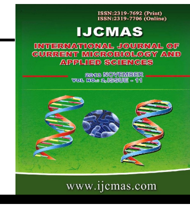


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**Original Research Article**

# Intercropping Efficiency and Yields of Intercropped Maize (*Zea mays* L.) and Dwarf Bean (*Phaseolus vulgaris* L.) Affected by Planting Arrangements, Planting Rates and Relative Time of Sowing

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**Keywords**

Intercropping; bean; *Phaseolus vulgaris;* maize; *Zea mays*, LER.

**A B S T R A C T**

In this study, the influence of two intercropping strategies, alternate row intercropping and same row intercropping for maize (M)-dwarf bean (B), practiced by farmers in Black Sea Region of Turkey, three planting rates (1M:1B, 1M:2B and 2M:1B) and three relative time of sowing of the component crops (T1: simultaneous sowing of component crops, T2: maize 15 days before bean, T3: bean 15 days before maize) on seed yields of intercropped maize and dwarf bean were studied over two years. Seed yields of intercrops were compared to the sole cropping yield of the component crops. Field experiments were designed in factorial arrangement based on Randomized Complete Block Design with three replications. The highest Land Equivalent Ratios (LERs) regarding seed yield were determined in alternate row sowing (1.39), in 2M:1B planting ratio (1.21) and at the simultaneous sowing (1.21), respectively. Over two years, seed yield losses of intercrop bean and maize due to intercropping were found 57.47 and 25.77%, respectively. Alternate row planting, 2M:1B planting rate and planting of the component crops simultaneously were recommended due to its simplicity, easily applicable and be usable in the most of ordinary farmer conditions.

## Introduction

In East Black Sea region of Turkey, intercropping is one of the most common traditional practice in farming systems due to topographic conditions of the region and most of fields are in very small size and also spreaded on hilly areas. It has been appeared in the result of a long duration farming experience of the regional farmers and there is no technical or scientific basis. Intercropping is one of most important planting modes widely distributed in the world (Francis, 1986) and broadly accepted as a sustainable practice due to its yield advantage (Vandermeer, 1992). Intercropping systems are a common practice amongst small scale farmers that in low-input agricultural systems. It is mostly practiced on small farms with limited production capacity due to lack of capital to acquire inputs (Lithourgidis *et al.*, 2011).

It is commonly used in tropical parts of the world and in most of the Asian countries. One-third of the cultivated lands are covered by intercropped crops and those areas produce about half of the total grain products in China (Zhang and Li, 2003). Zhang *et al*. (2007) informed that intercropping has been playing a very important role in ensuring grain supply and improving farmers' income in China.

Intercropping is the agricultural practice of cultivating two or more crop species simultaneously in the same field during the same growing season (Andrews and Kassam, 1976; Ofori and Stern, 1987). It provides an efficient utilization of environmental resources such as light, soil, water, plant nutrients, etc. and also reduces risk to the cost of production, provides greater financial stability for farmers, decreases pest damages, suppresses weeds growth more than monocultures, improves soil fertility through nitrogen increasing to the system and improves yield and quality (Francis *et al.*, 1976; Willey, 1979). When crops are complimentary in terms of growth pattern, aboveground canopy, rooting system, and their water and nutrient demand, intercropping effectively enables a more efficient utilization of available resources (sunlight, moisture and soil nutrients), and can result in relatively higher yields than when crops are grown separately, as pure stands (Willey, 1979).

In some legume-nonlegume intercropping systems, competition for nitrogen may be probably reduced by the legume component, since the legume depends mainly on its own nitrogen fixation while the cereal uses mineral nitrogen (Ofori and Stern, 1987; Rerkasem *et al.*, 1988). Ghosh (2004) stated that intercropping offers to farmers the opportunity to engage nature's principle of diversity at their farms. Intercropping is a possible way of increasing the productivity on small farms, as it provides security against potential losses of monoculture. The yield losses of sole crop due to environmental condition may be compensated by intercrop (Fukai and Ternbath, 1993). Competitive effect of intercropped beans on maize yields was high at higher plant populations, when maize at a constant plant population was intercropped with three bean plant populations (Morgado and Willey, 2003).

In an intercropping system, degree of competition varies depending on competitive ability of the intercropped plant species, component crop density, plant arrangements and inter/intra row spacing, relative time of planting of the component crops and plant nutrients (especially nitrogen) available in soil or applied by fertilizers. Despite its advantages, intercropping has traditionally been neglected in research on plant production systems in temperate agricultural ecosystems due to its complexity and because of the difficulties for its management and lesser relevance in cropping systems based on agrochemicals (Anonymous, 2013).

This study was conducted to determine the efficiency of maize-dwarf bean intercropping based on Land Equivalent Ratio (LER) regarding seed yield and the effects of planting arrangements, planting rates and relative time of planting of the component crops on seed yields and morphological characteristics of intercropped maize and dwarf bean.

## Materials and Methods

### Experimental site description

Field experiments were conducted at the Black Sea Agricultural Research Station, Carsamba, Samsun, Turkey (41°21' N latitude, 36° 15' E longitude, 4 m asl), for two years under irrigated conditions. The experimental site is located at the Black Sea Region of Turkey with total annual rainfall of 812.4 and 970.7 mm, respectively (Figure 1). In this region, the yearly mean air temperatures were recorded as 14.68 and 14.34°C, respectively (Figure 2).

### Soil characteristics

The study was conducted at clayey-loamy and slightly alkaline (pH=7.51) soil condition. The soil of the experimental site was rich in potassium, medium in organic matter, phosphorus and calcium and low in salt content in both study years.

### Experimental design, planting and cultivation practices

The experiments were set in Randomized Complete Block Design as a factorial trial with three replications. Combinations of three main factors consisted of planting arrangements, planting rates and relative planting time of the components and also sole planting of the component crops were randomly placed to the blocks.

*Zea mays* L. cv. TTM-813 and dwarf *Phaseolus vulgaris* L. cv. Yalova-5 were used in the study. Both maize (M) and bean (B) were harvested mainly for dry seeds. Planting arrangements included sowing of component crop seeds into the same row (within-row) and alternate rows. Three planting rates (1M:1B, 1M:2B and 2M:1B) and three relative planting times of the component crops (T1:simultaneous sowing, T2: maize 15 days before bean and T3: bean 15 days before maize) were investigated.

Distances between the rows and plants within the same rows were 70 x 25 cm and 50 x 10 cm in sole planting of maize and bean, respectively. Inter row spacing was 70 in same row and 50 cm in alternate row arrangement of the intercrops. Component crop density, total plant number per hectare and row spacing with respect to different planting arrangement, planting rates and relative time of planting of the component crops are presented in Table 1.

Sole bean, sole maize and intercropped crops were fertilized by ammonium sulphate at the rate of 40, 160 and 80 kg $ha^{-1}$ N, respectively. N was applied to sole maize and all intercropped plots as two split doses. Half of nitrogen was applied during the sowing and the other part was dressed when intercropped and sole maize plants were in 50 cm height. Phosphorus at the rate of 80 kg $ha^{-1}$ $P_2O_5$ was applied to all plots as basal dose in the form of triple super phosphate.

Land Equivalent Ratio (LER) proposed by Willey and Osiru (1972) were calculated as an index of combined yield to evaluate the effectiveness of all intercropping combinations. Values of LER greater than 1 showed an advantage, while those less than 1 showed a disadvantage of intercropping. Plant straw and seed yield of sole cropped and intercropped bean and maize were determined over ten plants in each treatment, while seed yield losses were calculated over seed yield per hectare.

**Figure.1** Monthly total rainfall recorded in Carsamba Black Sea Agricultural Research Station during 1995 and 1996 growing seasons and long-term

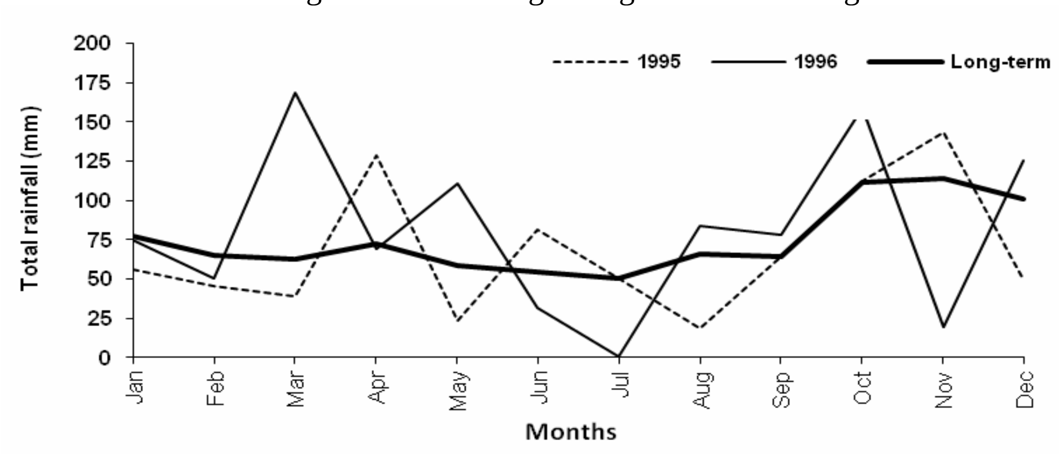



**Figure.2** Monthly mean temperature recorded in Carsamba Black Sea Agricultural Research Station during 1995 and 1996 growing seasons and long-term

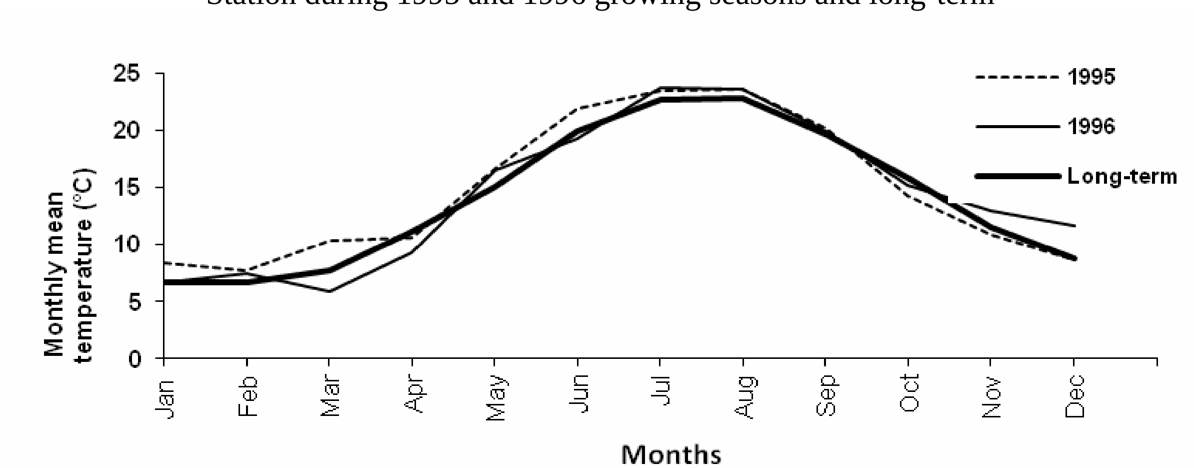
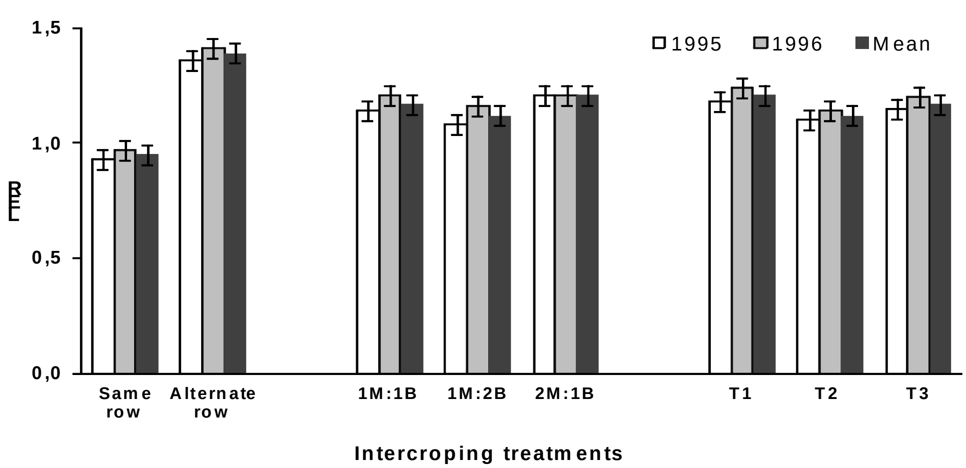



**Figure.3** Land Equivalent Ratios (LER) calculated for intercropping treatments based on seed yield



## Statistical analysis

Data were subjected to an analysis of variance (ANOVA) and means were compared by using Duncan's multiple range test. In addition, t control method was used to compare seed yield and related characters of sole and intercropped component crop.

## Results and Discussion

Morphological characteristics and seed yield per plant of intercropped dwarf bean with maize are presented in Table 2 over two years. Bean plant height determined in alternate row intercropping and T3 planting time were significantly higher than in sole bean. Lengthening of plant height was due to more competition between bean and maize to reach and capture sunlight in those situations. Light intensity reaching the legume canopy reduces when the legume intercropped with a taller component crop (Ofori and Stern, 1987).

First pod height and pod length weren't effected by none of the intercropping treatments. The number of pods per plant reduced in 2M:1B and T2 planting time, while it increased in T3. Lower 100 seed weights were found in both same and alternate row intercropping, 1M:2B, 2M:1B planting rates and T2 planting time when compared to sole bean. Bean plant seed yield determined in same row intercropping was over sole bean yield, while it was lower in alternate row planting than in sole bean crop. Planting of maize 15 days before bean significantly decreased bean seed yield per plant when compared to sole bean was shown in Table.2.

In contrast to bean, there were no significant differences regarding all investigated characteristics between sole and intercropped maize, except for seed yield per plant. Plant seed yields obtained from both same and alternate row planting arrangements, planting rates and relative times of sowing of the component crops were significantly higher than in sole maize. Reducing competition in both within and between the intercrop species for growth limiting factor increased seed plant yield in intercrop maize due to lowering plant density in intercropped maize than in sole maize (Table 2 and 3).

With the exception of same row intercropping, LER values were over 1.0 and showed that all intercropping treatments were superior to sole cropping of the components. Alternate row intercropping was superior to same row intercropping and gave the highest LER (1.39) value among all intercropping treatments according to average of two years study results. This means that sole culture of maize or bean requires 34% more land to produce equal yield. Among planting rates and relative planting times, 2M:1B planting rate and simultaneous planting (T1) gave higher LER values than in the others (Figure 3).

Total productivity measured by LER was greater in simultaneous intercropping of maize and cowpea than in staggered intercropping (Sesay, 2000). All the intercrops were productive as compared to the sole crops with an average land equivalence ratio (LER) of 1.3 for both dry matter and grain yield across all the sites (Rusinamhodzi, 2006). Morgado and Willey (2008) reported that intercropping is more productive than sole cropping and advantage as high as 28 and 64%, were obtained at 20000 and 40000 plant $ha^{-1}$ maize plant density, respectively.

**Table.1** Component crop density, total plant number, row spacing with respect to different row arrangement, planting rates and relative times of sowing of component crops

| Planting arrangements | Planting rates* | Relative time of planting | Plant density (plant ha$^{-1}$) | | Total plant number (plant ha$^{-1}$) | Inter- and intra -row spacing (cm)** |
|---|---|---|---|---|---|---|
| | | | Bean | Maize | | |
| Same row | 1M:1B | T1, T2, T3 | 2857 | 2857 | 5714 | 70x25 |
| | 1M:2B | T1, T2, T3 | 3809 | 1905 | 5714 | 70x25 |
| | 2M:1B | T1, T2, T3 | 1905 | 3809 | 5714 | 70x25 |
| Alternate row | 1M:1B | T1, T2, T3 | 10000 | 4000 | 14000 | 50x25 in maize rows |
| | 1M:2B | T1, T2, T3 | 13333 | 2666 | 14000 | 50x10 in bean rows |
| | 2M:1B | T1, T2, T3 | 6666 | 5333 | 14000 | |
| Sole bean | | | 20000 | - | 20000 | 50x10 |
| Sole maize | | | - | 5714 | 5714 | 70x25 |

* Planting rates indicates the number of component plant in same row intercropping and the number of rows of component crops in alternate row intercropping; **Inter row spacing was 70 cm in same row and 50 cm in alternate row intercropping

**Table.2** Some morphological characteristics and seed yields of intercropped dwarf bean with maize over two years combined results

| | Planting arrangements | | Planting rates | | | Relative time of planting | | |
|---|---|---|---|---|---|---|---|---|
| Sole bean | Same row | Alternate row | 1M:1B | 1M:2B | 2M:1B | T1 | T2 | T3 |
| **Plant height (cm)** | | | | | | | | |
| 44.14 | 44.25 | 46.29 | 45.24 | 45.54 | 45.03 | 45.36 | 44.74 | 45.72 |
| *t* value | 0.239 | 5.791* | 2.196 | 2.608 | 2.895 | 1.548 | 0.650 | 5.944* |
| **First pod height (cm)** | | | | | | | | |
| 20.86 | 18.86 | 20.92 | 19.60 | 19.89 | 20.18 | 20.49 | 19.57 | 19.63 |
| *t* value | 1.909 | 0.067 | 1.354 | 1.026 | 0.699 | 0.336 | 1.357 | 1.360 |
| **Pod length (cm)** | | | | | | | | |
| 9.11 | 9.50 | 9.53 | 9.58 | 9.55 | 9.42 | 9.58 | 9.49 | 9.48 |
| *t* value | 3.060 | 3.023 | 2.645 | 2.820 | 2.057 | 3.764 | 2.544 | 2.163 |
| **Pod number (pod plant$^{-1}$)** | | | | | | | | |
| 12.15 | 11.69 | 10.93 | 11.31 | 12.40 | 10.21 | 11.36 | 8.20 | 14.36 |
| *t* value | 1.077 | 2.593 | 2.605 | 0.960 | 4.483* | 1.507 | 23.754* | 6.918* |
| **100 seed weight (g)** | | | | | | | | |
| 46.97 | 44.22 | 44.74 | 45.10 | 44.46 | 43.87 | 45.28 | 42.06 | 46.10 |
| *t* value | 4.604* | 5.377* | 3.771 | 4.518* | 6.855* | 3.594 | 7.674* | 1.775 |
| **Seed yield (g plant$^{-1}$)** | | | | | | | | |
| 8.94 | 10.78 | 6.45 | 8.61 | 8.85 | 8.38 | 9.20 | 6.69 | 9.96 |
| *t* value | 4.828* | 6.623* | 0.825 | 0.248 | 1.461 | 0.652 | 5.956* | 2.722 |

* and ** significant at $P<0.05$ and $P<0.01$, respectively. For each characteristic, first and second lines indicate means and *t* values, respectively. T1: simultaneous sowing, T2: maize 15 days before bean, T3: bean 15 days before maize

**Table.3** Some morphological characteristics and seed yields of intercropped maize with dwarf bean over two years combined results

| | Planting arrangements | | Planting rates | | | Relative time of planting | | |
|---|---|---|---|---|---|---|---|---|
| **Sole maize** | **Same row** | **Alternate row** | **1M:1 B** | **1M:2 B** | **2M:1B** | **T1** | **T2** | **T3** |
| **Plant height (cm)** | | | | | | | | |
| 199.57 | 196.91 | 200.70 | 197.04 | 195.33 | 204.04 | 197.56 | 202.17 | 196.69 |
| *t* value | 0.399 | 0.182 | 0.354 | 0.661 | 0.698 | 0.295 | 0.381 | 0.475 |
| **Ear height (cm)** | | | | | | | | |
| 85.12 | 84.81 | 89.62 | 86.41 | 85.35 | 89.89 | 85.63 | 88.31 | 87.71 |
| *t* value | 0.074 | 1.123 | 0.274 | 0.059 | 1.175 | 0.118 | 0.752 | 0.660 |
| **Ear length (cm)** | | | | | | | | |
| 19.66 | 20.40 | 20.06 | 20.16 | 20.66 | 19.87 | 20.51 | 20.42 | 19.76 |
| *t* value | 0.965 | 0.546 | 0.662 | 1.392 | 0.267 | 1.158 | 1.022 | 0.124 |
| **Kernel number (kernel ear $^{-1}$)** | | | | | | | | |
| 552.23 | 599.95 | 602.96 | 604.02 | 608.92 | 591.42 | 606.91 | 629.10 | 568.34 |
| *t* value | 1.483 | 1.573 | 1.559 | 1.803 | 1.205 | 1.646 | 2.400 | 0.492 |
| **100 seed weight (g)** | | | | | | | | |
| 29.49 | 32.06 | 31.88 | 31.86 | 32.60 | 31.45 | 31.84 | 32.54 | 31.53 |
| *t* value | 1.218 | 1.056 | 1.053 | 1.450 | 0.913 | 1.101 | 1.285 | 0.965 |
| **Seed yield (g plant$^{-1}$)** | | | | | | | | |
| 146.83 | 193.14 | 164.69 | 175.92 | 196.09 | 164.74 | 184.08 | 185.59 | 167.07 |
| *t* value | 86.804** | 23.077** | 38.298** | 45.163** | 20.316** | 58.424** | 48.792** | 23.344** |

**significant at P<0.01. For each characteristic, first and second lines indicate means and *t* values, respectively. T1: simultaneous sowing, T2: maize 15 days before bean, T3: bean 15 days before maize.

**Table.4** Seed yield losses (%) in dwarf bean and maize due to intercropping

| Treatments | Seed yield losses (%) due to intercropping* | | | | | |
|---|---|---|---|---|---|---|
| | Dwarf bean | | | Maize | | |
| | 1995 | 1996 | Mean | 1995 | 1996 | Mean |
| Same row | 73.36 | 71.32 | 72.34 | 33.66 | 27.86 | 30.76 |
| Alternate row | 43.67 | 41.54 | 42.60 | 20.26 | 21.31 | 20.79 |
| 1M:1B | 58.67 | 56.88 | 57.77 | 27.60 | 12.31 | 19.95 |
| 1M:2B | 44.93 | 40.97 | 42.95 | 46.65 | 29.57 | 38.11 |
| 2M:1B | 71.95 | 71.43 | 71.69 | 6.63 | 31.88 | 19.26 |
| T1 | 56.43 | 54.28 | 55.36 | 25.53 | 21.97 | 23.75 |
| T2 | 64.27 | 64.68 | 64.47 | 24.92 | 29.80 | 27.36 |
| T3 | 54.85 | 50.32 | 52.58 | 30.43 | 21.99 | 26.21 |
| Mean | 58.52 | 56.43 | 57.47 | 29.96 | 24.58 | 25.77 |

*Seed yield losses were expressed as a percentage of sole bean and maize seed yield

Among all intercropping treatments, yield losses were evidently lower in intercropped maize than in intercropped bean. Overall mean of all intercropping treatments and years, bean and maize seed yield losses due to intercropping were found 57.47 and 25.77%, respectively (Table 4).

According the two years study results, higher seed yield losses were determined in intercropped bean with maize in the same row (72.34%) then in intercropped alternate rows (42.60%). Maize seed yield losses were also increased in the same row planting of component crops (30.76%) compare to alternate row planting (20.79%). Yield losses of each intercrops increased with its decreasing plant density in the intercropping treatment. However, intercropping were more productive than sole cropping of the components and gave more total seed yield associated with high LER values, except for same row intercropping (Figure 3). Practicing alternate-row sowings and benefiting from climbing types of legumes as component crop had better performances than same-row sowings and dwarf type legume (Geren *et al.,* 2008). In intercropping systems, plant arrangements of the component crops in alternate rows is more advantageous than in same row intercropping (Ofori and Stern, 1987).

Yield losses determined in intercrop bean increased with increasing rate of intercrop maize in the intercropping treatment. Among planting rates, the highest bean and maize seed yield losses were noted in 2M:1B and 1M:2B by 71.69 and 38.11%, respectively, due to be having the lowest plant density existing for each component crops in those planting rates. Although the highest bean seed yield losses determined in planting rate of 2M:1B, it gave the greatest LER values as reduced maize seed were compensated with bean seed yield even it was low. Similarly, Rusinamhodzi (2006) reported that cowpea suppressed cotton yields but the reduction in yield was compensated for by the yield of cowpea and also the residual fertility from cowpea residues. Changing maize density from 24000 plants $ha^{-1}$ to 37000 plants $ha^{-1}$ increased maize yield by 28 and 39% and reduced bean yields by 11 and 18% in the respective seasons. Maize yield was 19% less when intercropped bean (Mutungamiri, 2001). Afe and Olofintoye (2013) informed that the superiority and suitability of intercropping early and late maturing cowpeas at full population with early maturing maize at 25-75% full population particularly when the component crops are planted at the same time.

Adjustment of planting time is one of the most effective applications to minimize competition between the component crops for growth limiting factors in intercropping systems. In average of two years, simultaneous sowing resulted in yield reduction of 55.36 and 23.75% in bean and maize, respectively. Planting of maize 15 days before beans reduced bean yield by 64.47% while maize yield reduced by only 27.36%. Bean sown 15 days earlier reduced maize yield by 52.58% and bean yield reduced by 26.21% (Table 4). Cowpea seed yield was significantly higher in simultaneous intercropping than in staggered intercropping as sowing was delayed after maize. On average, staggered intercropping depressed cowpea yield by 58%, relative to the corresponding sole crop yields (Sesay, 2000). Simultaneous planting of cowpea with maize produced a greater LER than late planting Ranasinghe et al. (1996). Francis et al. (1982) found that simultaneous sowing resulted in bean yield reduction of 51% and maize yield reduction of 31%. Sowing maize 10 days before beans reduced bean yield by 69% and maize by only 7%. Beans sown 10 days earlier reduced maize yield by 53% and bean yield by 21%. Similar LER values were founded by staggered and simultaneous sowing of the component crops in the same study.

Nowadays, intercropping is a practice often associated with sustainable agriculture and organic farming. Based on two years study results, alternate row intercropping which giving the highest LER regarding seed (LER=1.39) was recommended for maize-dwarf bean intercropping instead of planting of the component crops same rows (LER=0.95) as this planting arrangements hadn't advantage over sole cropping of the components. Among planting rates of the intercrops, 2M:1B was the most efficient intercropping system for the total seed yield (LER=1.21) when compared to sole cropping of the component crops. Finally, simultaneous planting of the component crops (T1) that have higher LER values than in the others was recommended for maize-dwarf bean intercropping to maximize production per unit area of land and obtain more benefits than t in sole cropping. Simultaneous planting of the maize and dwarf bean on alternate rows at the rate of 2M:1B also could be recommended due to be very simple, applicable and practical application regarding cultural practices applied under the field conditions.

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