Effect of Plant Spacing and N Fertilization Levels of Watermelon Relay Intercropping with Faba Bean in Relation to Yield Productivity

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***Received:** 21/10/2022*

Abstract: This study suggested growing faba beans in the watermelon cultivated area by relay intercropped melon with faba bean to reduce the faba bean production-consumption gap, maximize the productivity per unit area, reduce the use of nitrogen fertilizer and increase the income of farms. So, A field experiment was implemented during 2020/2021 and 2021/2022 seasons at Ismailia Experiment Station, ARC, Ismailia Governorate, Egypt, to study the effect of plant spacing (50, 75 and 100 cm) and N fertilization levels (40, 60 and 80 kg/fad) of watermelon relay intercropping with faba bean on yield for both crops, land equivalent ratio (LER), and profitability per unit area. A split-plot design was used with three replications. Plant spacing of watermelon were assigned in main plots and N fertilization levels were arranged in sub-plots. Results indicated that growth, yield and its attributes of faba bean were insignificant effect by watermelon plant spacing and N fertilization levels of watermelon as well as their interaction. Contrary, plant spacing and N fertilization of watermelon relayed with faba bean significantly affected watermelon traits. Where, increasing plant spacing from 50 to 100 cm between hills with applied 80 kg N/fad significantly increased branch length, number of branches/plant, number of fruit and mean fruit weight. However, the highest fruit yield (25.2 ton/fad as average of both seasons) produced by planting watermelon spacing at 75cm with applied 80 kg N/fad, but without significant differences with 60 kg/fad. Therefore, intercropping watermelon at plant spacing 75cm with applied 60 or 80 kg N/fad had the highest LER 1.75, ATER 1.05 and the highest in both seasons. While, the highest net return 25511 L.E/fad was achieved with 60 kg N/fad and at par with the net return 25502 L.E/fad by 80 kg N/fad. In conclusion, relay intercropping watermelon with faba bean at 75 cm plant spacing with applied 60kg N/fad produced 24.9 ton/fad fruits of watermelon plus 8.3 ardab/fad of seed faba bean and increased net return by 80.2%, as well as saved land by 75% and N fertilizer by 25% compared to sole watermelon culture, as average of both seasons.

Keywords: Relay intercropping, N fertilization, land equivalent ratio (LER), ATER, net return

INTRODUCTION

Faba bean (*Vicia faba* L.) is one of the strategic crops; it is an important source of proteins and minerals for humans and animals (Khursheed *et al.,* 2018). Since faba beans are a significant component of the Egyptian diet, increasing faba bean production and improving yield quality are the main goals in order to meet the demand of the expanding Egyptian population (Zeidan, 2003). In Egypt, the cultivated area of faba bean decreased in the last years from 107621 to 89256 fad (Bulletin, 2013, 2020). Therefore, there is a gap between production and consumption of faba bean. This is due to the strong competition between faba bean and other strategic winter season crops on the limited cultivated land. Therefore, intercropping faba bean with watermelon in cultivated areas of watermelon can contribute in reduce the food gap of faba bean by increasing the area of faba bean without the need for additional land area in newly reclaimed sandy soils.

A promising method to sustainably maintain or increase yields is intercropping. Over yielding can occur in relay intercropping due to resource complementarity, which occurs when two or more species of an intercrop acquire different resources or the same resources at different places underground (Li *et al.,* 2018) or at different times (Zhang *et al.,* 2017).

Watermelon (*Citrullus lanatus* Thunb) is the most cultivated Cucurbitaceae species in the world, due to high nutritive value (Wehner, 2008). In Egypt, watermelon is cash crop and one of the important vegetables crops. Its cultivated area was 45,029 ha in the summer season (FAO, 2020), and about 90% of this area was in newly reclaimed land. Watermelon rows spacious allow for successful intercropping farming, which allows shares of land resources and production inputs as well as increased productivity, land use efficiency and farmer income (Huang *et al.,* 2015; Miller and Greene, 2018; Abd Allah *et al.,* 2020). Management of intercrops to reach maximum complementarity and minimum competition between both crops includes agriculture different decisions as population density and nutrients requirements, especially nitrogen.

Plant density management of watermelon is essential to obtain a greater number of commercial fruits of watermelon, because plant a densing can lead to increase in productivity, but with decrease in the mean fruit mass (Goreta *et al.,* 2005). Increased plant density usually raises biomass productivity to a certain limit, after which productivity remains equal or decreases (Campagnol *et al.,* 2012). Reducing plant spacing from 2 to 0.5 m decreased number of fruits/plant, fruit weight and fruit yield/ha (Cecílio Filho *et al.,* 2015). Total and marketable yields per ha were linearly decreased with an increase in plant spacing from 0.5 to 1.5 m, and the same was noticed with the total and marketable number of fruit per ha (Bellad and Umesh, 2018). However, several studies indicate that the plant density of the later sown crop, such as watermelon, did not have a significant effect on the early sown crop (as faba bean) in the relay intercropping system (Mao *et al.,* 2014;

Bitew *et al.,* 2014; Tilahun and Alemayehu, 2019; Fetene *et al.,* 2020).

Watermelon repeated cultivation can generate soil and water degradation due to the excessive use of synthetic fertilizers due to nutrient depletion (Ding *et al.,* 2021). Therefore, faba bean is the best companion crop, since it can increase the available N supply for other crops at low cost (Espinoza *et al.,* 2015), increase soil organic matter, and improvement of soil structure (Watson *et al.,* 2017). Intercropping faba bean can savings (up to 100–200 kg N/ ha) in the amount of N fertilizer required to maximize the yield of other crops (Jensen *et al.,* 2010). However, watermelon fertilization did not have a significant effect on the growth, yield and yield components of the faba bean, since it is a legume crop that can fix N from the air. Mueller *et al.* (2015) found that legume N-fixing plants can acquire 50 to 70% of the essential N needed from the air, resulting in a lack of competition for below-ground resources with co-crops. However, supply of N is associated with high photosynthetic activity, vigorous vegetative growth and a production of watermelon (John *et al.,* 2004; Kacha *et al.,* 2017). An application of 150 kg N/ha in watermelon significantly increased the fruit yield (Sabo *et al.,* 2013; Bellad and Umesh, 2018), but at 200 kg N/ha it had no significant effect (Sabo *et al.,* 2013). Kacha *et al.* (2017) found that maximum fruit yield/ hectare were registered under higher dose of nitrogen (125 kg/ha), whereas, maximum fruit number produce at 93 kg N/ ha (Nowaki *et al.,* 2017). To increase intercropping systems, agricultural management practices must optimize complementarity and decrease competition between intercrop components (Stomph *et al.,* 2020). Thereby, this study was undertaken to study the effect of plant spacing and N fertilization levels of watermelon on productivity of both crops, land equivalent ratio and economic feasibility of faba bean/watermelon relay intercropping.

MATERIALS AND METHODS

A field experiment was implemented during two successive seasons of 2020/2021 and 2021/2022 at Ismailia Research Station, ARC, Ismailia Governorate, Egypt. Drip irrigation system was used in both growing seasons. Soil texture of experimental site was sand and pH value was 7.45. Chemical and physical soil analyses (0-30 cm in depth) were conducted by the standard methods described by Tan (1996) as shown in Table (1). The experiment was laid out in split-plot in randomized complete block design with three replicates. Plant spacing of watermelon (50, 75 and 100 cm between hills) were assigned in main-plots and three N fertilization levels (40, 60 and 80kg N/fad) were allocated in sub-plots.

Table (1): Physical and chemical properties of soil (0 – 60 cm in depth) at experimental site in both seasons

Physical properties			**Chemical properties**		
Season	**2020/2021**	**2021/2022**	**Season**	**2020/2021**	**2021/2022**
Fine sand %	19.35	19.65	Available NPK (ppm)		
Coarse sand %	73.18	74.3	**N**	19.25	20.84
Silt %	2.64	2.13	**P**	5.46	6.52
Clay %	4.83	3.92	**K**	65.93	72.10
Soil texture	Sand		**pH**	7.86	7.89

Land preparation process started with ploughing by disk harrow, levelling, and division into terraces that were 2.40 m wide and 6 m long. Plot area was 43.2 m^2, and comprised of 3 terraces. The drip irrigation network was distributed in experimental area, which consists of main line (4-inch diameter), sub lines (63 mm diameter), and drip lateral (16 mm diameter) that were parallel to watermelon beds. Drippers spacing were 50 between drippers. Under intercropping system 3 laterals (16 mm diameter) per terrace was used. Two laterals established on the top of the terrace at 80 cm spaced to irrigate faba bean plants (Fig, 1), while the third lateral staying on the one side of the terrace for watermelon. In sole system, 1 lateral on one side of terrace at 240 cm was established for watermelon. While, three laterals on the top of the terrace at 80 cm apart were established to irrigate faba bean (Fig 1).

Faba bean seeds Giza 716 cultivar were sowing on November 1st, and harvest date were on April 15th and 18th in first and second season, respectively, in sole and intercropping system. Faba bean seeds were sowing on the terrace (240 cm) in 6 rows at 40 cm between rows and one plant/hill at 15 cm in sole culture to give 70 thousand plants/fad, while seeds of intercropped faba bean were sowing on the terrace (240 cm) in 4 rows on the terrace at 40 cm, with left one plant/hill at 15 cm apart (faba bean pant density was 46.7 thousand plants/fad, it is 67% of its recommended) as shown in Fig (1). Transplants of watermelon Giza 1 cultivar in stage of 3-4 true leaves were transplanted on March 15th on one side of the terrace (240 cm) and harvested on June 26th and July 2nd in first and second season, respectively, for both cultural system. Planting space of watermelon were 50, 75 and 100 cm between hills, in intercropping system and at 75 cm in pure stand to give 2333 plants/fad (Fig 1).

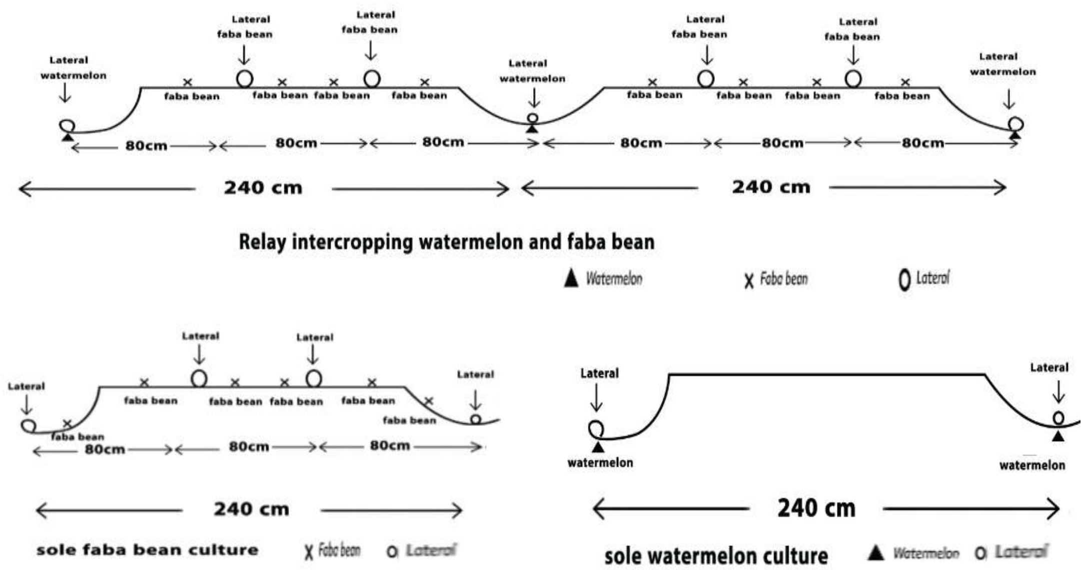

Figure (1): Sole and intercropping system of faba bean and watermelon

Nitrogen, potassium and phosphorus fertilizers applied were in form ammonium nitrate (33.5% N), potassium sulphate (48% K_2O) and phosphoric acid, respectively. Calcium superphosphate at 200 kg/fad was applied during soil preparation. For faba bean, ammonium nitrate at 20 kg N/ fad, as booster dose to the soil, while potassium sulphate at 50 kg/fad were applied at 5 equal doses as soil dressing, every 10 days, beginning of the third irrigation. For watermelon, poultry manure at 20 m^3/fad was added in ditch rows before transplanting. Phosphoric acid fertilizer at 10 L/fad was added as fertigation recommended. Meanwhile, potassium sulphate at 100 kg/fad and different levels of N (40, 60 and 80 kg N/fad) were divided into five equal parts and applied as top dressing near the drippers, beginning of the first irrigation, and repeat every 10 days. The other cultural practices for growing each crop were as recommended according to the instruction laid down by the Egyptian Ministry of Agriculture.

The studied characters

- Faba bean:

At harvest, plant height (cm), number of branches/plant (No.), number of pods/plant (No.), seeds yield/plant (g) and 100 seed weight (g) were estimated according ten plants were randomly chosen. Seed yield (ardab/fad) was measured as all harvested plants from each experimental unit were weighted then threshed to assess seed yield/fad.

- Watermelon:

Harvesting was carried out upon fruit maturity symptoms. Five fruits from each sub-plot were collected to measure main branch length (cm), branches number/plant (No.), fruits number/plant (No.) and mean fruit weight (kg). Fruits weight of each sub-plot was weighted to calculated total yield/fad (ton).

Competitive relationships:

- **Land equivalent ratio (LER)** was determined according to (Willey, 1979), by the following formula: LER = (Yab/Yaa) + (Yba/Ybb)

Where Yaa and Ybb = Pure stand yield of crop a (watermelon), and crop b (faba bean), Yab and Yba = Intercrop yield of crop a (watermelon) and crop b (faba bean), respectively.

Area Time Equivalent Ratio (ATER): ATER provides more realistic comparison of the yield advantage of intercropping over solid cropping than LER in terms of time taken by component crops in the intercropping systems. ATER was calculated by formula developed by Hiebsch (1980):

$$ATER = [(\frac{Yab}{Yaa} X\ Ta) + (\frac{Yba}{Ybb} X\ Tb)]/T$$

Ta and Tb = duration (in days) of watermelon and faba bean crop, respectively. T = total duration of the intercropping system in days.

- **Aggressivity (Ag):** Its values were determined according to Mc-Gilchrist (1965):

Ag a= [Yab/(YaaxZab)] – [Yba/(YbbxZba)] Ag b= [Yba/(YbbxZba)] – [Yab/(YaaxZab)]

where: Ag a and Ag b =aggressivity value for watermelon and faba bean, respectively.

Zab and Zba: sown proportion of watermelon and faba bean in intercropping system, respectively.

Economic evaluation:

The total return per feddan was calculated for each treatment in Egyptian pounds, using the average market price for both years. The farm prices were 1938 and 2015 L.E/ardab for seed faba bean and 1500 and 1700 L.E / ton for watermelon in 2020/2021 and 2021/2022season, respectively.

Net return = Total return – total cost (total cost of watermelon + variable cost of faba bean)

The Statistical Analysis:

The data of all characters were studied subjected to statistical analysis of variance technique using MSTATC statistical package (Freed, 1991). The treatment differences were tested by "F" test of significance according to Gomez and Gomez (1984). Duncan Multiple Range Test (DMRT) at 5% level of probability was used to compare treatment means.

RESULTS AND DISCUTIONS

I- Faba bean

Effect of plant spacing of watermelon:

Results presented in Table (2) confirm that plant spacing of watermelon did not show a significant effect on plant height, number of branches/plant, number of pods/plant, seed yield/plant, 100-seed weight and seed yield/fad of faba bean in both seasons. This might be due to the full mature of faba bean that watermelon crop was not able to create an inter-specific competition to reduce the yield and its components of faba bean. Where watermelon was planted when the faba bean plants reached later maturity stage before watermelon plants become a strong competitor for faba bean plants. This is in agreement with the work of Mao *et al.* (2014) who stated that plant densities (plant spacing) of cotton were 3.0, 4.5, 6.0 and 7.5 plants m^{-2}, had no significant effect on grain yield of wheat in relay intercropping system. Intercropping of lupine with different spacing did not show a significant effect on the biomass yield of barley (Bitew *et al.*, 2014). Similarly, parameters of tef did not affect significantly by intra-row spacing of safflower in relay intercropping system (Tilahun and Alemayehu, 2019) or intar-row spacing of lupine relay intercropping (Fetene *et al.,* 2020).

Effect of N fertilization levels of watermelon:

Concerning N fertilization levels of watermelon had no significant effect on growth, yield components and seed yield/fad of faba bean as shown in Table (2). A probable reason for irresponsibility of growth and yield characters to N fertilization levels, is applied N fertilizer of watermelon when faba bean reach to mature stage. This result in line with Huang *et al.* (2015) the intercropped watermelon had no effect on the growth of wheat in relay intercropping system. Another interpretation, faba bean has the ability to air N-fixation, this N is an important resource for the other intercrops. These results are in agree with those obtained by Mueller *et al.* (2015) found that legume N-fixing plants can acquire 50 to 70% of the essential N needed from the air, resulting in a lack of competition for below-ground resources with co-crops.

Interaction effects:

Interaction between plant spacing and N fertilization levels of watermelon had no significant effect on growth, yield and its components of faba bean in both season (Table 2). This result in line with Abd Allah *et al.* (2020) reported that interaction of studied factors of watermelon did not show any significant effect on wheat.

Table (2): Effect of watermelon plant spacing, N fertilization levels and their interaction on faba bean characters in both seasons

Trait / Treatment		Plant height (cm)		Number of branches/pl		Number of pods/pl		Seed yield/pl (g)		100- seed wt. (g)		Seed yield (ard./fad)	
		2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022	2020/2021	2021/2022
Plant spacing A													
50 cm		95.50	102.89	3.64	3.41	12.93	13.27	33.55	30.55	87.51	84.56	8.44	7.82
75 cm		94.90	104.17	3.56	3.43	13.56	12.71	34.26	29.36	88.23	84.78	8.35	8.00
100 cm		95.01	101.46	3.54	3.44	14.48	12.89	34.00	30.31	87.44	86.17	8.41	7.98
F test		n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s
N fertilization B													
40 kg/fad		94.79	103.78	3.59	3.46	13.50	13.30	33.56	30.61	86.59	84.50	8.24	7.93
60 kg/fad		95.07	101.16	3.62	3.43	14.29	12.77	34.20	29.64	88.40	85.16	8.45	7.95
80 kg/fad		95.54	103.57	3.53	3.38	13.18	12.80	34.04	29.96	88.20	85.83	8.50	7.91
F test		n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s
Interaction AxB													
50 cm	**40**	97.00	103.16	3.90	3.43	13.32	14.43	32.74	32.97	86.27	83.83	8.26	7.80
	60	93.23	101.00	3.60	3.46	13.60	12.67	37.37	29.40	88.10	85.17	8.50	7.76
	80	96.27	104.50	3.43	3.33	11.87	12.70	30.53	29.27	88.17	84.67	8.56	7.90
75 cm	**40**	994.20	105.83	3.73	3.43	13.13	12.37	34.63	28.37	87.10	84.50	8.23	7.90
	60	95.23	101.67	3.63	3.43	14.00	12.83	31.27	29.47	89.30	84.17	8.43	8.10
	80	95.27	105.00	3.60	3.43	13.53	12.93	36.87	30.23	88.30	85.67	8.40	7.99
100 cm	**40**	93.17	102.35	3.43	3.53	14.03	13.10	33.30	30.50	86.40	85.24	8.23	8.10
	60	96.77	100.82	3.63	3.40	15.27	12.80	33.97	30.07	87.80	86.17	8.43	8.00
	80	95.10	101.20	3.57	3.40	14.13	12.77	34.72	30.37	88.13	87.10	8.56	7.83
F test		**n.s**	**n.s**	**n.s**	**n.s**	**n.s**	**n.s**	**n.s**	**n.s**	**n.s**	**n.s**	**n.s**	**n.s**
Sole faba		**104.50**	**112.00**	**2.40**	**2.80**	**10.60**	**9.80**	**27.70**	**25.60**	**85.70**	**82.50**	**11.40**	**10.80**

ns: means not significant at 5% probability

Results in Table (2) clearly indicated that intercropped faba bean superiority in number of branches/plant and yield component over than pure stand of faba bean in both seasons. Whereas the highest values of plant height and seed yield/fad were recorded with pure stand of faba bean compared to intercropping system. Improved performance of individual faba bean plants in intercrops is mainly attributed to the greater light capture per plant over sole culture.

This result is consistent with other studies on faba bean/wheat intercropping (Abdel-Wahab and El Manzlawy, 2016). Notably number of faba bean rows per unit area and band-width between terraces could be related to the proportion of solar radiation that reaches faba bean plants during growth and development of faba bean. Similar results were obtained by Abd Allah *et al.* (2020), note that yield components of wheat intercropping with watermelon were higher than sole wheat, irrespective of wheat cultivar. However, the reduction of seed yield of intercropped faba bean could be attributed to plant density of faba bean in intercropping culture reached 67% of sole culture. This result is in accordance with those obtained by Abdel-Wahab and El Manzlawy (2016) and Abd Allah *et al.* (2020).

II- Watermelon

Effect of plant spacing of watermelon:

Watermelon yield and its components characters had significantly affect by plant spacing, N fertilization levels and their interaction in both seasons as shown in (Table 3). Increasing plant spacing from 50 to 100 cm between hills of watermelon plants gradually increased branch length, number of branches/plant, number of fruits/plant and mean fruit weight (g). A probable reason for responsibility of watermelon characters is the low intra-specific competition on water, nutrient and light between watermelon plants. These results are supported by the work done by Sabo *et al.* (2013) who reported an increase in watermelon vine length, number of branches and fruit weight with an increase in spacing. Cecílio Filho *et al.* (2015) they found that reducing plant spacing from 2.0 to 0.5 m decreased number of fruits/plant, and fruit weight.

However, the highest fruit yield per fad 23.97 and 23.79 ton /fad were produce with plant spacing 75 cm between hills as shown in Table (3). While the lowest fruit yield 22.48 and 22.35 ton/fad were obtained with plant spacing 50 cm apart. The authors claim that as plant spacing decreased, solar radiation incidence on the interior of the canopy shortage and individual leaf area on the mid and upper parts of the plant reduced. This resulted in less solar radiation interception and carbon dioxide absorption by the plant, which decreased solar radiation incidence and led to smaller mean fruit weight and fruit yield/fad. Corroborating the results obtained by Campagnol *et al.* (2012) who reported that increased plant density (by decreased plant spacing) usually, for most species, raises biomass productivity to a certain limit, after which productivity remains equal or decreases. Opposite trend reported by Bellad and Umesh (2018) they found that total and marketable yields/ ha were linearly decreased with an increase in plant spacing from 0.5 to1.5 m.

Effect of N fertilization levels of watermelon:

Significant effect of N fertilization levels on watermelon characters in both seasons (Table, 3). Increasing N fertilization levels from 40 up to 80 kg N/fad gradually increased growth, yield components and fruit yield/fad. Sufficient supply of N is associated with high photosynthetic activity and vigorous vegetative growth and also helpful for the production of female flowers (John *et al.,* 2004). Application of 80 kg N/fad increased yield and its components by 8.4 and 9.7% of branches number/plant; 9.7 and 10.6% of fruits number/plant; 11.6 and 8.6% of mean fruit weight and 15.8 and 17.1% of fruit yield/fad compared to 40 kg N/fad in first and second season, respectively. These results are agreement with those obtained by Kacha *et al.* (2017) who found that yield of fruit per plant and per hectare were registered maximum under higher dose of nitrogen (125 kg/ha). Nowaki *et al.* (2017) founded that the high response of watermelon to the supply of N fertilization. The nitrogen applied at 150 kg N/ha significantly increased fruit yield and fruit weight as compared to 100 and 125 kg N/ha (Bellad and Umesh, 2018).

Noteworthy, variation between two levels of 60 and 80 kg N/fad did not show a significant difference in most cases. These results may be due to positive residual effect of faba bean, which increased air fixed N and reduce applied doses of N fertilization. These results get support from the work was done by several studies have demonstrated substantial savings (up to 100–200 kg N/ ha) in the amount of N fertilizer required to maximize the yield of crops grown following faba bean (Jensen *et al.,* 2010; Espinoza *et al.,* 2015). Moreover, legume N-fixing plants can acquire 50 to 70% of the essential N needed from the air, resulting in a lack of competition for below-ground resources with co-crops (Mueller *et al.,* 2015). Also, fruit yield /fad may not affect by increasing N fertilization than recommended doses. These results are accordance with Sabo *et al.* (2013) application of 150 kg N/ha in watermelon significantly increased the fruit yield compared with that at 60 kg N/ha, but at 200 kg N/ha it had no significant effect, where the increase in yield was mainly due to significant increase in fruit size.

Interaction effects:

Regarding interaction effects, results in Table 3 show that all studied characteristics of watermelon did not significantly affect by the interaction of plant spacing and N fertilization levels of watermelon, except average fruit weight and fruit yield/fad, in both seasons. The lowest values of fruit weight and fruit yield/fad were obtained with intercropping watermelon at 50cm spacing with applied 40 kg N/fad. This indicates that the increase in plant density of watermelon with insufficient nitrogen fertilization resulted in an increase in competition between plants and reduce yield and its components. These results are in agreement with the findings of Sylvestre *et al.* (2014) who reported that decreased spacing may increase crowding and decrease yield of watermelon. So, growing watermelon at space 100 cm with applied 60 and 80kg N/fad had the highest average fruit weight 4.26 and 4.85 kg in first and second season, respectively. However, the maximum fruit yield 25.46 and 25.00 ton/fad were obtained with relay intercropping watermelon spacing at 75 cm between hills, that is received 80 kg N/fad. These results may be attributed to high plant population of watermelon at 75 cm compensated the reduction in average fruit weight compared to planting space at 100 cm. These results in line with Sabo *et al.* (2013) the use of 150 kg N/ha at a spacing of 1 × 1.5 m should be adopted by the farmers for watermelon production and profitable.

Table (3): Effect of watermelon plant spacing, N fertilization levels and their interaction on watermelon characters relay intercropping with faba bean in both seasons

Trait / Treatment		Branches Length (cm)		Number of branches /plant		Number of fruits /plant		Mean fruit weight (kg)		Fruit yield ton/fad	
		2020/21	2021/22	2020/21	2021/22	2020/21	2021/22	2020/21	2021/22	2020/21	2021/22
Plant spacing A											
50 cm		150.40C	154.40C	7.63C	6.70A	2.65C	2.45C	2.57C	2.78C	22.48B	22.35B
75 cm		157.83B	163.05B	8.97B	7.54B	2.98B	2.83B	3.60B	3.96B	23.97A	23.79A
100 cm		166.46A	172.56A	10.37A	8.93A	3.15A	3.16A	4.13A	4.75A	22.59B	23.36A
F test		**	**	**	**	**	**	**	**	**	*
N fertilization B											
40 kg/fad		152.51B	157.20B	8.62B	7.32C	2.78B	2.65 B	3.20B	3.68B	21.05B	20.95B
60 kg/fad		159.30A	163.66AB	9.02A	7.82B	2.95A	2.86A	3.54A	3.87A	23.61A	24.02A
80 kg/fad		162.88A	169.15A	9.34A	8.03A	3.05A	2.93A	3.57A	3.93A	24.38A	24.54A
F test		**	**	**	**	**	**	*	*	**	**
Interaction A×B											
50 cm	**40**	143.06	147.03	7.33	6.40	2.53	2.38	2.20e	2.55d	20.37f	20.02f
	60	152.66	155.76	7.73	6.80	2.70	2.46	2.71d	2.83c	22.77d	22.90d
	80	155.46	160.40	7.83	6.90	2.73	2.50	2.80d	2.96c	24.29b	24.13c
75 cm	**40**	154.46	157.46	8.63	7.03	2.70	2.65	3.46c	3.83b	21.68e	21.56e
	60	158.93	162.73	8.93	7.63	3.03	2.86	3.66bc	4.06b	24.97a	24.82a
	80	160.10	168.96	9.36	7.96	3.20	3.03	3.70bc	4.00b	25.26a	25.00a
100 cm	**40**	160.00	167.10	9.90	8.53	3.10	2.93	3.93b	4.66a	21.10e	21.26e
	60	166.30	172.50	10.40	9.03	3.13	3.30	4.26a	4.73a	23.10c	24.33b
	80	173.10	178.10	10.83	9.23	3.23	3.25	4.21a	4.85a	23.58c	24.50b
F test		n.s	n.s	n.s	n.s	n.s	n.s	*	*	*	*
Pure stand		184.50	192.00	12.23	10.60	3.30	3.10	3.52	3.39	24.91	24.65

* and **: significant at 5% and 1% probability in an F test; whereas ns means not significant. Different letters in the same row indicate significant differences according to Duncan test (P≤0.05).

Results in Table (3) confirm that growing watermelon in sole culture increased branch length and number of branches/plant over all intercropping treatments. These results could be attributed to increased interspecific competition of faba bean (overstory crop) and watermelon (understory) on solar radiation, where branching stage of watermelon initiate before harvesting faba bean. However, intercropping faba bean with watermelon increased fruit weight/plant, when watermelon planting at spacing 75 and 100 cm irrespective N fertilization levels. Whereas, fruit yield/fad of intercropped watermelon superior sole culture only in two cases, when watermelon planting at 75 cm and received 60 and/or 80 kg N/fad. This confirms that relay intercropping watermelon with faba bean at spacing 75 cm, as sole culture, and applied 80 kg N/fad (recommended level) or 75% of recommended level (60 kg/fad) improved mean fruit weight and fruit yield/fad compared sole watermelon. Faba bean is the best companion plants for nutrients, increasing the available N supply for intercrop at low cost (Espinoza *et al.,* 2015).

III- Competition index

Land equivalent ratio (LER)

Results presented in Table 4 show that the relative yield of faba bean crop was ever lower than those of the relative yield of the watermelon, could be attributed to plant density of intercropped faba bean was 67% of its sole culture. However, individual plants of faba bean had greater yield per plant in the intercrop than in the sole crop (Table, 2). Data also revealed that intercropping watermelon at spacing 75 cm and applied 60 and/or 80 kg N/fad had the highest relative yield of watermelon over pure stand. Therefore, the highest land equivalent rations 1.75 and 1.76 were produce with intercropping watermelon at 75 cm with applied 80 and 60 kg N/fad, in first and second, respectively. So, both of N fertilization levels at 60 and 80 kg/fad had the same value of LER as average of both seasons, which was 1.75. However, the lowest values of LER 1.54 and 1.53 were obtained with narrow spacing 50 cm and low levels of N fertilization 40 kg/fad in first and second seasons, respectively.

Table (4): Effect of interaction of plant spacing and N fertilization level of relay intercropping watermelon with faba bean on land equivalent ratio in both seasons

Treatment	Trait	Land equivalent ratio			Land equivalent ratio		
		L_{melon}	$L_{faba\ bean}$	LER	L_{melon}	$L_{faba\ bean}$	LER
		First season			Second season		
50 cm	40 kg N/fad	0.82	0.72	1.54	0.81	0.72	1.53
	60 kg N/fad	0.91	0.75	1.66	0.93	0.72	1.65
	80 kg N/fad	0.98	0.75	1.73	0.98	0.73	1.71
75 cm	40 kg N/fad	0.87	0.72	1.59	0.87	0.73	1.60
	60 kg N/fad	1.00	0.74	1.74	1.01	0.75	1.76
	80 kg N/fad	1.01	0.74	1.75	1.01	0.74	1.75
100 cm	40 kg N/fad	0.85	0.72	1.57	0.86	0.75	1.61
	60 kg N/fad	0.93	0.74	1.67	0.99	0.74	1.73
	80 kg N/fad	0.95	0.75	1.70	0.99	0.73	1.72

Although, all intercropping treatments increased LER than unit, implying a yield advantage for the intercropping system. In other words, 53 to 76 % land area will be required for the sole crop to obtain similar yield, as obtained from intercropping system. These results are in accordance with those obtained by Huang *et al.* (2015) and Miller and Greene (2018), Abd Allah *et al.* (2020) they found that watermelon relay intercropping attained yield advantage with LER values over than 1.0.

Area time equivalent ratio (ATER)

Results in Table (5) confirm that values of ATER always were less than LER and behaved the same trend of LER. The highest ATER 1.05 and 1.06 were produced with applied 80 kg N/fad, in first season, and 60 or 80 kg N/fad, in second season, to watermelon planting at 75 cm. In general, any intercropping treatment had value of ATER larger than 1.0, it implies yield advantage, while intercropping treatments had ATER values lesser than 1.0, yield disadvantages exist. In 2020/2021 season, ATER value were higher than unit with applied 80 kg N/fad, irrespective plant spacing of watermelon, while 60 kg N/fad had ATER higher than unit only with plant distance at 75 cm. However, both nitrogen levels 80 and 60 kg N/fad had values of ATER higher than unit, irrespective watermelon plant spacing, in 2021/2022 season. This indicated that the relative yield of watermelon more response to N fertilization levels than plant spacing in both seasons. Results are in line with Nowaki *et al.* (2017) founded that the high response of watermelon to the supply of N fertilization. The nitrogen applied at 150 kg N/ha significantly increased fruit yield and fruit weight as compared to 100 and 125 kg N/ha (Bellad and Umesh, 2018).

Table (5): Effect of interaction of plant spacing and N fertilization level of relay intercropping watermelon with faba bean on area time equivalent ratio and aggressivity in both seasons

Treatment	Trait	ATER	Aggressivity		ATER	Aggressivity	
			A_{melon}	A_{faba}		A_{melon}	A_{faba}
		First season			Second season		
50 cm	40 kg N/fad	0.93	-1.15	1.15	0.93	-1.15	1.15
	60 kg N/fad	1.00	-0.34	0.34	1.00	-0.25	0.25
	80 kg N/fad	1.03	0.24	-0.24	1.03	0.29	-0.29
75 cm	40 kg N/fad	0.96	-1.07	1.07	0.97	-1.09	1.09
	60 kg N/fad	1.04	-0.18	0.18	1.06	-0.20	0.20
	80 kg N/fad	1.05	0.35	-0.35	1.06	0.34	-0.34
100 cm	40 kg N/fad	0.94	-1.10	1.10	0.98	-1.17	1.17
	60 kg N/fad	1.00	-0.30	0.30	1.04	-0.21	0.21
	80 kg N/fad	1.02	0.19	-0.19	1.03	0.29	-0.29

Aggressivity (A)

Aggressivity estimated the variation in competitive ability of the component crops in intercropping system. The (+) sign confirms the dominant crop and the (-) sign confirms the dominated crop. Higher aggressive value indicates a greater difference in competitive ability, as well as a greater disparity between actual and expected yield in both crops. Results in Table (4) revealed that faba bean was the dominant crop component with applied 40 and 60 kg N/fad, while faba bean was the dominated crop with applied 80 kg N/fad, irrespective plant spacing of watermelon. The best aggressivity values 0.18 and 0.20 were obtained by intercropping watermelon at plant spacing 75 cm which received 60 kg N/fad in first and second season, respectively. While the worst values of aggressivity 1.15 were obtained with dense planting of watermelon at 50 cm along with applied 40 kg N/fad in both seasons. This indicated that insufficient N levels with the dense plant density per unit area increased crowding between intercrop components. These results are in agreement with those obtained by Abd Allah *et al.* (2020) also reported that values of aggressivity under intercrop showed that wheat was a higher competitive and dominant crop over watermelon in the intercropping systems.

Economic evaluation

The total return and net return of relay intercropped watermelon with faba bean as compared to solid watermelon in both seasons are shown in Table (6). Relay intercropping watermelon at plant distance 75 cm between hills in both seasons increased total and net returns compared to other plant spacing. Overall, application 80 kg N/fad gave the highest total return 54169 and 58600 L.E./fad, followed by 53792 and 58546 L.E/fad with applied 60 kg N/fad in first and second season, respectively, with unrecognized distinctions. Whereas, the highest net return 24036 and 27123 L.E/fed were obtained by intercropping watermelon at plant spacing 75 cm with applied 80 kg N/fad in first season and 60 kg N/fad in second season, respectively. However, net return as average of both seasons not substantial differences between N fertilization levels 60 and 80 kg/fad. Therefore, we recommended with applied 60 kg N/fad, to rationalize the fertilizer and reduce production costs. On the contrary, application 40 kg N/fad with plant spacing 50 cm had the lowest total and net income in both seasons. Although, the intercropping treatment with the lowest income increased net return by 31.6 and 20.3% as compared to sole watermelon in the first and second seasons, respectively. This result is in line with most other field studies reported that intercropping watermelon increased grower‘s profitability (Miller and Greene, 2018; Abd Allah *et al.,* 2020).

Table (6): Effect of interaction of plant spacing and N fertilization level of relay intercropping watermelon with faba bean on total return, cost and net return in both seasons

Treatment	Trait	Total return LE/fad	Total cost LE/fad	Net return L.E./fad	Total return LE/fad	Total cost LE/fad	Net return L.E./fad	Average of net return in both seasons
		First season			Second season			
50 cm	40 kg N/fad	46563	29653	16910	49751	31153	18598	17754
	60 kg N/fad	50628	29893	20735	54566	31393	23173	21954
	80 kg N/fad	53024	30133	22891	56940	31633	25307	24099
75 cm	40 kg N/fad	48470	29653	18817	52571	31153	21418	20117
	60 kg N/fad	53792	29893	23899	58516	31393	27123	25511
	80 kg N/fad	54169	30133	24036	58600	31633	26967	25502
100 cm	40 kg N/fad	47600	29653	17947	52464	31153	21311	19629
	60 kg N/fad	50987	29893	21094	57481	31393	26088	23591
	80 kg N/fad	51959	30133	21826	57427	31633	25794	23810
Sole watermelon		**37965**	**25115**	**12850**	**42075**	**26615**	**15460**	**14155**

CONCLUSION

In Egypt, there is large gap between production and consumption of faba bean, and it can be overcome by finding unconventional practices to increase faba bean production, such as relay intercropped with other crops. Our results indicated that relay intercropping watermelon with faba bean at plant spacing 75 cm apart with applied 60 kg N/fad produced 24.90 ton/fad of watermelon fruits, in addition to produced 8.3 ardab/fad seed of faba bean. Which increased the net return by 80.2 % and increased land use by 75%, as well as reduce N fertilizer use by 20 % compared to solid watermelon cultivation averaged over both seasons. It is evident that, intercropping is more profitable than the sole planting of watermelon.

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تأثير مسافات الزراعة ومستويات التسميد النتروجينى للبطيخ المحمل مناوباً مع الفول البلدي وعلاقته بالإنتاجية

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اقترحت هذه الدراسة زراعة الفول البلدي بمناطق زراعة البطيخ عن طريق التحميل المناوب للبطيخ المتبادل مع الفول لتقليل الفجوة بين إنتاج واستهلاك الفول، وزيادة إنتاجية وحدة مساحة من الأرض، وتقليل استخدام الأسمدة النيتروجينية وزيادة دخل المزارع. لذا أجريت تجربة حقلية بمحطة بحوث الإسماعيلية- محافظة الإسماعيلية - مصر، خلال موسمي ٢٠٢١/٢٠٢٠ و ٢٠٢٢/٢٠٢١ لدراسة تأثير ٣ مسافات لزراعة البطيخ المناوب مع الفول البلدي (٥٠- ٧٥- ١٠٠سم بين الجور) و٣ مستويات من التسميد النتروجينى المعدني (٤٠ – ٦٠- ٨٠ كجم نتروجين /ف)على إنتاجية كلا المحصولين و كفاءة استخدام الأرض والعائد الإقتصادي من وحدة المساحة. استخدم تصميم القطع المنشقة مرة واحدة في ثلاث مكررات، حيث وضعت مسافات الزراعة في القطع الرئيسية و معاملات معدلات التسميد في القطع الشقية. وأوضحت النتائج الآتي: صفات النمو والمحصول للفول البلدي لم تتأثر معنويا بمسافات الزراعة و مستويات التسميد النتروجينى للبطيخ وكذلك التفاعل في كلا الموسمين. على النقيض، أثرت مسافات زراعة ومستويات التسميد النتروجينى للبطيخ معنويا على محصول البطيخ ومكوناته في كلا الموسمين. أدت زيادة مسافة الزراعة من ٥٠ إلى ١٠٠سم مع إضافة ٨٠ كجم ن /ف إلى زيادة في طول الفرع وعدد الأفرع / نبات وعدد الثمار/النبات ومتوسط وزن الثمرة تدريجياً، بينما سجلت الزراعة على مسافة ٧٥ سم مع إضافة ٨٠ كجم ن/ف أعلى القيم لمحصول ثمار البطيخ في كلا الموسمين، ولكن دون فروق معنوية مع مستوى التسميد النتروجينى٦٠كجم/ فدان، في معظم الصفات. حقق تحميل البطيخ بزراعته على مسافة ٧٥سم وإضافة ٦٠ و ٨٠ كجم ن/ف أعلى القيم من كفاءة استخدام الأرض ١.٧٥ المكافئ الزمني ١.٠٥. بينما تحقق أعلى صافى دخل ٢٥٥١١جنية/ف مع ٦٠ كجم ن/ف وكان على قدم المساواة مع صافى الدخل ٢٥٥٠٢ بإضافة ٨٠ كجم نتروجين/ف، بفروق يمكن تجاهلها.

الخلاصة: التحميل المناوب للبطيخ مع الفول البلدي بزراعة البطيخ على مسافة ٧٥سم وإضافة ٦٠ كجم نتروجين/ف حقق ٢٤.٩طن ثمار بطيخ/ف + ٨.٣ أردب فول للفدان مع زيادة صافى الدخل بنسبة ٨٠.٢% و ترشيد استخدام السماد بنسبة ٢٥% مقارنة بالزراعة المنفردة للبطيخ.