American Journal of Plant Biology
2022; 7(1): 15-25
http://www.sciencepublishinggroup.com/j/ajpb
doi: 10.11648/j.ajpb.20220701.13
ISSN: 2578-8329 (Print); ISSN: 2578-8337 (Online)

Screening Common Bean Varieties Compatibility to Intercropping with Maize at Jejebicho Research Station in Sankura Wereda Silte Zone of Southern Ethiopia

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To cite this article:

Wondimkun Dikr, Nibret Tadesse. Screening Common Bean Varieties Compatibility to Intercropping with Maize at Jejebicho Research Station in Sankura Wereda Silte Zone of Southern Ethiopia. *American Journal of Plant Biology.* Vol. 7, No. 1, 2022, pp. 15-25.
doi: 10.11648/j.ajpb.20220701.13

Received: January 12, 2022; **Accepted**: January 27, 2022; **Published**: February 16, 2022

Abstract: Maize is among the most important cereal crops in Ethiopia. Intercropping results in high overall system productivity on a given piece of land due to efficient use of the available plant growth resources. Field experiment was conducted to were to evaluate and select the cropping systems and best performing common bean varieties in intercropping with maize at jejebicho research station for higher productivity and profitability in southern parts of Ethiopia, under Wondo genet Agricultural Research Center at Sankura wereda, Jejebicho research station in 2019/20 cropping season. Three varieties of common bean (Deme, KAT-B1 and Awash-2) and were intercropped with two maize varieties (Limu and Shone). The three common bean varieties and two maize varieties were included as a sole for comparison. Randomized complete block design in factorial with three replications was used. Aboveground biomass, days to tasseling, hundred kernel weight, grain yield and harvest index of maize were significantly affected by varieties of common bean, cropping system was also significantly affected leaf area, leaf index, days to tasseling, days to physiological maturity and grain yield of maize but their interaction effect were non significantly affected. Days to tasseling of maize were delayed (81.50 days) and hastened (74.23 days) by variety Awash-2 and Deme, respectively as compared to KAT-B1. The wider leaf area (910.20cm^2) was measured from intercropped maize than sole and the larger leaf area index (3.79) was also recorded from intercropped maize than sole one. Days to tasseling of maize were delayed (80.80 days) at sole cropped of maize. The longer days to physiological maturity (143.84 days) of maize was taken from sole cropping of maize. The highest grain yield (7.60 ton/ha) of maize was taken from Shone intercropped with Awash-2 as compared to varieties. In cropping system, the maximum grain yield (7.12 ton/ha) of maize was obtained from intercropped of it. Plant height, branch number per plant, number of seed per pod, number of pod per plant, days to physiological maturity, aboveground biomass, hundred kernel weight, grain yield and harvest index of common bean. The longest plant (132.13cm) was measured from Deme intercropped with Limu. The highest (5.17) number of branches was counted at Deme intercropped with Limu. The highest number of pods per plant and number of seed per pod (10.92 and 4.63) was counted at Deme intercropped with Limu and Limu with Awash-2 respectively. The highest grain yield (22.38 ton/ha) was obtained when Shone intercropped with Deme. The highest partial land equivalent ratio (LER) of maize and common bean non significantly affected by varieties of both. Monitory advantage index was also non significantly affected. However, the highest value of monetary advantage index (105,359 ETB ha^{-1}) was obtained at Shone intercropped with Deme. Therefore, any of the two (Limu or Shone) maize varieties could be recommended for intercropping with Deme of common bean variety.

Keywords: Common Bean, Cropping System, Deme, Grain Yield, Limu and Shone

1. Introduction

Intercropping is defined as the growing of more than one crop species more or less simultaneously in the same field during a growing season. Maize (*Zea mays*) is an important crop for feeding the increasing population of Ethiopia [41]. It is one of the most prominent cultivation systems of smallholder farmers due to shortage of land, with individually owned pieces of land rarely exceeding 1.5 hectare (Lunze *et al.,* 2012), and the practice ensures avoidance of risks associated with complete crop failure [14]. Production of common bean is highest in the densely populated highlands of Eastern and Central Africa [42]. For example, on the area basis, common bean is partly sown as sole crop (22%) and in intercrops with maize (43%), bananas (15%), root and tuber crops (13%), and other crops (7%) [40]. The return from component crops when cultivated in an association is compared with the more valuable of the sole crops as the practice may result in yield reduction [41, 33, 21, 18] indicated that farmers are often concerned with high labour demand and the general yield reduction of the main crop in cereal-legume intercropping compared with sole cropping.

Maize (*Zea mays* L.) and common bean (Phaseolus vulgaris L.) are important food and cash crops cultivated for subsistence on smallholder farms in many parts of the world, including Sub-Saharan Africa. It is originated in Central America and was introduced to Ethiopia during the 1600s to 1700s [34]. In Ethiopia maize is one of the most important cereal crops grown in the country. It covers the total area of cereal crop production in 2018/19 took 18.5% with the production of 9.5 million tons [7]. In Ethiopia, maize ranks second in total production (30.3%) after Ethiopian teff from cereal crops [7]. Its national mean yield is about 4 ton/ha [7]. In 2018/19 Ethiopian *Meher* (rain fed) cropping season maize production was estimated with an area of 2,367,797.39 hectare and a total production of 9,492,770.834 tons [7]. The *Meher* season production was estimated to be higher than the off season.

Common bean ranks third the most important food grain legume after soybean and peanut worldwide with nutritional and economic value to human and feed to livestock [22]. Common bean also improves soil fertility through fixation of atmospheric N_2 in symbiosis with rhizobia. It is thought that intercropping with maize and common bean would present an alternative to monoculture of maize and common bean as part of sustainable systems intensification on smallholder farms [18].

Intercropping results in high overall system productivity on a given piece of land due to efficient use of the available plant growth resources [6]. The overall productivity of intercrops is attributed to the differences in acquisition and utilization of growth resources such as nutrients, moisture, and light interception [14, 42]. The component crops also exhibit various mechanisms in resource acquisitions and utilizations such as complementarities, facilitation, and resource sharing [13, 6, 18]. Most studies on intercrops have been run over a short period making it difficult to realize the long-term effect of the practice on crop productivity and sustainable soil fertility management from a legume crop [26, 16]. The mechanisms associated with increase in yield due to enhanced nitrogen nutrition of the cereal crop sown in association with a grain legume are widely reported [10, 9, 14]. The options for intensification of intercrops are manifold: substituting the improved to the local varieties of grain legumes, timing of introducing early and late-maturing crops, modification of the spacing between rows of the two crops and that of the same crop within rows and choosing compatible crops [8, 27]. According to Hillocks *et al.* [15] intercropping of non-climbing bean varieties with maize enables more productive for maize, addition, the productivity of intercrops that involve improved common bean varieties relative to local common bean varieties under field conditions has not studied well.

The most common advantage of intercropping is the production of greater yield on a given piece of land by making more efficient use of the available growth resources using a mixture of crops of different rooting ability, canopy structure, height and nutrient requirements based on the complementary utilization of growth resources by the component crops [20]. Legume-cereal intercropping specially maize-bean intercropping is a common throughout developing world and can be the ideal ones for sustainable production and food security to resource poor farmers [1]. Many researchers have stressed the need of identification of suitable genotypes in intercropping that best cultivar for mono cropping might not be most suitable for mixed cropping due to change in micro climate within crop mixture [24]. The choice of compatible species and time of their establishment, therefore, seems relevant management options in improving the efficiency of this system. Aiming to maximize the yields of intercrop components through minimizing competition effects, selection of compatible genotypes and timing of intercropping, based on growth characteristics and requirements of the component species in question, are key agronomic issues in intercropping [5]. Therefore, varietal selection, understanding the physiology of the species to be grown together, their growth habits, canopy and root architecture, and water and nutrient use are important factors to be considered in intercropping [1, 36]. Similarly, complementarities in an intercropping situation can occur when the growth patterns of the component crops differ in time or when they make better use of resources in space. These factors affect the interaction between the component crops of intercropping and so affect their use of environmental resources and, as a result, the success of intercropping compared with sole cropping systems. However, farmers in Southern Ethiopia intercrop maize and common bean without consideration of the compatibility of the component crops to intercrop. The recently released common bean varieties are very productive but needs a research to know the compatibility between common bean and maize varieties. There is need of information on appropriate variety of common bean for intercropping with maize for the recently released common bean varieties were developed under sole cropping. Therefore, intercropping did not give the best returns in terms of yield or cash because farmers do not necessarily select the most compatible varieties for intercropping. Being the under-story crop in most intercropping systems, growth and yield of legumes are usually suppressed by the dominant crop. These factors affect the interaction between the component crops of intercropping and affect their use of environmental resources as a result, the success of intercropping compared with sole cropping systems.

Therefore, the objectives of this study were to evaluate and select the cropping systems and best performing common bean varieties in intercropping with maize at different agro-ecologies for higher productivity and profitability.

2. Materials and Methods

The experiment was conducted at Sankura wereda Jejebicho research station of Wondo Genet Agricultural Research Center in Silte zone of South nation nationalities and people's regional state tested.

2.1. Description of the Experimental Materials

Improved maize varieties (Shone and Limu) were used as main crops and adapted to an altitude of 1000m to 1800m above sea level and matures at 144 days. It requires 1000 mm to 1200 mm annual rainfall. The three common beans varieties namely Awash-2, KAT-B1 and Deme were used and including two maize varieties (Shone and Limu). The common bean varieties have different maturity date and potential yield and its seeds are varying in its color.

2.2. Treatments and Experimental Design

The experiment consisted of two factors, namely three common bean and two maize varieties. By combining these two factors we would have a total of eleven treatments including sole cropped of each intercropped as additive series between the two maize rows at the same time. Uniform populations of 44,444 plants ha^{-1} were maintained for maize in both intercropping and sole-cropped. The experiment was arranged in Randomized complete Block design with three replications in factorial arrangement of three common bean and two maize varieties totaling sex intercropping treatments and there were five additional treatments (sole of two maize and sole of three common bean varieties) totaling eleven treatments. The spacing for sole and intercropping maize was 75cm x 30cm between rows plants, respectively and the gross plot size was 15.75m^2 (3.9m x 4.5m) and the net plot area was 6.75m^2 (3.6m x 3.75m). Each intercrop maize plot consisted of six rows of maize and ten rows of common bean. The spacing of sole common bean was 40cm x 10cm between rows plants, respectively and the gross plot size 10.4m^2 (2.6m x 4m) and the net plot area was 9m^2 (2.5m x 3.6m). Common bean was intercropped between two maize rows at 37.5cm away from maize row with inter row and 10cm intra-row spacing. The data was taken from the central rows of common bean and harvested.

2.3. Experimental Procedures

The experimental field was ploughed and harrowed by a tractor to get a fine seedbed and leveled manually before the field layout was made. Maize was planted on April 28, 2019 and common bean varieties were planted on June 13, 2019. Two seeds per hill of both maize and common bean were planted and thinned to one plant per hill one week after emergence. At planting full dose of NPS at the rate of 150 kg ha^{-1} was applied uniformly into all plots. Half of N in the form of urea (46%N) at the rate of 250kgha^{-1} was applied into sole maize and maize/common bean intercropped plots at the time of planting and the remaining half N was applied at knee height growth stage of maize. Urea (N) was applied in to sole common bean by the rate of 50kg ha^{-1}. Hand hoeing and weeding were done as required. Both maize and common bean were harvested from the net plot after they attained their normal physiological maturity, i.e., when 75% of plants in a plot.

2.4. Data Collection

2.4.1. Maize Data Collection

(i). Growth and Phenology Data of Maize

Phenological data: like days to tasseling, days to physiological maturity of maize were recorded from the selected plants based on plot based.

(ii). Growth Parameters Leaf Area (cm^2)

Growth parameters leaf area was determined from the same five plants used for plant height per plot randomly as leaf length (L) x maximum leaf width (W) x 0.733 as described by McKee (1964).

(iii). Leaf Area Index (cm^2)

LAI were calculated as the ratio of total leaf area (cm^2) of the plant to the ground area coverage of maize.

(iv). Yield and Yield Components

Yield and yield components included aboveground biomass: was measured from five randomly sampled plants per plot at the end of harvest in each plot.

(v). Hundred Kernels Weight (g)

Hundred kernels weight was measured from the collected data of the five selected plants at the end of harvest in each plot.

(vi). Grain Yield (kg/ha)

Grain yield were measured from the net plot area and expressed as ton/ha. Grain yield was adjusted to 12.5% moisture content using a digital moisture tester.

2.4.2. Response of Common Bean Varieties

(i). Data on Physiological Maturity

Data on physiological maturity were recorded from five randomly taken plants as the number of days from emergence to the date on which physiologically matured of the plants in a plot matured.

(ii). Growth Parameters

Plant height (cm): Plant height was recorded as the height of plant grown from the ground level from five randomly sampled plants at the end of 50% flowering in each plot. Branch number: was also counted from the individual plants.

(iii). Yield and Yield Components

Number of pods per plant: - Number of pods was counted from the same ten randomly selected plants at the end of harvest in each plot. Number of seeds per pod: - Was taken from the same ten randomly selected pods at the end of harvest and each of seeds were counted manually in each plot. Above ground biomass, Harvest index (HI) and 100 kernel weight were recorded.

Grain Yield (ton/ha): Common bean yields were measured from the net plot area and expressed as kg/ha. Bean yield was adjusted to 12% moisture using a digital moisture tester.

2.4.3. System Productivity

(i). Land Equivalent Ratio (LER)

Partial land equivalent ratio: is the ration of intercropped and sole cropped yield of the individual crop. For instance, the partial land equivalent ratio of maize was calculated as, Partial LER of maize=; where YMi=intercropped yield of maize and YMs=grain yield of sole cropped maize. Similar to maize the partial land equivalent ratio of common bean was also calculated as; partial land equivalent ratio of common bean=where YCi=intercropped yield of common bean and YMs=sole cropped of common bean. The LER was calculated using the formula LER=Σ (Ypi/Ymi) (where Ypi is the yield of each crop in the intercrop, and Yms is the yield of each crop in the sole crop. So, in this study the LER was calculated as,

LER=YMi+ YCi YMs, YCs (from the sole crop the actual yield was used from the three varieties)

Where

YMi=Yield per unit area of maize intercrop (net plot area of intercropped maize)

YMs=Yield per unit area of Maize sole (net plot area of sole maize)

YCi=Yield per unit area of common bean in intercropping (net plot area of intercropped common bean)

YCs=Yield per unit area of common bean sole (net plot area of sole C)

(ii). Monetary Advantage Index (MAI)

First the Gross monetary value (GMV) was calculated as; Yield of component crops × respective market price; i.e., (yield of maize x price of maize + yield of common bean x price of common bean) [41]. In order to access the economic advantage of intercropping as compared to sole cropping of maize and common bean varieties, the gross monetary value (GMV) and the Monetary Advantage index (MAI) were calculated from the yield of maize and common (kg ha^{-1}). Gross monetary value and monetary advantages were calculated to measure the productivity and profitability of the intercropping as compared to sole cropping of the component crops.

Monetary Advantage Index: The most important part of recommending a cropping pattern was the cost: benefit ratio more specifically total profit, because farmers are mostly interested in the monetary value of return. The yield of all the crops in different intercropping systems and also in sole cropping system and their economic return in terms of monetary value were evaluated to find out whether maize grain yield and additional common bean grain yield were profitable or not. This is calculated with monetary advantage index (MAI) which indicates more profitability of the cropping system with the higher the index.

It was expressed as MAI=(Pab+Pba) *(LER-1)/LER Where, Pab=Pa ×Yab; Pba=Pb ×Yba; Pa=Price of maize and Pb=Price of common. In this research we used the price of common and maize was 12.5 and 11 Ethiopian birr per kilo gram of grain yield. We have taken the current the average price of common bean varieties from local market, the price of maize was also just taken from the local grain market of Shashemene. The price of both common bean and maize was fluctuated and seasonal but we used the average of maximum and minimum price of maize and common bean grain (ETB 12 kg^{-1}) at the time of harvet collection from Shashemene local market.

2.4.4. Statistical Data Analysis

All data were subjected to the analysis of variance (ANOVA) appropriate to the randomized complete block design using SAS (Version, 9.4). Least significant difference (LSD) test at 5% level of probability was also used for mean separation as procedure described by Gomez and Gomez, (1984). I used the linear model of RCBD while analyzed the data by SAS, Yijk=μ+ αi + βj + Yk + Ɛijk. Where, Yijk=the value of the response variable; μ=Common mean effect; αi=Effect of varieties of maize; βj=Effect of block; Yk=Effect of varieties of common bean and Ɛijk Experiment error. For cropping system Yij=μ+ αi + βj + Yk + Ɛijk, where Yij=the value of the response variable; Common mean effect; αi=Effect of intercropped; βj=Effect of bock and Yk=Effect of sole cropping.

3. Results and Discussions

3.1. Response of Maize Varieties

The analysis of variances showed that days to tasseling of maize was a highly significance difference in due to the varieties of common bean (Table 6). The longest (81.50) day of tasseling was taken when Limu intercropped with Awash-2 and shortest day of tasseling was taken due to Limu intercropped with KAT-B1. This may due to inter-specific competition between Limu and Awash-2 was low as compared to Limu and KAT-B1 intercropping, when the inter-specific competition is high, so it hastens the physiological maturity of maize to tassel. This study was disagreed with the experimental results of Jibril *et al*. [17, 12, 43, 11] reported that days to 50% emergence, days to tasseling and days to 50% maturity of maize/common bean and sorghum/common bean are not affected by component planting density.

Cropping system was showed a significant (P>0.05) difference on leaf area, leaf area index and day of tasseling (Table 6). The maximum (910.20 cm^2) and minimum (811.91 cm^2) leaf area was measured from intercropped and sole cropped of maize with common bean varieties respectively (Table 1). This may due to the presence of common bean varieties, which enables to fix atmospheric nitrogen. The reduction in leaf area of sole cropping maize may also be due to the absence of common bean varieties and presence of interspecific competition for sun light interception during the latter growth stages. This study was in contrast with the experimental result of Jibril *et al.* [17] which revealed that the maximum leaf area was measured from sole cropping of maize than the intercropped. The highest (3.79) and lowest (3.02) leaf area index was measured from intercropping and sole cropping system of maize varieties (Table 1). The experimental result of Rana *et al.* [29] showed that stature of plant moreover leaf area index (LAI) of corn crop was maximum in legumes-maize based intercropping systems compare to sole maize. However, Rashid *et al.* [30] reported the viability of inter-cropped legumes with sorghum and discussed that intercropping of legumes effect on leaf area index of intercropped sorghum is lower than the alone growing of sorghum, this leaf area index will be more less in case of intercropping of sorghum with cluster beans. This may due to the presence of common bean varieties which enables improve soil nitrogen and has a role for more photosynthesis rate.

Table 1. *Mean effects of varieties of maize and common bean, cropping system and their interaction on plant height, leaf area (cm^2), leaf area index and days to tasseling of maize.*

Treatments	PH	LA	LAI	DT
Shone+KAT-B1	248.93	914.05	3.81	75.10b
Shone+Awash-2	260.73	923.78	3.85	81.43a
Shone+Deme	261.60	907.65	3.78	74.33b
Limu+KAT-B1	253.27	908.72	3.79	74.23b
Limu+Awash-2	250.27	873.30	3.64	81.50a
Limu+Deme	253.80	933.70	3.89	75.50b
LSD	NS	NS	NS	3.00
CV (%)	2.82	6.46	6.46	2.14
Cropping system				
Intercropped	254.77	910.20a	3.79a	77.02b
Sole	250.00	811.91b	3.02b	80.80a
LSD	NS	45.20	0.20	3.67
CV (%)	2.89	5.20	5.52	4.39

Where PH=plant height, LA=leaf area, LAI=leaf area index, DT=days to tasseling, NS=not significant Means in a column followed by the same letters are not significantly different at p≤5% level of significance

The longer (80.80) and shorter (70.02) days of tasseling of maize varieties was taken from sole and intercropped maize-common bean cropping system respectively (Table 1). This may due to the absence and presence of intra-specific competition at intercropped and sole cropping system respectively.

The analysis of variance revealed that aboveground biomass, hundred kernel weight, grain yield and harvesting index of maize varieties were significantly affected by common bean varieties (Table 6). The highest hundred kernel weight (52.12g) of maize was obtained from when Limu intercropped with Awash-2, this statistically at par with Shone intercropped with Aash-2. This might be the interspecific competition Awash-2 was the most positive as compared to other common bean varieties.

The analysis of variances showed that day to physiological maturity and grain yield of maize was significantly affected by cropping system in common-maize varieties intercropping (Table 6). The longer (143.84 days) and shorter (142.92 days) of physiological maturity of maize was taken from sole and intercropped respectively (Table 2). Similarly supported by the experimental result of Alemayehu *et al.* [4] revealed that simultaneous intercropping of common bean variety with maize resulted longer days to flowering and maturity compared of sole maize. This may due to intra-specific competition in sole cropping of maize whereas the longer days due to inter-specific competition and absence of intra-specific competition intercropped of maize.

The highest (29.60 ton/ha) and lowest (21.24 ton/ha) aboveground biomass was obtained from Shone intercropped with Awash-2 and Limu intercropped with KAT-B1 intercropping respectively (Table 2). This may due to the genetic nature of both maize and common bean varieties. Variety KAT-B1 is a non-bushy and climbing variety, which enable more competent with Limu than Awash-2 and it may also due to a non-climbing and bushy type. The highest (51.53g) and lowest (42.59g) hundred kernel weights were obtained from Shone+Awash-2 and Shone+KAT-B1 intercropping respectively (Table 2). Cropping system was non significantly affected hundred kernel weight of maize. Similar with this result, Saban *et al.* [32] reported that hundred kernel weight of maize not significantly affected by common bean intercropping. It was also supported by the experimental results of Alemayehu *et al*. [4] revealed that hundred kernel weight of maize not significantly affected by common bean intercropping. The highest (7.60 ton/ha) and lowest (6.69 ton/ha) grain yield of maize was obtained when Shone intercropped with Awash-2 and Limu intercropped with KAT-B1, respectively (Table 2). This may due to the presence of KAT-B1 in both Shone and Limu for hundred kernel weight and grain yield. The experimental result of Alemayehu *et al.* [4] is disagreed with this study which revealed that varieties of common bean were not significantly affected grain yield of maize. The maximum (7.12 ton/ha) and minimum (5.95 ton/ha) grain yield was obtained from intercropped and sole cropping system of maize respectively (Table 2). According to experimental result of Viljoen and

Allemann [37] revealed that benefits of intercropping consist of higher grain yield as compared to sole cropped yields of maize, mostly because of less intra-specific competitiveness ability, maximum level of crop yield stand enables well use of natural resources good management for weed control, improve value by varieties in addition to corn grain yield obtained from a sole crop and it gives equal production as maize do in intercropping system. Intercropping enhances resource use efficiency, it improves the water use efficiency, land use efficiency as well as fertilizer and water. Intercrop pings help in maintaining fertility of soil and efficient use of nutrients [27, 25]. This experimental result is not supported by Belisti *et al*. [21] revealed that the maximum grain yield was obtained from sole cropping system of maize while the lower grain yield was maintained for intercropped maize. The amount of yield increment over sole crop was 19.66% (Table 2). This suggests lower intra-specific competition of intercropped maize for natural resources (light, water and nutrients) compared to maize intercropped with haricot bean and also revealed effective utilization of applied nitrogen and phosphorus fertilizer by intercropped maize.

Table 2. *Mean effects of varieties of maize and common bean, cropping system and their interaction on days to physiological maturity, above ground biomass (ton/ha), hundred kernel weight (g), grain yield (ton/ha) and harvest index of maize.*

Treatments	DPM	AGB	HKW	GY	HI
Shone+KAT-B1	141.71	22.22bc	42.59c	6.77b	0.31
Shone+Awash-2	144.70	29.60a	51.53a	7.60a	0.26
Shone+Deme	141.34	24.05bc	45.07b	7.23ab	0.30
Limu+KAT-B1	141.27	21.24c	42.64c	6.69b	0.32
Limu+Awash-2	146.15	26.25ab	52.12a	7.35ab	0.28
Limu+Deme	142.34	26.17ab	44.34b	7.10ab	0.27
LSD	5.52	4.93	1.59	0.81	0.06
CV (%)	2.12	10.87	1.90	6.22	10.51
Cropping system					
Intercropped	142.92b	24.92	0.289	7.12a	0.289
Sole	143.84a	21.48	0.293	5.95b	0.293
LSD	3.08	NS	NS	0.44	NS
CV (%)	2.18	17.56	8.47	6.61	16.20

Where DPM=days to physiological maturity, AGB=above ground biomass, HKW=Hundred kernel weight, GY=grain yield, HI=harvest index, NS=not significant Means in a column followed by the same letters are not significantly different at p≤5% level of significance.

3.2. Response of Common Bean Varieties

The analysis of variance showed that branch number per plant, number of seed per pod and days to physiological maturity of common bean varieties were significantly affected by maize varieties (Table 7). However, plant height, number of pods per plant, hundred kernel weight, grain yield and harvest index were a very highly significantly affected due to intercropped with maize varieties (Table 7). The tallest (132.13cm) and shortest (48.50cm) plant was measured from 'Limu intercropped with Deme' and 'Shone with KAT-B1' intercropping system respectively (Table 3). This may due to the highest inter-specific competition for light and other soil resources in between Shone and KAT-B1 intercropping, it may also due to the presence of shading effect by Shone on KAT-B1. This may also due to the climbing nature of this variety as compared to others. The maximum (5.17) and minimum (2.58) branch number per plant was counted from the association between Limu and Deme and between Limu and KAT-B1 cropping system respectively (Table 3). The reason may be similar with that of plant height may be the presence of competition for light, soil resources and shading effects in between the component crops. The highest and lowest number of pods per plant was counted from the intercropping of Limu with Deme and Shone with KAT-B1 intercropping system respectively (Table 3). The highest (4.63) and lowest (3.63) number of seed per pod was counted from the association Limu+Awash-2 and Limu+KAT-B1 intercropping system respectively (Table 3). The longest (112.67) and shortest (95.33) days of physiological maturity was recorded from the intercropping of Limu with Deme and Shone with that of Awash-2 respectively (Table 3). Intercropping of legumes in already established maize stand, significantly affected the number of pods per plant and number of seeds per pod of common bean [3, 31].

The analysis of variance showed that cropping system significantly affected branch number of common bean (Table 7). The highest (6.33) and lowest (3.58) number of branches were counted from sole and intercropped of common bean respectively (Table 3). This may due to the presence of inter-specific competition in intercropped cropping system i.e., less photo assimilation rate, shading effect for light resources and scarcity of available soil moisture and nutrients, finally less biomass (branch number) was produced. The maize/common bean intercropping reported that, number of branches per plant was significantly affected by maize varieties and cropping system [12, 38]. Adem [2] on sorghum-cowpea found a significant difference on branch number due to interspecific competition between the component crops. Turk *et al*. [35] confirmed that branch and pod number per plant was negatively related to plant density.

Table 3. *Mean effects of varieties of maize and common bean, cropping system and their interaction on plant height (cm), Branch number, number of pods per plant, number of seed per pod and days to physiological maturity of common bean.*

Treatments	PH	BN	NPP	NSP	DPM
Shone+KAT-B1	48.50d	2.79b	3.29b	3.92bc	98.00b
Shone+Awash-2	63.58c	3.46b	4.25b	4.46ab	95.33b
Shone+Deme	100.54b	4.04ab	8.83a	4.49a	104.67ab
Limu+KAT-B1	53.50cd	2.58b	3.50b	3.63c	98.33b
Limu+Awash-2	63.13c	3.42b	4.04b	4.63a	96.67b
Limu+Deme	132.13a	5.17a	10.92a	4.56a	112.67a
LSD	12.09	1.50	2.65	0.56	10.12
CV (%)	8.64	22.99	25.12	7.61	5.51
Cropping system					
Intercropped	76.90	3.58b	5.80	4.28	100.94
Sole	83.39	6.33a	7.35	4.51	99.22
LSD	26.02	0.93	NS	NS	NS
CV (%)	28.67	24.59	30.77	12.52	7.96

DPM=days to physiological maturity, NPP=Number of pods per plant, NSP=Number of seed per pod, means represented by the letter showed a non-significance effect.

The analysis of variance showed that maize and common bean varieties intercropping had a very highly significance effect on Aboveground biomass (ton/ha), Hundred grain weight (g), Grain yield (ton/ha) and Harvest index of common bean (Table 7). The highest (28.02 ton/ha) and lowest (14.49 ton/ha) aboveground biomass was obtained from Limu intercropped with Deme and Limu intercropped with Awash-2 respectively (Table 4). The maximum (64.90g) and minimum (21.99g) hundred kernel weights were recorded from Deme intercropped with Limu and Awash-2 intercropped with Limu respectively (Table 4). The highest (22.38ton/ha, 0.86) and lowest (8.02 ton/ha, 0.59) grain yield and harvest index were obtained due to Deme intercropped with Shone and Awash-2 intercropped with Limu for both grain yield and harvest index respectively (Table 4). Consistent with this result, Jibril *et al.* [17] reported a significant difference in hundred seed weight of common bean in maize-bean intercropping due to varietal difference hundred grain weight of common bean was significantly affected by varieties of common bean. The difference in hundred seed weight might be because of inherent characteristics of the variety. The highest Harvest index recorded for variety Deme intercropped with Shone this might be due to the high grain yield to biomass obtained by the variety as a result of high partitioning of dry matter to the grain. This may also due to a non-shading effect of maize varieties of on grain yield reduction of common bean varieties. On the other hand, Deme best competent with maize for limited resources and best compatible for intercropping with maize.

The analysis of variance showed that cropping system significantly affected aboveground biomass and grain yield of common bean (Table 7). The highest (24.03 ton/ha, 20.08 ton/ha) and lowest (20.29 ton/ha, 14.38 ton/ha) above ground biomass and grain yield of common bean were obtained from sole and intercropped cropping system respectively (Table 4). Correspondingly, cropping system significantly influenced the grain yield of common bean. Because of additive intercropping of maize and common bean, the yield of intercropped common bean was reduced by 28.39% as compared to sole cropped common bean. Higher grain yield (20.08-ton ha^{-1}) was obtained from sole cropped common bean than the intercropped common bean (14.38-ton ha^{-1}) (Table 4). Lower grain yield of intercropped common bean might be due to increase inter-specific competition and the depressive effect of the cereals on common bean in intercropping. This might be also due to the absence of inter-specific competition like shading and dominance of maize varieties to common bean varieties. This results less branch number and performance as compared to sole cropping of common bean varieties. The shading effect of the maize drastically reduced the light transmission that might have significantly reduced photosynthetic assimilates. The high population of the bean and maize component crops per unit area of land might cause greater inter-specific competition for growth resources like nutrient and light that leads to decreased yield of the component crops. Furthermore, yield reduction of common bean in an intercropping could be due to a more extensive root system; particularly a larger mass of fine roots of maize which compete more for soil nutrients. The yield of intercrops was reduced by intercropping with maize that was caused due to receipt of lower amount of solar radiation [21, 19]. Also agreed with the results of this study, Rezaei-Chianeh *et al.* [32] showed reduction in the yield of faba bean under intercropping system. This experimental result is supported by Teshome et al. [34] revealed that the maximum grain yield was obtained from sole cropping of soybean than intercropping in maize-soybean intercropping. Mean grain yield of common bean in the intercrop systems was significantly lower than the sole crop yield of common bean. The yield of intercropped common bean was reduced by 28.39% as compared to sole common bean. Lower grain yield of intercropped common bean might be due to increase inter-specific competition in intercropping than sole cropping. The yield reduction in common bean and soybean intercropped with maize and sorghum and attributed the yield depression to inter specific competition and the depressive effect of the cereals [4, 23].

Table 4. *Mean effects of varieties of maize and common bean, cropping system and their interaction on above ground biomass (ton/ha), hundred kernel weight (g), grain yield (ton/ha) and harvest index of common bean varieties.*

Treatments	AGB	HGW	GY	HI
Shone+KAT-B1	20.34b	44.65b	13.15b	0.65b
Shone+Awash-2	16.12bc	23.83c	9.25b	0.59b
Shone+Deme	25.58a	56.94ab	22.38a	0.86a
Limu+KAT-B1	17.22bc	44.07b	11.80b	0.68ab
Limu+Awash-2	14.49c	21.99c	8.02b	0.59b
Limu+Deme	28.02a	64.90a	21.68a	0.77ab
LSD	5.24	13.75	6.26	0.20
CV (%)	14.28	17.69	23.91	16.12
Cropping system				
Intercropped	20.29b	42.73	14.38b	0.69
Sole	24.03a	51.32	20.08a	0.71
LSD	3.24	NS	5.10	NS
CV (%)	22.86	20.22	23.30	27.43

Where AGB=above ground biomass, HGW=Hundred Grain weight, GY=grain yield, HI=harvest index, NS=not significant Means in a column followed by the same letters are not significantly different at p≤5% level of significance

The analysis of variance showed that partial LER of both maize and common bean varieties were non significantly (P>0.05) affected by maize common bean varieties intercropping (Table 8). However, the highest partial LER (0.96) of maize was due to, Limu intercropped with Awash-2 and Deme, Shone intercropped with Awash-2 but no significant in all treatments (Table 5). This may due to common bean varieties had no significant effect on yield reduction of maize and economical in intercropping system. The maximum (0.96) partial land equivalent ratio of maize was similarly obtained from Shone intercropped with Awash-2, Limu with Deme, and Limu with Awash-2, but the minimum (0.88) partial land equivalent ratio of maize was Shone intercropped with KAT-B1 respectively (Table 5). The maximum (0.85) and minimum (0.64) partial land equivalent ratio of common bean was due to Shone intercropped with Deme and Limu intercropped with Awash-2 respectively (Table 5). Even though a non-significance difference showed by maize common bean varieties intercropping on total land equivalent ratio. The highest and lowest value of total land equivalent ratio was due to Limu intercropped with Deme, and Limu intercropped with KAT-B1 respectively (Table 5).

Similar to total LER, maize–common bean varieties intercropping and their interaction effect did not show significant (P>0.05) variation on MAI (Table 8). Even though the maize-common bean varieties non significantly affected, the maximum (105,359 ETB) Monitory Advantage Index (MAI) value was obtained from Shone intercropped with Deme and the minimum (87,853 ETB) MAI was obtained from Limu intercropped with KAT-B1 (Table 5). Therefore, both Limu and Shone intercropped from Awash-2, Deme and KAT-B1 common bean varieties is more economical and advantageous for farmers.

Table 5. *Mean effects of varieties of maize and common bean, on partial land equivalent ratio of maize and common bean, total land equivalent ratio and monitory advantage index of maize-common bean intercropping.*

Treatments	PLERM	PLERC	TLER	MAI
Shone+KAT-B1	0.88	0.76	1.64	90,948
Shone+Awash-2	0.96	0.75	1.71	103,093
Shone+Deme	0.91	0.85	1.76	105,359
Limu+KAT-B1	0.87	0.67	1.54	87,853
Limu+Awash-2	0.96	0.64	1.59	89,637
Limu+Deme	0.96	0.82	1.78	99,037
LSD	NS	NS	NS	NS
CV (%)	5.70	23.12	12.37	10.35

Where ns=non significance difference, PLERM=Partial land equivalent ratio of maize, PLERC=Partial land equivalent ratio of Common bean, MAI=Monitory Advantage index

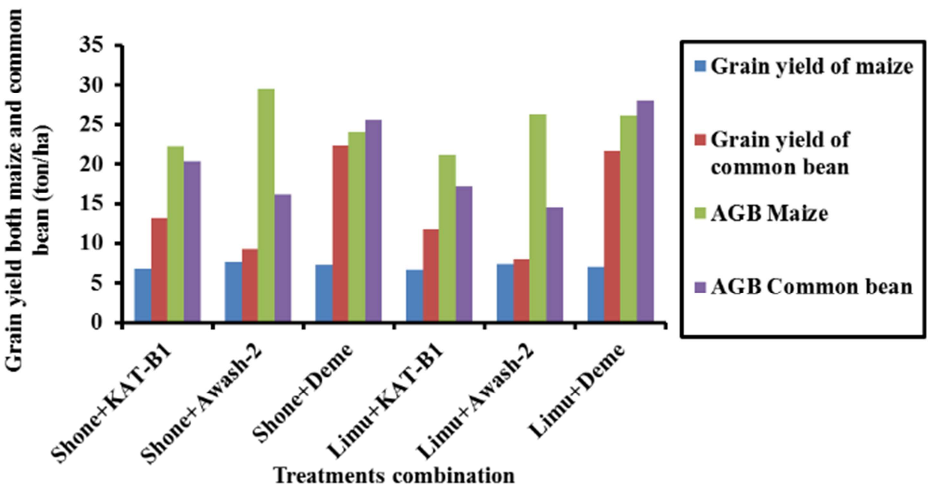

Figure 1. *Show the above ground biomass yield and grain yield of maize and common bean in (ton/ha) at jejebicho research station.*

4. Conclusions and Recommendation

The experiment was a one-year experiment at Sankura wereda Jejebicho research station and conducted in 2019/2020 cropping season. All necessary data was collected of the component crops from field experiment and analyzed. Data collected for maize were: on phenology, days to tasseling and growth parameters of maize, leaf area, leaf area index, aboveground biomass, hundred kernel weight, grain yield and harvest index of maize varieties. The data of common bean were; on growth parameters and yield related traits of common bean varieties like, number of pods per plant, number of seed per pod, days to physiological maturity, Hundred grain weight, Grain yield and Harvest index. Land equivalent ratio and monetary advantage were used to assess the system of productivity. The highest (7.60 ton/ha) and lowest (6.69 ton/ha) grain yield of maize was obtained from Shone+Awash-2 and Limu+KAT-B1, respectively. This may due to the presence of KAT-B1 in both Shone and Limu for hundred kernel weight and grain yield. Whereas the highest grain yields common bean (22.38to/ha, grain yield was obtained from Deme intercropped. Even though the land equivalent ratio (LER) and monitory advantage (MAI) of maize-common bean intercropping the highest (1.78, 105, 359 ETB) value of both LER and MAI from Limu intercropped with Deme and Shone intercropped with Deme respectively. Generally intercropping of maize varieties and other low land pulse crops is one of the best options to increase the production of additional grain yield of common bean in Ethiopia. Farmers can achieve greater benefit from their land by growing the main crop (maize like Limu and Shone) and in association with a common bean variety, which either Shone or Limu intercropped with Deme. Hence, maize/common bean intercropping could increase incomes obtained by smallholder farmers at Sankura area of Southern

Ethiopia, through enhancing efficient utilization of land. Therefore, any of the two (Limu or Shone) maize varieties could be recommended for intercropping with Deme of common bean variety.

Acknowledgements

We would like to acknowledge Wondo Genet Agricultural Research Center crop research process for providing all the necessary facilities and support during the entire experimentation. Our acknowledgement also to Mr. Wukyanos Erdachew of field assistance who collect all necessary data from all experimental fields during experimentation time and also, we want to acknowledge of Jejebicho research station workers and keepers, for their tireless field management and to be kept in safe of the experiment.

Appendix

Table 6. *Mean square values of ANOVA on the agronomic and yield components of Maize (Zea mays L.) under intercropping with common bean varieties.*

SOV.	DF	PH	LA	LAI	AGB	DT	DPM	HKW	GY	HI
Replication	2	65.31	315.91	0.0055	1.86	7.24	2.00	0.41	0.089	0.00026
Treatment	5	83.85	1273.04	0.022	28.07*	36.32**	12.39	56.22*	0.36*	0.00128*
Error	10	51.70	3457.41	0.06	7.33	2.72	9.20	0.76	0.196	0.00093
CV (%)		2.82	6.46	6.46	10.87	2.14	2.12	1.88	6.22	10.52
Cropping system										
Rep	2	39.26	533.23	0.024	4.36	6.53	2.23	0.0001	0.041	0.0004
CS	1	102.25	43471.51*	2.71*	53.25	64.43*	3.80*	157.00	6.21*	0.0001
Error	2	53.55	2112.66	0.040	17.84	11.72	9.78	17.57	0.20	0.002
CV (%)		2.88	5.19	5.52	17.55	4.39	2.18	9.00	6.61	16.21

*, **, Significant at p≤0.05 and p≤0.01 probability levels respectively; Rep=Replication; SOV.=Sources of Variation; CS=cropping system.

Table 7. *Mean square values of ANOVA on the Agronomic and Yield components of Common bean under intercropping with maize varieties.*

SOV.	DF	PH	BN	NPP	NSP	DPM	HGW	AGB	GY	HI
Replication	2	174.62	0.82	2.65	0.045	32.89	88.59	48.00	13.57	0.0364
Treatment	5	3197.96**	2.63*	31.47	0.50*	129.92*	891.84**	88.90	115.29**	0.0363*
Error	10	44.14	0.68	25.13	0.09	30.95	57.14	8.28	11.82	0.012
CV		8.64	22.97	25.12	7.16	5.51	17.69	14.18	23.91	16.11
Cropping system										
Rep	2	13.94	0.70	1.15	0.07	17.93	60.38	23.58	16.80	0.0264
CS	1	252.96**	45.60*	14.26	0.33	17.80	329.40	9.61*	10.14*	0.001
Error	2	949.40	1.22	14.75	0.30	63.94	297.74	29.71	36.46	0.019
CV (%)		28.67	24.59	30.77	7.32	7.97	22.85	27.42	23.30	20.21

*, **, significant at P≤0.05 and p≤0.01 probability levels respectively; Rep=Replication; SOV.=Sources of Variation; CS=cropping system.

Table 8. *Mean square values of ANOVA on the agronomic and yield components of common bean under intercropping with maize varieties.*

Sources of variation.	DF	PLERM	PLERC	TLER	MAI
Replication	2	0.00128	0.01	0.014	15176394.4
Treatment	5	0.0026	0.02	0.027	167706764.5
Error	10	0.0028	0.03	0.043	98758901
CV (%)		5.70	23.12	12.37	10.35

Where, PLERM=partial land equivalent ratio of maize, PLERC=partial land equivalent ratio of common bean, TLER=total land equivalent ratio and MAI=monitory advantage index.

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