can be ploughed multiple times (an average of three times). The sowing date was April 16 and harvested on October 11 for maize (BH 661 variety), and it was July 8 for wheat (Ogolcho

Table 1: *Croton macrostachyus* characteristics data mean height, DBH, Crown Radius and (GPS) X, Y coordinates.

Replications	Height in (m)	DBH in(cm)	Crown Radius (m)	X,Y coordinate (m)	
				X coordinate	Y Coordinate
1	15	68	5.2	391130	855499
2	16	62	5.4	391155	855700
3	14	72	5.3	391189	854566
4	16	75	5.6	391172	854506
5	14	66	6.1	390603	854324
6	15	62	5.2	391132	855408
7	13	67	5.4	391137	855427
8	14	67	5.7	391162	855821
Mean±st.dev	14.625±1.125	69.25±19.98	5.4875±0.1	-	-

variety) and harvested on October 31.

Maize plots were fertilized with 73 kg ha⁻¹ NPSB and 56 kg ha⁻¹ Urea (split applied 50% at sowing and the remaining side dressed at the age of 3–4 leaves), and wheat plots were fertilized with 80 kg ha⁻¹ NPSB and 50 kg ha⁻¹ Urea (split applied 50% at sowing and the remaining side dressed at the age of 25–30 days). Seed was drilled at a spacing of 30 cm between rows and plants, 25 kg ha⁻¹ for maize, and drilled at a spacing of 25 cm between rows at the rate of 100 kg ha⁻¹ for wheat (Figure 2). Field cultivation and site preparation involved the traditional “*Maresha*” plowing with a pair of oxen. Weeding was carried out using hoeing for maize, and a combination of herbicide (2,4D) and hand weeding were used for wheat.

For data collection, a compass and a tape meter were used to measure the directions of the transect lines and distances along the transect lines, respectively. As illustrated in Figure 3, the data were collected from four compass directions (east, west, south and north) and averaged for analysis. Threshing was done manually to separate the grain from the straw and grain yield (quintal ha⁻¹) and biomass (ton ha⁻¹) were determined for each quadrant after harvesting. Yield and dry biomass of the samples were determined using a total harvesting method. A wooden frame of 1 × 1 m dimension was used for sample harvesting along the demarcated lines at 1.5 m, 3.5m, and 25 m (control) far from the tree trunk.

Yield gain/loss of wheat and maize due to the presence of *Croton macrostachyus* was computed using the following equation:

$$\text{Yield gain/loss} = (\text{YUIT} - \text{YOIT}) / (\text{YUIT}) * 100$$

..... Equation 1

Where YUIT = yield under the influence of tree, YOIT = yield outside the influence of tree.

Data on other agronomic parameters such as total plant height, spike length, number of tillers m⁻² and per

plant, ear length and number of stem m⁻² were collected at physiological maturity prior to harvesting using five randomly selected plants from three points *i.e.* two from the edge and three from the center of each plot in four directions at 1.5m, 3.5m and 25m. The average measurements were used for statistical analysis.

- 1) The center of the circle represents a single *Croton macrostachyus* tree.
- 2) The circle represents the area covered by the canopy of the tree;
- 3) The area covered by the canopy is divided into two radial transects (fully labeled here);
- 4) Four plots (1 × 1 m each) were established on each radial transect at distances of 1.5m, 3.5m, and 25m away from the tree trunk in all directions, and a total of 12 plots were considered in a single tree.
- 5) The four plots or sub-samples located at a similar distance on each of the three radial transects were considered a single treatment, *e.g.*, the plots at a distance of 1.5 m on each of the three radial transects.

Note that the figure is not drawn to scale, and, of course, the area covered by the canopy is not a perfect circle.

2.4 Statistical Analysis

The experiment was laid out in factorial arrangements with a randomized complete block design (RCBD). Treatment means were compared using LSD at the 5% level of significance. Statically Analysis System (SAS 9.4M7 (TS1M7)) software was used for the analysis.

3. RESULTS AND DISCUSSION

3.1 Effect of *Croton macrostachyus* Tree on Maize yield and yield components

The analysis of variance of the study revealed that the grain yield and yield components of maize were



Figure 2: Site preparation, sowing, and seedling crops

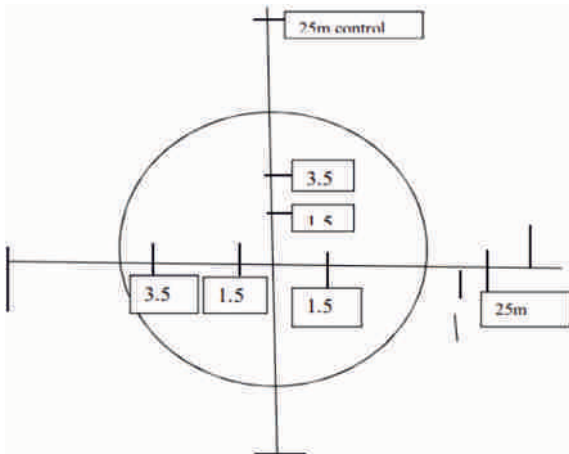


Figure 3: Experimental design used for crops yield data collection

significantly ($P \leq 0.05$) affected due to the presence of *Croton macrostachyus* tree. The grain yield of maize decreased significantly with increasing distance from the tree trunk. Considerably higher maize yield ($P \leq 0.05$) was found close to tree trunk (*i.e.*, at 1.5 m) than far from the tree trunk at 25m. As compared to the control (25m), there were a significant maize grain gain of 14.59% and 5.79% close to tree trunk and at the edge of the canopies (3.5m), respectively. Similarly, above ground biomass of maize showed statistically significant ($p=0.05$) difference among radial distance from *Croton macrostachyus* tree

trunk (Table 2). These results also agree with a similar study by Manjur *et al.* (2014), the maize grain yield varied greatly depending on the distance between the tree trunk and the *Croton macrostachyus* canopy, reaching its peaked value of 8.156 t ha^{-1} at a distance of 1.5m and decreased to 6.802 t ha^{-1} at a distance of 25 m. Likewise, Abebe (2006) reported increased grain yield of sorghum and haricot bean under the canopy of *C. macrostachyus F. albida*, and *Cordia africana* trees as compared to the open cultivated land on Harergie high lands.

Contrary to the result of this study, Hailemariam *et al.* (2010) studied the effect of *Balanites aegyptiaca L. Del*, a potential tree for parkland agroforestry systems, on sorghum yield and observed no significant difference in grain yield among treatments that were grown right under the tree canopy (0–4 m), near the tree canopy (4–6m), and far from the tree canopy (8–12 m).

3.2. Effect of Under *C. macrostachyus* on Wheat yield and yield components

Wheat yield was significantly affected by distance from the center of *Croton macrostachyus* tree trunk. The grain yield of wheat decreased significantly with increasing distance from the tree trunk. Considerably higher wheat yield ($P \leq 0.05$) was found close to tree trunk (*i.e.*, at 1.5 m) than far from the tree trunk at 25m. As compared to the control (25m), there were a

significant maize grain gain of 21.9% and 13.4% close to tree trunk and at the edge of the canopies (3.5m), respectively. Likewise, above ground biomass was strongly affected by distance from the tree trunk. Significantly higher above ground biomass ($p < 0.05$) was recorded at 1.5 m (17.22 ton ha⁻¹) and it was lower as it gets 25m (14.02 ton ha⁻¹) (Table 3).

Similar to the current study, Shiferaw *et al.* (2014) also found a higher wheat yield of 23% under a tree canopy than in an open area in the Rift Valley of Ethiopia. A similar study by Degu (2010) also showed higher wheat grain gains of 244.11% at 0.5 m, 206.38% at 1 m, 182.13% at 2 m, and 100% at 10 m from the tree trunk than the control in southern Ethiopia. Hadgu (2009) also reported a higher barley yield gain of 49% in northern Ethiopia compared to the control.

3.3. Effect of *C. macrostachyus* on grain yield and yield components of Maize and Wheat

Study results demonstrated that competitive interaction was observed, and the *Croton macrostachyus* tree has a facilitative effect when intercropped with wheat and maize. The yield benefits of cereal crops grown under parkland trees, such as *Croton macrostachyus* trees, have been extensively documented by other researchers and ranged from slight decreases to

doublings of yields (Nyamadzawo, 2015).

The results of the present study revealed that the presence of *Croton macrostachyus* trees significantly improved the yield and yield components of maize. The maize crop had a longer height, more stem per m², a longer ear length, a higher grain yield, and a higher straw yield under the tree canopy than far from it (25m).

The study results go well with the findings of Saka *et al.* (1994), who found 100% grain gain of maize beneath the tree trunk compared to the open area in Malawi. Our results are also comparable with similar studies by Poschen (1986), who found 76% maize grain gain in Eastern Ethiopia. The results of this study are in agreement with the findings of Jiru (1997), who found a higher maize yield gain of 67% than far from the tree trunk when maize was intercropped with lopped *Croton macrostachyus* trees in Central Ethiopia.

Our study showed a 14.59% yield increment of maize (BH661 Variety) at 1.5 m and 5.79% at 3.5 m, compared to the control (25m). Maize above ground biomass also showed an increment of 17.5% at 1.5 m and 6.25% at 3.5 m, compared to the control (25 m). At harvest, the wheat crop had a taller height, a longer

Table 2: The effect of *Croton macrostachyus* on maize yield and yield component

Parameters	Radial distance (m)							
	1.5m	3.5m	25m	Cv	LSD	F value	(Pr >f)	LS
Plant height (m)	2.55 ^a	2.375 ^b	2.25 ^c	2.698	0.1117	8.84	0.0097	**
Plant/m ²	5.75 ^a	5 ^b	4 ^c	5.871	0.4995	15.4	0.0023	**
Ear/plant	1.425 ^a	1.175 ^b	1.02 ^c	6.757	0.1413	9.88	0.0074	**
Ear length(cm)	26.225 ^a	22.57 ^b	21.6 ^c	1.802	0.7324	56.66	<.0001	***
Yield in quintel/ha	56.725 ^a	51.37 ^b	48.5 ^c	2.086	1.8833	24.95	0.0006	**
Agb in ton ha ⁻¹	22.175 ^a	19.52 ^b	18.3 ^c	2.329	0.8059	29.48	0.0004	**
Yield gain	14.59%	5.79%	-	-	-	-	-	-

N.B. Means with the same letter are not significantly different at $p = 0.05$; *** = ($P < 0.001$); ** = highly significant at $p \leq 0.01$; * = significant at $p \leq 0.05$; CV = coefficient of variation; LS = level of significance; LSD = list significant difference; Agb = above ground biomass.

Table 3: The effect of *Croton macrostachyus* on wheat yield and yield component

Parameters	Radial distance (m)							
	1.5m	3.5m	25m	Cv	LSD	F value	(Pr >f)	LS
Plant height in cm	81.25 ^a	78.75 ^b	75.87 ^c	1.36967	1.863	10.8	0.005	**
No. tillers/plant	5.825 ^a	4.7 ^b	4.3 ^b	7.50374	0.642	10.04	0.007	**
No. of tillers/m ²	606 ^a	523.7 ^b	500.2 ^b	4.9742	46.75	7.63	0.014	*
Spike length (cm)	7325 ^a	6.825 ^a	6.25 ^b	4.64394	0.546	5.22	0.0342	*
Yield in quintal/ha	44.65 ^a	40.27 ^b	34.87 ^c	2.82972	2.91	14.21	0.0028	**
Agb in ton ha ⁻¹	17.22 ^a	16.1 ^a	14.02 ^b	5.64226	2.45	5.64	0.0287	*
Yield gain	21.90%	13.40%	-	-	-	-	-	-

N.B. Means with the same letter are not significantly different at $p = 0.05$; *** = ($P < 0.001$); ** = highly significant at $p \leq 0.01$; * = significant at $p \leq 0.05$; CV = coefficient of variation; LS = level of significance; LSD = list significant difference; Agb = above ground biomass.

spike, more tillers per m² and per plant, a higher grain yield, and a higher straw yield under the tree canopy (1.5m) than far from it (25m). Results of the present study showed that the yield increment for wheat (Ogolicho variety) was increased by 21.9% at 1.5 m and 13.4% at 3.5m compared to the control (25m). Also, higher wheat aboveground biomass was recorded, which was increased by 18.6% at 1.5m and 12.9% at 3.5 m.

Results in this study complement and support the findings of other researchers in Ethiopia (Jiru, 1997; Gosaye, 2010; Shiferaw *et al.*, 2014; Tesfaye, 2017). For instance, Jiru (1997) found a higher wheat yield of 40% under the canopy than outside the canopy in central Ethiopia when wheat was grown under *F. albida*. Shiferaw *et al.* (2014) also found a higher wheat yield of 23% in the rift valley of Ethiopia. A similar study by Gosaye (2010) also found a higher wheat yield of 244.11% at 0.5m and 100% at 10m from the tree trunk than sole cropping.

These results also agree with a similar study by Tesfaye (2017), who found significantly higher ($P < 0.001$) plant height, total aboveground biomass, and wheat grain yield when wheat was intercropped with *Croton macrostachyus* tree compared with sole wheat in the Ethiopian central rift valley. Moreover, a study conducted by Hadgu *et al.* (2009) found a barely higher yield of 49% in northern Ethiopia. There has been extensive scientific documentation in the scientific literature that has extensively documented the remarkable positive effect of trees on the efficiency of nutrient recycling due to their deeper root systems and nitrogen-fixing ability.

The combined effects of improved soil fertility, soil water and microclimate modification such as reduction of air and soil temperature have been documented by Shiferaw *et al.* (2014). Tesfaye (2017) and ICRAF (1989) also observed that yield and yield components improvement of cereals could be associated with soil fertility improvement through different tree soil interaction process of nitrogen fixation, nutrient recycling, and accumulated soil organic matter.

According to Bayala *et al.* (2015), the tree can also enhance the microclimate, which in turn improves water availability through several ecological processes such as hydraulic redistribution and increases the water-use efficiency of understory crops. A study conducted in 2001 by Kho *et al.* found that, particularly on dry ground, the reduced temperature beneath the canopy of *C. macrostachyus* may be a

significant factor in increasing wheat yield.

4. CONCLUSION AND RECOMMENDATION

4.1 CONCLUSION

The study concluded that there were the presence of the *Croton macrostachyus* tree had a significant ($P \leq 0.05$) impact on the grain yield and yield components of wheat and maize. The findings clearly showed that the yield and yield components of maize and wheat decreased with increasing distance from the tree trunk. Similarly, yields of maize and wheat were higher ($P \leq 0.05$) under the tree canopy at 1.5 m than at a distance of 25 m from the tree trunk. In comparison to areas outside the canopy, maize and wheat associated with *Croton macrostachyus* trees showed considerably higher ($P < 0.05$) plant height, number of tillers per plant, spike length, total aboveground biomass, and grain yields. On the other hand, based on the present results, cereal crops like wheat are the first alternative crop suitable for cultivation with *Croton macrostachyus* trees. The second alternative crop with potential for cultivation under the *Croton macrostachyus* tree is maize.

According to the research, the *Croton macrostachyus* tree can be incorporated into annual cropping systems in order to increase soil fertility. This is because the tree's green leaves decompose rapidly during the growing season, releasing nutrients into the soil. In addition, the tree offers construction timber, firewood, and other advantages that are essential to rural populations. Therefore, resource-poor farmers in similar agro-ecological parkland agroforestry practices, including *Croton macrostachyus*, as an economically viable, ecologically acceptable, and sustainable alternative to preserve soil fertility.

4.2 RECOMMENDATION

The researcher encourages the following recommendation for future research and interventions:

- Croton macrostachyus* trees are found to have positive effects on crop yields. Therefore, there is a need to expand the species in similar agro ecology for those resource poor farmers in particular and in different farming systems for crop production improvement, soil nutrients enhancement, microclimate amelioration, and other uses for society.
- More research is needed to determine how tree management practices, such as pollarding trees and lopping, and fine root temporal and spatial distribution affect either directly or indirectly soil fertility and the yield associated with them. Litter quality is one of the various factors that affect soil fertility based on its type and chemical contents. Therefore, further investigations will also be needed on *Croton*

macrostachyus tree litters' decomposability and their chemical compositions.

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