Maximizing Land Use Efficiency by Intercropping Cowpea with Some Maize Cultivars under Different Maize Planting Geometries

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Abstract

Adjustment of planting geometry along with suitable maize cultivar can be a viable tool for maximizing land usage and net return. A two-year study was carried out at Serw Agricultural Experiments and Research Station, A.R.C., Domiate governorate, Egypt, during 2015 and 2016 seasons to evaluate intercropping cowpea with suitable maize cultivar and its planting geometry for maximizing land usage and net return. The treatments were the combinations between three maize cultivars (SC 30K08, TWC 310 and TWC 352) and three maize plant distributions (one plant/hill distanced at 25, 50 and 75 cm between hills, respectively). Ridge width with maize plant distribution formed maize planting geometry (25 cm × 140 cm, 50 cm × 140 cm and 75 cm × 140 cm). These treatments were compared in a split plot distribution in randomized complete block design with three replications. Maize cultivar SC 30K08 had the highest grain yield and its attributes compared with the other cultivars in both seasons. Also, maize planting geometry 25 cm × 140 cm resulted in the highest grain yield and its attributes compared with the other planting geometries in both seasons. Ear length, ear weight, 100-grain weight and grain yield/fad were affected significantly by maize cultivars × maize planting geometry. Intercropping cowpea with maize cultivar TWC 352 had the highest seed yield and its attributes compared with those intercropped with the other cultivars in both seasons. Also, maize planting geometry 75 cm × 140 cm resulted in the highest seed yield and its attributes through growing two cowpea rows between maize hills compared with the other maize planting geometries in both seasons. Number of pods/plant and seed yield/fad were affected significantly by maize cultivars × maize planting geometry. LER and LEC values of the intercrops were much greater than 1.00 and 0.25, respectively, for all the combinations indicating less land requirements of intercropping system than solid culture of both crops. Growing one row of maize

cultivar TWC352 in both sides of bed 140 cm width with cowpea two rows in middle of the bed increased land productivity and net return compared with solid culture of maize.

Keywords

1. Introduction

It is known that maize (*Zea mays* L.) is a strategic crop and it is used for human consumption, animal and poultry feeding, as well as, industrial purposes. It is the world's most widely grown cereal and produced cereal crops [1]. The total cultivated area of maize has reached about 1.7 million fads [2]. Consequently, it is expected that maize cultivar and its plant distribution could play a vital role with any cropping system to increase land usage. However, the cropping system adopted by the farmer in Egypt must be physically viable, sustainable, less exhaustive acceptable to farming community and most important thing is that it should be economical.

The biggest complementary effects and biggest yield advantages occur when the component crops have different growing periods, so make their major demands on resources at different times [3]. Certainly, legumes are noteworthy in that most of them have symbiotic N-fixing bacteria in structures called root nodules [4]. So, legumes are a useful means to sustain organic matter content and thereby enhance the biological activity, improve soil fertility and increase nutrient availability [5] and [6]. Cowpea (*Vigna unguiculata* [L.] Walp) is an important grain legume throughout the tropics and subtropics covering Africa, Asia, central and south America, its value lies in its high protein content and it fixes atmospheric nitrogen with high efficiency which allows it to grow on and improve poor soils [7]. Consequently, intercropping systems that include legumes can provide symbiotically fixed N and potentially increase yield through improved resource use efficiency [8].

Egyptian breeders produced many single and three-way hybrids such as single crosses (SC) 128, SC Ageeb, SC 101, SC 124 and SC161, as well as, three-way hybrids (TWC) 310 and TWC352. Such hybrids differed in their assimilating capacity and distribution of photosynthates between the various plant organs, which could be referred to source and sink relation [9]. Naturally, there were significant genetic differences for morphological parameter among maize genotypes [10]. Accordingly, selection of cultivars with more erect leaves, especially at the top of the canopy, has led to improved light environments inside a canopy and hence improved canopy photosynthetic CO_2 uptake rate [11]. In another study, Storck *et al.* [12] showed that there is variability among hybrids which

does not follow a tendency of genetic variability between single, three-way and double hybrids. Although S.C. 122 cultivar had more yield potential than TWC 310 or Giza 2 cultivar but it is not suitable for intercropping culture [13]. Consequently, maize cultivar that interacts positively with an intercropping pattern could play an important role to reach advantages of intercropping plantings.

Certainly, optimum plant spacing ensures plants to grow properly both in their above and underground parts through different utilization of solar radiation and nutrient. It is known that commercial crop as maize is typically grown at a smaller distance between hills (25 cm) within the same row than distance between these rows. However, plant spacing varies with the growth of plants and the growing environments [14]. On the other hand, crop geometry refers to the shape of the space available for individual plants and it is altered by changing planting pattern [15]. Accordingly, spacing is a practice that determines the spatial distribution of plants and affects canopy structure, light interception, and radiation use efficiency and, consequently, biomass or grain yield [16]. Although doubling maize number unit area^{-1} by increasing spacing between plants from 30 to 60 cm led to the similarity in plant density unit area^{-1}, there were significant increments in maize yield and its attributes under intercropping and sole culture [17]. Therefore, the objective of this investigation was to evaluate intercropping cowpea with suitable maize cultivar and its planting geometry for maximizing land usage and net return.

2. Materials and Methods

A two-year study was carried out at El-Serw Agricultural Experiments and Research Station, A.R.C., Domiate Governorate (Lat. 31˚24'59"N, Long. 31˚48'47"E, 16 m a.s.l.), Egypt during 2015 and 2016 seasons to evaluate intercropping cowpea with suitable maize cultivar and its planting geometry for maximizing land usage and net return. Wheat was the preceding winter crop in both seasons. Furrow irrigation was the irrigation system in the area. Cowpea cultivar Cream 7 and maize cultivars; SC 30K08, TWC 310 and TWC 352 were used in the study. The treatments were the combination between three maize cultivars and three maize plant distributions (Figure 1) as follows:

- Growing two plants of maize cultivar SC 30K08, TWC 310 or TWC 352 per hill distanced at 25 cm between hills which distributed to one row in both sides of bed 140 cm width (one row/side), meanwhile, 150 g of cowpea seeds were drilled in two rows in middle of the bed (two cowpea rows between maize rows) in the same direction of maize rows. After three weeks from planting, plants of maize and cowpea were thinned to one plant/hill distanced at 25 and 10 cm between hills, respectively, this system was expressed as 25 cm × 140 cm.

- Growing two plants of maize cultivar SC 30K08, TWC 310 or TWC 352 per hill distanced at 50 cm between hills which distributed to four rows in bed 140 cm width, meanwhile, 150 g of cowpea seeds were drilled into five rows
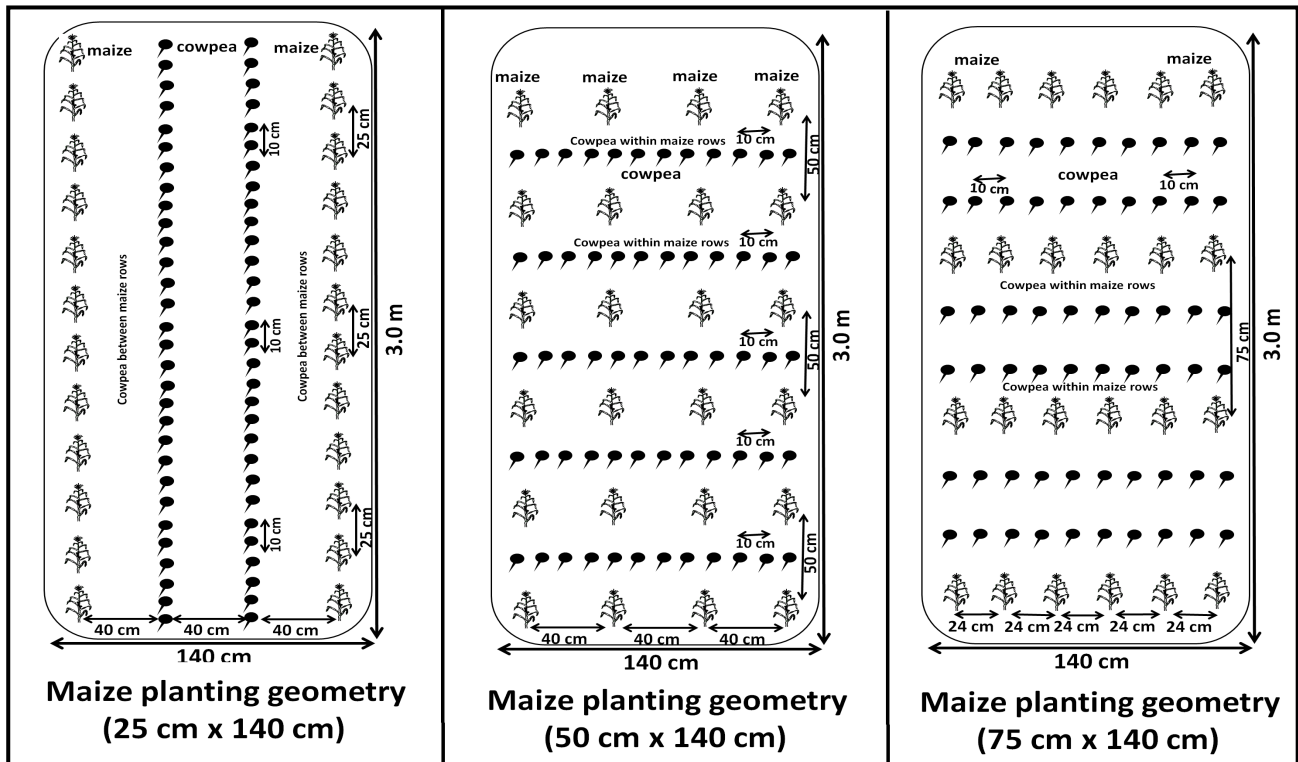
Figure 1. Intercropping cowpea with maize under different maize planting geometries.

within the four maize rows (one cowpea row between maize hills) in a perpendicular direction on the direction of maize rows. After three weeks from planting, plants of maize and cowpea were thinned to one plant/hill distanced at 50 and 10 cm between hills, respectively. This system was expressed as 50 cm × 140 cm.

- Growing two plants of maize cultivar SC30K08, TWC 310 or TWC 352 per hill distanced at 75 cm between hills which distributed to six rows in bed 140 cm width, meanwhile, 150 g of cowpea seeds were drilled into six rows within the six maize rows (two cowpea rows between maize hills) in a perpendicular direction on the direction of the maize rows. After three weeks from planting, plants of maize and cowpea were thinned to one plant/hill distanced at 75 and 10 cm between hills, respectively. This system was expressed as 75 cm × 140 cm.

In addition:

- Solid culture of maize cultivar SC30K08, TWC 310 or TWC 352 by growing two plants per hill distanced at 25 cm between hills which distributed to one row in one side of ridge 70 cm width. After three weeks from planting, the seedlings of maize were thinned to one plant/hill distanced at 25 cm between hills.

- Solid culture of cowpea by drilling one row of cowpea in both sides of ridge 70 cm width (one row/side). After three weeks from planting, the seedlings of cowpea were thinned to one plant/hill distanced at 10 cm between hills.

Solid cultures of crops were used to estimate the competitive relationships. Maize grains and cowpea seeds were sown on May 27th and 31st in 2015 and 2016 seasons, respectively. Calcium super phosphate (15.5% P_2O_5) at rate of 150 kg/fad was applied during soil preparation in the two summer seasons. Ridge width with maize plant distribution formed maize planting geometry (25 cm × 140 cm, 50 cm × 140 cm and 75 cm × 140 cm). Cowpea seeds were inoculated by *Rhizobium melitota* before seeding it and Arabic gum was used as a sticking agent. Mineral N fertilizer of maize was applied at rate of 120 kg N/fad at 15 and 30 days from maize planting under intercropping and solid cultures. Mineral N fertilizer of cowpea was applied at rate of 7.5 and 15 kg N/fad at 15 days from cowpea planting under intercropping and solid cultures, respectively. Cowpea plants were thinned to one plant per hill distanced at 10 cm between hills under intercropping and solid cultures. In all treatments, the population of maize was uniformly maintained at 24,000 plants per fad. On the other hand, the population of cowpea was uniformly maintained at 60,000 and 120,000 plants per fad in intercropping and solid cultures, respectively. These treatments were compared in a split plot distribution in randomized complete block design with three replications. Maize cultivars were randomly assigned to the main plots and maize plant distributions were allocated in sub-plots. The area of plot was 25.2 m², it consisted of 6 beds, and each ridge was 3.0 m in length and 1.4 m in width.

2.1. The Studied Traits

1) Maize grain yield and its attributes

At harvest, the following traits were measured on ten plants from each sub plot: plant height (cm), number of green leaves/plant, ear length (cm), ear weight (g), number of rows/ear and 100-grain weight (g). Grain yield of maize/fad (ardab) was recorded on the basis of experimental plot area by harvesting all plants of each sub plot (one fad = 1/2.38 ha, one ardab = 140 kg).

2) Cowpea seed yield and its attributes

At harvest, the following traits were measured on ten plants from each sub plot: plant height (cm), number of branches/plant, leaf area/plant, number of pods/plant, number of seeds/plant and 100-seed weight (g). Seed yield/fad (kg) was recorded on the basis of experimental plot area by harvesting all plants of each sub plot (one fad = 1/2.38 ha).

3) Competitive relationships

Land equivalent ratio (LER): LER defines as the ratio of area needed under sole cropping to one of intercropping at the same management level to produce an equivalent yield [18]. It is calculated as follows: LER = (Y_{ab}/Y_{aa}) + (Y_{ba}/Y_{bb}), where Y_{aa} = Pure stand yield of crop a (maize), Y_{bb} = Pure stand yield of crop b (cowpea), Y_{ab} = Intercrop yield of crop a (maize) and Y_{ba} = Intercrop yield of crop b (cowpea).

Land Equivalent Coefficient (LEC): LEC is a measure of interaction concerned with the strength of relationship [19]. It is calculated as follows: LEC = L_a

× L$_b$, where: L$_a$ = relative yield of crop a (maize) and L$_b$ = relative yield of crop b (cowpea).

4) Economic evaluation

Farmer's benefit was calculated by determining the total costs and net return of intercropping culture as compared to recommended solid culture of maize.

- Total return of intercropping cultures = Price of maize yield + price of cowpea yield (L.E.).

- Net return/fad = Total return − (fixed costs of maize + variable costs of cowpea according to intercropping pattern).

The average of maize price presented by Bulletin of Statistical Cost Production and Net Return [2] and the average of cowpea prices presented by maker price were used. The local prices were L.E. 343 of one ardab of maize grains and L.E. 25 of one kg of cowpea seeds.

2.2. The Statistical Analysis

Analysis of variance of the obtained results of each season was performed. The measured variables were analyzed by ANOVA using MSTATC statistical package [20]. Mean comparisons were performed using the least significant differences (L.S.D) test with a significance level of 5% [21].

3. Results and Discussion

3.1. Maize Grain Yield and Its Attributes

3.1.1. Maize Cultivars

Maize cultivars were differed significantly for plant height, ear length, ear weight, number of rows/ear, 100-grain weight and grain yield/fad, meanwhile number of green leaves/plant was not differed among maize cultivars in both seasons (Table 1 and Table 2). With regard to plant height, maize cultivar SC 30K08 gave higher plant height than TWC 310 or TWC 352 by 7.52 or 23.60% in the first season and by 10.82% or 25.14% in the second one, respectively, under intercropping conditions. These results probably due to there was more shading around canopy of maize plants of maize cultivar SC 30K08 which formed more amounts of plant hormones and resulted in an increase of the internode number and elongation compared with the other cultivars. Mutual shading is known to increase the proportion of invisible radiation, which has a specific elongating effect upon plants [22]. Certainly, maize plant needs to receive and absorb optimal solar radiation to strength the stems.

With respect to grain yield and its attributes, maize cultivar SC 30K08 had the highest ear length, ear weight, number of rows/ear, 100-grain weight and grain yield/fad compared with the other cultivars in both seasons (Table 1 and Table 2). These results probably due to genetic potential of maize cultivar SC 30K08 translated into suitable canopy architecture that induced a deeper root system and a faster horizontal root development, indicting efficient use of all nutrients by all parts of this cultivar compared with the others cultivars. Hence, genetic

variability among the three hybrids led to differences in ear characteristics as a result of assimilates and it's partitioning to the cob. It seems that maize cultivar SC 30K08 was more effective in translocating photosynthates from leaves and stalks to the developing ears than TWC 310 or TWC 352 under intercropping conditions. According to Abo-Shetaia *et al.* [9], the difference in the genetical constituent of different maize cultivars might account much to difference in length and size of ears, especially there was a positive and highly correlated relationship among ear fill, ear length and ear circumference with grain weight/ear [23]. So, it is likely that differences in canopy and root architectures among the maize cultivars played a major role in utilization from the basic growth resources which reflected on ear characteristics under intercropping conditions. Leaf area is usually influenced by genotype, planting density, climate and soil fertility [24]. On the other hand, Lamlom *et al.* [13] showed that maize cultivar SC 122 had high capacity of root system that can make a larger volume of soil available for root extraction of water and nutrients compared to the other cultivars.

3.1.2. Maize Planting Geometry

Ear length, ear weight, 100-grain weight and grain yield/fad were affected significantly by maize planting geometry, meanwhile plant height, number of green leaves/plant and number of rows/ear were not affected in both seasons (Table 1 and Table 2). Maize planting geometry 25 cm × 140 cm resulted in the highest ear length, ear weight and 100-grain weight and grain yield/fad compared with other planting geometries in both seasons. Decreasing distance between maize hills from 75 to 25 cm increased ear length, ear weight, 100-grain weight and grain yield/fad by 7.78%, 15.92%, 11.26% and 27.67%, respectively in the first season.

Also, ear length, ear weight, 100-grain weight and grain yield/fad were increased by 21.76%, 19.84%, 24.67% and 21.92%, respectively, by decreasing distance between maize hills from 75 to 25 cm in the second one. These results may be due to differences in maize planting geometry led to differences in ear characteristics through intra-specific competition between maize plants for climatic and edaphic environmental conditions. It is likely that spatial arrangement of maize plants was differed by growing maize plant at different distances between hills although similarity in plant density per unit area which reflected on grain germination, the timely appearance of seedling and the development of shoot and root systems. Accordingly, it is expected that the adverse effects of shading between maize rows was higher than those between maize hills and these effects were reduced by decreasing distances between maize hills from 75 to 25 cm. Extreme uneven plant distribution reduced grain yield [25] and [26]. These results reveal that canopy architecture of maize plant that distanced at 25 cm between hills benefited greatly from available environmental resources especially solar energy which reflected positively on more translocation of photosynthates

metabolites to the sink (ears). In maize crop canopy, leaf area and vertical leaf area profile influence the interception and utilization of solar radiation which consequently drive dry matter accumulation and results the grain yield [27].

3.1.3. Interaction between Maize Cultivars and Maize Planting Geometry

Ear length, ear weight, 100-grain weight and grain yield/fad were affected significantly by maize cultivars × maize planting geometry, meanwhile plant height, number of green leaves/plant and number of rows/ear were not affected in both seasons (Table 1 and Table 2). The highest values of ear length, ear weight, 100-grain weight and grain yield/fad were obtained by intercropping cowpea with maize cultivar SC 30K08 of planting geometry 25 cm × 140 cm compared with the others. These results may be due to maize cultivar SC 30K08 of planting geometry 25 cm × 140 cm led to largely balance in maize-to-maize competition for climatic and edaphic environmental conditions compared with the other

Table 1. Effect of maize cultivars, maize planting geometry and their interaction on grain yield of maize and its attributes in the first season.

Maize cultivars	Maize planting geometry	Plant height (cm)	Number of green leaves/plant	Ear length (cm)	Ear weight (g)	Number of rows/ear	100-grain weight (g)	Grain yield/fad (ardab)
SC 30K08	25 cm × 140 cm	292.00	14.08	23.16	284.33	18.05	32.51	26.20
	50 cm × 140 cm	289.00	14.39	23.01	276.66	16.20	31.94	24.49
	75 cm × 140 cm	300.33	14.55	21.80	261.00	14.28	30.82	21.36
	Mean	**293.77**	**14.34**	**22.66**	**273.96**	**16.17**	**31.76**	**24.01**
TWC 310	25 cm × 140 cm	285.66	14.41	18.00	221.00	15.00	28.31	20.91
	50 cm × 140 cm	273.33	14.58	17.91	187.00	14.93	27.53	17.56
	75 cm × 140 cm	260.66	14.91	16.10	164.66	14.31	24.66	15.55
	Mean	**273.22**	**14.63**	**17.33**	**190.88**	**14.75**	**26.83**	**18.01**
TWC 352	25 cm × 140 cm	228.66	14.33	17.43	217.66	16.41	30.45	20.59
	50 cm × 140 cm	238.00	14.40	16.90	213.33	14.02	28.73	17.72
	75 cm × 140 cm	246.33	14.56	16.48	198.00	13.29	26.55	16.10
	Mean	**237.66**	**14.43**	**16.93**	**209.66**	**14.57**	**28.57**	**18.14**
Average of maize planting geometry	25 cm × 140 cm	268.77	14.27	19.53	240.99	16.48	30.42	22.56
	50 cm × 140 cm	266.77	14.45	19.27	225.66	15.05	29.40	19.92
	75 cm × 140 cm	269.11	14.68	18.12	207.88	13.96	27.34	17.67
L.S.D. at 0.05 Maize cultivars		6.68	N.S.	1.01	21.92	0.87	2.65	3.62
L.S.D. at 0.05 Maize planting geometry		N.S.	N.S.	0.74	10.49	N.S.	1.93	2.80
L.S.D. at 0.05 Interaction		N.S.	N.S.	1.53	33.17	N.S.	3.08	5.32
Solid culture of maize	SC 30K08	265.00	16.00	22.00	280.00	17.09	31.30	26.95
	TWC 310	300.00	16.00	18.15	221.00	15.15	28.20	21.49
	TWC 352	350.00	15.00	18.10	225.00	14.85	30.40	21.68

One fad = 4200 m^2. One ardab = 140 kg of maize grains.

Table 2. Effect of maize cultivars, maize planting geometry and their interaction on grain yield of maize and its attributes in the second season.

Maize cultivars	maize planting geometry	Plant height (cm)	Number of green leaves /plant	Ear length (cm)	Ear weight (g)	Number of rows/ear	100-grain weight (g)	Grain yield/fad (ardab)
	25 cm × 140 cm	314.00	15.66	25.18	286.66	20.00	34.53	27.10
	50 cm × 140 cm	314.33	16.00	25.03	277.66	17.33	33.95	25.42
SC 30K08	75 cm × 140 cm	320.66	16.33	23.81	262.00	15.33	32.84	22.26
	Mean	**316.33**	**16.00**	**24.67**	**275.44**	**17.55**	**33.77**	**24.92**
	25 cm × 140 cm	296.66	16.00	20.01	231.66	16.66	30.33	21.84
TWC 310	50 cm × 140 cm	287.00	16.33	15.12	199.00	16.00	29.55	19.46
	75 cm × 140 cm	272.66	16.66	14.78	183.33	15.33	26.68	17.47
	Mean	**285.44**	**16.33**	**16.64**	**204.66**	**16.00**	**28.85**	**19.59**
	25 cm × 140 cm	243.66	16.00	19.44	228.33	18.00	32.46	21.49
TWC 352	50 cm × 140 cm	253.66	16.00	16.70	223.33	15.33	30.74	19.96
	75 cm × 140 cm	261.00	16.33	14.50	177.66	14.66	28.56	18.02
	Mean	**252.77**	**16.11**	**16.88**	**209.77**	**16.00**	**30.59**	**19.82**
Average of maize planting geometry	25 cm × 140 cm	284.77	15.88	21.54	248.88	18.22	32.44	23.47
	50 cm × 140 cm	285.00	16.11	18.95	233.33	16.22	31.41	21.61
	75 cm × 140 cm	284.77	16.44	17.69	207.66	15.10	26.02	19.25
L.S.D. at 0.05 Maize cultivars		17.24	N.S.	1.43	18.65	1.34	2.44	3.37
L.S.D. at 0.05 Maize planting geometry		N.S.	N.S.	1.01	12.97	N.S.	1.84	2.96
L.S.D. at 0.05 Interaction		N.S.	N.S.	1.75	29.16	N.S.	2.77	5.59
Solid culture of maize	SC 30K08	286.00	18.00	25.50	280.00	21.00	34.22	27.61
	TWC 310	312.00	18.00	20.16	228.00	17.10	31.31	22.32
	TWC 352	365.00	17.00	20.01	231.50	17.60	32.41	22.83

One fad = 4200 m². One ardab = 140 kg of maize grains.

treatments. These data show that each of these two factors act dependently on ear length, ear weight, 100-grain weight and grain yield/fad except plant height, number of green leaves/plant and number of rows/ear.

3.2. Cowpea Seed Yield and Its Attributes

3.2.1. Maize Cultivars

Plant height, number of branches/plant, leaf area/plant, numbers of pods and seeds/plant, 100-seed weight and seed yield/fad were affected significantly by maize cultivars in both seasons (Table 3 and Table 4).

With regard to plant height, intercropping cowpea with maize cultivar TWC 352 gave lower plant height than those intercropped with maize cultivar SC 30K08 or TWC 310 in both seasons. These results probably due to differences in canopy architecture of the studied maize cultivars in the intercrops resulted in a

shading percentage around cowpea plants with varying light proportions that required stimulating flower production. Obviously, intercropping cowpea with maize cultivar TWC 352 decreased plant height of cowpea by 24.37% and 12.92% in the first season and by 24.65% and 13.37% in the second one, than those intercropped with maize cultivar SC 30K08 and TWC 310, respectively. These results are in the same context with those obtained by Idoko *et al.* [28] who indicated that shading effect of maize reduced the amount of solar radiation reaching the cowpea crop.

With respect to seed yield and its attributes of cowpea, intercropping cowpea with maize cultivar TWC 352 had the highest number of branches/plant, leaf area/plant, numbers of pods and seeds/plant, 100-seed weight and seed yield/fad compared with those intercropped with the other cultivars in both seasons (Table 3 and Table 4). Intercropping cowpea with maize cultivar TWC 352 increased seed yield/fad of cowpea by 28.83% and 16.18% in the first season and by 28.18% and 7.98% in the second one, than those intercropped with maize cultivar SC 30K08 and TWC 310, respectively. These results could be attributed to

Table 3. Effect of maize cultivars, maize planting geometry and their interaction on seed yield of cowpea and its attributes in the first season.

Maize cultivars	maize planting geometry	Plant height (cm)	Branches /plant (no.)	Leaf area/plant (cm²)	Pods /plant (no.)	Seeds /plant (no.)	100-seed weight (g)	Seed yield/fad (kg)
	25 cm × 140 cm	65.00	3.33	4107.66	31.33	6.33	14.59	275.66
	50 cm × 140 cm	57.66	3.33	4220.00	36.33	6.33	14.65	292.33
SC 30K08	75 cm × 140 cm	52.33	3.33	4440.00	44.33	7.66	15.56	325.66
	Mean	58.33	3.33	4255.88	37.33	6.77	14.93	297.88
	25 cm × 140 cm	56.33	3.66	4310.00	36.00	7.33	16.21	306.33
TWC 310	50 cm × 140 cm	51.00	4.33	4466.66	41.00	8.66	16.57	334.33
	75 cm × 140 cm	44.66	4.66	4726.66	49.00	9.33	17.29	350.33
	Mean	50.66	4.22	4501.11	42.00	8.44	16.69	330.33
	25 cm × 140 cm	48.00	4.33	4683.33	39.00	8.66	17.92	365.33
TWC 352	50 cm × 140 cm	43.33	5.33	5000.00	44.00	9.66	18.12	386.00
	75 cm × 140 cm	41.00	5.66	5110.00	55.00	10.66	19.10	400.00
	Mean	44.11	5.11	4931.11	46.00	9.66	18.38	383.77
	25 cm × 140 cm	56.44	3.77	4367.00	35.44	7.44	16.24	315.77
Average of maize planting geometry	50 cm × 140 cm	50.66	4.33	4562.22	40.44	8.22	16.45	337.55
	75 cm × 140 cm	46.00	4.55	4758.88	49.44	9.22	17.32	358.66
L.S.D. at 0.05 Maize cultivars		5.60	1.41	344.13	2.32	2.02	0.86	10.93
L.S.D. at 0.05 Maize planting geometry		2.14	0.45	104.82	1.10	0.68	0.49	7.37
L.S.D. at 0.05 Interaction		N.S.	N.S.	N.S.	2.38	N.S.	N.S.	18.07
Solid culture of cowpea		42.33	7.33	6145.00	62.00	13.00	21.60	832.67

One fad = 4200 m².

Table 4. Effect of maize cultivars, maize planting geometry and their interaction on seed yield of cowpea and its attributes in the second season.

Maize cultivars	maize planting geometry	Plant height (cm)	Branches /plant (no.)	Leaf area/plant (cm²)	Pods /plant (no.)	Seeds /plant (no.)	100-seed weight (g)	Seed yield/fad (kg)
SC 30K08	25 cm × 140 cm	61.66	3.33	4136.66	27.00	5.33	13.55	195.66
	50 cm × 140 cm	55.33	3.33	4193.33	30.66	5.33	13.63	208.66
	75 cm × 140 cm	49.33	3.33	4396.66	37.66	6.33	14.58	231.00
	Mean	55.44	3.33	4242.22	31.77	5.66	13.92	211.77
TWC 310	25 cm × 140 cm	54.00	3.66	4280.00	32.00	6.33	15.21	254.33
	50 cm × 140 cm	49.00	4.33	4452.66	37.33	7.66	15.55	277.66
	75 cm × 140 cm	41.66	4.33	4703.33	40.33	8.33	16.61	290.66
	Mean	48.22	4.11	4478.66	36.55	7.44	15.79	274.21
TWC 352	25 cm × 140 cm	45.66	4.66	4623.33	32.33	7.66	17.25	279.33
	50 cm × 140 cm	40.66	5.33	4953.66	40.00	8.66	17.27	296.66
	75 cm × 140 cm	39.00	5.33	5093.33	46.66	9.33	18.45	312.33
	Mean	41.77	5.11	4890.11	39.66	8.55	17.65	296.10
Average of maize planting geometry	25 cm × 140 cm	53.77	3.88	4346.66	30.44	6.44	15.34	243.10
	50 cm × 140 cm	48.33	4.33	4533.22	36.00	7.22	15.48	260.99
	75 cm × 140 cm	43.33	4.33	4731.11	41.55	8.00	16.54	277.99
L.S.D. at 0.05 Maize cultivars		5.01	1.50	383.59	4.47	1.96	0.56	22.18
L.S.D. at 0.05 Maize planting geometry		2.09	N.S.	93.28	2.30	0.68	0.20	15.50
L.S.D. at 0.05 Interaction		N.S.	N.S.	N.S.	4.64	N.S.	N.S.	26.84
Solid culture of cowpea		49.66	7.00	6210.00	57.66	11.66	22.07	676.66

One fad = 4200 m².

genetic variability among the three hybrids which led to difference in yield attributes of cowpea as a result of intercropping conditions. It seems that cowpea plants was more adapted with maize cultivar TWC 352 and benefited from basic growth resources than those intercropped with maize cultivar SC 30K08 or TWC 310.

It is likely that canopy and root architectures of maize cultivar TWC 352 played a major role to furnish better above and underground conditions for cowpea growth and development. These findings imply that canopy architecture of maize cultivar TWC 352 contributed largely in climatic resources availability particularly solar energy which reflected positively on more translocation of photosynthates metabolites to the pod. It is known that shading throughout, or from first flower onwards, reduced seed yield by about 25% because fewer pods were produced [29]. Also, differences in the depth of roots, lateral root spread and root densities are some of the factors that affect competition between the component crops in an intercropping system for nutrients [30]. Naturally, cowpea plant as C_3 plant of photosynthetic pathways had lower ability to use available

growth resources than maize plant (C_4 plant of photosynthetic pathways) under intercropping conditions. These results are in accordance with those obtained by Idoko *et al.* [28] who showed that all growth and yield characters of cowpea were affected significantly by maize cultivars.

3.2.2. Maize Planting Geometry

Plant height, number of branches/plant, leaf area/plant, numbers of pods and seeds/plant, 100-seed weight and seed yield/fad were affected significantly by maize planting geometry in both seasons (Table 3 and Table 4). Growing two cowpea rows between maize hills by maize planting geometry 75 cm × 140 cm decreased plant height of cowpea by 9.19% and 18.49% in the first season and by 10.34% or 19.41% in the second one, than those of maize planting geometry 50 cm × 140 cm or 25 cm × 140 cm, respectively. Plant height and leaf area appeared to be the most important factor determining competition effects [31].

On the other hand, maize planting geometry 75 cm × 140 cm resulted in the highest number of branches/plant, leaf area/plant, numbers of pods and seeds/plant, 100-seed weight and seed yield/fad compared with the other maize planting geometries in both seasons. Increasing distance between maize hills from 25 to 75 cm increased number of branches/plant, leaf area/plant, numbers of pods and seeds/plant, 100-seed weight and seed yield/fad by 20.68%, 8.97%, 39.50%, 23.92%, 6.65% and 13.58%, respectively in the first season. Also, number of branches/plant, leaf area/plant, numbers of pods and seeds/plant, 100-seed weight and seed yield/fad were increased by 11.59%, 8.84%, 36.49%, 24.22%, 7.82% and 14.35%, respectively, by increasing distance between maize hills from 25 to 75 cm in the second one. These results probably due to growing two cowpea rows between maize hills through maize planting geometry 75 cm × 140 cm had higher potential to harvest more light and thereby produced more branches, leaves, pods and seed per plant than those grown with the other planting geometries of maize.

It seems that when cowpea rows run north-south, maize as tall crop cannot shade easily cowpea as shorter crop and these adverse effects were increased negatively by decreasing distances between maize hills from 75 to 25 cm. In other words, two cowpea rows between maize hills produced more leaves with greater soil cover and continued to grow and flower although the shade effects of the maize component compared with the other maize planting geometries. These results suggest that planting geometry 75 cm × 140 cm formed suitable spatial arrangement of cowpea plants which reflected on decrease in inter-specific competition between the two species for climatic and edaphic environmental conditions; especially biological nitrogen fixation of the legume is dependent on the legume's ability to intercept light [32]. Accordingly, the system of intercropping is an important factor which affected the quantity on N fixed by legumes [33].

3.2.3. Interaction between Maize Cultivars and Maize Planting Geometry

Number of pods/plant and seed yield/fad were affected significantly by maize

cultivars × maize planting geometry, meanwhile plant height, number of branches/plant, leaf area/plant, number of seeds/plant and 100-seed weight were not affected significantly by maize cultivars × maize planting geometry in both seasons (Table 3 and Table 4). The highest values of number of pods/plant and seed yield/fad were obtained by intercropping cowpea with maize cultivar TWC 352 of planting geometry 75 cm × 140 cm compared with the others. These data may be due to maize cultivar TWC 352 of planting geometry 75 cm × 140 cm furnished better basic growth recourses for cowpea growth and development compared with the other treatments. These data show that maize cultivars responded differently to maize planting geometry for number of pods/plant and seed yield/fad.

3.3. Competitive Relationships

3.3.1. Maize Cultivars

RY_{maize}, RY_{cowpea}, LER and LEC were affected significantly by maize cultivars in both seasons (Table 5). With respect to RY_{maize}, it ranged from 74% to 97% in the first season and from 78% to 98% in the second season. The highest RY_{maize} was obtained by intercropping cowpea with SC 30K08 compared with others in both seasons. These results may be due to plants of this cultivar had some morphological and physiological characteristics that adapted with intercropping conditions through maintaining carbon dioxide assimilation rates that reflected on better translocation of available assimilates from source to sink. On the other hand, RY_{cowpea} ranged from 33% to 48% in the first season and from 28% to 46% in the second season. The highest RY_{cowpea} was obtained by intercropping cowpea with TWC 352 compared with others in both seasons. It is important to mention that the effects of maize cultivar SC 30k08 on RY_{cowpea} were similar to those of maize cultivar TWC 310. Consequently, cowpea plants suffered from higher shading of canopy architecture of maize cultivar SC 30k08 or TWC 310 than those intercropped with maize cultivar TWC 352 which reflected negatively on their RY.

The values of LER were estimated by using data of recommended solid cultures of both crops. LER of more than 1.00 indicates yield advantage, equal to 1.00 indicates no gain or no loss and less than 1.00 indicates yield loss [34]. It can be used both for replacement and additives series of intercropping. The results obtained were strongly coincided with the definition of LER. The total LER values were greater than one in all the studied treatments (Table 5). LER ranged from 1.14 to 1.38 in the first season and from 1.14 to 1.35 in the second one. LER of 1.35 indicates that the planted area to solid cultures would need to be 35% greater than the planted area to intercrop to produce the same combined yields (*i.e.* 35% more land would be required as a solid crop to produce the same yield as intercropping). The advantage of the highest LER by intercropping cowpea with maize cultivar TWC 352 probably due to the canopy architecture of maize cultivar TWC 352 was more compatible with cowpea plants to continue in their growth and development compared with the others.

Table 5. Competitive relationships of intercropping cowpea with maize cultivars and its planting geometry in the two seasons.

Maize cultivars	Maize planting geometry	RY_{maize}	RY_{cowpea}	LER	LEC
		2015 season			
S.C. 30K08	25 cm × 140 cm	0.97	0.33	1.30	0.32
	50 cm × 140 cm	0.90	0.35	1.25	0.31
	75 cm × 140 cm	0.79	0.39	1.18	0.30
	Mean	**0.88**	**0.35**	**1.24**	**0.31**
T.W.C. 310	25 cm × 140 cm	0.97	0.36	1.34	0.34
	50 cm × 140 cm	0.81	0.40	1.21	0.32
	75 cm × 140 cm	0.72	0.42	1.14	0.30
	Mean	**0.83**	**0.39**	**1.23**	**0.32**
T.W.C. 352	25 cm × 140 cm	0.94	0.43	1.37	0.40
	50 cm × 140 cm	0.81	0.46	1.27	0.37
	75 cm × 140 cm	0.74	0.48	1.22	0.35
	Mean	**0.83**	**0.45**	**1.28**	**0.37**
Average of maize planting geometry	25 cm × 140 cm	**0.96**	**0.37**	**1.33**	**0.35**
	50 cm × 140 cm	**0.84**	**0.40**	**1.24**	**0.33**
	75 cm × 140 cm	**0.75**	**0.43**	**1.18**	**0.31**
L.S.D. at 0.05 Maize cultivars		**0.04**	**0.05**	**0.04**	**0.05**
L.S.D. at 0.05 Maize planting geometry		**0.03**	**0.03**	**0.02**	**0.03**
L.S.D. at 0.05 Interaction		**0.04**	**0.06**	**0.06**	**0.06**
Solid culture		1.00	1.00	1.00	1.00
		2016 season			
S.C. 30K08	25 cm × 140 cm	0.98	0.28	1.26	0.27
	50 cm × 140 cm	0.92	0.30	1.22	0.27
	75 cm × 140 cm	0.80	0.34	1.14	0.27
	Mean	**0.90**	**0.30**	**1.20**	**0.27**
T.W.C. 310	25 cm × 140 cm	0.97	0.37	1.34	0.35
	50 cm × 140 cm	0.87	0.41	1.28	0.35
	75 cm × 140 cm	0.78	0.42	1.20	0.32
	Mean	**0.87**	**0.40**	**1.27**	**0.34**
T.W.C. 352	25 cm × 140 cm	0.94	0.41	1.35	0.38
	50 cm × 140 cm	0.87	0.43	1.30	0.37
	75 cm × 140 cm	0.78	0.46	1.24	0.35
	Mean	**0.86**	**0.43**	**1.29**	**0.36**
Average of maize planting geometry	25 cm × 140 cm	**0.96**	**0.35**	**1.31**	**0.33**
	50 cm × 140 cm	**0.88**	**0.38**	**1.26**	**0.33**
	75 cm × 140 cm	**0.78**	**0.40**	**1.19**	**0.31**
L.S.D. at 0.05 Maize cultivars		**0.03**	**0.06**	**0.07**	**0.06**
L.S.D. at 0.05 Maize planting geometry		**0.02**	**0.03**	**0.04**	**0.02**
L.S.D. at 0.05 Interaction		**0.05**	**0.08**	**0.08**	**0.08**
Solid culture		1.00	1.00	1.00	**1.00**

With respect to LEC, it was a measure of interaction concerned with the strength of relationship. LEC is used for a two-crop mixture, the minimum expected productivity co-efficient (PC) is 25 percent, that is, a yield advantage was obtained if LEC value was exceeded 0.25. LEC was affected significantly by maize cultivars in both seasons (Table 5). LEC ranged from 0.30 to 0.40 in the first season and from 0.27 to 0.38 in the second one. The advantage of the highest LEC by intercropping cowpea with maize cultivar TWC 352 probably due to there was a decrease in interspecific competition between cowpea and maize cultivar TWC 352 for above and underground environmental conditions which reflected to higher economic yield of both species per unit area compared with the others.

3.3.2. Maize Planting Geometry

RY_{maize}, RY_{cowpea}, LER and LEC were affected significantly by maize planting geometry in both seasons (Table 5). Maize planting geometry 25 cm × 140 cm resulted in the highest RY_{maize}, LER and LEC compared with the other maize planting geometries in both seasons. On the other hand, maize planting geometry 75 cm × 140 cm resulted in the highest RY_{cowpea} only compared with the other maize planting geometries in both seasons. It seems that increasing distance between maize hills from 25 to 75 cm by growing six rows of maize in the bed (140 cm width) increased intraspecific competition between plants of maize for basic growth resources especially light intensity indicating low carbon dioxide assimilation rate. These results could be attributed to increase in the distance between maize hills in the same row with decreasing distance between these rows cannot increase LER and LEC which reflected negatively on the competition ability between the intercrops.

3.3.3. Interaction between Maize Cultivars and Maize Planting Geometry

RY_{maize}, RY_{cowpea}, LER and LEC were affected significantly by maize cultivars × maize planting geometry in both seasons (Table 5). The highest RY_{maize} was obtained by intercropping cowpeas with maize cultivar SC 30K08 that distanced at 25 cm between hills compared with the others. On the other hand, the highest RY_{cowpea} was obtained by intercropping cowpea with maize cultivar TWC 352 that distanced at 75 cm between hills compared with the others. However, the highest LER and LEC were obtained by intercropping cowpea with maize cultivar TWC 352 of planting geometry 25 cm × 140 cm compared with the others. It seems that two rows of cowpea plants that grown between rows of maize cultivar TWC 352 in the same bed decreased competitive ability between the intercrops for available environmental resources compared with the other treatments. Competition is a dynamic process that depends on amount of resources acquired by the competing species and their efficiency in converting resources to biomass [35]. Moreover, intercropping conditions of cereals and legumes would be valuable because the component crops can utilize different sources of N [36]. Accordingly, these results reveal that the advantage of the highest LER and LEC were

Table 6. Economic evaluation of maize cultivars and its planting geometry in the two seasons.

Maize cultivars	Maize planting geometry	Economic return (L.E./fad)			
		Maize	Cowpea	Total	Net
2015 season					
Intercropping culture SC 30K08	25 cm × 140 cm	8986	6891	15878	8728
	50 cm × 140 cm	8400	7308	15708	8558
	75 cm × 140 cm	7326	8141	15467	8317
	Mean	8235	7447	15682	8532
TWC 310	25 cm × 140 cm	7172	7658	14830	7680
	50 cm × 140 cm	6023	8358	14381	7231
	75 cm × 140 cm	5333	8758	14091	6941
	Mean	6177	8258	14435	7285
TWC 352	25 cm × 140 cm	7062	9133	16195	9045
	50 cm × 140 cm	6077	9650	15727	8577
	75 cm × 140 cm	5522	10000	15522	8372
	Mean	6222	9594	15816	8666
Solid culture of maize SC 30k08		9243	---	9243	2605
TWC 310		7371	---	7371	733
TWC 352		7436	---	7436	798
Mean		8016	---	8016	1378
2016 season					
Intercropping culture SC 30K08	25 cm × 140 cm	9295	4891	14186	7036
	50 cm × 140 cm	8719	5216	13935	6785
	75 cm × 140 cm	7635	5775	13410	6260
	Mean	8547	5294	13841	6691
TWC 310	25 cm × 140 cm	7491	6358	13849	6699
	50 cm × 140 cm	6674	6941	13616	6466
	75 cm × 140 cm	5992	7266	13258	6108
	Mean	6719	6855	13574	6424
TWC 352	25 cm × 140 cm	7371	6983	14354	7204
	50 cm × 140 cm	6846	7416	14262	7112
	75 cm × 140 cm	6180	7808	13989	6839
	Mean	6798	7402	14200	7050
Solid culture of maize SC 30k08		9470	---	9470	2832
TWC 310		7655	---	7655	1017
TWC 352		7830	---	7830	1192
Mean		8318	---	8318	1680

Prices of main products are that of 2018: L.E. 343 for one ardab of maize grains and L.E. 25 for one kg of cowpea seeds. One fad = 4200 m^2. One adrab = 140 kg of maize grains. US$ 1 = L.E. 18.

achieved by growing two rows of cowpea plants between rows of maize cultivar TWC 352 in the same bed compared with the other treatments. Obviously, RY_{maize} contributed largely in LER and LEC than RY_{cowpea}.

3.4. Economic Evaluation

The financial return of intercropping cowpea with maize as compared with solid culture of maize is shown in Table 6. Net return of intercropped cowpea with maize varied between treatments from L.E. 6941 to 9045/fad as compared with solid culture of maize (L.E. 1378/fad) in the first season. Also, net return of intercropped cowpea with maize varied between treatments from L.E. 6108 to 7204/fad as compared with solid culture of maize (L.E. 1680/fad) in the second one. Net return of the intercrops recorded the highest total and net returns by growing cowpea between rows of maize cultivar TWC 352 in comparison with maize solid culture in the two growing seasons. These results show that intercropping cowpea with maize cultivar TWC 352 of planting geometry 25 cm × 140 cm is more profitable than maize solid culture for Egyptian farmers.

4. Conclusion

It could be concluded that growing cowpea plants with maize in the same bed to obtain high yield per unit area depend on suitable maize cultivar and its planting geometry. Regardless of maize cultivar, increasing distance between maize hills in the same row with decreasing distance between these rows cannot counterbalance the reduction in land usage and net return under intercropping conditions. Growing one row of maize cultivar SC 30K08 in both sides of bed 140 cm (one plant distanced at 25 cm) with two rows of cowpea in middle of the bed (one plant distanced at 10 cm) between maize rows recorded higher land usage and profitability than maize solid culture for Egyptian farmers.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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