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Evaluation of Tomato (Lycopersicon esculentum Mill) and Maize (Zea mays L.) Intercropping System for Profitability of the Crops in Wolaita Zone, Southern Ethiopia

Hailu Gebru[1]* Kebede W/Tsadik[2] Tamado Tana[2]
1. Departement of Horticulture, Wolaita Soddo University, P O Box 138, Wolaita, Ethiopia
2. Departement of Plant Sciences, Haramaya University, P O Box 138, Dire dewa, Ethiopia
* Email of the corresponding author: hailugebru13@yahoo.com

Abstract
Food shortage is known to have been caused by limiting factors such as inappropriate planting time, diseases and insect pests, use of low yielding varieties, etc in Ethiopia. In areas facing food insecurity, such as Africa, farmers have practiced intercropping since old times. The study was aimed to improve productivity and profitability of tomato/maize intercropping by determining their best compatible combination and right intercropping time for sustainable production of the crops in the area. Treatments consisted of factorial combinations of three component populations of tomato (T) and maize (M) i.e. (100T:50M, 67T:33M and 50T:50M) and five maize intercropping dates (30 DBTT, 15 DBTT, ATT, 15 DATT and 30 DATT) together with their respective sole crops and laid out as Randomized Complete Block Design (RCBD) with three replications. Determinate tomato and early maturing maize were used for the intercropping system. The highest total LER value of 2.06, with GMV of 171,077.73 Birr/ha and MA of 88,030.29 Birr/ha was obtained from component populations of 100T:50M. However, the highest GMV of 216,065.00 Birr/ha and MA of 144,044.00 Birr/ha was obtained from sole tomato crop. Although, sole tomato production would be beneficial in the study area, the 100% tomato population with 50% maize by intercropping maize 15 days after transplanting of tomato is a promising treatment in order to minimize risks where farmers fear risk of sole crop due to disease or market conditions.
Keywords: Intercropping, maize, profitability, tomato

1. Introduction

Food security is a key priority for the over 200 million people of Eastern Africa, and this population is predicted to double by 2030 (Kyamanywa *et al*., 2011). This puts increasing pressure on the fixed land for food production. This is further aggravated by the increasingly degraded environment and the uncertainties resulting from climate change. Such declining and variable environments require optional cropping systems to reduce yield failure that occur due to disease and pest risks which are common due to the climate change.

In terms of cropping systems, the solutions may not only involve the mechanized rotational mono-culture cropping systems used in developed countries but also the poly-culture cropping system traditionally used in developing countries (Tsubo *et al*., 2003). The main reason for using a multiple cropping system is the fact that it involves integrating crops using space and labour more efficiently (Baldy and Stigter, 1997). Biophysical reasons include better utilization of environmental factors, greater yield stability in variable environments and soil conservation practices. Socio-economic reasons include the magnitude of inputs and outputs and their contribution to the stabilization of household food supply (Beets, 1982).

Intercropping practice could modify the microclimate by reducing light intensity, air temperature, desiccating wind and other climatic components. For example, tomato intercropped with grain sorghum as the shade crop yielded more than pure stand tomato with little loss of sorghum yield and the land equivalent ratio of the tomato + sorghum intercrop ranged from 2.58 to 2.99 (Kamel *et al.*, 2004). The shade crop (sorghum) reduced air temperatures surrounding intercropped tomato canopy to as less 5-7 ^{0}C as compared with the pure stand tomato. Poor foliage development, dropping of blossom, poor fruit set, breakage of leaves and branches, fall over of plants in irrigation furrow and high dust coverage on the leaves cause poor plant development and reduce fruit yield in the Rift Valley (Lemma, 2002). Wind protected tomato plants with strip intercropping of maize and sorghum plants gave higher yield (7.4 t/ha) compared to unprotected ones (5.7 t/ha) in Ethiopia (Lemma, 2002).

Planting pattern of intercrops is an important management practice that can improve better use of these resources and opportunities (Willey, 1990). Planting pattern defines the pattern of distribution of plants over the ground, which determines the shape of the area available to the individual plants (Willey, 1979b). Of the agronomic options open to resource poor farmers, perhaps the selection of planting pattern *i.e.* positioning of one component plants relative to that of the other component plant(s) offers the greatest scope to maximize interspecies complementary (Midmore, 1993).

Thus, investigating optimum component population of tomato and maize and determining the right intercropping time for maize would have great significance for sustainable production and to ensure highest yields of the component crops. Therefore, the study was aimed to improve productivity and profitability of tomato/maize intercropping by determining their best compatible combination and right intercropping time for sustainable production of the crops in Wolaita Zone of Southern Ethiopia.

2. Materials and Methods

2.1 Description of the study area

The experiment was conducted in Wolaita Zone of Southern Nations Nationalities and Peoples' Regional State, Ethiopia from December, 2008 to April, 2009. The experimental site is located at 37^0 7' E, and 6^0 7' N at an elevation of 1360 meter above sea level. The area has a mean annual rainfall of 549.2 mm and air temperatures of 26 ^{0}C. The soil of the area is Nitisols (FAO/Unesco classification).

2.2 Treatments and experimental design

The determinate tomato (*Lycopersicon esculentum* Mill) cultivar ''Roma VF'', early maturing (95-100 days), was used as one component crop. Maize (*Zea mays* L.) variety ''Melkssa-I'', early maturing (90 days) variety was the other component crop used for intercropping. It is one of the dry land grown varieties, in the altitude range of 0 to 1750 meter above sea level with 450-750 mm/year rain fall. It is commonly cultivated in the Central Rift valley, Kobo, Borena, Liben and Miesso areas of Ethiopia. It produces an average grain yield of 4.2 t/ha and 3 t/ha on station and on farm, respectively, as reported by Gelana (unpublished). Both crops (tomato and maize) are adaptable and suitable crops for the study area.

Treatments comprised factorial combinations of three levels of component populations of tomato/maize intercropping, *i.e.* 100%T: 50%M, 67%T: 33%M, and 50%T: 50%M of recommended component population of tomato: maize density, respectively, and five levels of intercropping date of maize, *i.e.* 30 days before tomato transplanting, 15 days before tomato transplanting, just at tomato transplanting, 15 days after tomato transplanting and 30 days after tomato transplanting were factorially combined. Tomato transplanting was done on the same day when the 3rd round maize was intercropped. A sole stand of maize (44,444 plant populations/ha) and tomato (33,333 plant populations/ha) were included at the time of tomato transplanting as controls for comparison.

The experimental plots were arranged in Randomized Complete Block Design (RCBD) with three replications. The three population combinations were arranged alternatively, *i.e.* row of tomato and maize in which maize was planted with 75 cm between rows and 30 cm within rows and the tomato crop intercropped between maize rows simulating farmers' practices with the following adjustments for the treatments:

Two rows of tomato were planted in between each maize row of 150 cm apart in the 100%T: 50%M component population. Two rows of tomato and one row of maize were planted alternatively, 75 cm apart in the case of 67%T: 33%M component population. Alternative rows of tomato were planted 75 cm apart for the component population of 50%T: 50%M. Sole tomato was transplanted at the spacing of 75 cm between rows and 40 cm between plants. While sole maize was planted at the spacing of 75 cm between rows and 30 cm between plants.

Total size of experimental field was 2517.2 m^2 (81.2 m x 31 m) with each plot gross size of 9 m in width by 3.6 m in length in order to accommodate a minimum of two center rows of each component crops while net plot size was 14.7 m^2 (5.25 m x 2.8 m). A distance of 1 m between plots and replications were maintained for walk way.

2.3 Agronomic practices

After seedbed preparation, using conventional methods, 250 g/ha (0.125 g/5 m^2) of tomato seeds were sown on the seedbed to produce seedlings for about 34 days of time (from December 4, 2008 to January 10, 2009). A 100 g DAP (Diammonium phosphate, 46% P_2O_5 and 18 % N) and 100 g urea (46% N) at thinning (at first true leaf stage) were applied to the seedlings as recommended by (Lemma, 2002). Proper nursery management (mulching, watering, shade making, thinning and weeding) practices were followed in order to produce healthy seedlings. Seedlings were hardened for a week before transplanting to enable them withstands the field conditions. This was done by gradual reduction of watering frequency and amount from daily application to two days and then to three days interval and allowing the soil water to fall as the seedlings became ready for field planting and shade level reduction as well. Healthy and vigorous stocky succulent seedlings were selected for transplanting.

The experimental field was ploughed by using oxen and leveled with hand and dividing in to plots with row orientation of S-N directions. Maize was sown at the rate of 20 kg/ha sowing two seeds per hill, which was thinned to one plant per hill one month after planting. After five weeks, about 3-4 leaf stage, uniform and vigorous seedlings of tomato were inter-transplanted to the plots as per the treatments mentioned above early in the morning and late in the afternoon, to reduce the risk of poor establishment which may occur because of strong noon sunlight. Management practices were done uniformly as follows: Each plant of tomato and maize received recommended dose of N and P fertilizers as DAP and Urea to obtain the maximum biological and economic advantage of the cropping system. Two hundred kg/ha DAP (92 kg P2O5/ha and 36 Kg N/ha) was applied basally at transplanting and 100 kg/ha urea (46 kg/ha N) was side dressed at early flowering stage (Lemma, 2002). One hundred kg DAP/ha (46 kg P2O5) was applied basally at sowing; 100 kg/ha urea (46 kg N/ha), half at sowing and half one month later applied by side dressing as recommended by Gelana (unpublished). The experimental plots were kept free from weeds by weeding manually by hand. Inter-cultivation and furrow depth of 5 cm were maintained equally in all of the plots throughout the growing periods of the crops in order to apply irrigation water uniformly for all of the plots by furrow irrigation method. Water is applied every 5 days for the first one month after transplanting and every week subsequently. Mancozeb was applied at the rate of 2.5 kg/ha to control leaf blight of tomato. Malathion was also applied at the rate of 1.5 L/ha to control maize stalk borers.

2.4 Productivity and economic values of tomato/maize intercropping

In this study, Land Equivalent Ratios (LERs), Gross Monetary Values (GMVs) and Monetary Advantages (MAs) were computed to assess the yield advantages from the tomato/maize intercropping system at different component populations and intercropping dates of maize. Yield per hectare was calculated per net plot area of 14.7 m^2. From the total yield per hectare relative yield was calculated as:

$$Relative\ yield\ of\ tomato = \frac{\text{Intercropped yield of tomato}}{Sole\ crop\ yield\ of\ tomato}$$

The relative yield of maize after conversion to yield per hectare was also calculated as:

$$Relative\ yield\ of\ maize = \frac{\text{Intercropped yield of maize}}{Sole\ crop\ yield\ of\ maize}$$

Land Equivalent Ratio (LER) was calculated by using a formula described by Willey (1979):

$$LER = \frac{\text{Intercropped yield of tomato}}{Sole\ crop\ yield\ of\ tomato} + \frac{\text{Intercropped yield of maize}}{Sole\ crop\ yield\ of\ maize}$$

GMV and MA were calculated as the product of yields of the component crops multiplied by their respective unit price to measure the productivity and profitability of intercropping as compared to sole cropping of tomato and maize. Gross Monetary Value (GMV) was computed from the yield of tomato and maize component crops. Accordingly, tomato fruit yield was valued at an average open market price of Birr 400 per 100 kg, husked green cob maize at 246.90 Birr per 100 kg and maize stalk yield at 20 Birr per 100kg for the months of March-May of the year 2009 in the local market of the study area, southern Ethiopia, to estimate the GMV of component crops. The total value obtained from the component crops were used to indicate the GMV. Monetary Advantage (MA) and was computed from the yield of tomato and maize components as per the equation indicated by Willey (1979b):

$$MA = Value\ of\ combined\ intercrop\ yield \times \frac{\text{LER} - 1}{LER}$$

2.5 Data analysis

The main and interaction effects of plant population of component crops and time of intercropping maize on growth, yield parameters of the associated tomato/maize and productivity of the system were statistically analyzed using the general linear model procedure of the Statistical Analysis System (SAS, 1996). Differences between means were separated by using Least Significant Difference (LSD) test at 5% when the analysis of variance indicated the presence of significant differences (Gomez and Gomez, 1984).

3. Results and Discussion

3.1 Partial and total land equivalent ratios of the intercropping system

To show the real land productivity, Land Equivalent Ratio (LER) is the best method for evaluating land productivity of intercropping (Khatun *et al*., 2001). Therefore, both partial and total LERs of tomato/maize intercropping were calculated to evaluate the land productivity of the intercropping system (Table 1). Component population highly significantly affected the partial LER of tomato. However, the effect of intercropping dates and interactions were not significant. The highest tomato partial LER was obtained from the 100T:50M followed by 67T:33M and the lowest from 50T:50M with 89%, 68% and 51% partial LERs relative to the sole crops, respectively, showing direct proportionality with tomato population in their mixtures.

Both component population and maize intercropping dates did highly significantly affect maize cob relative yield; but interaction effect was not. Maize stalk yield was also influenced significantly by component populations and maize intercropping dates without influence of their interaction effects. These result also had direct proportionality with the maize population in the combinations. Because maize relative yields (cob and stalk relative yields) were higher in the 100:50 population combinations and 50:50 population combinations but lower in 66:33 combinations. The increment of relative yields with respect to population increment may be due to the fact that yield has positive relation with population per unit area of land. Maize sown 15 and 30 days after tomato transplanting gave best returns in terms of cob and stalk relative yields, whereas the one sown on 30 days before tomato transplanting yielded poorly. The reason for the highest partial LERs obtained for the system may be due to microclimate created in the canopy of tomato/maize intercropped 15 DATT and lower competition occurred at that time, which may be making suitable conditions for both crops, *i.e.* at the time of maize intercropped 15DATT reached its reproductive phases, tomato was almost at its maturity stage. Thus, competition for resources with companion maize was low at that time. As the consequence, the tomato/maize intercropped 15DATT may result in more productive situation.

The case of chili pepper/taller soybean intercropping result found by Hulugalle and Willatt (1987) confirmed the current study result in that chili pepper used soil moisture resources more effectively after soybean reached the reproductive stage, while leaf water potential of intercropped chili pepper was higher than sole cropped chili pepper, most likely due to a windbreak effect by the taller soybean; and of complementary use by component crops of the same resource pool is less common. Complementary use of resources therefore takes place over space both vertically and horizontally, and over time, and in any combination of these two. This judicious choice of relative planting date and variety can enhance over-yielding in mixtures (Midmore, 1993). Especially where alterations of relative planting date have marked influence on relative canopy heights and widths, the choice of sowing date may have an overriding effect on the range of suitable population densities, as they affect final yield outcome (Cenpukdee and Fukai, 1992). For example, delay of planting of tall pigeon pea until 35 days after cassava led to greater total biological and economic yield than did a doubling of the pigeon pea population (Cenpukdee and Fukai, 1992). Alteration of relative planting dates, besides modifying the relative periods of complementarity and competition, also influences the extent to which plants of component crops reach their yield potential (Midmore, 1993). For example, a 22% reduction in sole-crop yield was evident following a 3 week delay in soybean sowing dates (Nnko and Dota, 1982) as was a 40% reduction in pigeon pea yield following a 5-week delay in planting in Australia (Cenpukdee and Fukai, 1992). This must be taken into account when determining the net profitability of intercrop systems.

There was no significant difference between sole and intercropped partial LER of tomato crops too. However, at any tested population, the partial LER of sole maize were significantly higher than the intercropped ones. Similar results were observed by Gemma and Thiruketheeswaran (1984) in their maize/bean intercropping studies. The interaction of the main effects did not significantly affect total LERs of the system.

Similar result were reported by Olufemi and Olatunde (2006) from their investigation obtaining that cowpea yields were influenced by both time of intercropping and cropping system; in the intercrop, the highest yield was obtained at 2 weeks after transplanting tomatoes. However, maize sowing dates did not show any significance effects on the relative yield of tomato (Table 8). There was no significant difference between sole and intercropped relative yields of tomato crops. At any tested population, the sole crop cob and stalk relative yields of maize per unit area were significantly higher than the intercropped yields.

Component population did highly significantly affect the total Land Equivalent Ratio, whereas intercropping dates did affect significantly at 0.05 significance level. Total LER continued to rise with increased number of crop components in the intercrop per unit area of land, and the highest LER of 2.06 recorded when component populations were 100T:50M followed by 50T:50M which gave LER of 1.62. The least total LER (1.25) was obtained from 67T:33M showing similar trends with that of the partial LERs as discussed earlier, *i.e.* positive relation with population per unit area of land. Similar result was found by Adeniyi and Omotunde (2001) in that growth and yield of tomato in the 2:1 planting pattern were greater than those in the 1:1 and 1:2 patterns in their tomato/cowpea intercropping.

Regarding the intercropping dates, the highest LER (1.83) was recorded from the plots of tomato to which maize was intercropped after 15 days of tomato transplanting followed by those plots of tomato to which maize was intercropped after 30 days of tomato transplanting with the value of 1.71, whereas the lowest LER of intercropping system (1.50) was recorded from maize plots to which tomato was transplanted after 30 days of its intercropping. This result may be due to shade tolerance ability of tomato, Roma VF variety under maize canopy because of internal (genetic) factor mainly resulted in competition for light as it agrees with the findings of Villareal and Lai (1981) in that most genotypes of tomato were suffered a 10% reduction in yield when maize intercepted 40-60% of prevailing irradiance, but two genotypes yielded similarly with or without maize, and one had greater yields when relay cropped according to their identification of tomato genetic variability for yield subjecting to a 30 day relay cropping period with maize. Thus, manipulation of component crop densities, spatial arrangements, planting dates, and choice of appropriate genotypes, will minimize competition for light energy and provide a quicker practical return (Midmore, 1990). Similarly, Olufemi and Olatunde (2006) reported that the highest land equivalent ratio (LER) for cowpea (1.8 and 1.6) or okra (0.7 and 0.8) was obtained at 2 weeks after transplanting tomatoes, from two years study, in their tomato/cowpea and tomato/okra intercropping. The highest LER was recorded in 4 and 6 weeks after planting (WAP) in maize/cowpea intercropping (Pitan and

Odebiyi 2001). In the all component population, total LER was higher in the tomato/maize intercrops than that of the sole crops (Table 8). Intercropping yield advantages were 106% in 100T:50M combination, 62% in 50T:50M combinations and 25% advantages were observed in the component populations, respectively, (Table1).

The intercropping advantages over sole cropping indicated the biological efficiency of this system over the sole cropping system which was previously reported by Vandermeer (1989). Similarly, Prasad and Brook (2005) found that land equivalent ratios of all intercrops were greater than unity in their maize/soybean intercropping. The results by other researchers also indicated that intercropping gave higher land use efficiency than mono-cropping. Rahman *et al*. (2007) obtained the highest LER of 1.97 with a tomato–red amaranth mixture, 1.93 mixing tomato with bush bean, while tomato in garden pea intercrop combination yielded 1.90. Similarly, Teasdale and Deahl (1987) calculated LER of 1.17 for intercropping tomato with snap bean. Higher LER in intercropping than mono-cropping has been also reported in maize/groundnut by Mandimba (1995) and in potato/wheat by Khatun *et al*. (2001). Yildirim and Guvenc (2005) explained the high efficiency of intercropping by the complementary use of growth resources in vegetable production. An explanation for the beneficial effect of intercropping might be the more efficient use of available resources per unit area particularly when manure and water were provided in adequate quantities (Sharaiha and Hattar, 1993).

3.2 Gross monetary values and monetary advantage of the intercropping system

Practical significance of productivity in intercropping could only be fully assessed when related to the actual economic or monetary returns (Willey, 1979b). Accordingly, a monetary value of the sole and intercropping systems was analyzed. Table 9 in this study have shown positive relationship among LER, Gross Monetary Values (GMV) of each crops and Monetary Advantages (MA) in terms of Birr/ha. Component population highly significantly affected gross monetary value of maize cob and tomato's.

Direct proportionality of gross monetary value with the population of component crops in the intercropped system was also similar to their LERs. In the case of tomato, the highest gross monetary value (167620 Birr/ha) was obtained from the higher proportion of tomato in the combination (100T:50M); the second and third GMV were obtained from 67:33 and 50:50 combinations with the amount of 128666 Birr/ha and 95215 Birr/ha, respectively.

Similar GMV trends of maize yields were also observed as shown in the Table 9. Maize intercropping dates did not show significant influence on tomato gross monetary value, but significantly affected maize cob gross monetary values. The highest return (2175.9 Birr/ha) for maize cob was obtained from those intercropped 15 days after tomato transplanting. The interaction effect did not also show any influence either on tomato or maize GMVs.

Even if there was no significant difference between the GMV of sole cropped tomato and its respective GMV of intercropped tomato, there was highly significant difference between GMV of sole maize cob and GMV of intercropped maize cob; whereas total gross monetary value of the system did significantly similar (there was no statistically significance difference between total GMV of intercropping system (133310.7 Birr/ha) and total GMV of sole cropping 216065 Birr/ha) (Table 2). The results by Ullah *et al*. (2007) revealed that intercropping systems gave substantially higher net income over mono- cropping with higher net income in case of maize + soybean followed by sole crop of maize. Jat *et al*. (2006) also reported that net monetary returns in US Dollar of 396.36, 88.89 and 465.24 from maize, tomato and maize/tomato intercropping system were obtained, respectively, in the eastern Ganges not only to intensify the system but also to diversify it through crop substitutions.

Total gross monetary values of the yields of the two crops were affected highly significantly by component populations. However, maize intercropping dates and interaction effects did not show any significant influences on the total GMVs (Table 2). As it can be observed from the table, reducing maize population from 50% to 33%, decreased its gross monetary values from 171077.73 Birr/ha of 100T:50M combinations to 130364.10 Birr/ha of the 67T:33M and to 98490.91 Birr/ha of the 50T:50M population combination.

The highest total gross monetary values obtained from the combinations in which tomato involved higher proportions than maize. This may be due to the higher productivity and profitability of tomato and also its efficient utilization of both under ground and above ground growth resources since the component crops differ in their root and canopy systems. The gross income given by the component population (100T: 50M) followed by 67T:50M combination and the least by 50T:50M have similar relation with their respective total yields per hectare. These results; however, indicate that tomato grown in component populations of 100T:50M faced the least stress compared to that grown in the other combinations. Therefore, this study confirms that next to sole tomato intercropping of tomato/maize in 100T:50M combination incorporating 15 days after tomato transplanting during hot time in the hot low land areas of the tropics is the best choice to reduce severe stress and to get profitable income as it benefits the farmers through reducing risk. In agreement with this finding, Achenif (2006) indicated that the highest money was obtained from intercropping high population of pepper and less population of black cumin component. Similar study result was reported by Selamawit (2007) in that the highest total gross monetary value of 31692.86 Birr ha^{-1} was obtained from treatment combinations of 100P:50M than 100P:25M, 75P:50M and 75P:25M treatment combinations in potato: maize intercropping study.

Only sole cropping maize gave significantly higher gross monetary value than its respective intercropping system (Table 9). This may be due to the higher population per unit area of maize in the sole cropping situation than intercropping with tomato in the current component population treatments. Similar results were reported by Tamado and Eshetu (2000) where sole maize gave the highest MV than intercropping due to the higher yield of maize component in monocropping, and Tolera (2003) also reported that the highest gross monetary value (5022 Birr/ha) from monocropped maize in maize/climbing bean intercropping. Even though, monetary value of sole planting was higher, intercropping gave diversity of products and income as compared to monocropping (Tolera, 2003).

The other method by which profitability of tomato/maize intercropping evaluated in this study was monetary advantage. All component populations showed positive yield advantages in terms of monetary advantage; the highest monetary advantages of 88030.29 Birr/ha was obtained from the component population of 100T:50M followed by 50T:50M combinations that returned 37694.05 Birr/ha (Table 9). But 67T:33M combinations gave a lower value comparatively *i.e.* 26072.82. Therefore, growing of the intercropped crops in all cases is profitable, although the 100T:50M is more productive than the other intercropping next to sole tomato. Maize intercropping dates significantly affected the gross monetary advantages of the system. Yields obtained from the plots to which maize was intercropped 15 and 30 days after tomato transplanting gave better advantages than the others, whereas those maize plots into which tomato seedlings were transplanted 30 days after maize sowing gave lower gross monetary advantage (Table 2).

The population combination of tomato/maize in the ratio of 100T:50M consistently gave greater incomes. This might be attributed to increased biological productivity in the intercropping system. The high efficiency and positive effect of intercropping on LER, GMV and MA in this study was in agreement with the results of Abidin *et al*. (1989) in garlic/bean; Quayyum and Akanda (1990) in cabbage/bean; Prabhakar and Shukla (1991) in okra/bean; Erdogan and Karatas (2000) in cucumber/pepper and tomato/lettuce and Yildirim and Guvenc (2005) in cauliflower/lettuce, cauliflower/radish, cauliflower/bean, and cauliflower/onion intercrops. Thus, intercropping systems of plants with different size, suitable under and above ground architecture, and different growth cycle may be more productive and they can use the resources like light, water and nutrients more efficiently.

4. Summary and Conclusion

Tomato/maize intercropping experiment was conducted under the lowland tropical climate of Humbo, Southern Ethiopia with specific objectives of to improve yield per unit area though evaluation of productivity and profitability level of tomato/maize intercropping and to determine the best compatible combination and right intercropping time of maize for sustainable production of the crops in the areas. Factorial combinations of three mixtures of tomato: maize crop components and five intercropping dates of maize accompanied with soles crops of tomato and maize were used.

The highest partial LER value of 0.89 and Gross Monetary Value of 167620 Birr/ha of tomato were obtained from the combinations of 100% tomato: 50% maize. Similarly, this highest partial LER and GMV of the tomato were obtained due to incorporation of maize crop 15 days after tomato transplanting. The same was true for maize partial LER (0.59 of cob and 0.57 of its stalk) and Gross Monetary Values of 3457.73 Birr/ha in that the highest values were obtained from the 100T:50M combinations; where maize was incorporated 15 days after tomato transplanting. The highest LER, GMV and MA values of 2.06, 171077.73 Birr/ha and 88030.29 Birr/ha, respectively, were recorded from the 100T:50M combinations, where maize was intercropped 15 days after tomato transplanting.

The yield reduction in maize and tomato obtained with intercropping of tomato/maize compared with their corresponding sole cropping of both crops was essentially due to competition from the component crops. Although sole crops gave higher yield than in the average of intercrops, intercropping resulted in higher economic yield, 100T:50M intercropping gave higher LER, MV, and MA from tomato/maize intercropping.

As a general conclusion, through intercropping farmers can achieve the full production of the main crop (tomato) and also an additional yield (bonus) associated with an increased plant population of the maize component. Hence, tomato/maize intercropping will increase incomes obtained by smallholder farmers in hot low land tropics, like Humbo-Southern Ethiopia, through reduction of economic risk and market fluctuation resulting from growing a single crop which is more prone to natural hazards and helping the farmers in better utilization of land by having more than one crop produced per unit area. Though all intercrops produced higher productivity, the farmers could better use the 100% tomato population with 50% maize by intercropping it into tomato 15 days after transplanting of tomato in order to maximize yield of both crops as well as total productivity, but growing of sole tomato is more productive in the absence of risk at the study area.

It is, therefore, important to support tomato/maize intercropping systems with appropriate agronomic practices such as timely irrigation, pest protection and the likes to sustain the cropping system in the study area in particular and in the low land areas of the country in general even though sole cropping of tomato became more productive. However, the experiment should be repeated in different places of the same climatic conditions for different times as this is a single trial to recommend for the farmers. Moreover, this study was with limited materials to measure chemical qualities of tomato fruit yield such as total soluble solid, pH and acid to sugar ratio, and the accurate amounts and the effects of different microclimatic factors [temperature (both in the canopy and around root system in the soil), solar radiation (both in the canopy and above canopy), wind velocity (within the canopy and out) and relative humidity (within the canopy and out)], which were created due to the intercropping of tomato with maize. Hence, the future research could quantify using appropriate instruments and facilities to show precise effects after growing condition on the productivity of the system.

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Table 1. Partial and total land equivalent ratios of tomato/maize intercropping as affected by component populations, maize intercropping dates and cropping systems

Treatments	Partial LER of Tomato fruit yield	Partial LER of Maize cob yield	Partial LER of Maize stalk yields	Total LER of the system
Component Populations				
100T:50M	0.89	0.59	0.57	2.06
67T:33M	0.68	0.29	0.28	1.25
50T:50M	0.51	0.56	0.54	1.62
LSD (0.05)	0.08	0.06	0.08	0.14
Maize intercropping dates				
30DBTT	0.70	0.39	0.41	1.50
15DBTT	0.71	0.47	0.40	1.58
ATT	0.65	0.46	0.47	1.58
15DATT	0.74	0.55	0.54	1.83
30DATT	0.68	0.53	0.50	1.71
LSD (0.05)	NS	0.08	0.10	0.18
CV (%)	14.94	17.65	22.40	11.43
Cropping Systems				
Intercropping	0.70	0.48	0.46	1.64
Sole cropping	1.00	1.00	1.00	1.00
LSD (0.05)	NS	0.12	0.11	0.37
CV (%)	12.00	3.85	4.30	4.56

NS= non significant

Table 2. Gross monetary values and monetary advantages as affected by component populations, intercropping dates of maize and cropping systems

Treatments	GMV of Maize cob yield (Birr/ha)	GMV of Tomato yield (Birr/ha)	GMV of Maize stalk yield (Birr/ha)	Total GMVs (Birr/ha)	MAs (Birr/ha)
Component Populations					
100T:50M	2314.70	167620.00	1143.03	171077.73	88030.29
67T:33M	1147.10	128666.00	551.00	130364.10	26072.82
50T:50M	2186.80	95215.00	1089.11	98490.91	37694.05
LSD (0.05)	238.85	14219.00	150.04	14270	-----
Maize intercropping dates					
30DBTT	1548.80	129721.00	825.23	132095.03	44031.68
15DBTT	1839.00	134921.00	806.12	137566.12	50498.95
ATT	1778.90	122336.00	936.93	125051.83	45905.10
15DATT	2175.90	137046.00	1078.64	140300.54	63633.58
30DATT	2071.60	128477.00	991.64	131540.24	54616.12
LSD (0.05)	308.36	NS	193.7	NS	-----
CV (%)	16.96	14.57	21.62	14.31	-----
Cropping Systems					
Intercropping	1883.00	130500.00	927.7	133310.7	49577
Sole cropping	21315.00	192741.00	2009.0	216065	144044
LSD (0.05)	6321.80	NS	518.72	NS	-----
CV (%)	15.51	19.11	10.06	18.14	-----

NS= non significant