Cross Current International Journal of Agriculture and Veterinary Sciences
Abbreviated Key Title: Cross Current Int J Agri Vet Sci
ISSN: 2663-2454 (Print) & Open Access
DOI: 10.36344/ccijavs.2024.v06i01.002

Volume-6 | Issue-1 | Jan-Feb, 2024 |

Original Research Article

Optimizing Basil (*Ocimum basilicum* L.) Planting Densities and Row Arrangements in Tomato-Basil Intercropping System

Midekesa Chala[1*], Amsalu Nebiyu[2], Belistie Lulie[3]

[1]Ethiopian Institute of Agricultural Research, Ambo Agricultural Research Center, P. O. Box, 37, Ambo, Ethiopia
[2]Jimma University, College of Agriculture and Veterinary Medicine, P. O. Box, 307, Jimma, Ethiopia
[3]Ethiopian Institute of Agricultural Research, Debre Markos Agricultural Research Center, 8PMP+CH8, Debre Markos, Ethiopia

***Corresponding author:** Midekesa Chala
| **Received:** 23.12.2023 | **Accepted:** 29.01.2024 | **Published:** 07.02.2024 |

Abstract: A field experiment was conducted at Wondo Genet Agricultural Research Center under irrigated conditions during 2018, to evaluate the performance of tomato yield and yield components under an intercropping system with different basil planting densities and row arrangements. it was arranged in a 2 × 4 factorial arrangement in randomized complete block design with three replications each consisting of ten treatments: two basil row arrangements (one tomato row alternating with one basil row (1T:1B) or with two basil rows (1T:2B)) and four basil population densities (66666, 50000, 33333 and 16666 plants ha $^{-1}$). Results of the study indicated that intercropping system significantly ($p<0.05$) affected the yield and yield components of tomato. Inter-cropped tomato with basil had the highest yield (36657.8 kg ha^{-1}) as compared to sole cropped tomato (31004.3kg ha^{-1}) and inter-cropping with basil increased its yield by 15.42%. Therefore, basil with a density of 33,333 plants ha^{-1}and intercropped with tomato with 1T:1B row arrangement could be recommended for the wondo genet and similar agroecology area. However, the effect of tomato-basil intercropping on the incidence and severity of major tomato insects and diseases needs further study.
Keywords: Intercropping, population density, Alternating.

1. INTRODUCTION

Tomato is a widely grown vegetable crop in Ethiopia. It is consumed by every household in different forms and as an important co-staple food (Gemechis *et al*., 2012). It is mainly cultivated as a mono-crop by intensive use of chemical inputs**.** Different agricultural systems that can increase crop production or yield per unit area have been investigated to overcome the problem of the decrease arable land worldwide. Intercropping is one of these systems, characterized as the production of two or more different crop species simultaneously on the same land by utilizing resources such as soil, water, nutrients, and solar radiation more efficiently (Bocken *et al*., 2013). Intercropping is one of the most effective methods in agricultural production with a long history and widespread application in the tropics, as it reduces losses caused by pests, diseases, and weeds, and also guarantees better yields. Some short-duration crops, especially spices condiments and medicinal plants, if planted as an intercrop in or around the main crop, may reduce pest incidence, due to their pungent aromatic odor in the field (Gebru, 2015).

Tomato and basil are pairs of crops that are commonly intercropped in different parts of the world (Bomford, 2009). Several studies have reported the performance of inter-cropping of aromatic and medicinal plant species with selected major horticultural crops in Ethiopia and different countries (Bomford, 2004; Neelam and Lokho, 2009; Girma, 2015; Mutisya *et al.*, 2016; Nigussie *et al*., 2017). Girma (2015) reported that inter-cropping of maize with basil at a 1:1-row arrangement could provide farmers with the best yield advantage and income over sole planting of component (maize) crops. For vegetable crops, intercropping systems to be successful in a given geographical location, effective cultural practices such as optimum plant population must be determined. Success in intercropping over sole cropping systems can be achieved by some agronomic manipulations. These manipulations involve plant density, planting time,

Quick Response Code

Journal homepage:
https://www.easpublisher.com/

Citation: Midekesa Chala, Amsalu Nebiyu, Belistie Lulie (2024). Optimizing Basil (*Ocimum basilicum* L.) Planting Densities and Row Arrangements in Tomato-Basil Intercropping System. *Cross Current Int J Agri Vet Sci*, *6*(1), 6-14.

available resources, and intercropping patterns (Mousavi and Eskandari, 2011). Enhancing the productivity of tomato and basil intercrops requires improving the interspecies complementary action or reducing the competition effects. Planting density is one of the most important agronomic management decisions to be considered when deciding to practice intercropping. Wheeler *et al.*, (2000) noted that poor management of planting density could be detrimental to intercropping. Plant densities that are too low may limit the potential yield while plant densities that are too high may lead to increased stress on the plants, and increased interplant competition for light, water, and nutrients (Adeniyi *et al*., 2001) which also decrease the yield. The other important management aspect is row arrangement which can improve radiation interception through more complete ground cover and determine whether an intercropping system would be advantageous or not concerning yield gains (Nthabiseng *et al.*, 2015). However, the greater challenge for farmers is to know the correct combination of the intercropping pattern and planting density that would maintain or enhance the growth and yield of the main crop under the increased population of the component crop in the intercrop (Lulie *et al.*, 2016). During intercropping arrangement of crops is at random with an improper planting density of component crops, which results in poor crop yields. Even though it is possible to increase tomato production by intercropping with basil, yet no research has been done to determine optimum population density and row arrangement of basil for tomato-basil intercropping in the area. Considering the above-indicated gaps this work was initiated to evaluate yield and yield components of tomato under intercropping at different basil planting densities and row arrangements.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The experiment was conducted in the field at Wondo Genet Agricultural Research Center (WGARC), southern Ethiopia, under irrigated conditions in 2017/2018. The research center is located 264 km south of Addis Ababa and 14 km southeast of Shashemene town. It is located in Sidama Zone, Southern Nations Nationalities and People's Region (SNNPR), of Ethiopia at latitude $7^0$19'N and longitude $38^0$38'E an altitude of 1780 meters above sea level (m.a.s.l). The site has mean annual total rainfall of 1121.8 mm with mean maximum and minimum temperatures of 26°C and 12°C, respectively. The soil of the study area has clay loam texture (sand=38, clay=37, and silt=25) with pH values of 6.92, (neutral in reaction) and is low in organic matter content, medium in total N, low in available P, and high in CEC (Lulie *et al.*, 2016). Wondo Genet has a bimodal rainfall distribution with two rainy seasons. Short rains occur from March to May and long rains from July to October.

2.2 Experimental Materials, Design, and Treatments

Seeds of a tomato variety Melka Shola obtained from Melkassa Agricultural Research Center (MARC) and a promising genotype (B04) of basil from Wondo Genet Agricultural Research Center (WGARC) were used for the experiment. Tomato variety Melka Shola is a determinate type and can be used for dual purposes and well adapted to Wondo Genet conditions. Melka Shola which was released by MARC in 1998, is still widely produced by small-scale farmers and is a high yielder (under farmers condition 30 t ha^{-1}) (Benti *et al.*, 2017) and (43 t ha^{-1}in research plots) (Regassa *et al.*, 2012). Basil genotype B04 is also a high yielder (herbage and essential oil yields) in the Wondo Genet area (Abewoy, 2018).

The field experiment was laid down in Randomized Complete Block Design (RCBD) with the factorial arrangement in three replications, each with ten treatments (including sole plots of basil and tomato). The experiment consisted of four population densities of basil (100%, 75%, 50%, 25%) and two-row arrangements of intercropping tomato (T): basil (B) (1T:1B and 1T:2B), as well as sole plots of tomato and basil, making the total number of treatments ten. A uniform population of 33,333 plants $ha^{-1}$with 100 cm by 30 cm inters and intra-row spacing, respectively, was maintained for tomato in both cropping systems (for sole and intercropped plots). A population of 66,666 plants ha^{-1} with 50 cm by 30 cm inters and intra row spacing, respectively, was considered as an optimum density for a sole crop of basil. Besides, four different intercrop proportions of basil: (25% (16666 plants ha^{-1}), 50% (33333 plants ha^{-1}), 75% (50000 plants ha^{-1}) and 100% (66666 plants ha^{-1})) were also maintained in the experiment.

2.3 Data Collection and Analysis

Plant height, Number of branches per plant, number of clusters per plant, number of fruits per cluster, Number of fruits per plant, Number of marketable and unmarketable fruits per plant, Total fruit weight per plant, Marketable fruit weight per plant, Unmarketable fruit weight per plant, Fruit length and Fruit diameter were recorded from five central plants selected at random. Besides, days to 50% flowering and days to maturity were recorded. Marketable fruit yield per hectare and Unmarketable fruit weight per hectare was calculated based on fruit yield per plant and converted to the hectare and the average value was computed.

For each measured response variable, analysis of variance (ANOVA) was carried out using Statistical Analysis System (SAS) software version 9.3 (SAS, 2012). Means of treatments showing significant effects were further separated by the least significant difference (LSD) test at 5% probability level to indicate the minimum difference between mean values under comparison for the variation to be significant or not. The results of the analysis were combined and presented together under the results and discussion.

3. RESULTS AND DISCUSSION

3.1. Tomato Growth and Yield Responses

3.1.1 Plant Height

Plant height was significantly (p=0.05) influenced by row arrangement and basil population density and by their interaction. The result of this study indicated that the maximum plant height (62.66 cm) was recorded for the interaction of 100% basil population density with 1T:2B row arrangements, which was statistically similar to that of 100% population density by 1T:1B row arrangement (62.30 cm) (Figure 1). The possible reason for this might be more competition between tomato and basil plants for light at higher population densities. In line with the present study, El-Gaid *et al.*, (2014) indicated that intercropping system of tomato with common bean significantly (P=0.05) affected tomato plant height. A similar result was also reported by Gebru *et al.*, (2015), indicated that the denser the canopy under which tomato was grown, the greater was the struggle to enlarge its inter-nodal length, and in lesser rates that the plant increases the number of nodes and branches. The findings of Hussain (2003) also confirmed that the tomato plant was taller when intercropped with okra and maize as compared to sole planting. Similarly, the cropping system showed significant (P<0.05) variation for tomato plant height (Appendix Table 1), where intercropped plants had maximum height (59.15cm) compared to those in sole plots (56.58cm) (Table 2). The maximum plant height of tomato in intercropped plots might be due to more struggles for light in high population density per unit area. In agreement with this result El-Gaid *et al*., (2014) reported the highest mean values of plant height for intercropping tomato with common bean.

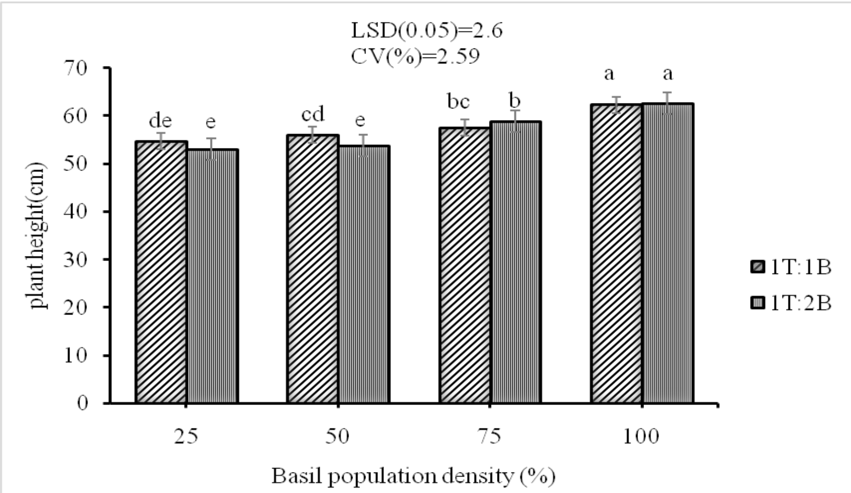

Figure 1: Interaction of population density and row arrangement of basil for plant height of intercropped tomato. Bars capped with the same letter (s) are not significantly different at P≤0.05

3.1.2. Number of Primary Branches

The result of the present study revealed that the interaction of row arrangement and population density had no significant (p>0.05) effect on primary branches of tomato plants. However, the main factor, population density significantly (P<0.05) affected the number of primary branches. Tomato intercropped with 25% basil population density had the highest number of primary branches (9.17), followed by 50% (8.92) while the least value was recorded for 100% basil population density (7.15) (Table 2). This might be due to low competition for light that occurred in low population density (least dense canopies) as compared to denser canopies and increased rates of lateral growth and, thus number of nodes and branches. This result was in agreement with the finding of Hussain (2003) who reported that the number of branches of tomato decreased as plant density increased in the maize okra intercropped system.

Table 1: Mean values for growth parameters of tomato as affected by row arrangement, population densities, and cropping system under intercropping with basil at Wondo Genet during 2017/2018 season

Treatments	50% DF	DPM	PH (cm)	NPB	NCPP	NFPC	NCPP
Row arrangements							
1T:1B	57.00	96.17^{a}	59.15^{a}	8.58	9.80	7.21^{a}	9.80
1T:2B	56.08	93.92^{b}	56.58^{b}	8.13	9.88	5.88^{b}	9.88
$LSD_{0.05}$	Ns	1.31	1.27	ns	Ns	0.47	Ns
Population density							
100%	51.13^{b}	90.17^{c}	59.00^{a}	7.15^{c}	9.02^{b}	6.88^{a}	9.02^{b}
75%	56.50^{a}	93.67^{b}	58.15^{a}	8.17^{b}	10.25^{a}	6.10^{b}	9.68^{ab}
50%	59.67^{a}	97.33^{a}	57.95^{ab}	8.92^{a}	10.41^{a}	6.50^{ab}	10.25^{a}
25%	58.67^{a}	99.00^{a}	56.35^{b}	9.17^{a}	9.68^{ab}	6.70^{ab}	10.41^{a}

Treatments	50% DF	DPM	PH (cm)	NPB	NCPP	NFPC	NCPP
$LSD_{0.05}$	3.50	1.85	1.79	0.74	1.12	0.66	1.12
CV (%)	5.00	1.57	2.50	7.13	9.23	8.12	9.23
Cropping systems							
Sole	55.67 [a]	99.00 [a]	56.58[b]	8.57	9.80	7.20[a]	9.80
Intercropped	52.92 [b]	95.08 [b]	59.15[a]	8.12	9.88	5.88[b]	9.88
$LSD_{0.05}$	1.86	2.43	2.52	ns	0.97ns	0.78	Ns
CV (%)	2.75	2.00	5.09	12.08	11.55	14.00	11.55

Means followed by the same letter within the column for a given treatment level are not significantly different at a 5% level of probability. ns= not significant; DF=days to flowering, DPM=days to physiological maturity, PH=plant height, NPB=number of primary branches, LL=leaf length, LW=leaf width, NCPP=number of cluster per plant, NFPC=number of fruit per cluster, NFPP=number of fruit per plant, cm=centimeter, RA=row arrangement, and PD=population density; 1T:1B= one tomato row alternating with one basil row, 1T:2B= one tomato row alternating with two basil rows.

3.1.2. Number of Clusters Per Plant

The analysis of variance showed that row arrangement didn't show a significant effect on the number of clusters per plant of tomato. However, basil population density significantly affected the number of clusters per plant of tomato ($P<0.05$), where high values (10.41 and 10.25) were recorded for 25% and 50% basil population density intercropped with tomato, respectively, while the minimum number of clusters per plant (9.02) was recorded for 100% basil population density (Table 1). The maximum cluster number for 25% basil population density could be due to the wider spacing, which had less competition for light and favored more flower bud formation. This implies that as with the increased basil population the decrease in the number of clusters per plant of tomato was in agreement with the findings of Benti *et al.*, (2017) who reported that the number of fruit clusters per plant may vary between seven (7) to 16 (sixteen).

3.1.3. Number of Fruits Per Cluster

The analysis of variance showed that interaction of row arrangement and population density had a significant ($P<0.05$) effect on the number of fruits per cluster of tomato (figure 2). Similarly, the cropping system significantly ($P<0.05$) affected the number of fruits per cluster. The maximum number of fruits per cluster (8.3) was recorded for 50% basil population density with 1T:1B row arrangement, while the minimum value (4.7) was recorded for 100% basil population density with 1T:2B row arrangement tomato to basil (Table 1). This result was in line with the finding of Benti *et al.*, (2017) who indicated that an average number of fruits per cluster would lay between 2.27 and 5.89.

The number of fruits per cluster of tomato, on the other hand, was affected by the cropping system where intercropped tomato with basil gave more numbers of fruits per cluster (7.20) as compared to the solely planted tomato (5.88) (Table 1). This might be due to tomato plants tended to benefit from polyculture, suggesting lower inter-specific competition than the intra-specific competition for growth resources. The present result is in agreement with Bomford (2004) who reported that tomato plants grown in monoculture bore fewer fruits than those grown in bean, cabbage, or basil dicultures.

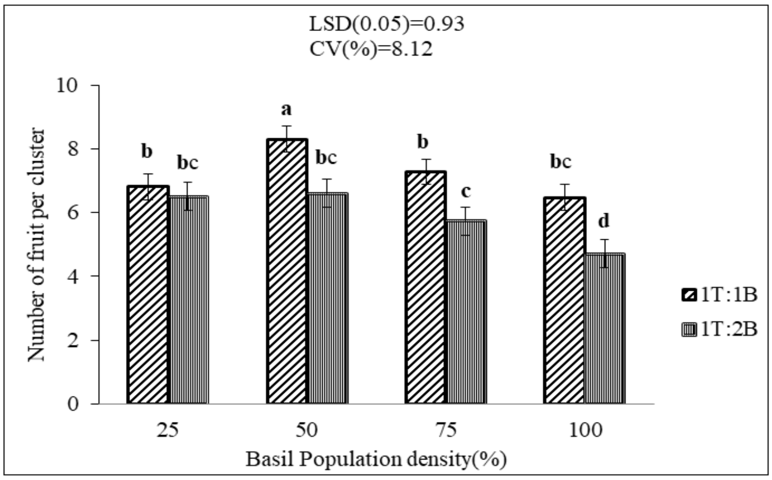

Figure 2: Interaction of population density and row arrangement of basil for the number of fruits per cluster of intercropped tomato. Bars capped with the same letter (s) are not significantly different at P≤0.05

3.1.4. Number of Fruits Per Plant

The analysis of variance showed that the interaction of row arrangement and population density was highly significant for the number of fruits per plant of tomato. The maximum number of fruits per plant (71.73) was recorded for 50% basil population density with 1T:1B row arrangement, while the minimum value (55.6) was recorded for 100% basil population density with 1T:1B row arrangement, which was statically similar to those of 75% and 25% basil population with 1T:2B row arrangement (Figure 3). This might be because basil protects the surface of the soil against unfavorable factors and improve growing conditions for tomato. This result was in agreement with the findings of Maboko *et al.,* (2017) reported that the number of fruits per plant decreased with increased plant density when tomato was grown in a closed hydroponic system. Maboko and Du Plooy, (2018) have also reported that increased plant density resulted in fewer fruits and lower marketable and total yield per plant of tomato.

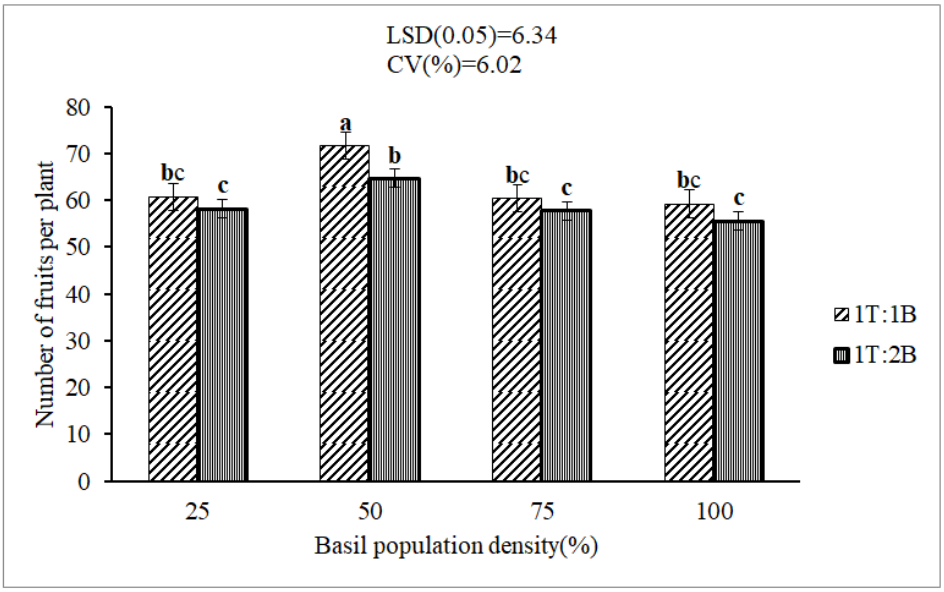

Figure 3: Interaction of population density and row arrangement for the number of fruits per plant of tomato intercropped with basil. Bars capped with the same letter (s) are not significantly different at P≤0.05

3.2 Yield and Quality of Tomato Fruit

3.2.1 Marketable Fruit Yield Per Plant

The result of the present study revealed that the main effects of population density, row arrangement, and cropping system were significant for marketable fruit per yield plant (P<0.05). The current result is in line with the finding El-Gaid *et al.,* (2014) who reported that the number of fruits per plant was significantly (p<0.05) influenced by intercropping tomato with common bean at different plant densities. The maximum fruit yield per plant (1.1 kg) was recorded for the 1T:1B row arrangement as compared to the value for 1T:2B row arrangements (0.95 kg) (Table 2). El-Gaid *et al.,* (2014) have reported that one tomato plant with three common bean plants rows arrangement produced the highest mean number of fruits per plant (58.00), while the lowest mean value (48.20) was obtained from sole tomato.

The highest marketable fruit yield per plant (1.1kg) was obtained from 50% basil population density intercropped with tomato, followed by 75% basil population density (1.06 kg), while the least value was recorded for 100% basil population density (0.92 kg) (Table 2). The present result is in line with the finding of Maboko and Du Plooy (2018), who reported that marketable yield and total yield per plant decreased with increasing plant density. Similarly, the cropping system also affected fruit yield per plant of tomato, where intercropped tomato with basil exhibited a higher value (1.1 kg) than the solely planted plot (0.95 kg) (Table 2). This might be because intercropping modify extreme temperatures both in the air and in the soil and, thus, improve the microclimate favoring yield of tomato during the offseason. A similar result has also been reported by Gogo *et al.,* (2015) were shading effect offered by intercropping basil with tomato modified air temperature and the diurnal temperature range, hence, providing ideal growth condition for tomato resulting in improved yield. Bomford (2004) has also reported that tomato plants grown in monoculture bore fewer fruits than those grown in bean, cabbage, or basil dicultures. Similarly, de Carvalho *et al.,* (2010) reported that the number of marketable fruits was on average 59% higher in tomato-basil intercrop than in the tomato monocrop.

3.2.2 Unmarketable Fruit Yield Per Plant

The analysis of variance showed that the main factors (row arrangement and population density) had a significant (P<0.05) effect on unmarketable fruit yield per plant. It was observed that the highest unmarketable fruit yield per plant (0.089kg) was recorded for the 1T:2B row arrangement as compared to the 1T:1B row arrangement (0.082kg) (Table 2). The lower unmarketable fruit yield per plant in the 1T:1B row arrangement might be due to better air circulation around plants and lower relative humidity as compared to the 1T:2B row arrangement. Warner *et al.,* (2002) reported that a higher incidence of fruit disease symptoms with the closest row arrangement may be attributed to the more rapid plant canopy filling, providing a wetter environment for the microorganisms to spread and develop early in the season.

The maximum unmarketable fruit yield per plant was obtained from 25% basil population density (0.093kg) and, as basil population density increases the unmarketable fruit yield per plant decreases (Table 2). This might be due to intercropping basil with tomato might have decreased disease severity and the volatiles oil odor of basil masked or degrested the insect pests. In line with this, Carvalho *et al.,* (2017) reported that intercropping tomato with basil reduced the incidence of whitefly in an open field.

Unmarketable fruit yield per plant was significantly (P<0.05) affected by cropping system. The maximum unmarketable fruit yield per plant (0.099 kg) was recorded for sole planted tomato, while the plot intercropped with basil had the lowest value (0.085 kg) (Table 2). In agreement with this result, Mutisya *et al.,* (2016) have reported that intercropping tomato with a row of basil in between adjacent rows of tomato result in the lowest number of non-marketable fruits compared to the sole cropped tomato. The result of this study was also in agreement with the findings of Carvalho *et al*., (2017), who reported that the percentage of damaged fruits of tomato was higher for sole planted (43.64 %) than for intercropped tomato with basil (29.37 %). This could be due to the release of Allelopathic oils of basil into the soil in the surrounding areas (Jenkins, 2016). Simon *et al.,* (1999) have also reported that basil's essential oils like linalool, citronellol, terpineol, and eucalyptol serve as pest repellents and insecticides for both basil and the plants around it.

3.2.3 Marketable Fruit Yield Per Hectare

Analysis of variance showed that the main factors (row arrangement and population density) and cropping system significantly (P<0.05) affected marketable fruit yield per hectare. The highest marketable fruit yield per hectare was obtained for 50% basil population (36691.3 kg ha^{-1}) and the least was recorded for 100% basil population density (30736.9 kg ha^{-1}) intercropped with tomato (Table 1). The result of this study was in agreement with the findings of Carvalho *et al.,* (2017), who reported that the highest number of marketable tomatoes yields was obtained in tomato-basil intercrop in the field with the optimum planting density. Gebru *et al.,* (2015) also reported that marketable fruit yield increased with increasing population density due to efficient utilization of resources such as light and nutrients as a result of total ground coverage by higher plant populations per unit area of land.

Single row arrangement (1T:1B) gave maximum marketable fruit yield per hectare of tomato (36657.8 kg ha^{-1}) (Table 3). The increase in marketable yield of tomato, when intercropped with basil in a single (1T:1B) row arrangement, could be due to wider spacing between rows of basil that makes less competition for resources as compared to double rows of basil (1T:2B). Sharaiha and Gliessman (1992) reported that lettuce intercropped with faba bean at 2:1 and 2:2 row arrangements gave less production as compared to 1:1 row arrangement and lettuce sole crop. Higher marketable fruit yield of tomato per hectare was obtained (34862 kg ha^{-1}) from tomato intercropped with basil as compared to solely planted tomato (30737 kg ha^{-1}) (Table 2). In agreement with this result, Mutisya *et al*., (2016) reported that companion planting tomato with basil significantly increased tomato fruit weight per hectare. Miyazawa *et al.,* (2010) also reported that better yields of intercrops compared to the yield of some of the component species grown alone and attributed the good performance to better use of available growth resources such as nutrients, water, and light. Basil has on the other hand been reported to be a poor resource (water, nutrient, space, and light) competitor when grown together with tomatoes in the open field (Bomford, 2004). Moreno *et al*., (2002) reported that tomato requires adequate soil moisture for its growth and development, and thus, intercropping basil with tomato may have enhanced the shading effect on the soil through the provision of living mulch (Banik *et al*., 2006), leading to a reduction in the rate of evapotranspiration and improved soil moisture status (Gurr *et al.*, 2003), which in turn, encouraged better growth and development, and higher yields of tomato, as observed in the current study.

3.2.4 Unmarketable Fruit Yield Per Hectare

It was observed that unmarketable fruit yield per hectare was not significantly (P>0.05) affected by the interaction of row arrangement and population density, but the independent effect of row arrangement and population density was significant (P<0.05). Mean result revealed that the highest unmarketable fruit yield per hectare (2970.66 kg ha^{-1}) was recorded from 1T:2B row arrangement as compared to 1T:1B tomato basil row arrangement (2738.86 kg ha^{-1}) (Table 2). This might be due to a higher incidence of fruit symptoms with the closest row arrangement that attributed to plant canopy filling more quickly, providing a wetter environment for the microorganisms to spread and develop early in the season. Yarou *et al.,* (2017) reported that single row-intercropping of cabbage with basil seems to be the best arrangement of plants for reducing pest damage.

The maximum unmarketable fruit yield per hectare was obtained from tomato plots intercropped with 25% basil population density (3089.97 kg ha^{-1}), while the minimum value was recorded for 100% basil population density (2622.20 kg ha^{-1}). Unmarketable fruit yield per hectare was decreased as basil population density from 25% to 100% (Table 2). This might be due to the release of more amount of essential oils by basil plants with increasing population density of basil would lower the level of fruit damage by insects and disease Yarou *et al.*, (2017) also reported that unmarketable cabbages in an intercropped plot with tropical basil were significantly low compared to the sole cabbages and cabbage plots surrounded by tropical basil.

Similarly, unmarketable fruit yield per hectare was significantly (P<0.05) affected by the cropping system. The maximum unmarketable tomato fruit yield per hectare (3312.2 kg ha^{-1}) was recorded for solely planted plots as compared to tomato intercropped with basil (2854.8 kg ha^{-1}) (Table 3). This might be due to intercropping tomato with basil provides alternate food as intermediate hosts for predators, thus increasing natural enemy's population in an intercropped system better growth and more flowers on basil translate to a higher concentration of volatile compounds, leading to more insect pests and beneficial insect attraction. This result is in line with that of Mutisya *et al.*, (2016) who reported that tomato basil intercropping causes higher attraction of *B. tabaci* onto the basil, deterring them from feeding on tomato plants and for this reason, the reduction in non-marketable tomato fruits. Hordofa (2000) also reported that tomato-bean intercropping gave higher marketable fruit yield and lower fruit worm damage as compared to solely planted tomato.

3.2.5 Fruit Diameter

The analysis of variance showed that row arrangement and basil population density significantly affected tomato fruit diameter. Similarly, the cropping system also significantly affected tomato fruit diameter. The highest and lowest fruit diameter (4.61 cm and 4.12 cm) was recorded for 75% and 50% basil population intercropped with tomato, respectively. Higher tomato fruit diameter (4.47cm) was recorded for 1T:2B, as compared with 1T:1B tomato to basil row arrangement (4.21cm) (Table 2). This showed that the population density of basil important factor influencing the fruit size of the intercropped tomato. In addition, when crops are sown densely, competition among plants is more for growth factors resulting in a reduction in size and yield of the plant. In line with the present result, Kirimi *et al*., (2011) reported that the fruits were bigger and unit fruit weight was higher in wider spacing size.

The highest tomato fruit diameter was recorded from intercropped than solely planted tomato (4.46 cm and 4.21 cm), respectively (Table 2). This indicated that intercropping basil with tomato modifies soil microclimate and, thus helps attain potential fruit growth, which improves diameter of the fruits. On the other hand, Ahamd and Singh (2005) have reported that wider spacing minimizes competition for nutrients, water, and radiation which in turn favored fruit size.

3.2.6 Fruit Length

The analysis of variance showed that row arrangement significantly affected tomato fruit length. The highest fruit length (6.38 cm) was recorded for 1T:2B rows arrangement of tomato to basil and the lowest value (6.09 cm) was for the 1T:1B row arrangement. On the other hand, Maboko *et al.*, (2017) reported that tomato fruit size decreased with increased plant density which did not affect overall yield per plot area. Unlike row arrangement, population density did not show a significantly affected on fruit length (P>0.05). A similar result has been reported by Kirimi *et al*., (2011) indicating that fruit height and diameter were not affected the population density. However, the cropping system significantly affected the fruit length of tomato (P<0.05). Higher fruit length was recorded for tomato intercropped with basil as compare to solely planted tomato (Table 2). This might be because basil modifies the microclimate when intercropped with tomato and thus improves the growth condition for tomato.

Table 2: Fruit size and yield of tomato intercropped with basil as affected by row arrangement, population density, and cropping system at Wondo Genet during 2017/2018 cropping season

Treatments	FD (cm)	FL (cm)	MFPP (kg)	UMFPP (kg)	MF (kg ha^{-1})	UMF (kg ha^{-1})
Row arrangements						
1T:1B	4.210^b	6.090^b	1.100^a	0.082^b	36657.800^a	2738.860^b
1T:2B	4.470^a	6.380^a	0.950^b	0.089^a	31004.300^b	2970.660^a
$LSD_{0.05}$	0.180	0.270	0.050	0.003	1313.200	93.520
Population densities						
100%	4.300^b	6.280	0.922^c	0.079^d	30736.900^b	2622.200^d
75%	4.610^a	6.070	1.064a^b	0.083^c	35498.800^a	2781.640^c
50%	4.120^b	6.210	1.101^a	0.088^b	36691.300^a	2925.250^b
25%	4.310^b	6.370	1.009^b	0.093^a	32397.200^b	3089.970^a
$LSD_{0.05}$	0.260	Ns	0.067	0.004	1857.100	132.260
CV (%)	4.87	4.90	5.30	3.74	4.43	3.74
Cropping systems						
Sole	4.210^b	6.080^b	0.949^b	0.099^a	30737.000^b	3312.200^a
Intercropped	4.460^a	6.370^a	1.099^a	0.085^b	34862.000^a	2854.800^b

Treatments	FD (cm)	FL (cm)	MFPP (kg)	UMFPP (kg)	MF (kg ha^{-1})	UMF (kg ha^{-1})
$LSD_{0.05}$	0.244	0.259	0.050	0.008	2130.100	257.460
CV (%)	6.57	4.85	5.70	6.97	6.36	6.97

Means followed by the same letter within a column for a given treatment are not significantly different at 5% level of probability; ns=not significant; FD=Fruit diameter; FL=fruit length, MFPP=marketable fruit yield per plant, UMFPP=unmarketable fruit yield per plant, MF=marketable fruit yield per hectare, UMF=unmarketable fruit yield per hectare, LSD= Least significant difference, CV= Coefficient of variation; 1T:1B= one tomato row alternating with one basil row, 1T:2B= one tomato row alternating with two basil rows.

4. CONCLUSION

The present experiment showed that plant height, the number of fruits per cluster, and the number of fruits per plant of tomato was significantly affected by the interaction of basil population density and row arrangement. As a result, the tallest plant (62.30cm) was obtained at 1T:1B tomato to basil row arrangement with 100% basil population density. The highest number of fruits per cluster and number of fruits per plant (8.3 and 71.73) were recorded at 1T:1B row arrangement with 50% basil population density. On the other hand, population density, row arrangement, and cropping system showed a significant effect on tomato yields. The highest marketable fruit yield per plant and marketable fruit yield per hectare (1.1kg plant^{-1} and 36691.3kg ha^{-1}) were obtained from tomato plots intercropped with 50% basil population density and from 1T:1B tomato to basil row arrangement (1.1kg plant $^{-1}$ and 36657.8 kg ha^{-1}). In general, it could be concluded that different intercropping systems compared to sole planting did not affect yield and some yield components of tomato. Therefore, from the practical perspective tomato producer around the study area can maximize tomato productivity by intercropping with basil at 1T:1B row arrangements with 50% basil population density.

REFERENCE

- Abewoy, D. (2018). Influence of harvesting age and genotype on herbage and essential oil yields of sweet basil (*Ocimum basilicum* l.) at Wondo Genet, Southern Ethiopia. MSc thesis, Jimma University School of graduate studies, Jimma, Ethiopia.
- Adeniyi, O. R., & Omotunde, C. T. (2001). Effect of planting pattern on growth and yield of tomato-cowpea intercrops. *Journal of vegetable crop production*, *7*(2), 75-81.
- Ahamd, A., & Singh, A. (2005). Effects of staking and row spacing on the yield of tomato (*Lycopersicon esculentum* Mill.) Cultivar Roma VF in the Sokoto Fadama Nigeria. *Nig J Horti, Sci*, 10, 94-98.
- Banik, P., Midya, A., Sarkar, B. K., & Ghose, S. S. (2006). Wheat and chickpea intercropping systems in an additive series experiment: advantages and weed smothering. *European Journal of Agronomy*, *24*(4), 325-332.
- Benti, G., Degefa, G., Biri, A., & Tadesse, F. (2017). Performance Evaluation of Tomato (*Lycopersicon esculentum* Mill.) Varieties under Supplemental Irrigation at Erer Valley, Babile District, Ethiopia. *Journal of Plant Sciences*, *5*(1), 1-5.
- Bocken, N., Short, S., Rana, P., & Evans, S. (2013). A value mapping tool for sustainable business modelling. *Corporate Governance*, *13*(5), 482-497.
- Bomford, M. K. (2004). Yield, pest density, and tomato flavor effects of companion planting in garden-scale studies incorporating tomato, basil, and brussels sprout (Doctoral dissertation, West Virginia University).
- Carvalho, M. G., Bortolotto, O. C., & Ventura, M. U. (2017). Aromatic plants affect the selection of host tomato plants by *Bemisia tabaci* biotype B. *Entomologia Experimentalis et. Applicata*, *162*(1), 86-92.
- De Carvalho, L. M., de Oliveira, I. R., Almeida, N. A., & Andrade, K. R. (2010). The Effects of Biotic Interaction between Tomato and Companion Plants on Yield. In *XXVIII International Horticultural Congress on Science and Horticulture for People (IHC2010): International Symposium*, *933*, 347-354.
- El-Gaid, A., Al-Dokeshy, M. H., & Nassef, D. M. (2014). Effects of intercropping system of tomato and common bean on growth, yield components and land equivalent ratio in new valley governorate. Research Article Science Alert. *Asian Journal of Crop Science*, *6*(3), 254-261.
- Gebru, H. (2015). A review on the comparative advantages of intercropping to mono-cropping system. *Journal of Biology, Agriculture and Healthcare*, *5*(9), 1-13.
- Gebru, H., Tsadik, K. W., & Tana, T. (2015). Evaluation of Tomato (*Lycopersicon esculentum*Mill) and Maize (*Zea mays*L.) Intercropping System for Profitability of the Crops in Wolaita Zone, Southern Ethiopia. *Journal of Biology, Agriculture, and Healthcare*, *5*(1), 132-140.
- Gemechis, A. O., Struik, P. C., & Emana, B. (2012). Tomato production in Ethiopia: constraints and opportunities. *Tropentag 2012, International Research on Food Security, Natural Resource Management and Rural Development. Resilience of Agricultural Systems against Crises: Book of Abstracts*, pp 373.
- Girma, A. (2015). Yield advantage and economic benefit of maize basil intercropping under different spatial arrangements and nitrogen rates. *Scholarly Journal of Agricultural Science*, *5*(8), 296-302.
- Gogo, E. O., Saidi, M., Itulya, F. M., Martin, T., & Ngouajio, M. (2014). Eco-friendly nets and floating row covers reduce pest infestation and improve

tomato (*Solanum lycopersicum* L.) Yields for Smallholder Farmers in Kenya. *Agronomy*, *4*, 1-12.

- Gurr, G. M., Wratten, S. D., & Luna, J. M. (2003). Multi-function agricultural biodiversity: pest management and other benefits. *Basic and Applied Ecology*, *4*(2), 107-116.
- Hussain, S. A. (2003). Growth, yield and economic impacts of intercropping in vegetables. A PhD Dissertation Submitted to the NWFP Agricultural University, Peshawar. Pp5-14.
- Ibrahim, H. A. (2000). The Effect of Some Cultural Practices on Growth and Oil Yield of three Basil's Species. M. Sc. (Agric) Thesis, University of Khartoum, Khartoum, Sudan.
- Jenkins, K. (2016). An Analysis of the Allelopathic Relationship between Basil (*Ocimum basilicum*) and Tomatoes (*Solanum lycopersicum*) as an Alternative to Fertilizer. Student scholar and creative work, Virginia Community College System. Student Writing, 11.
- Kirimi, J. K., Itulya, F. M., & Mwaja, V. N. (2011). Effects of nitrogen and spacing on fruit yield of tomato. *African Journal of Horticultural Science*, *5*, 50-60.
- Lulie, B., Worku, W., & Beyene, S. (2016). Determinations of Haricot Bean (*Phaseolus vulgaris* L.) Planting Density and Spatial Arrangement for Staggered Intercropping with Maize (*Zea mays* L.) at Wondo Genet, Southern Ethiopia. *Acad Res J Agri Sci Res*, *4*(6), 297-320.
- Maboko, M. M., & Du Plooy, C. P. (2018). Response of field-grown indeterminate tomato to plant density and stem pruning on yield. *International Journal of Vegetable Science*, *25*(2), 1-10.
- Maboko, M. M., Du Plooy, C. P., & Chiloane, S. (2017). Yield of determinate tomato cultivars grown in a closed hydroponic system as affected by plant spacing. *Horticultura Brasileira*, *35*(2), 258-264.
- Miyazawa, K., Murakami, T., Takeda, M., & Murayama, T. (2010). Intercropping green manure crops—effects on rooting patterns. *Plant and soil*, *331*(1-2), 231-239.
- Moreno, D. A., Víllora, G., Soriano, M. T., Castilla, N., & Romero, L. (2002). Floating row covers affect the molybdenum and nitrogen status of Chinese cabbage grown under field conditions. *Functional plant biology*, *29*(5), 585-593.
- Mousavi, S. R., & Eskandari, H. (2011). A general overview on intercropping and its advantages in sustainable agriculture. *Journal of Applied Environmental and Biological Sciences*, *1*(11), 482-486.
- Mutisya, S., Saidi, M., Opiyo, A., Ngouajio, M., & Martin, T. (2016). Synergistic effects of agro net covers and companion cropping on reducing whitefly infestation and improving the yield of open field-grown tomatoes. *Agronomy*, 6(3), 42.
- Neelam, R., & Lokho, P. 2009. Intercropping of medicinal and aromatic plants with vegetable crops-a review. *MFP News*, *19*(2), 14-18.
- Nigussie, A., Lulie, B., & Chala, M. (2017). Intercropping of Onion with Rosemary as Supplementary Income Generation at Wondo Genet Sidama zone, Southern Ethiopia. *Acad Res J Agri Sci Res*, *5*(2), 107-115.
- Nthabiseng, T. R., Irvine, K. M., & Moshibudi, P. M. (2015). Response of a maize or dry bean intercrop to maize density and dry bean arrangement under rainfed conditions. *International Journal of Agronomy and Agricultural Research (IJAAR)*, *6*(06), 18-29.
- Regassa, M. D., Mohammed, A., & Bantte, K. (2012). Evaluation of tomato (Lycopersicon esculentum Mill.) genotypes for yield and yield components. *Afr J Plant Sci Biotechnol*, 6, 45-49.
- SAS Institute, 2012. SAS Version 9.3 User's Manual.
- Simon, J. E., Morales, M. R., Phippen, W. B., Vieira, R. F., & Hao, Z. (1999). Basil: A source of aroma compounds and a popular culinary and ornamental herb. *Perspectives on new crops and new uses*, *16*, 499-505.
- Warner, J., Hao, X., & Zhang, T. Q. (2002). Effects of row arrangement and plant density on yield and quality of early, small-vined processing tomatoes. *Canadian journal of plant science*, *82*(4), 765-770.
- Wheeler, T. R., Craufurd, P. Q., Ellis, R. H., Porter, J. R., & Prasad, P.V. (2000). Temperature variability and the yield of annual crops. *Agriculture, Ecosystems & Environment*, *82*(1-3), 159-167.
- Yarou, B. B., Assogba Komlan, F., Tossou, E., Mensah, C. A., Simon, S., Verheggen, F. J., & Francis, F. (2017). Efficacy of Basil-Cabbage intercropping to control insect pests in Benin, West Africa. *Communications in Agricultural and Applied Biological Sciences*, *82*(2), 157-16.