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# COMPETITIVE AND FACILITATIVE EFFECTS OF INTERCROPPING SOME SOYBEAN VARIETIES WITH CORN UNDER DIFFERENT SOYBEAN PLANT DENSITIES

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## Abstract

Choice of suitable soybean variety can exhibit plasticity in their traits associated with plant density in response to intercropping. A two–year study was carried out at Giza Agricultural Experiments and Research Station, Agricultural Research Center, during the two summer seasons 2016 and 2017 to evaluate competitive and complementary interactions in intercropped soybean varieties with corn under three soybean plant densities. Nine treatments were the combinations of three soybean plant destinies (two rows, three rows and four rows per bed were expressed as 50, 75 and 100% of soybean sole planting) and three soybean varieties (Giza 21, Giza 82 and Giza 111) in addition to sole plantings of both crops. A split plot distribution in randomized complete blocks design with three replicates was used. Soybean plant densities were randomly assigned to the main plots and soybean varieties were allocated in sub-plots. The results indicated that soybean plant densities or soybean varieties affected significantly ear leaf N content and ear leaf area per plant (LA). Increasing soybean plant density of soybean variety Giza 111 from 50 to 100% of sole soybean under intercropping system recorded high ear leaf N content, meanwhile ear LA was not affected by soybean plant densities x soybean varieties. Soybean plant densities or soybean varieties, as well as the interaction between them did not affect corn grain yields per plant and per hectare significantly. Soybean plant density did not affect soybean seed yield per plant but it had significant effect on soybean seed yield per hectare. Increasing soybean plant density from 50 to 100% of sole soybean under intercropping system increased significantly seed yield per hectare. Soybean variety Giza 111 gave higher seed yields per plant and per hectare than soybean variety Giza 82 or Giza 21. Increasing soybean plant density of soybean variety Giza 111 from 50 to 100% of sole soybean under intercropping system recorded the highest seed yield per hectare compared with the other treatments. High land equivalent ratio (LER), system productivity index (SPI) and land equivalent coefficient (LEC) were obtained by increasing soybean plant density of soybean variety Giza 111 from 50 to 100% of sole soybean under intercropping system. Growing four rows of soybean variety Giza 111 in the middle of corn beds (140 cm width) had high yield of both crops per hectare, LER, SPI and LEC.

***Keywords:*** Intercropping, soybean varieties, soybean plant densities, corn, complementarity and competition.

## Introduction

In Egypt, corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merrill] are best partners under intercropping conditions because both crops have complementary characteristics. Thus, choice of improper soybean variety with inappropriate plant density for intercropping with corn could increase inter-specific competition between the intercrops for basic growth resources. There is much less agreement about the mechanisms of inter-specific competition. Higher yields associated with intercropping occur when the component crops are complementary to each other, resulting in a more effective use of environmental resources (light, water and nutrients) compared to when grown alone. The nutrient use efficiency is higher in legume and cereal intercropping than sole crops, due to the N complementarity in time and space (Willey, 1979). Interspecies interaction may be seen as a conglomerate of all the ways that different species affect resource use and growth of one another, spanning from negative effects of resource competition to positive effects of resource facilitation. Inter-specific competition may occur when two crops are grown together (Vandermeer, 1989).Vegetative growth and development of corn plant benefited from the available fixed N by soybean, which reflected positively on the ear leaf N content as reported by El-Shamy *et al.* (2015). Moreover, Abdel-Wahab *et al.* (2019d) concluded that intercropping N-fixing crops with cereals in the same row increased the capacity of starch and sucrose synthesis in cereals with reducing N leaching and gas emissions.

Various measures of the efficiency of intercropping systems relative to sole cropping were employed (Hiebesch and McCollum, 1987). Land equivalent ratio (LER) became the focus for much of the intercropping research in the 1970s until now. It is known that biological efficiency is based on total yield of the intercrop and the areas of sole crops required to obtain the same component yields. It is generally accepted that LER values above one indicate that an intercropping system offers a land-use advantage over a sole planting. These advantages of intercropping occurred usually when species complementarity for nutrient and light resources is stronger than competition effects. Niche differentiation refers to the process by which competitive species use the resources differently in time or space, which reduces inter-specific competition and maintains species coexistence and complementarily in resource use by the species (Loreau, 2000). Accordingly, the yield advantage in intercropping systems is often obtained through the coordination of the interspecies interaction for above- and/or belowground competition (Li *et al.*, 2006).

The effects of intercropping on the yield of the intercrop components can be evaluated by observing how the yield of corn at constant seed rate alters in response to changes in seed rate of the other. According to Muoneke *et al.* (2007), increasing the density of one of the intercrops increased inter-specific competition for available resources and reduced the yield of the other component crop. However, soybean have the ability to regulate growth and yield component productivity in response to changes in plant population and competition (Mellendorf, 2011). In this concern, Metwally *et al*. (2012) concluded that increasing soybean plant density by 25 per cent under common patterns between corn and soybean increased seed yield per hectare without any adverse effects on intercropped corn grain yield. On the other hand, Abdel-Wahab and Abd El-Rahman (2016) reported that the differences among the three varieties (Giza 82, Giza 111 and Giza 22) were attributed to the fact that these varieties were developed for growth in different climates. Thus, the local soybean varieties have a wide range of maturity and diverse morphology where the studied soybean varieties differed in their relative yields under intercropping conditions (Metwally *et al*., 2018; 2019a and b). Therefore, the main objective of the present research was to evaluate competitive and complementary interactions in intercropped soybean varieties with corn under three soybean plant densities.

## Materials and Methods

A two-year experiment was carried out at Giza Agricultural Research Station (Lat. 30°00′30″ N, Long. 31°12′43″ E, 26 m a.s.l), Agricultural Research Center, during two summer seasons (2016 and 2017) to evaluate competitive and complementary interactions in intercropped soybean varieties with corn under three soybean plant densities. This study included nine treatments which were the combination between three soybean plant density (2, 3 and 4 rows per bed were expressed as 50, 75 and 100% of sole soybean plant density) and three soybean varieties (Giza 21, Giza 82 and Giza 111) under intercropping system with corn, as well as, sole plantings of both crops. Corn variety T.W.C. 321 was used in this study. Origin, pedigree and maturity group of the studied soybean varieties are shown in Table (1). Figure (1) shows intercropping soybean with corn under different soybean plant densities and sole plantings of both crops.

**Table 1 :** Origin, pedigree and maturity group of the studied soybean varieties

| Soybean variety | Origin | Pedigree | Maturity group |
|---|---|---|---|
| Giza 21 | Egypt | Crawford x Forrest | IV |
| Giza 82 | Egypt | Crawford x Maple presto | III |
| Giza 111 | Egypt | Crawford x Celest (late) | IV |

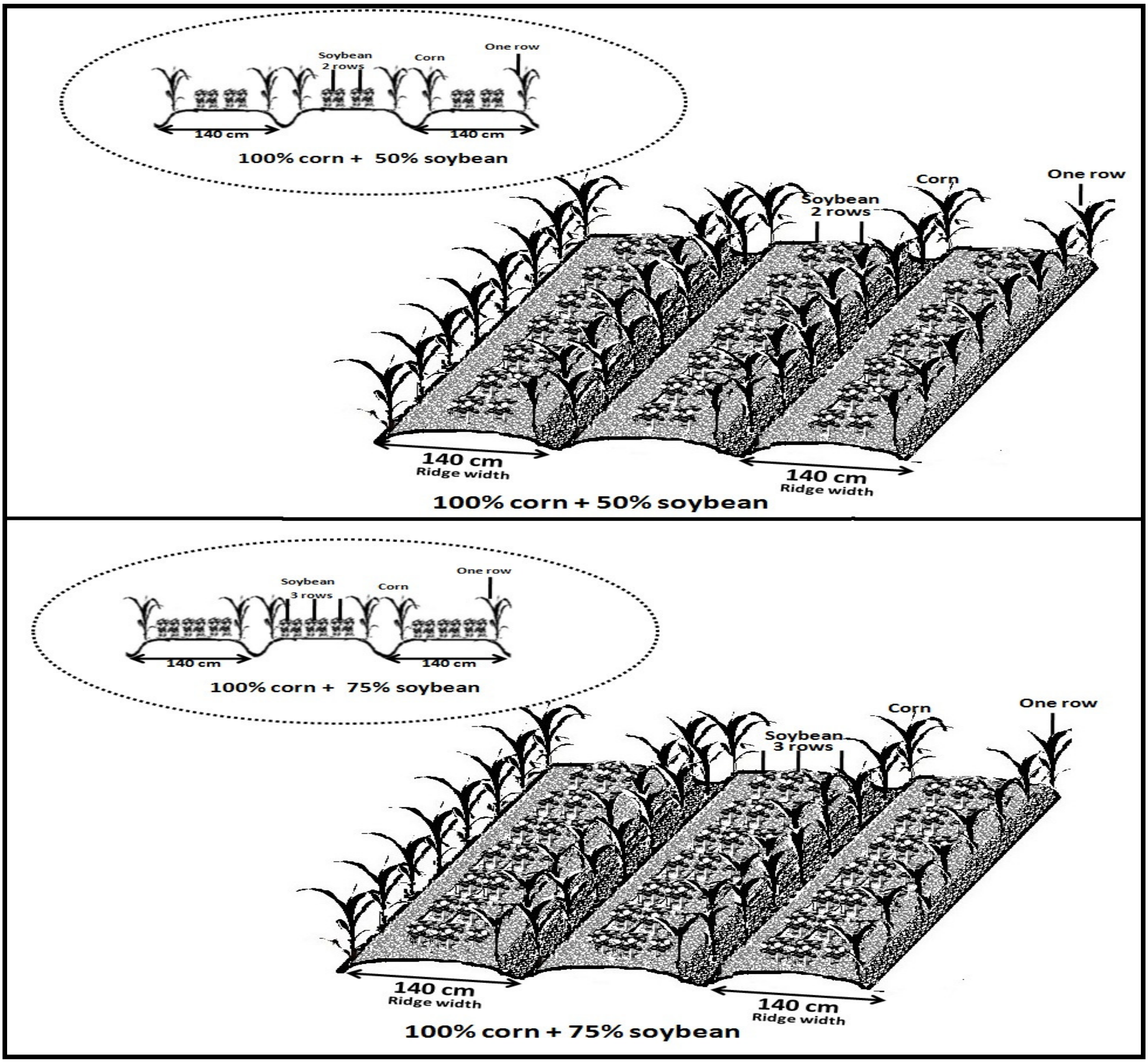


**Fig. 1 :** Intercropping soybean with corn under different soybean plant densities and sole plantings of both crops.

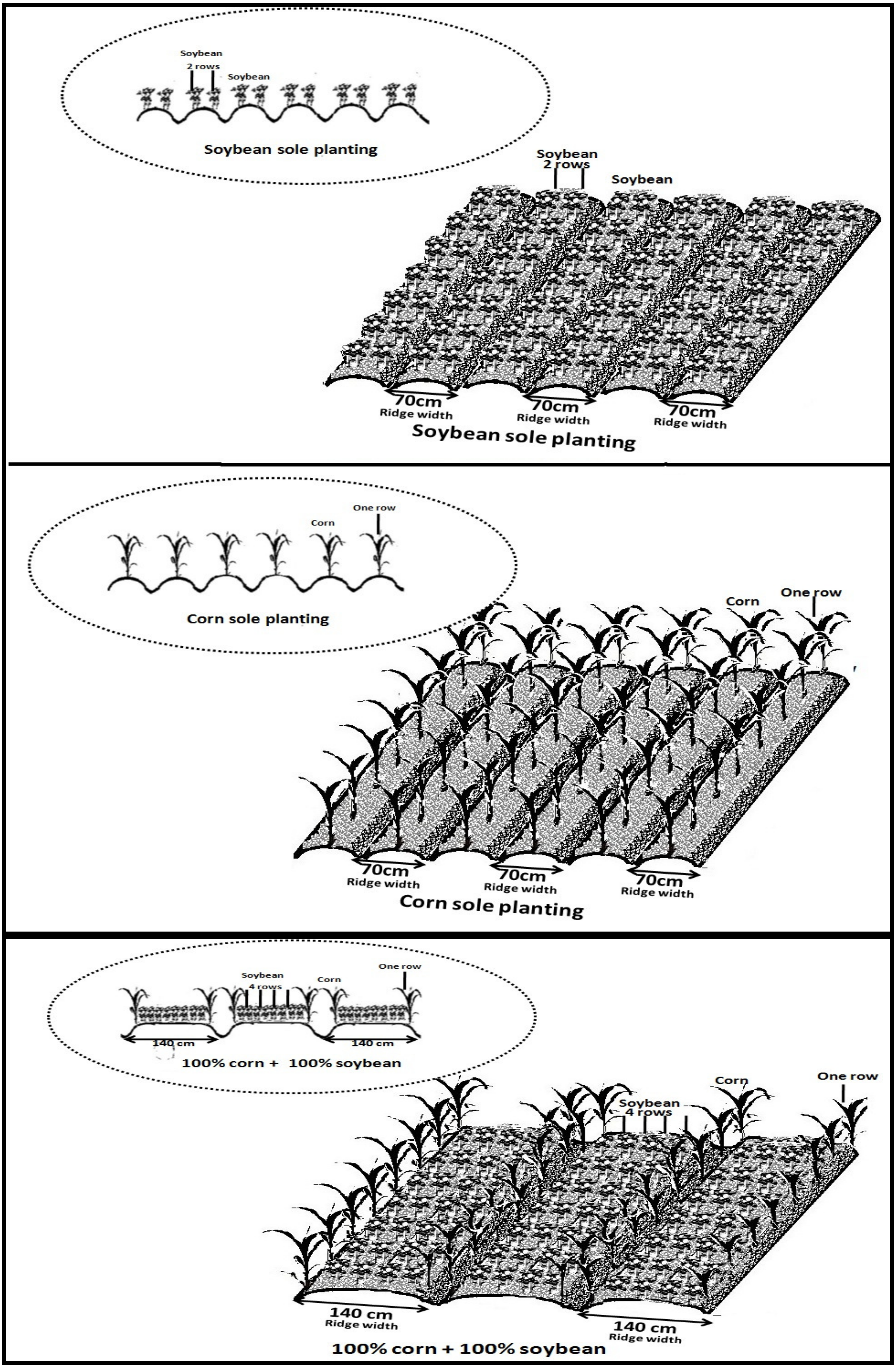


**Fig. 1 : Continued.**

Calcium super phosphate (15.5% $P_2O_5$) at rate of 357 kg per hectare was applied during soil preparation in the two summer seasons. Soybean seeds were inoculated with *Bradyrhizobium japonicum* and gum Arabic was used as a sticking agent. Soybean seeds were sown on 23rd and 28th May in 2016 and 2017 seasons, respectively, meanwhile, corn variety T.W.C. 321 was sown 15 days later. Mineral N fertilizer was added for corn at a rate of 285.6 kg N per hectare as ammonium nitrate (33.5% N) in two equal doses applied before the first and the second irrigation, respectively, under intercropping and sole plantings. Also, mineral nitrogen (N) fertilizer was added for soybean at a rate of 35.7 kg N per hectare as ammonium nitrate (33.5% N) before the first irrigation under intercropping and sole plantings. Three soybean plant densities were grown in mixed intercropping system (140 cm beds width) as follows: growing corn plants in both sides of raised beds and soybean seeds were drilled in two rows in middle of the raised beds (100% corn + 50% soybean). Growing corn plants in both sides of raised beds and soybean seeds were drilled in three rows in middle of raised beds (100% corn + 75% soybean). Growing corn plants in both sides of raised beds and soybean seeds were drilled in four rows in middle of raised beds (100% corn + 100% soybean). With respect to sole plantings of both crops, corn sole planting was conducted by growing corn plants in one side of ridges (70 cm width), meanwhile soybean sole planting was conducted by drilling two rows of soybean in ridges 70 cm width. Sole plantings of both crops were used to estimate the competitive relationships. Corn was grown in hills distanced at 25 cm between hills with one plant per hill under intercropping and sole plantings, meanwhile soybean was thinned to 20 plants per one meter length under intercropping and sole plantings. All normal agricultural practices were performed. Furrow irrigation was the irrigation system in this study. Soybean varieties Giza 21 and Giza 111 were harvested on 2nd and 4th October in 2016 and 2017, respectively, meanwhile soybean variety Giza 82 was harvested on 29th and 31st August in 2016 and 2017 seasons, respectively. Corn plants were harvested on 25th and 28th September in 2016 and 2017 seasons, respectively.

A split plot distribution in randomized complete blocks design with three replicates was used. Soybean plant densities were randomly assigned to the main plots, soybean varieties were allocated in sub-plots. Plot area was 12.6 $m^2$. Each plot consisted of three raised beds, 3.0 m long and 1.4 m wide (in case of sole plantings, each plot consisted of six ridges, 3.0 m long and 0.7 m wide).

**Data recorded**

**I. Corn traits**

At 75 days from corn sowing, ten guarded plants were randomly taken from each sub plot to record ear leaf nitrogen (N) content (mg/g) and area of topmost ear leaf per plant (LA). LA = Ear leaf length x greatest leaf width x 0.75. Ear leaf N content was analyzed by the General Organization for Agricultural Equalization Fund, Agricultural Research Center, Giza, Egypt. At harvest, ten guarded plants were randomly taken from each sub plot to record grain yield per plant (g). Grain yield per hectare (ton) was determined from weight of each sub plot and converted to ton per hectare.

**II. Soybean traits**

Ten guarded plants were randomly taken from each sub plot at harvest to record seed yield per plant (g). Seed yield per plot (kg) was recorded on basis of experimental plot and expressed as ton per hectare.

**III. Competitive relationships**

The competitive relationship, namely Land equivalent ratio (LER) (Mead and Willey, 1980), System productivity index (SPI) (Odo, 1991) and Land equivalent coefficient (LEC) (Adetiloye *et al.*, 1983) were worked out to discuss the results obtained during the investigation. These relationships were worked out as follows: LER = $(Y_{ab} / Y_{aa}) + (Y_{ba} / Y_{bb})$. SPI=$[(Y_{aa}/Y_{bb})\times Y_{ba}]+Y_{ab}$. LEC = $(Y_{ab} / Y_{aa}) \times (Y_{ba} / Y_{bb})$. Where, $Y_{aa}$ = Pure stand yield of crop a (corn); $Y_{bb}$ = Pure stand yield of crop b (soybean); $Y_{ab}$ = Intercrop yield of crop a (corn); $Y_{ba}$ = Intercrop yield of crop b (soybean).

**Statistical analysis**

All obtained data were subjected to statistical analysis of variance according to Snedecor and Cochran (1980) and the least significant differences (LSD) at 5% level of significance, tests were done according to Freed (1991) to compare the means of studied traits.

## Results and Discussion

**I. Corn crop**

**A. Vegetative growth traits at 75 days from corn sowing**

**1. Soybean plant densities**

Ear leaf N content and ear LA were affected significantly by soybean plant densities in both seasons (Table 2). Increasing soybean plant density from 50 to 100% of sole soybean increased ear leaf N content and ear LA under intercropping system. These results could be attributed to inter-specific competition between the different species (corn + soybean) was higher than intra-specific competition between the same species (soybean) for climatic and edaphic environmental conditions. These results show that increasing soybean plant density from 50 to 100% of sole soybean decreased negative effects of resource competition and increased positive effects of resource facilitation between the intercrops.

**2. Soybean varieties**

Ear leaf N content and ear LA were affected significantly by soybean varieties in both seasons (Table 2). Soybean variety Giza 111 had higher ear leaf N content and ear LA than the others. These results may be due to canopy architecture of soybean variety Giza 111 facilitated soil N availability for corn plants that reflected positively on their vegetative growth and development (Table 2).

**3. Interaction between soybean plant densities and soybean varieties**

Ear leaf N content was affected significantly by the interaction between soybean plant densities and soybean varieties in both seasons, meanwhile ear LA was not affected (Table 2). Increasing soybean plant density of Giza 111 from 50 to 100% of sole soybean increased ear leaf N content than the other treatments under intercropping conditions. Conversely, decreasing soybean plant density of Giza 82 from 100 to 50% of sole soybean increased leaf N content than the others under intercropping system. These results may be attributed to canopy architecture of soybean variety Giza 111 was more compatible with increasing soybean plant density per unit area from 50 to 100% of sole soybean to reduce intra and inter-specific competition between the same and different species, respectively for climatic and edaphic environmental conditions compared with the other treatments.

## B. Grain yields per plant and per hectare

### 1. Soybean plant densities

Corn grain yields per plant and per hectare were not affected significantly by soybean plant densities in both seasons (Table 3). Although there was an increase in ear leaf N content and ear LA under high soybean plant density (100% of sole soybean), it was not great enough to affect corn yield attributes. These results are in accordance with those obtained by Metwally *et al*. (2009) who indicated that increasing intercropped soybean plant density without adverse effects on corn crop.

### 2. Soybean varieties

Corn grain yields per plant and per hectare were not affected significantly by soybean varieties in both seasons (Table 3). These results may be attributed to higher ability of corn as $C_4$ plant of photosynthetic pathways played important role in different corn characteristics to be grown successfully during growth and development than soybean, and hence all the investigated soybean varieties did not exert any effect on corn plant. The results are in the same context with those of Metwally *et al.* (2018), Abdel-Wahab *et al.* (2019b) and Abdel-Wahab *et al.* (2019c) who proved that corn grain yields per plant and per unit area were not affected by soybean varieties.

### 3. Interaction between soybean plant densities and soybean varieties

Corn grain yields per plant and per hectare were not affected significantly by the interaction between soybean plant densities and soybean varieties in both seasons (Table 3). These results show that soybean varieties responded similarly to soybean plant densities for corn grain yields per plant and per hectare.

**Table 2 :** Ear leaf N content and ear LA as affected by soybean plant densities, soybean varieties and their interaction.

| Soybean plant density | Soybean variety | Ear leaf N content (mg/g) | | Ear LA ($cm^2$) | |
|---|---|---|---|---|---|
| | | First season | Second season | First season | Second season |
| 100% corn + 100% soybean | Giza 21 | 31.72 | 34.56 | 1149.80 | 1177.72 |
| | Giza 82 | 28.76 | 30.06 | 1121.26 | 1161.67 |
| | Giza 111 | 31.82 | 34.56 | 1153.33 | 1179.86 |
| | Mean | 30.76 | 33.06 | 1141.46 | 1173.08 |
| 100% corn + 75% soybean | Giza 21 | 30.63 | 33.85 | 1151.73 | 1180.54 |
| | Giza 82 | 30.36 | 33.63 | 1080.24 | 1139.02 |
| | Giza 111 | 30.77 | 33.90 | 1159.19 | 1169.92 |
| | Mean | 30.58 | 33.79 | 1130.38 | 1163.16 |
| 100% corn + 50% soybean | Giza 21 | 28.90 | 30.13 | 1131.55 | 1144.35 |
| | Giza 82 | 31.55 | 34.24 | 1093.72 | 1122.63 |
| | Giza 111 | 28.94 | 30.22 | 1146.21 | 1148.18 |
| | Mean | 29.79 | 31.53 | 1123.82 | 1138.38 |
| Average of soybean varieties | Giza 21 | 30.41 | 32.84 | 1144.36 | 1167.53 |
| | Giza 82 | 30.22 | 32.64 | 1098.40 | 1141.10 |
| | Giza 111 | 30.51 | 32.89 | 1152.91 | 1165.98 |
| L.S.D. 0.05 Soybean plant densities | | 0.29 | 0.11 | 10.79 | 9.06 |
| L.S.D. 0.05 Soybean varieties | | 0.10 | 0.04 | 8.38 | 7.82 |
| L.S.D. 0.05 Interaction | | 0.37 | 0.17 | N.S. | N.S. |

**Table 3 :** Corn grain yields per plant and per hectare as affected by soybean plant densities, soybean varieties and their interaction.

| Soybean plant density | Soybean variety | Grain yield/plant (g) | | Grain yield/hectare (ton) | |
|---|---|---|---|---|---|
| | | First season | Second season | First season | Second season |
| 100% corn + 100% soybean | Giza 21 | 150.68 | 171.03 | 8.26 | 9.08 |
| | Giza 82 | 141.12 | 170.66 | 8.23 | 8.92 |
| | Giza 111 | 142.19 | 174.02 | 8.25 | 9.07 |
| | Mean | 144.66 | 171.90 | 8.24 | 9.02 |
| 100% corn + 75% soybean | Giza 21 | 148.40 | 180.05 | 8.26 | 9.08 |
| | Giza 82 | 143.72 | 171.56 | 8.20 | 8.91 |
| | Giza 111 | 143.43 | 169.87 | 8.22 | 9.06 |
| | Mean | 145.18 | 173.83 | 8.22 | 9.01 |
| 100% corn + 50% soybean | Giza 21 | 138.66 | 173.66 | 8.11 | 9.01 |
| | Giza 82 | 138.57 | 171.34 | 8.45 | 9.14 |
| | Giza 111 | 134.48 | 180.62 | 8.23 | 9.08 |
| | Mean | 137.23 | 175.21 | 8.26 | 9.07 |
| Average of soybean varieties | Giza 21 | 145.91 | 174.91 | 8.21 | 9.05 |
| | Giza 82 | 141.13 | 171.19 | 8.29 | 8.99 |
| | Giza 111 | 140.03 | 174.84 | 8.23 | 9.07 |
| L.S.D. 0.05 Soybean plant densities | | N.S. | N.S. | N.S. | N.S. |
| L.S.D. 0.05 Soybean varieties | | N.S. | N.S. | N.S. | N.S. |
| L.S.D. 0.05 Interaction | | N.S. | N.S. | N.S. | N.S. |
| Corn sole planting | | | | 8.33 | 9.17 |

## II. Soybean Crop

### 1. Soybean plant densities

Seed yield per hectare was affected significantly by soybean plant densities in both seasons, meanwhile seed yield per plant was not affected (Table 4).

**Table 4 :** Soybean seed yields per plant and per hectare as affected by soybean plant densities, soybean cultivars and their interaction.

| Soybean plant density | Soybean variety | Seed yield/plant (g) | | Seed yield/hectare (ton) | |
|---|---|---|---|---|---|
| | | First season | Second season | First season | Second season |
| 100% corn + 100% soybean | Giza 21 | 8.82 | 7.12 | 1.99 | 1.66 |
| | Giza 82 | 9.20 | 8.92 | 2.39 | 2.12 |
| | Giza 111 | 11.47 | 10.23 | 2.72 | 2.41 |
| | Mean | 9.83 | 8.75 | 2.36 | 2.06 |
| 100% corn + 75% soybean | Giza 21 | 10.74 | 8.01 | 1.35 | 1.11 |
| | Giza 82 | 11.83 | 10.94 | 1.67 | 1.45 |
| | Giza 111 | 12.77 | 11.81 | 1.88 | 1.63 |
| | Mean | 11.78 | 10.25 | 1.63 | 1.39 |
| 100% corn + 50% soybean | Giza 21 | 10.89 | 8.41 | 1.10 | 0.83 |
| | Giza 82 | 12.54 | 11.72 | 1.21 | 0.99 |
| | Giza 111 | 12.93 | 12.36 | 1.49 | 1.19 |
| | Mean | 12.12 | 10.83 | 1.26 | 1.00 |
| Average of soybean varieties | Giza 21 | 10.15 | 7.84 | 1.48 | 1.20 |
| | Giza 82 | 11.19 | 10.52 | 1.75 | 1.52 |
| | Giza 111 | 12.39 | 11.46 | 2.03 | 1.74 |
| L.S.D. 0.05 Soybean plant densities | | N.S. | N.S. | 0.22 | 0.16 |
| L.S.D. 0.05 Soybean varieties | | 1.82 | 1.18 | 0.08 | 0.12 |
| L.S.D. 0.05 Interaction | | N.S. | N.S. | 0.21 | 0.21 |
| Sole planting of soybean variety Giza 21 | | | | 3.03 | 2.70 |
| Sole planting of soybean variety Giza 82 | | | | 3.69 | 3.43 |
| Sole planting of soybean variety Giza 111 | | | | 3.90 | 3.71 |

Increasing soybean plant density from 50 to 100% of sole soybean increased seed yield per hectare under intercropping system (Table 4). These results probably due to number of soybean per unit area played a major role in soybean productivity per unit area under intercropping conditions. These results are in agreement with those obtained by Metwally *et al.* (2012).

### 2. Soybean varieties

Soybean varieties were differed significantly for seed yields per plant and per hectare (Table 4). Soybean variety Giza 111 gave higher seed yields per plant and per hectare than other varieties. These results could be due to the genetic potential of the studied varieties interacted with environmental basic resources through duration of vegetative and reproductive stages that translated finally into seed yield. It is known that soybean variety Giza 21 enhanced self-shading and seed yield was depressed compared with the other varieties (Noureldin *et al.*, 2002; Metwally *et al.*, 2018; Safina *et al.*, 2018; Abdel-Wahab *et al.*, 2019a; Abdel-Wahab *et al.*, 2019b; Abdel-Wahab *et al.*, 2019c and Metwally *et al.*, 2019b). These results reveal that soybean variety Giza 111 was able to utilize the available environmental resources more efficiently than other varieties.

### 3. The interaction between soybean plant densities and soybean varieties

The interaction between soybean plant densities and soybean varieties affected significantly seed yield per hectare in both seasons, meanwhile seed yield per plant was not affected (Table 4). Increasing soybean plant density of Giza 111 from 50 to 100% of sole soybean increased seed yield per hectare than the others under intercropping system. Conversely, decreasing soybean plant density of Giza 21 from 100 to 50% of sole soybean decreased seed yield per hectare than the others under intercropping system. These results may be attributed to canopy architecture of soybean variety Giza 111 was more compatible with increase in soybean plant density per unit area from 50 to 100% of sole soybean to reduce intra and inter-specific competition between the same and different species, respectively for climatic and edaphic environmental conditions compared with the other treatments. According to Naeem *et al.* (1994), differences in shoot architectures may allow species to fill aboveground space more efficiently with leaves, increasing overall leaf-area index and light interception. These data show that each of these two factors act dependently on seed yield per hectare. Similar results were obtained by Abdel-Wahab *et al.* (2019c).

## III. Competitive relationships

### 1. Land equivalent ratio (LER)

LER values were estimated by using data of recommended sole plantings of both crops. Intercropping soybean with corn increased LER compared with sole plantings of both crops in both seasons (Figure 2). In general, increasing soybean plant density to reach 100% of sole soybean under intercropping system increased LER in both seasons. Conversely, decreasing soybean plant density to reach 50% of sole soybean under intercropping system decreased LER in both seasons. LER ranged from 1.33 (by decreasing soybean plant density of Giza 21 from 100 to 50%

of sole soybean) to 1.68 (by increasing soybean plant density of Giza 111 from 50 to 100% of sole soybean) under intercropping system in the first season. Also, LER ranged from 1.28 (by decreasing soybean plant density of Giza 21 from 100 to 50% of sole soybean) to 1.63 (by increasing soybean plant density of Giza 111 from 50 to 100% of sole soybean) under intercropping system in the second one. Advantages of increasing soybean plant density of Giza 111 from 50 to 100% of sole soybean could be due plants of this variety acclimated to their external environment by changing the biomass distribution among various components which reflected on seed yield per hectare than the other treatments (Figure 2). These results are parallel with Abdel-Galil *et al.* (2014a and b) and Metwally *et al.* (2017 and 2018).

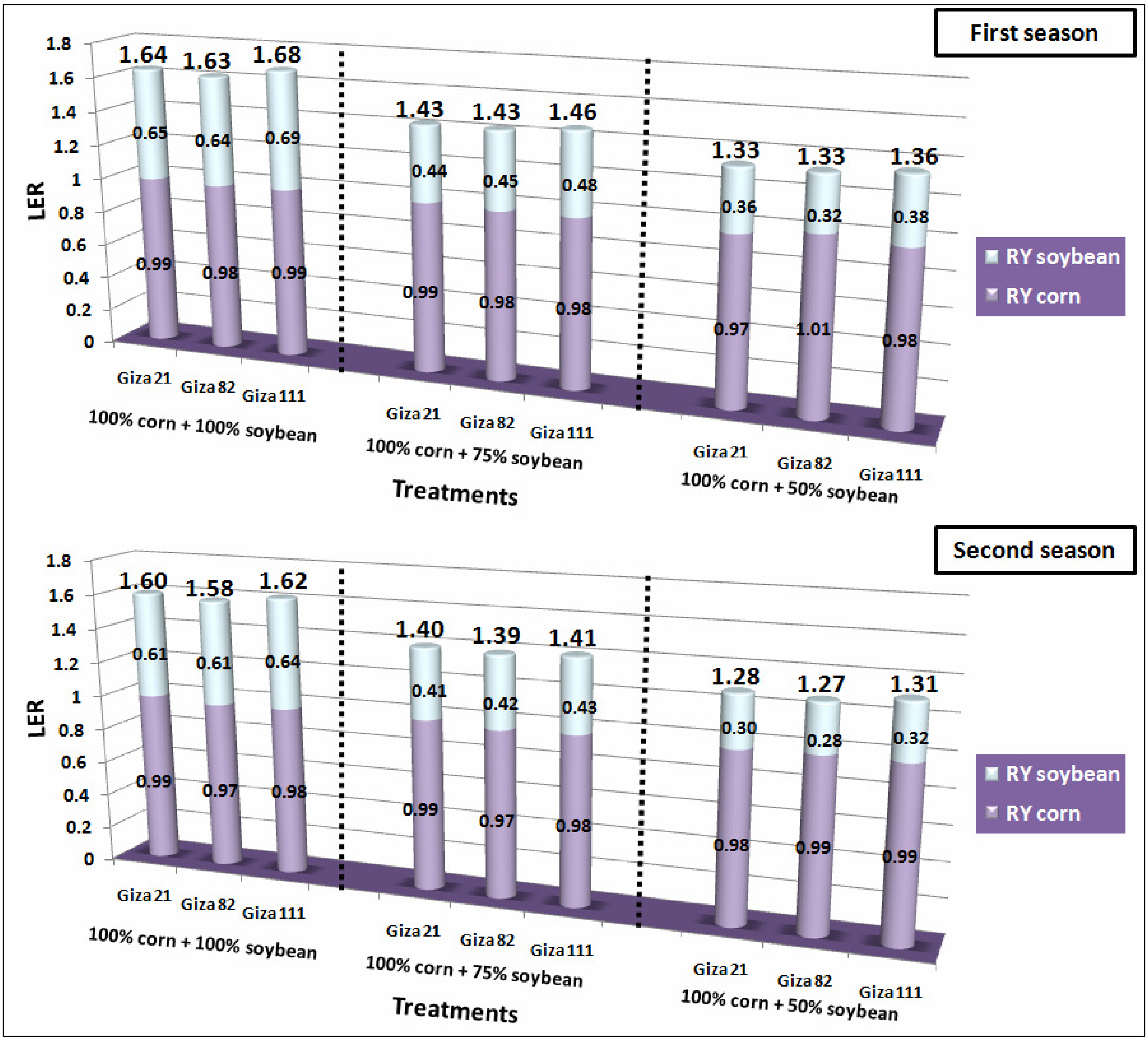


**Fig. 2 :** Land equivalent ratio (LER) of intercropping soybean varieties with corn under different soybean plant densities.

**2. System productivity index (SPI)**

In general, increasing soybean plant density to reach 100% of sole soybean under intercropping system increased SPI in both seasons (Figure 3). Conversely, decreasing soybean plant density to reach 50% of sole soybean under intercropping system decreased SPI in both seasons. SPI ranged from 2.06 (by decreasing soybean plant density of variety Giza 21 from 100 to 50% of sole soybean) to 3.68 (by increasing soybean plant density of Giza 111 from 50 to 100% of sole soybean) under intercropping system in the first season. Also, SPI ranged from 1.79 (by decreasing soybean plant density of Giza 21 from 100 to 50% of sole soybean) to 3.35 (by increasing soybean plant density of Giza 111 from 50 to 100% of sole soybean) under intercropping system in the second one. These results probably attributed to increase in soybean plant density from 50 to 100% of sole soybean promoting changes in the foliage area, branch angle, number of branches, and length of branches, allowing soybean plants of Giza 111 to achieve a suitable canopy architecture to benefit from basic growth resources. These results reveal that soybean variety Giza 111 showed higher plasticity in response to different levels of inter and intra-specific competition between different and same species, respectively, for available resources through changes in soybean plant density per unit area than soybean variety Giza 21 or Giza 82. These results are in agreement with those obtained by Metwally *et al.* (2018).

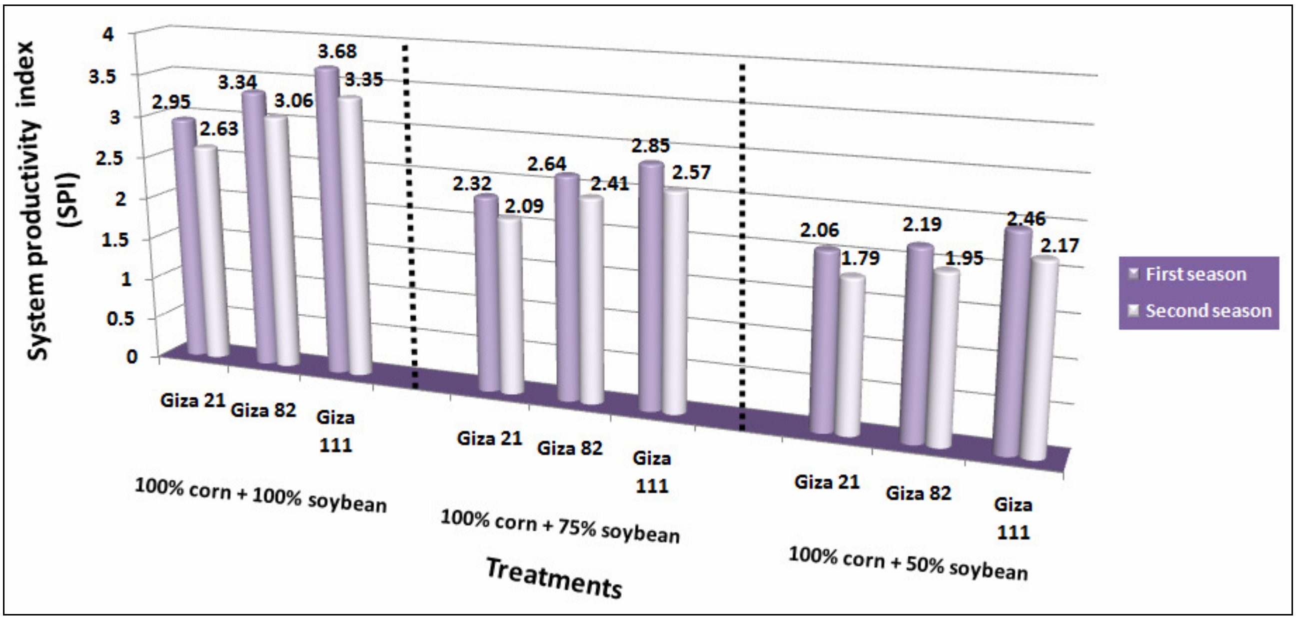


**Fig. 3 :** System productivity index (SPI) of intercropping soybean varieties with corn under different soybean plant densities.

### 3. Land equivalent coefficient (LEC)

In general, increasing soybean plant density to reach 100% of sole soybean under intercropping system increased LEC in both seasons (Figure 4). Conversely, decreasing soybean plant density to reach 50% of sole soybean under intercropping system decreased LEC in both seasons. LEC ranged from 0.34 (by decreasing soybean plant density of Giza 21 from 100 to 50% of sole soybean) to 0.68 (by increasing soybean plant density of Giza 111 from 50 to 100% of sole soybean) under intercropping system in the first season. Also, LEC ranged from 0.29 (by decreasing soybean plant density of Giza 21 from 100 to 50% of sole soybean) to 0.62 (by increasing soybean plant density of Giza 111 from 50 to 100% of sole soybean) under intercropping system in the second one. These results may be due to soybean variety Giza 111 had some facilitative interactions through different mechanisms to reduce inter and intra-specific competition between different and same species, respectively, for available resources by increasing soybean plant density of Giza 111 from 50 to 100% of sole soybean under intercropping conditions. Reduced competition by complementary effects has been suggested to be a primary reason for improved yields in intercropping (Vandermeer 1990). These results show that soybean plant density per unit area generated competitive stress for available resources among the studied soybean varieties under intercropping conditions. These results are in accordance with Abdel-Galil *et al.* (2014a) and Metwally *et al.* (2018).

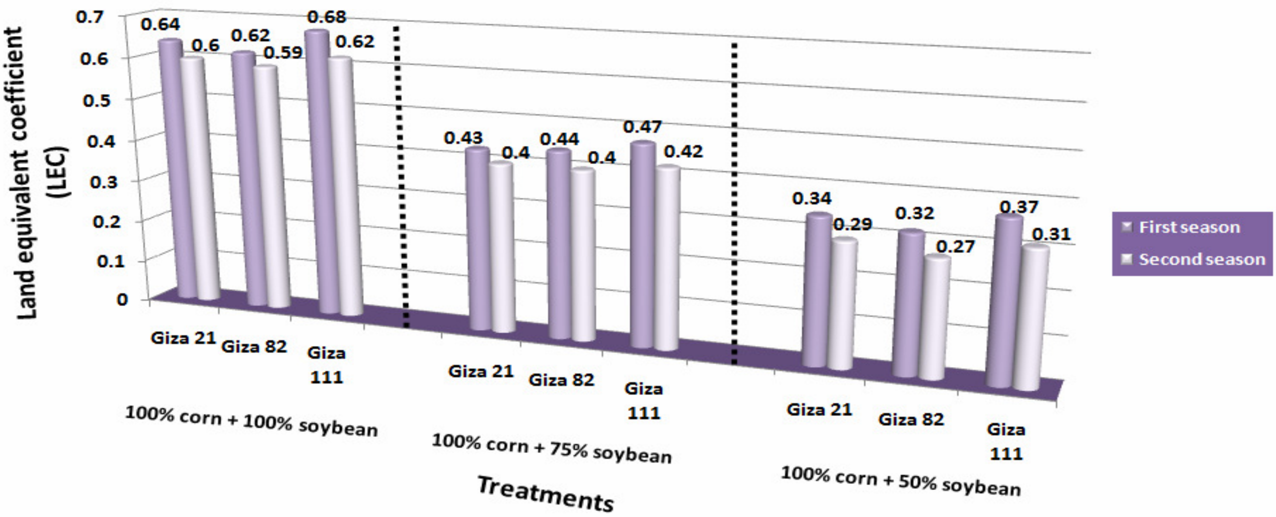


**Fig. 4 :** Land equivalent coefficient (LEC) of intercropping soybean varieties with corn under different soybean plant densities.

## Conclusion

It can be concluded that the impact of competition on soybean and corn plants varies between species and that the extent of the impact is constrained by soybean plant density. To increase complementary interactions between soybean and corn, choice of suitable soybean plant density per unit area and soybean variety should be considered. Growing four rows of soybean variety Giza 111 in the middle of corn beds increased facilitative interactions between soybean and corn through decreasing competitive pressure between them for basic growth resources.

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