American Journal of Plant Sciences, 2017, 8, 2159-2179
http://www.scirp.org/journal/ajps
ISSN Online: 2158-2750
ISSN Print: 2158-2742

Effect of Intercropping of Legumes and Rates of Nitrogen Fertilizer on Yield and Yield Components of Maize (*Zea mays* L.) at Arba Minch

Ewnetie Takele[1*], Zenebe Mekonnen[1], Dereje Tsegaye[1], Arega Abebe[2]

[1]Department of Plant Science, Arba Minch University, Arba Minch, Ethiopia
[2]Arba Minch Agricultural Research Center, Arba Minch, Ethiopia
Email: *ewnetie.takele@gmail.com

How to cite this paper: Takele, E., Mekonnen, Z., Tsegaye, D. and Abebe, A. (2017) Effect of Intercropping of Legumes and Rates of Nitrogen Fertilizer on Yield and Yield Components of Maize (*Zea mays* L.) at Arba Minch. *American Journal of Plant Sciences*, **8**, 2159-2179.
https://doi.org/10.4236/ajps.2017.89145

Received: June 29, 2017
Accepted: August 8, 2017
Published: August 11, 2017

Abstract

Intercropping of legumes and cereals, an old practice since ancient civilization, plays pivotal role to increase land use efficiency, improve income and food production per unit area and minimize the risks of crop failure for small scale farmers. Thus, field experiment was conducted to determine the effect of intercropping of legumes and rates of nitrogen fertilizer on yield and yield components of maize (*Zea mays* L.). The experiment consisted of 0, 23, 46, 69 and 92 kg·N·ha^{-1} and sole maize, maize + commom bean, maize + common bean – mung bean cropping systems with Random Complete Block Design factorial experiment in three replications using maize variety, "BH-140", common bean variety (Hawassadume) and mung bean variety. Maximum plant heights, dry matter and grain yield, were observed from sole cropped maize and maize + common bean, when applying 92 kg·N·ha^{-1}. Significantly higher total Land Equivalent Ratio of 2.2, Gross Monetary Value of 87,191 birr ha^{-1}, Monetary Advantage of 47,068.2 Birr ha^{-1}, total productivity (80,568.49 birr) and net return (55,214.0 birr) were recorded from maize + common bean – mung bean. The, maximum marginal rate of return was obtained from maize + common bean – mung bean and applying 69 kg·N·ha^{-1} (1080%). Thus, farmers should be advised to practice cropping of maize + common bean – mung with 69 kg·N·ha^{-1} to get economical maize production.

Keywords

Phenology, Cropping System, Gross Monetary Value, Land Equivalent Ratio

1. Introduction

Agriculture is a fundamental instrument for poverty reduction, food security, and economic growth. Almost 80% of the Ethiopia's populations living in rural areas were directly or indirectly linked to agriculture for their livelihood [1]. However, the sector continues to be undermined by land degradation, depletion of soil organic matter, soil erosion, recurrent drought, poor infrastructure in quality and quantity, backward cultural practices and lack of adequate plant-nutrient supply [2] [3]. In Sub-Saharan countries, like Ethiopia, where the small-scale farming dominates the overall national economy, agricultural production and productivity were still getting very poor.

World population is exponentially growing indicating the need for an attractive strategy for increasing productivity to fulfill their food requirements such as intercropping. Intercropping is a practice of advanced agro technique of cultivating two or more crops in the same space at the same time for decades where the goals of agriculture have been achieved.

Maize *(Zea mays* L.*)* is the most important cereal after wheat and rice with regards to cultivated area in the world [4]. It is one of the major staple crops in Ethiopia, ranking first in yield potential per hectare and fourth in total area coverage [5]. The area and production in 2012 were 2.05 million ha (17%) and 6 million tons respectively [6]. It is compatible with many intercropping systems, gives relatively high productivity per unit area, adaptability to major agro ecologies, and ease in traditional dish preparation. It is food security crop in the country where recurrent drought is a common phenomenon [7]. Maize production requires adequate supply of nutrients, particularly nitrogen, phosphorus and potassium for good growth and high yield.

But the growing of urbanization and salinization due to improper agricultural land management decreased maize production per unit area each year [8] [9]. In moisture stress areas of Ethiopia, farmers were adopted harvesting from mono cropping systems only once in a year from a shower of rainfall and cultivating multiple crops in order to harvest best survived crop during the season. Such traditional practices were not potential to harvest adequate amount of food for the family with very small land holding. Improving food production at the national level requires best crop production practices such as intercropping. The maize-legume intercropping has become one of the solutions for food security in small holders farming systems [10]. Intercropping system showed 41% advantages from maize intercropped with common bean and 23% advantage from maize intercropping with mung bean [11].

In addition legume-based cropping system showed 20% to 67% yield benefit of intercropping over sole crop and saved 38% more farm land [12]. However, no substantial research was done on effect of inter cropping of maize + CB − MB in rates of nitrogen fertilizer on maize production around Arba Minch. Thus studies to look for potential legume as alternative nitrogen source under intercropping system through supplementary nitrogen application was required.

Farmers around the study area were practicing cereal legume intercropping with respect to food harvest but not from the knowhow legume contribution to production, and fertilization. However, the integration of legumes and cereals could significantly contribute to food production and through soil fertility improvement [13] and enhances efficiency of space and resource utilization which was not noted by the farmers.

These practices in some pockets of land at different parts of the regions were not supported with research findings. Knowledge on combined effects of maize + common bean – mung bean under different rate of fertilizer and benefits of legumes under intercropping system was required in the study area. So the aim of this study was to determine theeffect of intercropping of legumes and rates of Nitrogen fertilizer on yield and yield components of Maize (*Zea mays* L.)

2. Materials and Methods

2.1. Description of Study Area

The study was conducted at Chano Mille Kebele of Arba Minch zuriaWereda, Gamo-Gofa zone from August to mid January during 2015/16 cropping season. The study area is situated at an elevation of 1216 m.a.s.l., and between 5˚42' and 6˚13'N and 37˚19' and 37˚41'E latitude and longitude ranges, respectively [14].

2.2. Weather Conditions

The total rainfall during the growing period, (August to mid January 2015/16) was 614.6 mm the average minimum and maximum air temperatures during the cropping season was 17.4˚C and 33.20˚C, respectively [15]. The mean temperature comparison indicated that the year 2015 was not warmer than the long term average temperature (**Figure 1**).

2.3. Physicochemical Properties of Soil

A physical and chemical property of soils of the experimental site from a composite soil sample of 0 - 30 cm depth was analyzed and the result is presented in **Table 1**.

2.4. Experimental Design and Trial Management

The experiment consists three levels of cropping systems (sole maize, maize intercropped with common bean, and maize inter cropped with mung bean after common bean harvested) and five levels of nitrogen fertilizer rates (0, 23, 46, 69, 92 kg·N·ha^{-1}). The cropping systems and levels of N fertilizer rates were combined in factorial randomized complete block design with three replications. The

Table 1. Physical and chemical properties of soils or the experimental site.

Soil depth (cm)	pH	EC ds·m^{-1}	OC (%)	N (%)	Available P (ppm)	CEC Cmol (+) kg^{-1}	Texture
0 - 30	6.9	0.24	1.5	0.13	13.3	45.8	Loam

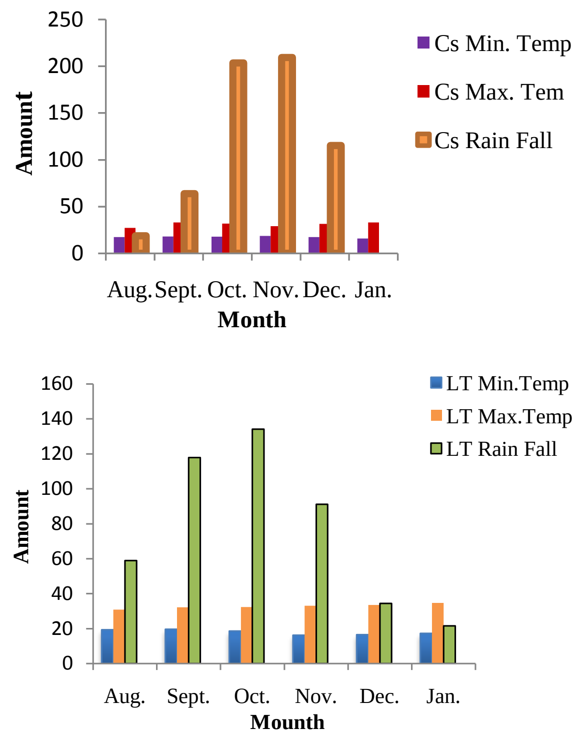

Figure 1. Cropping season and the long term monthly averages of the main climatic variables of the experimental site. Source: National Meteorology Agency (2015).

combinations of treatments were as follows:

Sole Maize with 0 kg·N·ha^{-1}
Sole Maize with 23 kg·N·ha^{-1}
Sole Maize with 46 kg·N·ha^{-1}
Sole Maize with 69 kg·N·ha^{-1}
Sole Maize with 92 kg·N·ha^{-1}
Maize + common bean with 0 kg·N·ha^{-1}
Maize + common bean with 23 kg·N·ha^{-1}
Maize + common bean with 46 kg·N·ha^{-1}
Maize + common bean with 69 kg·N·ha^{-1}
Maize + common bean with 92 kg·N·ha^{-1}
Maize + common bean with mung bean with 0 kg·N·ha^{-1}
Maize + common bean with mung bean with 23 kg·N·ha^{-1}
Maize + common bean with mung bean with 46 kg·N·ha^{-1}
Maize + common bean with mung bean with 69 kg·N·ha^{-1}
Maize + common bean with mung bean with 92 kg·N·ha^{-1}

2.5. Experimental Material and Sowing

The experiment was conducted with BH-140 maize variety, common bean (variety Hawassadume) and Mung bean (variety shewarobit). The seeds of maize cultivar were planted at inter and intra-row spacing of 75 and 25 cm. The seeds of common bean were intercropped at the same time with maize in between two consecutive maize rows at inter and intra-row spacing of 37.5 and 10 cm. The seeds of mung bean, for treatments 11 to 15, were planted after harvesting common bean. Each plot had a size of 2 × 3 m^2 consisting 4 rows for maize, 3 rows for common bean and 3 rows for mung bean. The experimental plots within a block and blocks were spaced at 0.5 m and 1m, respectively. Sole maize was planted within 2 m × 3 m length plot size having inter and intra-row spacing of 75 and 25 cm. Two central rows with net plot size of 2.25 m^2 were harvested and used for data collection. Under intercropping condition maize was planted with the same plot size as that of sole maize.

2.6. Fertilizer Application

Recommended phosphorus fertilizer rate of 46 kg P_2O_5 ha^{-1} in the form of TSP was applied for both sole and intercropped crops as basal application during sowing for easy establishment of crops. Specified rates of nitrogen in the form of urea at 0, 23 , 46, 69 and 92 kg·ha^{-1} was applied once a time to all treatments as side dressing when the maize crop reached knee height.

2.7. Data Collection

2.7.1. Phenological and Growth Parameters of Maize

During the cropping season data of days to 50% emergence, days to tasseling, days to silking, days to maturity (dm), plant height (cm) and dry matter production (kg·ha^{-1}) were collected.

2.7.2. Yield and Yield Components of Maize

Number of ears per plant, Ear height (cm), Number of kernels per ear, Hundred kernels weight (g), Grain yield (kg·ha^{-1}) and Harvest index were collected at the time of data collection.

2.7.3. Assessing Yield Advantages

Land equivalent ratio compares the yields from growing two or more crops together with yields from growing the same crops in monocultures [16]. LER were calculated using the following formula:

$$\text{LER} = \sum \frac{Y_{ni}}{Y_{mi}}$$

where, Y_{ni} is the yield of each crop or variety in the intercrop and Y_{mi} is the yield of each crop or variety in the sole crop or monoculture.

Average or maximum sole crop yields at the optimum fertilizer used as standardization factors for all mixture plot yields of maize as described by [17].

Gross monetary value (GMV) was calculated as a product of yields of component crops (kg·ha^{-1})) multiplied by their respective price of maize, common bean and mung bean. The price was taken from local markets and monetary advantage (MA) was calculated as:

$$\text{MA} = \text{value of combined inter crop yield} \times \frac{(\text{LER} - 1)}{\text{LER}} \quad [16]$$

2.8. Economic Analysis

The economic advantage of the cropping systems was evaluated by estimating net benefit, total cost and marginal rate of return according to [18]. Market price of maize, common bean and mung bean was obtained by assessing of the market at harvest. In addition to this Labors cost used to estimate cost of production.

2.9. Data Analysis

Statistical analysis of variance of the field experimental data of various parameters was carried out using PROC GLM procedure [19] version 9.2. Fisher's Least Significant Difference (LSD) test at $P < 0.05$ was used to separate significant differences between and among the means.

3. Results and Discussion

3.1. Phenology and Growth Analysis of Maize

3.1.1. Days to Tasseling (DTS)

As indicated in **Table 2**, increasing N fertilizer from 0 to 92 kg·N·ha^{-1} showed increment of days to 80% tasseling from 73.4 to 75.0. The maximum mean days to attain tasseling were recorded at 92 kg·N·ha^{-1}. This result was in agreement

Table 2. Days to 50% emergence, days to 80% tasseling and days to 80% silking of maize as affected by intercropping system and rate of nitrogen application during 2015/16 cropping season.

Treatment N rate (Kg·ha^{-1})	Days to 50% emergence	Days to 80% tasseling	Days to 80% silking
0	9.7^{a}	73.4^{c}	79.3^{c}
23	9.7^{a}	74.1^{bc}	80.1^{bc}
46	9.2^{a}	74.4^{ab}	80.8^{ab}
69	9.4^{a}	74.6^{ab}	80.8^{ab}
92	10.2^{a}	74.9^{a}	81.4^{a}
SEM (±)	0.6	0.3	0.3
LSD$_{(0.05)}$	NS	0.7	0.9
Cropping Systems			
SM	9.9^{a}	74.3^{a}	80.1^{a}
M + CB	9.2^{a}	74.2^{a}	80.7^{a}
M + CB − MB	9.8^{a}	74.4^{a}	80.7^{a}
SEM (±)	0.5	0.2	0.3
LSD$_{(0.05)}$	NS	NS	NS
CV (%)	19.3	1.0	1.3
Mean	9.6	74.3	80.5

Where SM = Sole maize; M + CB = maize intercrop with common bean; M + CB − MB = maize intercrop with common bean and mung bean; NS = Non-significantly different at 0.05 probability level; Means followed by the same letters were not significantly different at 0.05 level of significance.

with findings by Moges (2015), who indicated that increasing N from 0 to 128 kg·N·ha^{-1} showed consistent increment of days to tasseling [20]. Rajcan and Tollenaar also reported that high Nitrogen fertilizer delayed to maize tasseling [21].

3.1.2. Days to Silking (DSI)

The mean number of days to attain silking was significantly ($P < 0.05$) affected by the nitrogen rate but effect of cropping systems was not significant (**Table 2**). The number of days required to attain silking ranged from 79.3 to 81.4. The maximum number days to silking was recorded at nitrogen rate of 92 kg·ha^{-1}. This finding was in agreement with the findings reported by Kassahun *et al.* who documented significant influence of nitrogen fertilizer rate and no significant effect of cropping system on days to silking during maize-bean intercropping system and nitrogen fertilizer application study at wolaitasodo [22].

3.1.3. Plant Height

The result showed that plant height was significantly ($P < 0.05$) affected by N fertilizer rate and cropping system is presented in **Table 3**. The cultivation of maize attained maximum plant height of 242.4 cm and 236.4cm with full dose of nitrogen (92 Kg·ha^{-1}) N. The minimum (204.3 cm) plant height was recorded

Table 3. Plant height and days to physiological maturity of maize as affected by rate of nitrogen and intercropping system during 2015/16 cropping season.

Treatment	Plant Height (cm)	Days to physiological maturity (days)
N rate (Kg·ha^{-1})		
0	204.3^{d}	142.7^{d}
23	221.8^{c}	142.7^{d}
46	229.0^{b}	145.2^{c}
69	236.4^{a}	146.7^{b}
92	242.4^{a}	150.3^{a}
SEM (±)	2.2	0.5
$LSD_{(0.05)}$	6.3	1.4
Cropping Systems		
SM	231.6^{a}	145.8^{a}
MZ + CB	224.7^{b}	145.3^{a}
MZ + CB − MB	224.0^{b}	145.5^{a}
SEM (±)	1.7	0.19
$LSD_{(0.05)}$	4.9	NS
CV	2.9	1.0
Mean	226.8	145.5

where SM = sole maize; M + CB = maize intercrop with common bean; M + CB − MB = maize intercrop with common bean and mung bean; NS = Non-significantly different at 0.05 probability level; Means followed by the same letters were not significantly different at 0.05 level of significance.

with no fertilizer (0 kg·ha^{-1}) applied. The result suggested that plant height was increased with increasing application of nitrogen fertilizer. The present findings was in agreement with the findings by Haseebur *et al.* who described that cultivation of maize alone with full dose of nitrogen showed maximum (216.5 cm) plant height whereas, minimum height of maize 184.5 cm was recorded from no fertilizer application [23]. Furthermore, Dawadi *et al.* also observed that increasing nitrogen level from 120 kg·ha^{-1} to 200 kg·ha^{-1} increased plant height of maize varieties [24].

Effect of plant height was significant due to cropping system (**Table 3**). Maximum plant height of 231.6 cm was recorded from sole cropped maize (SM) and the minimum plant height of 224.7 cm was recorded in a cropping system of MZ + CB which is on par with MZ + CB − MB. The maximum (220 cm) and minimum (170.5 cm) plant height was also recorded in sole cropping system and intercropping of maize and fababean, respectively reported by [25]. The result suggested that plant height was associated with population and competition per unit area where less populated plot with minimum competition showed high plant height. The present findings was in agreement with the findings by Farzaneh *et al.* who observed higher plant height in sole cropped maize while the minimum in maize intercropped with faba bean [26]. In addition, Thakur *et al.* described that maximum (220 cm) and minimum (170.5 cm) plant height was recorded insole cropping system and intercropping of maize, respectively [25].

The results of regression analysis as depicted at **Figure 2** suggested that the change in fertilizer rate from 0 to 92 kg·ha^{-1} accounted for 94.6% of total variation in plant height. The variation in cropping system also accounted for about 81.8% of total variation in plant height suggesting the significant contribution of fertilizer and cropping system for plant height.

3.1.4. Days to Physiological Maturity

As indicated in **Table 3**, the mean number of days required to attain physiological maturity was significantly ($P < 0.05$) affected due to rate of nitrogen application-

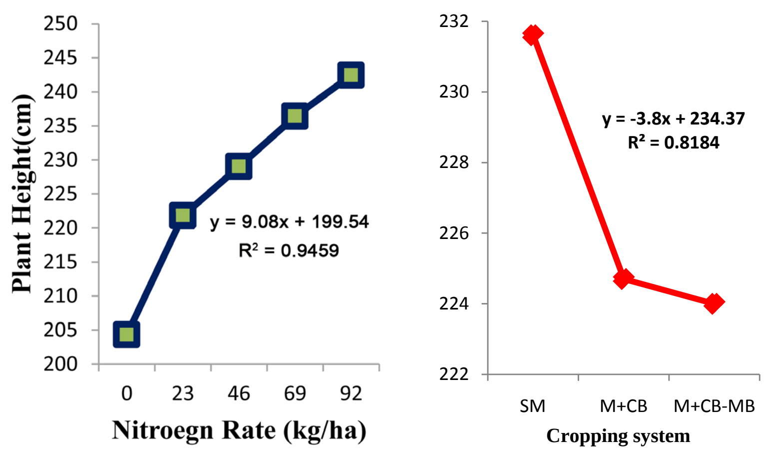

Figure 2. The relationships between rate of nitrogen fertilizer and cropping system on plant height.

tion. The result showed that maximum (150.3) days to reach maturity was recorded from 92 kg·N·ha^{-1} whereas, the minimum (142.7) days to reach DPM was recorded for the control treatment. This finding was in agreement with a result obtained from a study conducted at Haromaya district by Kidist who observed significant effect of increasing nitrogen fertilizer effect on days to physiological maturity where plants in a control treatment matured early, while plants at the highest N rates matured lately [27]. The regression analysis result depicted in **Figure 3** showed a linear proportional increase to the number of days required to mature with increasing application of nitrogen rate. The result showed that the change in fertilizer rate from 0 to 92 kg·ha^{-1} accounted for about 94.3% of total variation in days to maturity which suggested nitrogen fertilizer application extends the maize growth period.

3.2. Yield and Yield Components of Maize

3.2.1. Kernel Number Per Ear

Application of nitrogen fertilizer showed significant ($P < 0.05$) effect on kernel number per plant is presented in **Table 4**. Number of kernel per ear of 420.2 was obtained in plots applied with 92 kg·N·ha^{-1} while the lowest kernel number per ear of 307.7 was recorded in plots with 0 fertilizers. This finding was supported

Table 4. Kernel number per ear, number of ear per plant and ear height as affected by rate of nitrogen and intercropping system during 2015/16 cropping season.

Treatment	Kernel Number per ear	Number of ear per plant	Ear height per plant (cm)
N rate (Kg·ha^{-1})			
0	307.7^{c}	1.3^{a}	106.2^{c}
23	357.6^{b}	1.3^{a}	115.8^{ab}
46	381.6^{ab}	1.2^{a}	120.4^{a}
69	395.4^{ab}	1.2^{a}	109.8^{bc}
92	420.2^{a}	1.2^{a}	120.1^{a}
SEM (±)	14.6	0.1	2.7
$LSD_{(0.05)}$	42.3	NS	7.8
Cropping System			
SM	383.4^{a}	1.1^{a}	120.8^{a}
MZ + CB	361.9^{a}	1.3^{a}	117.6^{a}
MZ + CB − MB	372.3^{a}	1.3^{a}	104.9^{b}
SEM (±)	11.3	0.1	2.1
$LSD_{(0.05)}$	NS	NS	NS
CV (%)	11.6	24.9	7.0
Mean	372.5	1.2	114.5

Where SM = sole maize; M + CB = maize intercrop with common bean; M + CB − MB = maize intercrop with common bean and mung bean; NS = Non-significantly different at 0.05 probability level; Means followed by the same letters were not significantly different at 0.05 level of significance according to LSD test.

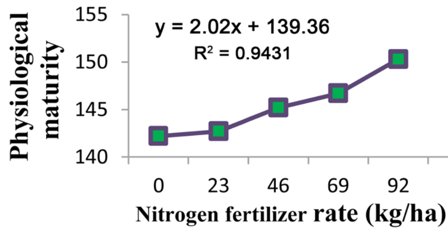

Figure 3. Relationship between rate of nitrogen fertilizer and physiological maturity of maize.

by Lawrence and Dawadi who described Nitrogen fertilizer application showed significant effect on maize kernel number per cob [24] [28].

Application of nitrogen showed a linear response to kernel number per ear (**Figure 4**). The result of regression analysis result showed that the change in fertilizer rate from 0 to 92 kg·ha^{-1} accounted for about 93.6% total change in kernel number per ear.

3.2.2. Ear Height per Plant

As presented in **Table 4**, the ear height due to nitrogen application ranged from 106.2 to 120.4 cm and maximum ear height per plant was recorded when applying 46 kg nitrogen per hectare.

Mean ear height per plant was significantly affected due cropping system. The mean height was ranged from 104.9 cm to 120.8 cm where the maximum ear height was recorded from sole cropped maize which was on par with maize intercropped with common bean (MZ + CB). The result suggested that ear height per plant was affected due to increased population per unit area which increased competition among the component crops. The present findings was in agreement with the findings by Farzaneh *et al.* who observed high ear height in sole cropped maize while the minimum in maize intercropped with faba bean [26].

The relationship between the rate of fertilizer application and cropping system with ear height per plant is depicted in **Figure 5**. The change in rate of fertilizer (0 to 92 kg·ha^{-1}) and various cropping system accounted 29.9% and 89.4% of total variation in total ear height per plant.

3.2.3. Grain yield (kg·ha^{-1})

Analysis of grain yield as affected by fertilizer application and cropping system is presented in **Table 5**. The grain yield of maize due to fertilizer application ranged from 3731.3 kg·ha^{-1} to 5345.1 kg·ha^{-1}. The maximum grain yield was attained applying nitrogen at 92 kg·ha^{-1}. The result suggested that significant contribution of nitrogen for maximum grain yield. This result was in consistent with Kassahun *et al.* who described that grain yield of 6751.69 kg·ha^{-1} was obtained with nitrogen fertilizer applied at 92 kg·ha^{-1}. Application of nitrogen significantly increased monoculture maize yield by 30% and soybean yield by 13% reported by Zada and Ahmed [29].

Significant responses of maize was observed at highest level of nitrogen application was also documented by Habtamu, Rashid *et al.* and Siame *et al.* [30] [31]

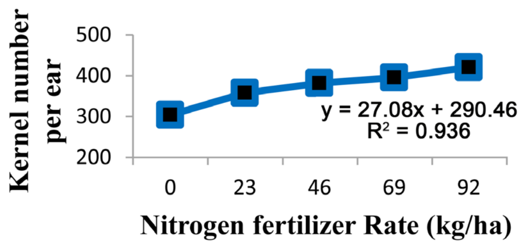

Figure 4. Effect of rate of nitrogen fertilizer on kernel number per ear.

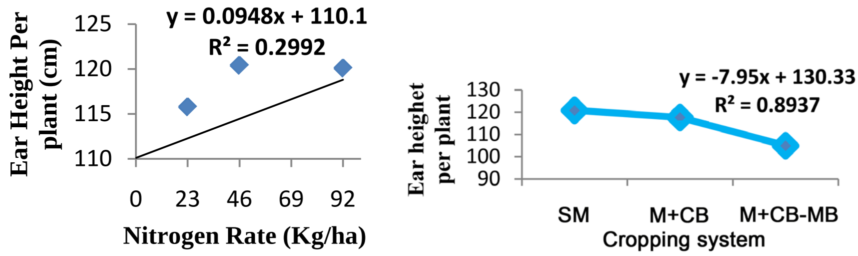

Figure 5. The relationships between nitrogen and cropping system with ear height per plant.

Table 5. Yield and yield components of maize as affected by nitrogen fertilizer application and intercropping system during 2015/2016 cropping season.

Treatment	Grain Yield (Kg ha^{-1})	Dry Matter (kg ha^{-1})	Hundred Seed Weight (g)	Harvest Index (HI)
N rate (Kg·ha^{-1})				
0	3731.3^{d}	10272.2^{c}	30.2^{b}	25.7^{d}
23	4429.2^{c}	10698.9^{b}	30.2^{b}	28.8^{c}
46	4761.6^{bc}	10894.0^{ab}	31.5^{ab}	30.4^{bc}
69	5032.7^{ab}	10814.1^{ab}	31.8^{a}	31.0^{ab}
92	5345.1^{a}	11081.8^{a}	33.6^{a}	32.2^{a}
SEM (±)	118.1	114.4	0.9	0.6
LSD$_{(0.05)}$	344.7	331.5	2.5	1.8
Cropping System				
SM	4838.2^{a}	11166.8^{a}	30.55	29.9^{a}
MZ + CB	4843.3^{a}	10655.7^{b}	32.64	29.7^{a}
MZ + CB − MB	4298.5^{b}	10434.2b	31.18	29.3^{a}
SEM (±)	102.1	110.7	0.7	0.5
LSD$_{(0.05)}$	267	256.8	NS	NS
CV	7.6	3.2	8.2	6.2
Mean	4659.1	10752.2	31.4	29.6

Yield is adjusted to 12.5% moisture content; SM = sole maize; M + CB = maize intercrop with common bean; M + CB − MB = maize intercrop with common bean and mung bean; NS = Non-significantly different at 0.05 probability level; Means followed by the same letters are not significantly different at 0.05 level of significance.

[32]. Maximum grain yield of 4843.3 kg·ha^{-1} was obtained in maize + common bean cropping system. The amounts of yield obtained under maize +common bean was on par with sole cropped maize yield (4838.2 kg·ha^{-1}). The result suggested that maize grain yield was reduced with increasing competition of the component crops. The presence result was inconsistent with the findings documented by Kassahun *et al.* who reported grain yield of 6496.0 kg·ha^{-1} was obtained when common bean intercropped with maize. Furthermore, intercropping effect on grain yield of maize was reported by Tolera (2003) and Kmni *et al.* (1999) when haricot bean intercropped with maize [33] [34].

Alemayehu *et al.* also reported that maize grain yield was 16% more on maize-narrow leaf lupine intercropping relative to sole crop maize studied on Maize-common bean/lupine intercrop productivity and profitability in maize-based cropping system of Northwestern Ethiopia [35].

The regression analysis result depicted in **Figure 6** showed a linear response increase to the grain yield with increasing application of nitrogen rate and inversely with cropping system. The result showed that the change in fertilizer rate from 0 to 92 kg·ha^{-1} and cropping system accounted for about 95.7% and 74.3% of total variation in maize grain yield respectively, which suggested significant contribution of nitrogen fertilizer application in maize grain yield.

3.2.4. Dry Matter (kg·ha^{-1})

As presented in **Table 5**, dry matter production was significantly affected due to nitrogen fertilizer application and cropping system. The maximum (11,081.8 kg·ha^{-1}) maize dry matter was recorded when applying 92 kg·ha^{-1}. The result indicated importance of nitrogen in dry matter accumulation. Similar results were reported by Kena, who described that maximum dry matter yield of (16,529 kg·ha^{-1}) recorded at the highest nitrogen rate [36]. In addition dry matter yield increased with increasing nitrogen level also documented by Singh *et al.* (2000) [37] studies on intercrops and nitrogen application influence growth and yield of winter maize (*Zea mays* L.) Furthermore, Cassman *et al.* (2003) reported that 25% to 75% maize dry matter yield increment over the control treatments was noted with N application [38].

The maximum dry matter of 11,168.8 kg·ha^{-1} was obtained from sole cropped maize. The present finding coincides with the reports documented by Zeljko *et al.* [39]. They discribed that soya bean intercropped with maize showed minimum biomass 17.4 t·ha^{-1} when compared to above-ground biomass achieved in

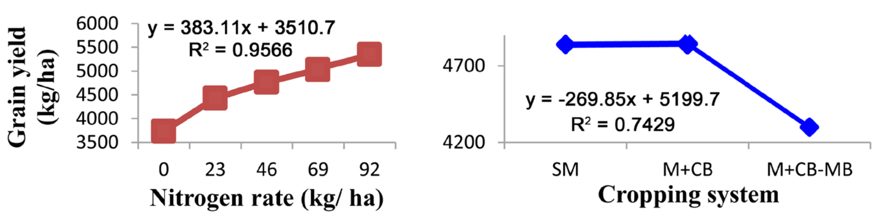

Figure 6. The relationships between rate of nitrogen fertilizer and cropping system on grain yield of maize.

mono crops maize (21.2 t·ha^{-1}) suggesting advantage of sole cropped maize for growth resources in ability of competition.

The result of regression analysis is depicted in Figure 7. The regression line suggested that dry matter production increased simultaneously with application of fertilizer and inversely with cropping system where the change in fertilizer rate from 0 to 92 kg·ha^{-1} and cropping system accounted for 82.2% and 95.6% of total variation in dry matter respectively.

3.2.5. Harvest Index (HI)

Harvest index was significantly ($P < 0.05$) affected by application of nitrogen (Table 5). The maximum harvest index of 32.2% was recorded when applying 92 kg·N·ha^{-1}. The result suggested that the need for nitrogen application to maximize production. This finding was in consistent with the result documented by Moges who reported significant and consistent HI increase with increasing application of nitrogen from 0 to 120 kg·ha^{-1}.

The result of regression analysis is depicted in Figure 8. Suggested that harvest index increased simultaneously with application of fertilizer where the change in fertilizer rate from 0 to 92 kg·ha^{-1} accounted for 91.7% of total variation in harvest index.

3.3. Correlation Analysis

Correlation analysis between grain yield and yield components of maize, phenological and growth parameters was worked out and presented in Table 6. The correlation analyses revealed that there was a significant ($P < 0.05$) correlation

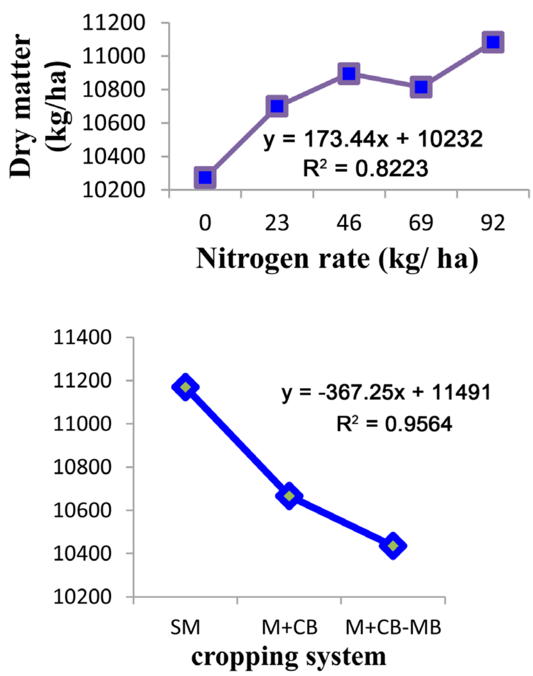

Figure 7. The relationships between rate of nitrogen fertilizer and cropping system on dry matter of maize.

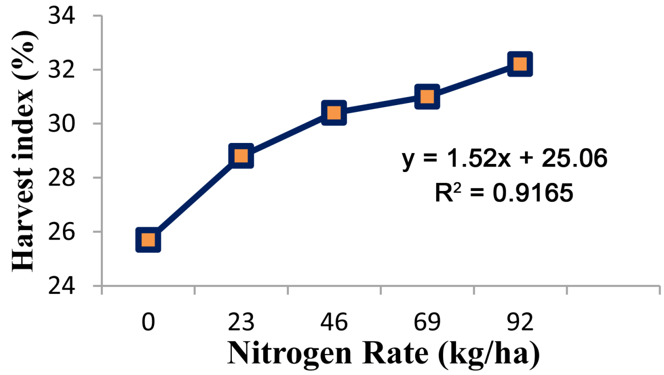

Figure 8. Relationships between rate of nitrogen fertilizer and harvest index.

Table 6. Correlation analysis of growth, yield, phenology and yield component of maize.

	DEM	DTS	DSI	DMA	PH	DMT	EHPP	NEPP	KNNP	GYLD	HSW	HI
DEM	1											
DTS	0.1^{ns}	1										
DSI	0.4^{ns}	0.3^{ns}	1									
DMA	0.4^{ns}	-0.1^{ns}	-0.0^{ns}	1								
PH	0.9^{ns}	0.1^{ns}	0.5^{ns}	-0.1^{ns}	1							
DMT	0.4^{ns}	0.2^{ns}	0.4^{ns}	0.9^{ns}	0.0^{ns}	1						
EHPP	0.2^{ns}	0.2^{ns}	0.7^{ns}	0.5^{ns}	0.0^{ns}	0.8*	1					
NEPP	0.1^{ns}	0.0^{ns}	0.5^{ns}	0.2^{ns}	0.0^{ns}	0.6^{ns}	0.8**	1				
KNNP	-0.1^{ns}	0.2^{ns}	-0.8^{ns}	0.3^{ns}	0.1^{ns}	-0.6^{ns}	−0.9**	-0.6^{ns}	1			
GYLD	0.5^{ns}	0.2^{ns}	0.4^{ns}	0.8**	0.1^{ns}	1.0***	0.8^{ns}	0.5^{ns}	0.6^{ns}	1		
HSW	0.4^{ns}	0.1^{ns}	0.4^{ns}	0.8	0.0^{ns}	1.0***	0.8**	0.7^{ns}	-0.6^{ns}	0.9***	1	
HI	0.5^{ns}	0.1^{ns}	-0.1^{ns}	0.7*	-0.0^{ns}	0.7^{ns}	0.4^{ns}	0.4^{ns}	-0.1^{ns}	0.7^{ns}	0.8*	1

Where; DEM = days to emergency; DTS = Days to tasseling; DSI = Days to silking; DMA = Days to maturity; PH = Plant height; DMT = Dry matter; EHPP = Ear height per plant; NEPP = Number of ear per plant; KNNE = Kernel number per ear; GYLD = Grain yield; HSW = Hundred seed weight; HI = Harvest index; NS, *, ** and *** = non-significant and significantly different at 0.05%, 0.01% and 0.001% respectively.

between grain yield and yield components of maize while the association of yield with phenological and growth parameters showed not significant but positive except days to physiological maturity.

Grain yield was significantly and positively correlated with above ground biomass ($r = 1.0^{**}$), HSW (r = 0.9**) and HI (r = 0.88**) which suggested significant contribution of yield components on grain yield of maize. This finding was similar with a result obtained from a study conducted at Haromaya district by Kidist who observed a positive correlation of grain yield and biomass yield. Significant and positive correlation was also observed between hundred seed weight and above ground dry matter ($r = 1.0^{**}$) and ear height per plant ($r = 0.8^{**}$) and negative and non significant correlation with number of kernel per ear (−r = 0.6).

3.3.1. Intercropping Advantages

The productivity advantage of maize + common bean and maize + common bean with mung bean intercropping system was assessed with land equivalent ratio and monetary value of the treatment combination. As shown in Table 7, cropping system showed significant ($P < 0.05$) effect on partial land equivalent ratio of maize, total LER, gross monetary values and monetary advantage of the component crops.

3.3.2. Partial LER of Maize

The effect of intercropping system was significant for LER when the maximum LER 1.0 was recorded at Maize + Bean cropping system. Maize + Bean cropping system greater than by 20% compared to maize + common bean − mung bean. The result suggested that maize yield advantage decreased with increase in the no of legumes in the cropping system.

3.3.3. Total LER

Total LER was also significantly affected by the cropping system. The maximum (2.2) total LER was recorded from Maize + Common Bean-Mung Bean. Intercropping three cropping species was greater by 40% compared to intercropping of two crop species. This result agreed with the findings by chemeda who indi-

Table 7. Partial land Equivalent Ratio (LER), total LER, Gross Monetary Value (GMV) and Monetary Advantage (MA) of maize as influenced by intercropping with legumes and rates of Nitrogen fertilizer during 2015/16 cropping season.

Treatments N rates ($kg \cdot ha^{-1}$)	Maize LER	Bean LER	Mung Bean LER	Total LER	GMV $Birr \cdot ha^{-1}$	MA $Birr \cdot ha^{-1}$
0					67,015^{d}	28,371^{d}
23					75,341^{c}	36,641^{c}
46					76,104^{c}	37,675^{c}
69					80,731^{b}	42,297^{b}
92					83,662^{a}	45,368^{a}
SEM (±)					864.4	849.7
$LSD_{(0.05)}$					2568.2	2524.5
Cropping System						
SM					31,448.1^{c}	
MZ + CB	1.0^{a}	0.8^{a}		1.8^{b}	65,950.8^{b}	29,072.5^{b}
MZ + CB − MB	0.8^{b}	0.9^{a}	0.5^{a}	2.2^{a}	87,191.0^{a}	47,068.2^{a}
SEM (±)	0.02	0.0	0.1	0.0	546.7	537.4
$LSD_{(0.05)}$	0.1	0.9	0.0	0.0	1624.3	1596.6
CV (%)	7.6	4.9	16.8	2.7	2.8	5.5
Mean	0.9	0.8	0.2	2.0	76,570.9	38,070.4

Where LER = Land equivalent ratio; GMV = Gross monetary value; MA = Monitory advantage; Means followed by the same letters are not significantly different at 0.05 level of significance according to LSD test.

cated 28% total productivity increase of maize-bean intercropping compared to pure stand [40].

Similarly, yield advantages of intercropping on maize was in other study conducted at Kombolcha on system productivity of forage legumes intercropped with maize and performance of the component crops [41].

3.3.4. Gross Monetary Value (GMV)

Significant effect of fertilizer application and cropping system also noted on gross monetary values (**Table 7**). GMV of 83,662 birr·ha^{-1} was recorded when applying nitrogen at 92 kg·ha^{-1}. Application of 92 kg·ha^{-1} nitrogen fertilizer gave greater GMV by 16,647 birr·ha^{-1} compared to no nitrogen application. Intercropping maize + common bean with mung bean gave significantly higher GMV of 87,191.0 Birr·ha^{-1}. It was greater than by 55,742.9 birr sole maize. This result supported by a study conducted on productivity evaluation of maize -soybean intercropping system under rain fed condition at Bench-Maji Zone by Solomon *et al.* (2014) who indicated that the GMV of intercrops was higher than sole maize on maize-soybean intercropping [42].

3.3.5. Monetary Advantage (MA)

Significant effect of fertilizer application and cropping system also noted on monetary advantages (**Table 7**). MA of 45,368 birr·ha^{-1} was recorded when applying nitrogen at 92 kg·ha^{-1}. Applying of 92 kg·ha^{-1} nitrogen fertilizer was greater than by 16,997 as compared to no nitrogen application. Intercropping maize + common bean with mung bean gave significantly higher MA of 47,068.2 Birr·ha^{-1} when compared to MA of 29,072.5 Birr·ha^{-1} obtained in maize + common bean cropping system. This result supported by a study conducted on soybean-maize intercropping integrated fertilizer application with various proportions of NP with FYM by Abebe *et al.* who indicated that significantly increased MA over the unfertilized intercrops [43].

3.4. Economic Analysis

Economic analysis of fertilizer application and legumes under maize based cropping system analyzed and presented in **Table 8**. There was variation in maize fertilizer and legume combination on total variable cost, net return and marginal rate return. Market price of maize (6.50 birr·kg^{-1}), common bean (12 birr·kg^{-1}) and mung bean (20.00 birr·kg^{-1}) was obtained by assessing of the market at harvest. Labors cost also used to estimate cost of production.

3.4.1. Net Return (NR)

As presented in **Table 8**, the maximum net return of 55,214.0 birr·ha^{-1} was obtained when maize intercropped with common bean followed by mung bean at 92 kg·ha^{-1} nitrogen application. The net return of sole maize with all level of nitrogen application exhibited low net return. This result suggested that intercropping and application of nitrogen fertilizer increase net returns for maize production. The finding was similar with a result obtained from a study conducted in

Table 8. Economic of maize as influenced by rates of Nitrogen and intercropping system during 2015/2016 cropping season.

Treatment	TVC (Eth. Birr)	NB(Eth. Birr)	MRR%
	SM		
0	0	19,561	-
23	715	26,119.3	917
46	1630	28,269.8	235
69	2445	29,475.9	148
92	3260	30,040.7	69
	M + CB		
0	0	22,568	-
23	9058	47,839.8	279
46	9843	49,505.5	212
69	10,658	51,710.7	270
92	11,523	54,123.4	279
	M + CB − MB		
0	0	23,561	-
23	22,938.7	50,816.7	119
46	23,730.5	49,678	D
69	24,162.6	54,346.2	1080
92	25,354.5	55,214	73

SM = Sole maize; M + CM = Maize intercropped with common bean; M + CB − MB = Maize intercropped with common bean and mung bean; TVC = Total variable cost; NB = Net benefit; D = Dominance and MRR = Marginal rate of return.

southern Ethiopia by Walelign (2013) who observed highest net return from sequential intercropping of common bean and mung bean with maize.

3.4.2. Marginal Rate of Return (MRR)

Maximum marginal rate of 1080% was recorded when maize intercropped with common bean followed by mung bean when applying 69 kg·ha^{-1} nitrogen showed above the minimum (100%) rate of return needed for adoption by farmers [18].

Greater economic returns were reported in cereal–legume intercropping systems [44] [45]. This result was similar with a finding obtained from a study on total productivity and net returns of different sorghum-legume intercropping system under varying N levels [46].

4. Conclusion

The result of this study showed that days to maturity, teaseling, silking and kernel number were significantly affected by the main effects of nitrogen rate at 92 kg·ha^{-1}. In addition grain yield, dry mater and plant height were significantly affected by both the main effects of cropping system and rate of nitrogen fertilizer. The maximum grain yield, dry mater and plant height were observed in maize + common bean cropping system and sole maize at 92 kg·ha^{-1} Nitrogen rate respectively. The maximum partial LER was recorded when maize intercropped with common bean. Higher (2.2) total LER were recorded in Maize + common bean with mung bean cropping system. Maximum gross Monetary Value (GMV) of 83,662 Birr ha^{-1} and 87,191.0 Birr·ha^{-1} were obtained when applying nitrogen at 92 kg·N·ha^{-1} and maize intercropped with common bean followed by mung bean cropping system respectively. Results of economic analysis showed that maize intercropped common bean followed by mung bean with nitrogen at 92 kg·N·ha^{-1} gave higher total productivity (80568.49 birr) and net return (55,214.01 birr). Whereas, higher marginal rate of return (1080%) was obtained from maize intercropped with common bean followed by mung bean with nitrogen at 69 kg·ha^{-1}.

Acknowledgements

I would like to express my deepest gratitude and sincere thanks to Dr. Zenebe Mekonnen and Dr. Dereje Tsegaye for their guidance and constructive comments at all stages of the research work and thesis write up. Next, I would like to thank Arba Minch Agricultural Research Center for their financial and technical supports. I am also forwarding my heartfelt thanks to Arba Minch University Department of Plant Sciences for their technical support.

References

[1] Adefris, T., Eshetu, A. and Solomon, A. (2012) Values That Foster Effectiveness of Partnership for Agricultural Innovation. *Proceedings of the 3rd national Maize Workshop of Ethiopia*, Addis Ababa, 18-20 April 20011.

[2] Grepperud, S. (1996) Population Pressure and Land Degradation: The Case of Ethiopia. *Journal of Environmental Economics and Management*, **30**, 18-33. https://doi.org/10.1006/jeem.1996.0002

[3] Pender, J. and Gebremedhin, B. (2006) Land Management, Crop Production, and Household Income in the Highlands of Tigray, Northern Ethiopia: An Econometric Analysis. In: Pender, J., Place, F. and Ehui, S., Eds., *Strategies for Sustainable Land Management in the East African Highlands*, International Food Policy Research Institute, Washington DC.

[4] Osagie, A.U. and Eka, O.U. (1998) Nutritional Quality of Plant Foods: Post-Harvest Research Unit. University of Benin, Benin City, 62.

[5] Shahidur, R., Chilot, Y., Befekadu, B. and Solomon, L. (2010) Maize Value Chain Potential in Ethiopia Pulse Export Promotion Agency, Constraints and Opportunities for Enhancing Exports. International Food Policy Research Institute, Addis Ababa, 44 p.

[6] Central Statistical Agency (CSA) (2012) Agricultural Sample Survey: Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Central Statistical Agency, Addis Abeba.

[7] Tesfa, B., Tolessa, D., Setegn, G., Tamado, T., Negash, G. and Tenaw, W. (2001) Development of Appropriate Cropping Systems for Various Maize Producing Re-

gions of Ethiopia. 2*nd National Workshop of Ethiopia*, Addis Ababa, 12-16 November 2001, 61-63.

[8] Awal, M.A., Koshi, H. and Ikeda, T. (2006) Radiation Interception and Use by Maize/Peanut Intercrop Canopy. *Agricultural and Forest Meteorology Journal*, **139**, 74-83.

[9] Federer, W. (1999) Statistical Design and Analysis for Intercropping Experiments. Springer-Verlag, New York.

[10] Thobatsi, T.J. (2009) Growth and Yield Response of Maize (*Zea mays L.*) and Cowpea (*Vigna unguiculata L.*) in Intercropping System. PhD Dissertation, University of Pretoria, Pretoria.

[11] Walelign, W. (2013) Sequential Intercropping of Common Bean and Mung Bean with Maize in Southern Ethiopia. *Experimental Agriculture Journal*, **50**, 90-106.

[12] Tenaw, W. (2014) Legume-Based Cropping for Sustainable Production, Economic Benefit and Reducing Climate Change Impacts in Southern Ethiopia. *Journal of Agricultural and Crop Research*, **2**, 11-21.

[13] Barnes, P.B. and Addo-Kwafo, A. (1994) Under-Sowing Maize with Stylosanthes: Effects of Spacing, Time of Planting, and Fertilization on Maize Grain and Stylo Herbage Yields. *African Crop Science Conference Proceedings*, **1**, 174-176.

[14] Arba Minch Zurea Woereda Agricultural Office (2014) Reports on Description of Arba Minch Zurea Woereda and the Study Area.

[15] National Meteorology Agency (2015) Reports on Rain Fall and Temperature of Ariba Minich Zuria Wereda. Arba Minch University, Arba Minch.

[16] Willey, R.W. (1979) Intercropping, Its Importance and Research Needs. Competition and Yield Advantages. *Field Crops Abstract Journal*, **32**, 2-5.

[17] Neto, F.B. (1993) Effects of Spatial Arrangement and Density on Efficiency, Yield and Yield Components, Dry Matter Partitioning and Growth of an Annual Cotton/Cowpea/Maize Intercrop. PhD Dissertation, University of Arizona, Tucuson.

[18] International Maize and Wheat Improvement Center (CIMMYT) (1988) Farm Agronomic to Farmer's Recommendation. An Economic Training Manual, D.F. Mexico.

[19] SAS Institute (2002) SAS User's Guide. Version 9.2. SAS Inst., Cary.

[20] Moges, A. (2015) Effect of Nitrogen Fertilizer Rates and Plant Densities on Yield and Yield Related Traits of Maize (*Zea mays*) under Irrigation in Southern Tigray, Ethiopia. MSc Thesis, Haromaya University, Haromaya.

[21] Rajcan, I. and Tollenaar, M. (1999) Source-Sink Ratio and Leaf Senescence in Maize: I. Dry Matter Accumulation and Partitioning during Grain Filling. *Field Crops Research*, **60**, 245-253.

[22] Kassahun, A., Tamado, T. and Nigussie, D. (2013) Influence of Maize-Bean Intercropping Pattern and Nitrogen Fertilizer Application on the Productivity of the Crops at Wolaita Sodo, Southern Ethiopia. M.Sc Thesis, Haromaya University, Haromaya.

[23] Haseebur, R., Asghar, M.A., Waseem, A., Muhammad, T., Muhammad, A. and Muhammad, S.Z. (2010) Impact of Nitrogen Application on Growth and Yield of Maize (*Zea mays L.*) Grown alone and in Combination with Cowpea (*Vigna unguiculata L.*). *American-Eurasian Journal of Agricultural and Environmental Science*, **7**, 43-47.

[24] Dawadi, D.R. and Sah, S.K. (2012) Growth and Yield of Hybrid Maize (*Zea mays L.*) in Relation to Planting Density and Nitrogen Levels during Winter Season in Nepal.

Tropical Agricultural Research Journal, **23**, 220-224.

[25] Thakur, D.R., Prakash, O., Kharwara, P.C. and Bhalla, S.K. (1997) Effect of Nitrogen and Plant Spacing on Yield, Nitrogen Uptake and Economics in Baby Corn (*Zea mays L.*). *Indian Journal of Agronomy*, **43**, 668-671. https://doi.org/10.4038/tar.v23i3.4659

[26] Farzaneh, J., Safar, N., Mohammad, R. and Adel, A.B. (2015) Effect of Different Intercropping Patterns on Yield and Yield Components of Maize (*Zea mays* L.) and Faba Bean (*Vicia faba L.*). *Biological Forum an International Journal*, **7**, 854-858.

[27] Kidist, A. (2013) Growth, Productivity, and Nitrogen Use Efficiency of Maize (*Zea mays*) as Influenced by Rate and Time of Nitrogen Fertilizer Application in Haramaya District, Eastern Ethiopia. M.Sc Thesis, Haramaya University, Haromaya.

[28] Lawrence, O. (2014) Effect of Management Practices under Cowpea-Maize Cropping Systems in South Africa: Maize Yield Case Study. *Agricultural Research Council*, **29**, 282-285.

[29] Zada, K. and Ahmed, S. (1988) Yield and Yield Components of Intercropped Maize and Soybean in Relation to Inorganic Nitrogen. *Pakistan Journal of Agricultural Research*, **9**, 473-477.

[30] Habtamu, A. (2015) Response of Maize (*Zea mays L.*) to Different Levels of Nitrogen and Sulfur Fertilizers in Chilga District, Amhara National Regional State, Ethiopia. *Basic Research Journal of Soil and Environmental Science*, **3**, 38-49.

[31] Rashid, S. and Minot, N. (2010) Staple Food Markets in Africa Efficient. Spatial Price Analyses and Beyond.

[32] Siame, J., Willey, R.W. and Morse, S. (1997) The Response of Maize/Phaseolus Intercropping to Applied Nitrogen on Oxisols in Northern Zambia. *Field Crops Research Journal*, **55**, 73-81.

[33] Kimani, K.K., Gathua, R., Delu, D.J.T. and Cadish, G. (1999) Effects of Maize Bean Intercropping, Phosphorus and Manure Additions on Maize Production in the Central Kenya Highlands. *Proceedings of the 6th Eastern and South Africa Regional maize Conference*, Addis Ababa, 21-25 September 1998, 293-295.

[34] Tolera, A. (2003) Effects of Nitrogen, Phosphorus, Farmyard Manure and Population of Climbing Bean on the Performance of Maize (*Zea mays* L.)/Climbing Bean (*Phaseolus vulgaris L.*) Intercropping System in Alfisols of Bako. M.Sc. Thesis, Haromaya University, Kewet Wereda.

[35] Alemayehu, A., Tamado, T., Nigusie, D., Yigzaw, D., Kinde, T. and Wortmann, C.S. (2016) Maize-Common Bean/Lupine Intercrop Productivity and Profitability in Maize-Based Cropping System of Northwestern Ethiopia. *Ethiopian Journal of Science and Technology*, **9**, 69-85.

[36] Kena, K. (2015) Effect of Nitrogen Rates and Inter Row Spacing on Growth, Yield and Yield Components of Maize (*Zea mays L.*) at Nejo, Western Ethiopia. M.Sc. Thesis, Haromaya University, Haromaya.

[37] Singh, D.P., Rana, N.S. and Singh, R.P. (2000) Growth and Yield of Winter Maize (*Zea mays L.*) as Influenced by Intercrops and Nitrogen Application. *Indian Journal of Agronomy*, **45**, 515-519.

[38] Cassman, K., Roberts, B. and Bryant, D. (2003) Dry Matter Production and Productivity of Maize as Influenced by Residual Fertilizer Nitrogen and Legume Green Manuring. *Journal of Soil Science Society of America*, **56**, 823-830. https://doi.org/10.2136/sssaj1992.03615995005600030025x

[39] Zeljko, D., Snezana, O., Dusan, K., Milena, S., Nebojsa, M. and Zivota, J. (2013)

Dependence of the Productivity of Maize and Soyabean Intercropping Systems on Hybrid Type and Plant Arrangement Pattern. *Russian Journal of Genetics*, **45**, 138-142.

[40] Chemeda, F. (2003) Relationship between Bacterial Blight Severity and Bean Yield Loss in Pure Stand and Bean-Maize Intercropping Systems. *International Journal of pest Management*, **49**, 177-185. https://doi.org/10.1080/0967087021000049269

[41] Getachew, B., Ketema, B. and Sharma, J.J. (2013) System Productivity of Forage Legumes Intercropped with Maize and Performance of the Component Crops in Kombolcha, Eastern Ethiopia. *East African Journal of Sciences*, **7**, 99-108.

[42] Solomon, K.W., Ketema, B. and Tamado, T. (2014) Productivity Evaluation of Maize-Soybean Intercropping System under Rain Fed Condition at Bench-Maji Zone, Ethiopia. *Sky Journal of Agricultural Research*, **3**, 158-164.

[43] Abebe, Z., Sharma, J.J., Dechasa, N. and Kanampiu, F. (2013) The Effect of Integrated Organic and Inorganic Fertilizer Rates on Performances of Soybean and Maize Component Crops of a Soybean/Maize Mixture at Bako, Western Ethiopia. *African Journal of Agricultural Research*, **8**, 3921-3929.

[44] Rusinamhodzi, L., Corbeels, M., Nyamangara, J. and Giller, K.E. (2012) Legume Intercropping Is an Attractive Option for Ecological Intensification That Reduces Climatic Risk for Smallholder Farmers in Central Mozambique. *Field Crops Research Journal*, **136**, 12-22.

[45] Workayehu, T. and Wortmann, C.S. (2011) Maize-Bean Intercrop Weed Suppression and Profitability in Southern Ethiopia. *Agronomy Journal*, **103**, 1058-1063. https://doi.org/10.2134/agronj2010.0493

[46] Waghmare, A.B. and Singh, S.P. (1982) Total Productivity and Net Returns of Different Sorghum-Legume Intercropping Systems under Varying N Levels. *Indian Journal of Agronomy*, **27**, 423-428.