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Relay Cropping Mung Bean by Plant Density and Row Arrangements with Maize on Yield and Yield Components of Component Crops at Jejebicho, Southern Ethiopia

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Abstract: Maize is among the most important cereal crops in Ethiopia. Rely-intercropping of mung bean between maize enable to get grain yield of maize instead sole alone. Field experiment was conducted to assess the effects of relay intercropping mung bean at different population density and row arrangements with maize yield components and yield of the component crops, to evaluate the productivity and economic value of maize-mung bean intercropping at Sankura Wereda Jejebicho research station in 2019-2021 main cropping season. Three spatial row arrangements (1:1, 1:2 and 1:3) with four population densities (PD) (25%, 50%, 75% and 100%) were intercropped with maize variety 'Shone'. Each of the component crops were included as a sole for comparison. Randomized complete block design in factorial with three replications was used. days to tasselling, days to physiological maturity, leaf area, leaf area index, hundred kernel weight, grain yield and harvest index of maize significantly affected by the interaction effects of population density and spatial arrangements of mung bean. The highest (8.19 ton/ha) grain yield of maize was obtained from 100% population density and 1:3 spatial row arrangement of mung bean. This may due to the presence of high interspecific competition with related high plant population density per plot area compared to other treatments. Whereas the highest grain yield mung bean (18.54 Quintal/ha) was obtained from when mung rely intercropped with 100% population density and 1:3 row arrangements. The highest thousand seed weight (42.18g) was recorded from 25% population density and 1:1 row arrangements of mung bean. The maximum Land equivalent ration value was calculated from 1.88 from 100% population density in 2019 cropping season. The highest monitory advantage index value 110,280 Ethiopian birr) was obtained from 100% population density with all the three spatial row arrangement of mung bean. Therefore, this experiment could be recommended for mung bean rely cropped with maize by 100% population density and 1:3 row arrangement able the famers to get better grain yield of maize as well as mung bean.

Keywords: Grain Yield, Mung Bean, Population Density, Row Arrangements

1. Introduction

Maize was originally domesticated in Mesoamerica approximately 10,000 years ago. The native Mesoamericans developed an ingenious maize intercropping system with beans (known as "the three sisters, "along with squash) that sustained agricultural productivity for millennia. Mung bean is originated from India and it has diversified to East, South, Southeast Asia (China) and some countries in Africa. Mung bean (*Vigna radiata* L. Wilczek) is an essential short duration, self-pollinated diploid legume crop with high nutritive values and nitrogen fixing ability [15]. It is an eco-friendly food grain leguminous crop of dry land agriculture with rich source of proteins, vitamins, and minerals.

Maize and mung bean are important food crops for smallholder farmers in the arid and semi-arid areas of Ethiopia [1]. However, due mainly to drought stresses and poor soil fertility conditions, productivity of these crops is low. Under this condition prevailing that in the semi-arid areas of Ethiopia, management practices that optimize water conservation and efficient use of soil moisture an area of priority research. So, intercropping of mung bean with other crops like maize is one of the best options to alleviate such a type of problem. The main purpose of intercropping is to produce a greater yield on a given piece of land by making use of resources that would otherwise not be utilized by a single crop efficiently. Legume intercropping systems play a significant role in the efficient utilization of resources. Cereal-legume intercropping is a more productive and profitable cropping system in comparison with solitary cropping [16]. Philosophy of intercropping is improvement of resource utilization efficiency and increase production per unit area [33]. Kumar *et al*. [19] concluded that soil surface remained moist in the intercrop during dry spell of 6-8 days when compared to sole maize cropping. Decline of external inputs and increased demand of homegrown feed together with a more efficient nutrient use from leguminous symbiotic dinitrogen (N2) fixation (SNF) can result in a decrease of nitrogen and mineral losses. In this intercropping system the particular biology of the two crops is exploited and synergized. Maize is a heavy feeder of soil nitrogen. Pulse crops are legumes, meaning they are able to increase soil nitrogen by biologically extracting nitrogen from the air, termed nitrogen fixation. Smallholder farmers in Africa also commonly use maize/bean intercropping to increase soil nitrogen and agricultural productivity.

Maize + legume intercropping was found more productive and remunerative compared to sole cropping [26]. Intercropping is being considered to utilize these resources in an efficient way and is also the most economical way to increase production per unit area and per unit time. Intercropping is becoming popular in Pakistan among farmers due its multiple benefits [27]. Maize-legume intercropping systems are able to lessen amount of nutrients taken from the soil in comparison to a maize monocrop [24]. The maize-legume intercropping was a more productive system and a less risky technology. Higher crop productivity and efficiency in resource use was observed in maize bean intercropping systems than in the respective sole cropping [30]. Among legume-cereal intercropping system, the combination of maize + pigeon pea was considered to be highly suitable with a minimum competition for nutrients, while legume + legume intercropping system, pigeon pea + groundnut system was the most efficient one in terms of resource use-efficiency [25].

Maize is one of the stable food crops in Ethiopia. In the past, growth in food production was achieved by using more land but, more recently, the increase in productivity per unit area is the concern. Intercropping of maize with mung bean is one of the methods of achieving high yield per unit area and harvesting more than one crop per season from a piece of land. Intercropping is receiving attention because it offers potential advantages for resource utilization, decreased inputs and increased sustainability in crop production, but our understanding of interactions and planting density among the intercropped species (like, maize and mung bean) is still very limited. Intercropping might positively impact on the future food problems in developing countries. Also, optimization of land resource could be achieved when crops are grown under intercropping and plant population density increased. Intercropping might positively impact on the future food problems in developing countries. Also, optimization of land resource could be achieved when crops are grown under intercropping and plant population density increased. The common goals of intercropping cereals with other legume crops are to produce greater yield on a given piece of land, making use of resources that would otherwise not be utilized by a single crop.

Mung bean (*Vigna radiata* (L.) Wilczek) is an important pulse crop in Asia because of its high protein content and ability to improve soil fertility [5]. In Thailand, it is widely cultivated and occupied a cultivated area of 143,931 ha with the production of 102,799 ton of grain in 2009 [23]. In Uganda, it is widely grown by smallholder farmers in the eastern and northern regions of the country [23]. The genus Vigna has been broadened to embrace about 150 species; twenty-two species are indigenous to India and sixteen to Southeast Asia, but the principal number of species are originated in Africa [11]. Mung bean is an annual food legume belonging to the sub genus Ceratotropis in the genus Vigna. It is the seed of *Phaseolus radiates* L. and an annual herb of the Leguminosae family. It has green skin and is also called green bean. It is sweet in flavour and cold in nature [8]. Mung bean (*Vigna radiata* L.), a member of the Fabaceae family, is a tropical legume. It is a warm season annual, highly branched and having trifoliate leaves with plants varying from one to five feet in length [14]. Intercropping is the practice of growing two or more crops together in a single field.

Mung bean a recent introduction in Ethiopian pulse production and grown in the north eastern part of Amhara region (North Shewa, Oromia special zone and Southern Wollo), SNNPR (Gofa area) and pocket areas in Oromia region (Hararge). The average yield of the crop is limited to 600-800 kg/ha due to different reasons [8]. Ethiopia Commodity Exchange (ECX) announces the debut of a new commodity, green mung bean, into its trade floor. Green mung bean is the sixth product that Ethiopian Commodity Exchange is trading. Coffee, sesame, white pea, beans, maize and wheat have been traded in Ethiopian Commodity Exchange so far. Mung bean is mostly produced in Amhara regional state particularly in some areas of North Shewa and South Wollo as well as in some woreda's of Benishangul Gumuz regional state [17]. Mung bean (*Vigna radiate* L.) Wilczek), also known as green gram, is an important pulse crop not only in the Indian sub-continent where it has been cultivated for centuries, but also globally, where it serves both as a food crop and source of income [13]. The crop is rich in nutrients, especially lysine, proteins (23-25%) and micronutrients (iron and zinc), and is associated with low ant-nutritional factors such as those which cause flatulence, making it a suitable food for weaning babies [12, 14]. Mung bean is considered a wonder crop due to its ability to tolerate or escape drought conditions, yet has short maturity periods and improves soil fertility through biological nitrogen fixation [29]. Mung bean seeds are primarily used for food purposes. In Pakistan, the whole or split seed is usually cooked as dhal or boiled with rice [28, 22]. Mung bean stalks, leaves and husk constitute a significant proportion of livestock feed. Intercropping is the practice of growing two or more crops together in a single field. Since mung bean is recently introduced to the country, but it is very economic and industrial, so we have to promote the production and increase productivity of mung bean in Ethiopia. Thus, is a need of identifying different crops such as Mung bean (*Vigna radiata* L. Wilczek) to be intercropped with maize.

Therefore, the main objectives of this study are: to assess the effects of relay intercropping mung bean at different population density and row arrangements with maize yield components and yield of the component crops. To evaluate the productivity and economic value of maize-mung bean intercropping.

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 from 2019-2021 main cropping season.

2.1. Description of the Study Area

Sankura wereda was located in Silte zone of southern Ethiopia and it takes 214 km from our capital city Addis Ababa and it takes also 40km from Worabe city of Silte Zone Southern Ethiopia. The geographical coordinate of the research site is 7°63'N and 38°22'E with an altitude of 1879 m.a.s.l.

2.2. Description of the Experimental Materials

Mung bean: the available released variety of mung bean 'MH-97-6 (Borda) which was released in 2008 by South Agricultural Research Institute SARI/AWRC' will be used. It matures in 90-120 days [10].

Maize: Improved maize varieties Shone was 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 maize variety ''SHONE" which was released by Bako Agricultural Research Center under Ethiopian Agricultural Research Institute in 2013 [10].

2.3. Treatments and Experimental Design

This experiment was consisted of two factors, the four plant population densities of Mung bean (100%, 75%, 50% and 25%) and, three row arrangements of mung bean *(vigna radiata* W.) one row, two and three rows (i.e., 1:1, 1:2 and 1:3). The plant population density of maize for both sole and intercropped was 41,667 plants ha^{-1} and the sole planting of mung bean will be 250,000 plants ha^{-1}. Randomized complete block design with three replications in factorial arrangement was used. The detail of treatments is given in Table 1. Mung bean was sown between in different row arrangements within the two maize rows. Uniform populations of 41,667 plants ha^{-1} were also maintained for maize in both intercropping and sole cropping.

Table 1. *Detail description of the Treatments combination.*

Trts.	MG. spacing						Remark
	Intra-row spacing (cm)	Inter-row spacing (cm)	Rows/plot	Plants/row	plants/plot	PD/ha	
1	37.5	40	10	4	40	62,500	25% and 1:1
2	18.75	40	10	8	80	125,500	50% and 1:1
3	13.63	40	10	11	110	187,500	75% and 1:1
4	10	40	10	15	150	250,000	100% and 1:1
5	37.5	26.67	15	3	45	62,500	25% and 1:2
6	18.75	26.67	15	5	75	125,500	50% and 1:2
7	13.63	26.67	15	7	105	187,500	75% and 1:2
8	10	26.67	15	10	150	250,000	100% and 1:2
9	37.5	20	20	2	40	62,500	25% and 1:3
10	18.75	20	20	4	80	125,500	50% and 1:3
11	13.63	20	20	6	120	187,500	75% and 1:3
12	10	20	20	8	160	250,000	100% and 1:3
13	30	80	6	6	36	41,667	Sole maize
14	10	40	18	10	180	250,000	Sole MG.

Where 100% population density throughout the treatments, Trts = treatments, PD = population density, MG = Mung bean, ha= hectare.

2.4. Experimental Procedures and Field Management

2.4.1. Land Preparation, Sowing and Other Agronomic Management

The experimental field was ploughed and harrowed by a tractor to get a fine field. It was also levelled by manually before the field layout. The distance between plot and block will be 1.5 m and 2 m, respectively. The sole and intercropped maize was consisted of six rows, while sole and intercrop mung bean was consisted of ten and five rows, respectively. Inter-row spacing of 80 cm and with the intra-row spacing of 30 cm used for both sole and intercropped maize. The inter-row and intra- row spacing for sole mung bean was 40 cm and 10 cm respectively. The row length of both maize and mung bean was 1.8 m; therefore, the gross plot of maize was also 8.64 m^2 (1.8 m x 4.8 m). The gross plot area of sole mung bean was 7.2 m^2 (4 m x 1.8 m). The net plot area for sole and intercrop maize will be 6 m^2 (1.5 m x 4 m) while, for sole and intercrop mung bean was 7.48 m^2 (4.4 m x 1.7 m) and 6 m^2 (4 m x 1.5 m), respectively. This experimental field had a total area of 38.2 m x 17.4 m (664.68 m^2). The data was taken from the central rows for both maize and mung bean by taking the five and ten randomly taken plants, respectively while in data collection. The mung bean intercropped between two rows of maize at different inter and intra-row spacing depends on its population density and row arrangements of mung bean. The sole population density of 250,000 plants ha^{-1} mung bean was used. Uniform populations of 41,667 plants ha^{-1} maintained for sole and intercropped maize. The crop was sown manually on a well-prepared experimental field dibbling three seeds per hill. Soon after the germination, a single seedling per hill was kept to obtain a uniform stand of the crop. Crop management practices such as weeding, fertilization and plant protection measures were kept normal and uniform in all treatments.

2.4.2. Fertilizer Application Rates and Other Agronomic Practices

Both Urea and NPS with a rate of 250kg ha^{-1} and 150 kg ha^{-1} was applied on maize, but the whole NPS and one-third rate of urea will be applied at the time of sowing the remaining two-third rate of urea will applied at 2-3 ear stage of maize.

Harvesting: the grain of mung bean harvested after 3 months; maize was also be harvested when it reaches full maturity.

2.5. Data Collection and Measurements

2.5.1. Maize Component (Growth, Phenology, Yield Related Traits and Yields of Maize)

i. Plant Height of Maize

ii. Days to Tasselling

Days to tasselling of maize were recorded from the selected plants based on plot based.

iii. Days to 50% Flowering

Days to 50% flowering of maize were recorded from the selected plants based on plot based.

iv. Days to 90% Physiological Maturity

Days to 90% physiological maturity were recorded from five randomly taken plants as the number of days from emergence to the date on which 90% physiologically matured of the plants in a plot matured. The leaf of the plants totally changed to yellow and grain is firmed.

v. Above Ground Biomass Weight (ton ha^{-1})

Above ground biomass was measured from distractive sampled plants per plot at the end of harvest in each plot.

vi. Grain Yield (kg ha^{-1})

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.

vii. Hundred Seed Weight (kg ha^{-1})

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

2.5.2. Mung Bean Component (Growth, Phonological, Yield Related and Yields of Mung Bean)

i. Plant Height of Mung Bean

At maturity ten plants were taken randomly from the net plot area of each plot then the height will be measured from the ground to the tip plants excluding the pod length and the mean determined in cm.

ii. Branch Number per Plant

The number of branches per plant was counted at time of data collection (at the time of physiological maturity) of ten random plants.

iii. Days to 50% Flowering

Days to flowering was recorded when about 50% of the plants in a plot produce flower.

iv. Days to 90% Physiological Maturity

Days to physiological maturity was recorded when about 90% of the plants reached physiological matured based on visual observation. It will be indicated by senescence (turning to light yellow) of the leaves and vegetative parts as well as free threshing of grain from the grains when pressed between the finger and thumb.

v. Number of Pods per Plant

From ten plants the number pods per plant from the mature plant's parts were randomly taken from the net plot area and counted at time of harvesting.

vi. Number of Seed per Pod

At maturity the number of pods were counted from the selected plants.

vii. Above Ground Biomass

At maturity, the whole above plant parts, including leaves, stems and pods including seeds from the net plot area in each plot was harvested and sun dried until a constant weight and then the above ground biomass will be measured and expressed in $kgha^{-1}$.

viii. Harvest Index

It refers to the ratio of economic yield (grain yield at---% moisture content to the above ground biomass (AGB) (seed + straw) and it is expressed in percentage. It will be calculated according to the following formula.

$$HI = \frac{\text{Grain yield}}{\text{Above ground biomass}} x100$$

Where, HI= harvest index, GY= grain yield (at --% moisture base) and AGBY = above ground biomass (yield + straw).

ix. Grain Yield (GY)

After harvesting, threshed grains were separated, cleaned and weighed by electronic balance. The grain yield will be corrected to moisture content of 12.5%, wet bases while moisture tester will be employed for measuring the moisture content.

x. Thousand Seed Weight (g)

Thousand seed weight was be counted by electronic counter and weighed by electronic balance later 1000-seed weight will be expressed in gram.

2.6. System Productivity

2.6.1. Land Equivalent Ratio (LER)

Partial land equivalent ratio: is the ratio of intercropped and sole cropped yield of the individual crop. For instance, the partial land equivalent ratio of maize will be calculated as, Partial LER of maize = $\frac{YMi}{YMs}$; where YMi= intercropped grain yield of maize and YMs = grain yield of sole cropped maize. Similar to maize the partial land equivalent ratio of mung bean will also calculated as; partial land equivalent ratio of mung bean = $\frac{YMGi}{YMGs}$ where YMGi = intercropped yield of mung bean and YMGs = sole cropped of mung bean.

The LER will be calculated using the formula LER= Σ (Ypi/Yms) (where Ypi is the yield of each crop in the intercrop, and Yms will be the yield of each crop in the sole crop.

So, in this study the LER was calculated as,

$$LER = \frac{YMzi}{YMzs} + \frac{YMgi}{YMgs}$$ (from the sole crop the actual yield will be used for the component crops)

Where

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

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

YMgi =Yield per unit area of mung bean in intercropping (net plot area of intercropped mung bean)

YMgs = Yield per unit area of mung bean sole (net plot area of sole mung bean).

2.6.2. Monetary Advantage Index (MAI)

First the Gross monetary value (GMV) will be calculated as; Yield of component crops × respective market price; i.e., (yield of maize x price of maize + yield of mung bean x price of mung bean) [31].

In order to access the economic advantage of intercropping as compared to sole cropping of maize and mung bean, the gross monetary value (GMV) and the Monetary Advantage index (MAI) will be calculated from the yield of maize and mung bean (kg ha^{-1}). Gross monetary value and monetary advantages will be calculated to measure the productivity and profitability of the intercropping as compared to sole cropping of the component crops.

Monetary Advantage Index (MAI): The most important part of recommending a cropping pattern will be 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 will be evaluated to find out whether maize grain yield and additional mung bean yield will be profitable or not. This is calculated with monetary advantage index (MAI) which indicates more profitability of the cropping system with the higher the index value (Mahapatra, 2011). It will be expressed as MAI= (Pab+Pba) * (LER-1)/LER Where, Pab = Pa ×Yab; Pba =Pb ×Yba; Pa = Price of maize and Pb = Price of mung bean.

2.7. Data Analysis

All data will be subjected to the analysis of variance (ANOVA) appropriate to the randomized complete block design using SAS (SAS, 2002). Least significant difference (LSD) test at 5% level of probability will be also used for mean separation as procedure described by Gomez and Gomez, (1984). We also used the linear model of RCBD while analysed the data by SAS.

3. Results and Discussion

3.1. Weather Data of (Temperature and Rain Fall) on 2019 and 2020 Cropping Season at Jejebicho Research Station

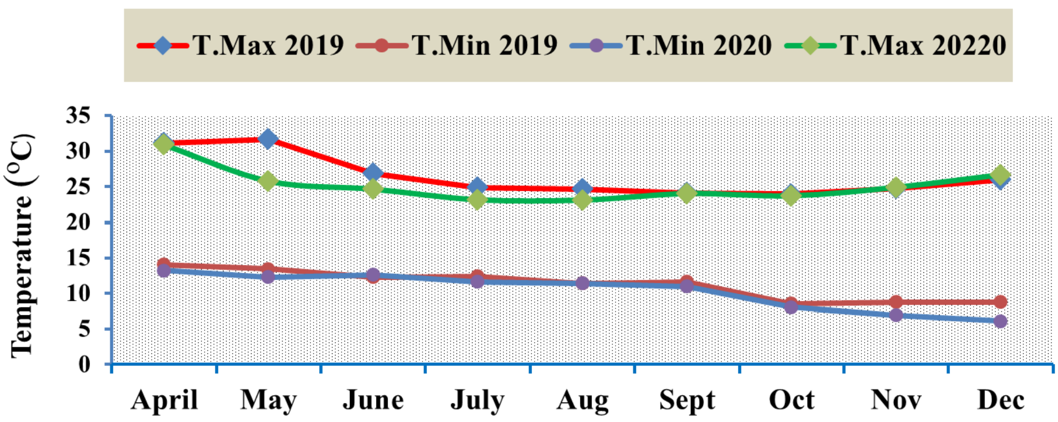

Figure 1. *Mean monthly maximum and minimum temperature (°C) on 2019 and 2020 cropping season at jejebicho.*

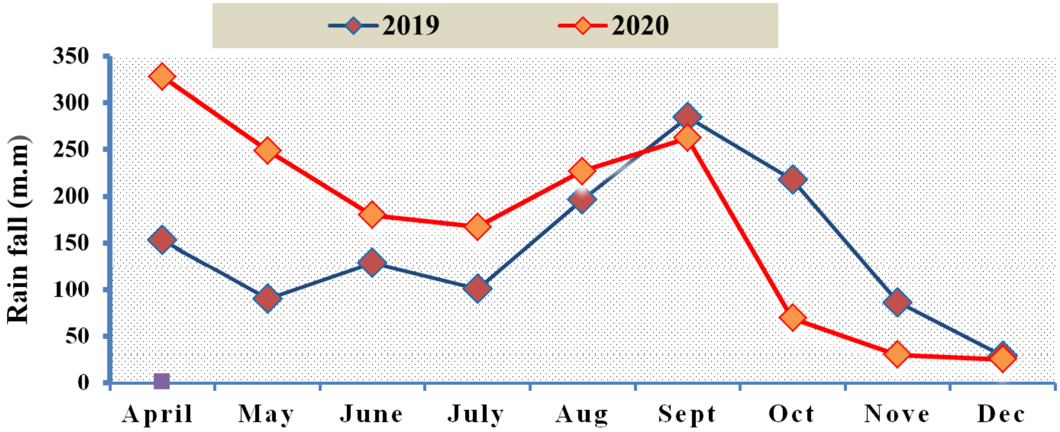

Figure 2. *Total monthly rain fall (m.m) for 2019 and 2020 cropping season at jejebicho station.*

3.2. Effects of Population Density, Spatial Arrangements and Cropping System on Crop Phenology of Maize

The analysis of variance showed that population density had significantly affected days to tasseling of maize in both 2019 and 2020 cropping season. However non significantly affected by spatial arrangement of mung bean. The longest days to tasseling (80.81 and 81.11 days) of maize was taken when maize intercropped with 25% population density of mung bean in both 2019 and 2020 cropping season respectively (Table 2). However, the minimum days to tasseling (74.49 and 76.78 days) was taken at 75% population density for both 2019 and 2020 cropping season respectively (Table 2).

Cropping system was significantly affected days to tasseling of maize in both cropping seasons. Days to physiological maturity of maize was significantly affected by cropping system at 2019 cropping season not for 2020. The longest days to tasseling (77.60 and 77.86 days) of maize was taken when maize intercropped with mung bean but the minimum days to tasseling was taken when maize sow alone. These experimental results disagreed with the foundlings of Wondimkun and Nibret [32], Alemayehu *et al.* [4] who revealed that the highest days to maturity and days to tasseling was recorded at sole cropping of maize than intercropped treatment. This may due to the absence of intraspecific competition between maize and mung bean in intercropped treatment.

Table 2. *Showed the Mean Effect of Population Density and Spatial Arrangement of Days of tasselling and days of physiological maturity of Maize in Mung-Maize rely Cropping.*

Population density	Days to tasselling			Days to physiological maturity		
	2019/20	2020/21	Mean	2019	2020	Mean
100%	77.05ab	75.11d	76.08	144.69b	197.44	171.07
75%	74.49b	76.78c	75.64	143.97bc	153.00	148.49
50%	78.04ab	78.44b	78.24	151.13a	156.11	153.62
25%	80.81a	81.11a	80.96	141.64c	156.22	148.93
LSD (0.05)	3.92	0.97		2.51	NS	
Spatial arrangement						
1:3	78.18	77.58	77.88	145.30	154.92	150.11
1:2	77.64	78.17	77.91	145.63	186.17	165.9
1:1	76.98	77.83	77.41	145.15	156.00	150.58
LSD (0.05)	NS	NS		NS	NS	
CV (%)	5.24	1.28		1.79	35.62	
Cropping system						
Sole maize	74.54b	74.00b	74.27	152.05a	160.33	156.19
Intercropped	77.60a	77.86a	77.73	145.36b	165.78	155.57
LSD (0.05)	1.95	1.01		1.62	5.70	3.16
CV (%)	0.73	0.38		0.31	7.45	

3.3. Yield and Yield Components of Maize

Above ground biomass non significantly affected by both population density and arrangement of mung bean for 2019 cropping season of it. However, population density was significantly affected above ground biomass yield of maize at 2020 cropping season. The maximum yield (20.55 Qt/ha) and minimum (13.90 Qt/ha) biomass yield was obtained from 50% and 75% population density respectively (Table 3). Legume intercropping systems play a significant role in the efficient utilization of resources. As cited by Azim *et al.* [6] cereal-legume intercropping is a more productive and profitable cropping system in comparison with solitary cropping. Different literatures reviewed that intercropping is improvement of resource utilization efficiency and increase production per unit area. The experimental result of Kumar *et* *al*. [21] concluded that soil surface remained moist in the intercrop during dry spell of 6-8 days when compared to sole maize cropping. Decline of external inputs and increased demand of home-grown feed together with a more efficient nutrient use from leguminous symbiotic dinitrogen (N2) fixation (SNF) can result in a decrease of nitrogen and mineral losses [6].

Table 3. *The Effects of population density and spatial arrangements of above ground biomass yield of maize in mung bean maize rely cropping at Jejebicho research station at both 2019/20 and 2020/21 main cropping season.*

Treatments	Above ground biomass (quintal ha^{-1})		
Population density	**2019**	**2020**	**Mean**
100%	22.87	17.35b	20.11
75%	21.91	13.90c	17.91
50%	21.74	20.55a	21.15
25%	18.24	16.73b	17.49
LSD (0.05)	NS	2.15	
Spatial arrangement			
1:3	21.80	17.19	19.50
1:2	21.02	17.71	19.37
1:1	20.75	16.67	18.71
LSD (0.05)	Ns	NS	
CV (%)	12.45	5.08	
Cropping system			
Sole	19.21b	14.91	17.06
Intercropped	21.19a	17.49	19.34
LSD (0.05)	1.04	4.83	2.94
CV (%)	1.46	8.56	

Where treatments assigned by the same letter was a non-significantly different at p<0.05.

Analysis of variance showed that population density was significantly affected hundred kernel weights of maize at 2020 cropping season. The highest (40.79g) and the lowest (38.71g) hundred kernel weight was measured when maize intercropped with 100% and 25% population density of mung bean (Table 4). Spatial arrangement was significantly affected hundred kernel weights of maize at both cropping seasons. The highest (40.41g and 40.05g) and the lowest (38.27g and 39.08g) hundred kernel weight was measured when maize intercropped with 1:3 and 1:1 spatial arrangement of mung bean respectively (Table 4). The grain yield of maize was significantly affected by both population density and spatial arrangement of mung bean at 2019 and 2020 cropping season. The highest (8.79ton/ha) grain yield of maize was obtained from 100% density the minimum grain yield (5.83ton/ha) was obtained also when maize intercropped with mung bean with 25% population density at 2019 cropping season (Table 4).

But the highest grain (7.49 ton/ha) yield was obtained from 25% population density at 2020 cropping season (Table 4). Spatial arrangement was significantly affected grain yield for both cropping seasons. The highest (7.96ton/ha and 7.68ton/ha) and lowest (7.45ton/ha and 6.79ton/ha) grain yield was obtained from 1:3 and 1:1 spatial arrangement at both cropping seasons respectively (Table 4). Cropping system was significantly affected the grain yield of maize at 2019 cropping season. The highest grain yield was obtained from sole cropping of maize as compared to intercropped maize with mung bean (Table 4). This might be due to the absence of interspecific competition in between maize and mung bean.

Table 4. *Mean Effects of population density and spatial arrangements on Hundred kernel weight and Grain yield of maize n in mung bean maize relay cropping at Jejebicho research Station in 2019/20 and 2020/21 main cropping season.*

Treatments	Hundred Kernel weight (g)			Grain yield (ton ha^{-1})		
Population density	**2019**	**2020**	**Mean**	**2019**	**2020**	**Mean**
100%	40.63	40.79a	40.71	8.79a	7.26ab	8.03
75%	36.91	40.16ab	38.54	8.13b	6.56b	7.35
50%	38.91	40.00ab	39.46	7.78b	7.31ab	7.55
25%	40.16	38.71b	39.44	5.83c	7.49a	6.66
LSD (0.05)	NS	1.97		0.51	0.92	1.43
Spatial arrangement						
1:3	41.41a	41.05a	41.23	7.96a	7.68a	7.82
1:2	37.77ab	39.63ab	38.70	7.50b	6.99ab	7.25
1:1	38.27b	39.08b	38.68	7.45b	6.79b	7.12
LSD (0.05)	3.81	1.70		0.44	0.80	
CV (%)	11.65	5.25		6.97	13.26	
Cropping system						
Sole maize	43.71	40.19	41.95	8.84a	5.83	7.34
Intercropped maize	39.15	39.92	39.54	7.63b	7.16	7.40
LSD (0.05)	Ns	2.70		0.68	2.13	
CV (%)	12.52	1.92		2.79	9.34	

Table 5. *Mean Effects of population density and spatial arrangements on partial land equivalent ratio of both maize and mung bean in mung bean maize relay cropping at Jejebicho research Station in 2019/20 and 2020/21 main cropping season.*

Treatments	Partial land equivalent ratio of maize			Partial land equivalent ratio of mung bean			Total land equivalent ratio		
Population density	**2019**	**2020**	**Mean**	**2019**	**2020**	**Mean**	**2019**	**2020**	**Mean**
100%	0.99a	0.65	1.64	0.89	0.82a	1.71	1.88a	1.46a	1.67
75%	0.92b	0.59	1.51	0.88	0.71b	1.59	1.80ab	1.29b	1.55
50%	0.88b	0.65	1.53	0.90	0.59c	1.49	1.78b	1.25b	1.52
25%	0.66c	0.66	1.32	0.87	0.53c	1.40	1.53c	1.19b	1.36
LSD (0.05)	0.04	NS		NS	0.1		0.19	0.13	

Treatments	Partial land equivalent ratio of maize			Partial land equivalent ratio of mung bean			Total land equivalent ratio		
Population density	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean
Spatial arrangement									
1:3	0.86	0.68a	1.54	0.90	0.66	1.56	1.76	1.35	1.35
1:2	0.89	0.60b	1.49	0.85	0.65	1.5	1.74	1.25	1.25
1:1	0.91	0.63ab	1.54	0.84	0.67	1.51	1.75	1.29	1.29
LSD (0.05)	NS	0.08		NS	NS		NS	NS	
CV (%)	7.38	15.04		11.87	16.65		8.35	10.00	

Where, treatments assigned by the same letter indicates a non-significance difference between them.

The analysis of variance showed that partial land equivalent ratio of maize was significantly affected by both population density at 2019 cropping season and spatial arrangement of mung bean at 2020. The highest partial land equivalent ration (0.99) of maize was obtained from 100% population density of mung bean in 2019 cropping season (Table 5). The intercropped maize yield increased from 66% to 99% and 86% to 91% of its sole crop yield in terms of mung bean population densities and spatial row arrangements, respectively in 2019 cropping season. The highest partial land equivalent ratio value (0.68) of maize was obtained from 1:3 spatial arrangement whereas the lowest partial land equivalent ratio value (0.60) was obtained from 1:1 population density at 2020 cropping season (Table 5). The partial land equivalent ratio of mung bean was significantly affected by population density at 2020 cropping season. The highest partial land equivalent ratio value (0.82) of mung bean was obtained from 100% population density whereas the lowest partial land equivalent ratio value (0.53) was obtained from 25% population density at 2020 (Table 5). The intercropped mung bean yield increased from 59% to 66% and 60% to 68% of its sole crop yield in terms of mung bean population densities and spatial row arrangements, respectively in 2020 cropping season. This may be due to directly related to grain yield i.e., the highest grain yield was obtained from 100% population density as compared to other population density and treatments. Total land equivalent ratio was significantly affected by population density of mung bean. The highest (1.46) and lowest (1.19) total land equivalent ration was obtained from 100% and 25% population density respectively (Table 5). This showed that intercropping was an advantageous as compared to sole cropping of either of the component crops as depicted by total LER values above one indicated complimentarily in resource utilization by the component crops.

Monitory advantage index was also evaluated to find out whether maize yield and the added mung bean yield is profitable or not. The highest economic benefit was obtained from 100% population density as compared to other population density at 2019 (Table 6). Among the row arrangements the highest monitory advantage index was obtained from 1:3 maize-mung bean intercropping at both cropping seasons. The highest benefit of 105,453 ETB (2019) and 112,374 ETB ha^{-1} (2020) was also obtained from 100% and 25% population density respectively in maize-mung bean intercropping (Table 6). However, in 2020 cropping season there is no significance difference between 100% and 25% population density of mung bean except 50% population density.

Table 6. *Mean effects of, population density and spatial arrangements on monitory advantage of both maize and mung bean in mung maize relay cropping at Jejebicho research station at 2019/20 and 2020/21 main cropping season.*

Treatments	Monitory advantage of maize			Monitory advantage of mung bean		
Population Density	2019	2020	Mean	2019	2020	Mean
100%	105,453a	108,864ab	107,158.5	68,382	87,500a	77,941
75%	97,021b	98,430b	97,725.5	67,589	56,600b	62,094.5
50%	93,394b	109,663ab	101,528.5	67,155	52,000c	59,577.5
25%	70,003c	112,374a	91,188.5	66,133	46,250c	56,191.5
LSD	6196.2	13,854		NS	9,200	
Spatial Arrangements						
1:3	95,510a	115,164a	105,337	67,467ab	62,800a	65,133.5
1:2	88,942b	101,917b	95,429.5	65,213b	59,500ab	62,356.5
1:1	89,950b	104,917ab	97,433.5	69,265a	59,450b	64,357.7
LSD	5,366.1	11,998		3,321.7	2,030.4	
CV (%)	7.02	13.27		5.90	15.04	

The analysis of variance showed that number of pods/plants was significantly affected by population density in both 2019 and 2020 cropping seasons. The highest number of pods/plant (28.44) was counted from 50% population density at 2019, but at 2020 cropping the highest number of pods/plant (15.51) was counted from 100% population density (Table 7). The Above ground biomass yield of mung bean was also significantly affected by population density at 2020/21 cropping season only. The highest biomass yield of mung bean also obtained from (44.84 ton/ha) from 100% population density (Table 7).

Table 7. *Mean effects of population density, spatial arrangements and cropping system of number of pods per plant and above ground biomass yield of maize in mung bean maize rely cropping at Jejebicho research station in 2019 and 2020 main cropping season.*

Treatments	Number of pods per plant			Above Ground Biomass (Qt ha^{-1})		
Population densities	**2019**	**2020**	**Mean**	**2019**	**2020**	**Mean**
100%	26.22ab	15.51a	20.87	40.38	44.84a	42.61
75%	26.04ab	12.58bc	19.31	39.55	40.46a	40.01
50%	28.44a	11.73bc	20.09	40.70	37.04a	38.87
25%	19.40b	9.40c	14.40	37.24	25.60b	31.42
LSD (0.05)	8.17	2.80		NS	10.80	
Spatial arrangements						
1:3	27.48	12.47	19.89	39.81	39.44	39.63
1:2	24.42	12.30	18.36	37.73	38.32	38.03
1:1	23.18	12.15	17.67	40.86	33.21	37.04
LSD	NS	NS		NS	NS	
CV (%)	33.81	10.20		9.48	12.15	
Cropping System						
Sole mung bean	20.13	16.96a	18.55	45.09a	51.14a	48.12
Intercropped	25.03	12.30b	18.67	39.47b	36.98b	38.23
LSD (0.05)	NS	4.61		2.35	10.36	
CV (%)	14.50	8.97		2.96	6.69	

Table 8. *Mean effects of population density, spatial arrangements and cropping system on thousand seed weight and grain yield of mung bean in mung bean maize rely cropping at Jejebicho research station in 2019 and 2020 Budget year.*

Population densities	Thousand Seed weight (g)			Grain yield (quintal ha^{-1})		
	2019	**2020**	**Mean**	**2019**	**2020**	**Mean**
100%	38.33	38.50	38.42	14.69	17.50a	16.10
75%	37.54	38.70	38.12	14.60	11.32bc	12.96
50%	38.63	39.57	39.10	14.87	10.40bc	12.64
25%	35.34	40.09	37.72	14.38	9.25c	11.82
LSD (0.05)	NS	NS		NS	1.84	
Spatial arrangements						
1:3	37.79	39.79a	38.79	14.18b	12.56	13.37
1:2	35.82	36.49b	35.16	14.67ab	11.90	13.29
1:1	38.78	41.30a	40.04	15.06a	11.89	13.48
LSD	NS	2.90		0.72	NS	
CV (%)	9.84			5.90		
Cropping System						
Sole mung bean	39.60	45.08a	42.34	16.48a	17.42a	16.95
Intercropped	37.46	39.21b	38.34	14.64b	12.12b	13.38
LSD (0.05)	NS	4.33		1.58	4.26	
CV (%)	4.39	2.67		2.75	8.21	

Number of pods plants^{-1} also significantly affected by Cropping system at 2020/21 cropping season. The more number pod per plant (16.96) was counted from sole cropping (Table 7). Above ground biomass yield was showed a significance difference by cropping system at both cropping seasons. The highest above biomass yield was obtained from sole cropping (45.09 Qt/ha, 51.14 Qt/ha) from 2019 and 2020 cropping season respectively (Table 7). The maximum biomass yield was obtained from the treatment of mung alone [9, 20]. The experimental results of Bechem *et al*. [7], Wondimkun and Nibret [32] reported that the highest number of pods/plants were counted from sole cropping of common bean than intercropped common bean with maize. This might be due to higher number of pods plant^{-1} in sole mung bean plots could be attributed to availability of more nutrients and less interspecific competition between maize and mung bean crop for available resources. The treatments where mung bean was sown alone were fully exploited to irradiance that improved yield components and light penetration to the canopy of the legume component. The experimental results of Azim *et al*. [6] who revealed that mung bean drought resistant nature cannot tolerate excess water if it is grown with maize as intercrop where more water is applied. The experimental results of Islam *et al*. [24] also revealed that number of pods plant^{-1} of mung bean were higher in monoculture as compared to their corresponding intercropped.

The analysis of variance showed that thousand seed weight was significantly affected by spatial row arrangement of mung at 2020/21 cropping season. The highest thousand seed weight (41.30g) was measured from 1:1 row arrangement (Table 8). The grain yield of mung bean was significantly affected by population density at 2020/21 cropping season. The highest grain yield of mung bean (17.50 Qt/ha) was obtained from 100% population density (Table 8). Grain yield of mung bean was significantly affected by spatial row arrangement at 2019 cropping season. The highest grain yield of mung bean (15.06 Qt/ha) was obtained from 1:1 row arrangement of it

(Table 8). Under this study thousand seed weight was significantly affected by cropping system at 2020/21 cropping season. The highest thousand seed weight (45.08g) was measured from sole cropping of mung bean (Table 8). This might be due to the absence of interspecific competition from maize. Grain yield of mung bean was significantly affected by cropping system at both 2019 and 2020 cropping season. The highest grain yield (16.48Qt/ha and 17.42Qt/ha) was obtained from sole cropping of mung bean at 2019 and 2020 cropping seasons respectively (Table 8). Grain yield of mung bean was higher from sole cropping than the intercropped [2, 18, 3]. According the experimental founding of Khan *et al.* [9] number of pods $plant^{-1}$ of mung bean directly influences grain yield of it. In general, grain yield of maize reduced in intercropping situation compared to the sole maize.

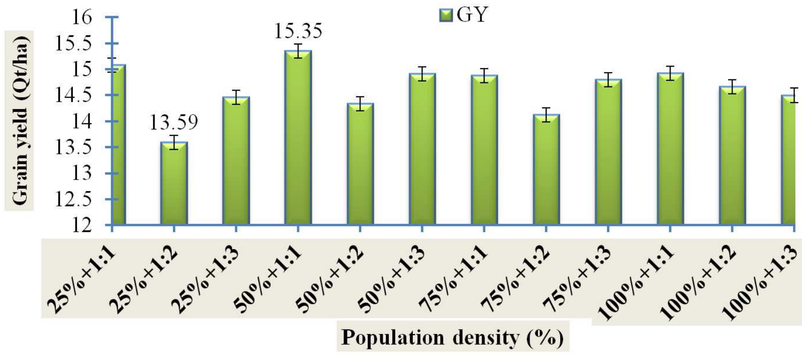

Figure 3. *The Interaction effects of population density and spatial arrangement on grain yield (Qt/ha) of mung bean (2019).*

The analysis of variance showed that the interaction effects of both population density and spatial arrangement significantly affected monitory advantage index of maize.

The highest monitory advantage index value of maize (110,280 Ethiopian birr) was obtained from the interaction effects of 100% population density and combined with all the three row arrangements of mung (Table 9).

Table 9. *The interaction means effect of both population density and spatial row arrangements of mung bean on monitory advantage index of maize 2021 cropping season.*

Population Density	Monitory advantage index of maize (Ethiopian birr)		
	Row arrangement		
	1:3	1:2	1:1
100%	110,280a	110,280a	110,280a
75%	103,600abc	103,600abc	103,600abc
50%	97,160bcd	97,160bcd	97,160bcd
25%	71,001e	71,001e	71,001e
LSD (0.05)	11,685		
CV (%)	7.54		

The statistical data analysis revealed that both leaf area and leaf area index of maize significantly affected by the interaction effects of population density and spatial arrangements of mung bean. The longest leaf area ($13,719cm^2$) was measured and the highest value of leaf area index (1.22) was gained from the interaction 100% population density and 1:3 row arrangements of mung bean, respectively (table 11).

Table 10. *Showed the interaction effects of both population density and spatial arrangement on days to tasseling and days to physiological maturity of maize in 2020/21 main cropping season at jejebicho research station.*

Pp. Density	Days to tasselling (days)			Days to physiological maturity (day)		
	Row arrangements			Row arrangements		
	1:3	1:2	1:1	1:3	1:2	1:1
100%	75.00e	75.00e	75.33de	158.00b	276.33a	152.00b
75%	76.67cd	76.00de	78.00bc	154.33b	152.67b	158.00b
50%	78.33b	79.00b	80.67a	153.67b	159.00b	156.00b
25%	81.67a	81.67a	81.00a	153.67b	159.00b	156.00b
LSD (0.05)	1.61			120.60		
CV (%)	1.22			6.75		

Where, Pp. Density=Population density.

Above ground biomass yield of mung bean responded significantly to various by the interaction effects of population density and spatial row arrangements. The highest above ground biomass yield of maize was obtained from 50% population density and 1:1spatial row arrangements (Table 11). This might be due to the inter specific competition at 50% population density might not be as low as 25% and as high as 100% population density and other row arrangements. The interspecific competition which it might be very positive and very efficient soil resource utilization. Hundred kernel weight of maize was significantly affected by both population density and spatial row arrangements. The highest hundred kernel weight of maize (42.48g) was recorded at 75% population density and 1:3 row arrangements of mung bean (Table 11).

Table 11. *Showed the interaction effects of both population density and spatial arrangement on yield and yield components of maize in 2020/21 main cropping season at jejebicho research station.*

Pp. Density	Above ground biomass (ton/ha)			Hundred Kernel Weight (g)		
	Row arrangements			Row arrangements		
	1:3	1:2	1:1	1:3	1:2	1:1
100%	15.60b	16.35ab	20.08ab	42.15ab	41.90abc	38.33e
75%	15.21ab	16.36ab	10.13b	42.48a	39.21a-d	40.26a-d
50%	19.19ab	16.14ab	26.32a	40.76a-d	39.00a-d	40.26a-d
25%	19.76ab	17.31ab	13.14b	38.79bcd	38.40cd	38.93bcd
LSD (0.05)	11.64			3.55		
CV (%)	40.11			5.25		

The data analysis of revealed that the interaction effects of both population density and spatial row arrangements significantly affected grain yield and harvest index of maize. The highest and lowest grain yield of maize was obtained from 100% population density and 1:3 row arrangements and from 75% population density and 1:1 row arrangements of mung bean respectively (Table 12). Harvest index of maize significantly affected by population density and spatial arrangements simultaneously. The lowest harvest index (0.28) value of maize calculated from 50% population density and 1:1 row arrangement (Table 12).

Table 12. *Showed the interaction effects of both population density and spatial arrangement on grain yield and harvest index of maize in 2020/21 main cropping season at jejebicho research station.*

Pp. Density	Grain yield (ton/ha)			Harvest index		
	Row arrangements			Row arrangements		
	1:3	1:2	1:1	1:3	1:2	1:1
100%	8.19a	6.66ab	6.92ab	0.54a	0.43b	0.35bc
75%	7.04ab	6.60ab	6.05b	0.47a	0.41b	0.59a
50%	7.34ab	7.10ab	7.49ab	0.39b	0.50a	0.28b
25%	7.14ab	6.82ab	7.51ab	0.36b	0.39b	0.57a
LSD (0.05)	1.67			0.15		
CV (%)	13.77			8.17		

The number of seed per pod and above ground biomass yield of mung bean significantly affected by the interaction effect of population density and spatial arrangement. The more umber of seed per pod (10.67) was counted from 100% population density and 1:1 spatial row arrangement of mung bean (Table 13). The highest above ground biomass yield (52.10 ton/ha) was measured from 75% population density and 1:3 row arrangement (Table 13).

Table 13. *The interaction effects of both population density and spatial row arrangements on number of seed per pod and above ground biomass yield of mung bean in 2020/21 main cropping season at Jejebicho research station.*

Pp. Density	Number of seed per pod			Above ground biomass (ton/ha)		
	Row arrangements			Row arrangements		
	1:3	1:2	1:1	1:3	1:2	1:1
100%	9.73ab	8.87ab	10.67a	47.05ab	44.26a-d	43.22a-d
75%	10.40a	8.40b	9.53ab	52.10a	36.78a-e	32.52b-e
50%	9.40ab	9.40ab	9.20ab	32.72b-e	45.34abc	33.06b-e
25%	8.93ab	9.47ab	9.33ab	25.88de	26.88cde	24.03e
LSD (0.05)	1.91			18.71		
CV (%)	11.97			29.88		

Where Pp. Density= population density.

The analysis of variance revealed that the interaction effects of population density and spatial arrangement significantly affected thousand grain weight and grain yield of mung bean rely intercropping of mung bean with maize. The highest thousand grain weight (42.18g) was recorded from 25% population density and 1:1 spatial arrangement of it (Table 14). These may be due to the existence of less interspecific competition as compared to other population density and row arrangement. The highest grain yield (18.54 quintal/ha) was obtained from 100% population density and

1:3 row arrangement (Table 14). These might be due to the presence high plant population per experimental plot area.

Table 14. *The interaction effects of both population density and spatial arrangements on thousand grain weight and grain yield components of mung bean in 2020/21 main cropping season at Jejebicho research station.*

Pp. Density	Thousand grain weight (g)			Grain yield (quintal/ha)		
	Row arrangements			Row arrangements		
	1:3	1:2	1:1	1:3	1:2	1:1
100%	39.15abc	34.43c	41.93ab	18.54a	16.23ab	17.74a
75%	38.76abc	36.16bc	41.17ab	12.27cd	13.28bc	9.41d
50%	41.48ab	37.05abc	40.18abc	10.79cd	9.95d	10.47cd
25%	39.76abc	38.32abc	42.18a	9.65d	8.17d	9.92d
LSD (0.05)	5.80			3.19		
CV (%)	8.74			15.55		

4. Conclusion and Recommendation

Intercropping of maize with mung bean is one of the methods of achieving high yield per unit area and harvesting more than one crop per season from a piece of land. Intercropping is receiving attention because it offers potential advantages for resource utilization, decreased inputs and increased sustainability in crop production. This experiment was a two-year experiment at Sankura wereda Jejebicho research station and conducted in 2019/2020 to 2020/21 cropping season. All necessary data was collected of the component crops from field experiment and analysed. Data collected for maize were: on phenology, days to tasselling and days to physiological maturity 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 mung bean were; on growth parameters and yield related traits of mung bean varieties like, plant height, branch number per plant, number of pods per plant, number of seed per pod, days to physiological maturity, thousand grain weight, Grain yield and Harvest index. Land equivalent ratio and monetary advantage were used to assess the system of productivity. The highest (8.19 ton/ha) grain yield of maize was obtained from 100% population density and 1:3 spatial row arrangement of mung bean. This may due to the presence of high interspecific competition with related high plant population density per plot area compared to other treatments. Whereas the highest grain yield mung bean (18.54 Quintal/ha) was obtained from when mung rely intercropped with 100% population density and 1:3 row arrangements. The highest thousand seed weight (42.18g) was recorded from 25% population density and 1:1 row arrangements of mung bean. The maximum Land equivalent ration value was calculated from 1.88 from 100% population density in 2019 cropping season. The highest monitory advantage index value 110,280 Ethiopian birr) was obtained from 100% population density with all the three spatial row arrangement of mung bean. Generally, rely-intercropping of maize and other low land pulse crops is one of the best options to increase the production of additional grain yield of mung bean in Ethiopia. Farmers can achieve greater benefit from their land by growing the main crop (maize and in lately association with a mung bean, which is maize intercropped with 100% population density and 1:3 row arrangements of mung bean. Hence, maize/mung bean intercropping could increase incomes obtained by smallholder farmers at Sankura area of Southern Ethiopia, through enhancing efficient utilization of land. Therefore, this experiment could be recommended for mung bean rely cropped with maize by 100% population density and 1:3 row arrangement able the famers to get better grain yield of maize as wel as mung bean.

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