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INFLUENCE OF ONION PLANTING DENSITY INTERCROPPED WITH SUGAR BEET ON PRODUCTIVITY CHARACTERS AND ROOT ROT INCIDENCE OF SUGAR BEET

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ABSTRACT

The present investigation was carried out at Kafr El-Hamam, Sharkia Governorate, Egypt during 2018/2019 and 2019/2020 seasons to investigate the effect of onion density intercropped with sugar beet on the productivity of the two crops, competitive indices, net returns and root rot incidence of sugar beet. The treatments were arranged in randomized complete block design with three replications. The experiment included 6 treatments: one, two, three and four rows of onion intercropped with sugar beet as well as solid sugar beet and onion. Solid sugar beet gave the highest root diameter and the lowest purity (%) in the two seasons. Also, it gave the highest value for each of studied trait as compared with intercropped sugar beet in one season. Solid onion (T2) gave the highest values in onion yield and the studied traits followed by T4. Yield components of onion intercropped with sugar beet were decreased by increasing onion row number. The highest LER and net return were obtained with intercropping two rows of onion between sugar beet rows meanwhile, the lowest LER was recorded by intercropping four rows of onion. Intercropping onion decreased root rot (%). It is recommended intercropping two rows of onions on the middle terrace, 10 cm between hills and 15 cm between the two rows: with sugar beet which were growing in both sides of terrace 120 cm width, this system gave the highest value for each of rate of yield, LER, net income and reducing root rot (%) without using chemical methods.

INTRODUCTION

Sugar beet was planted in Egypt to help fulfilling the gap between sugar production and consumption, besides sugarcane. So, Sugar beet was commercially grown in Egypt in 1982, where it covered 16.900 thousand fad., which extended to 982.771 thousand fad in 2021. Nowadays, it contributed to 67.7% of the total sugar production amounted to 2.711 million tons (**Sugar Crops Council, 2021**). Egypt suffers from the defragment of arable land tenure, where small growers want to satisfy their social needs from small-sizes fields. Therefore, they tend to intercrop some winter crops as onion with sugar beet. Also, sugar beet is the suitable crop for intercropping because sugar beet as (C3 crop) has a slow growth rate, especially at early growth stages, which encourage to intercropping some winter crops with sugar beet to increased food production per unit area and farmers benefit as well as to optimize utilizing land, water and other resources. Moreover, intercropping sugar beet characterized with its tap root with onion, having superficial root system and

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tabular leaves, will help in an efficient utilization of soil rhizosphere, water and solar radiation (**Dunn *et al.*, 1999**). In the same direction, onion is very much suite to intercropping with sugar beet. Root rot diseases of sugar beet caused by *Rhizoctonia solani* (*AG 2-2 IIIB* and *AG 2-2 IV*), *R. crocorum*, *Aphanomyces cochlioides*, *Phoma betae*, *Macrophomina phaeseolina*, *Fusarium oxysporum f.sp. radicis-betae*, *Pythium aphanidermatum Phytophthora drechsleri*, *Rhizopus stolonifer*, *R. arrhizus* and *Sclerotium rolfsii* cause significant losses wherever sugar beets are grown. However, not all these soil-borne pathogens have been reported in all sugar beet production areas. Losses include reduced harvestable tonnage and reduced white sugar recovery. Many of these pathogens also cause post-harvest losses in storage piles **(Windels *et al*., 1997)**. In plant protection programs, it has become necessary to utilize non-chemical methods for controlling insect pests and diseases. There are two ways, by which intercropping can suppress soil-borne disease, one of them is to reduce the attacks by pathogens, and the other one is to increase disease resistance of host plant **(Ratnadass *et al*., 2012; Boudreau, 2013)**. Control for diseases caused by these pathogens include disease resistant cultivars, avoidance of stresses, cultural practices such as water management and the use of intercropping systems. **Abd Allah *et al*. (2020)** showed that intercropping two rows of onion with sugar beet under sand soil significantly increased root, top and sugar yields/fad of sugar beet, total soluble solids and bulb characters as well as nitrogen use efficiency (NUE). Meanwhile, increasing onion plant density up to four rows significantly increased plant height and onion yield/fad. **(Agu, 2008)** showed that intercropping reduced weed, pest and diseases. **Xiao *et al*. (2012)** reported that intercropping between cucumber and garlic has stimulated population of bacteria and actinomycetes, and inhibited fungi, which suggests that this intercropping system can improve soil biology. In variable environments, plants have evolved defense systems to response to pathogen attacks **(Chisholm *et al*., 2006)**. The potential agents in disease resistance system include pathogenesis-related proteins (PRs), defense enzymes, plant hormones and other defense related proteins (**Shamrai, 2014)**.

Ning *et al.* (2012) reported that, the allelopathy of welsh onion root exudates collected by continuous root exudates trapping system (CRETS) was studied on *Fusarium oxysporum* f. sp. *cucumerinum,* The results showed that Inhibitory effects on hypha growth and spore germination of *Fusarium oxysporum* f. sp. *cucumerinum* enhanced with increasing concentration of root exudates.

The objective of this study was to find out the appropriate planting density of onion intercropped with sugar beet to increase the productivity, quality characters of both crops, land equivalent ratio and decrease root rot incidence of sugar beet without using chemical methods.

MATERIALS AND METHODS

The present investigation was carried out at Kafr El-Hamam, Sharkia Governorate, Agriculture Research Center (ARC),, Egypt (Lat. 30º 44′ 22″ N, Long 30º 58 ′09″ E) during 2018/2019 and 2019/2020 seasons to investigate the effect of onion planting density intercropped with sugar beet on the productivity, quality characters of the two crops, competitive indices, net returns and root rot incidence of sugar beet. The experiment included six treatments: (T1): solid sugar beet sown on both sides of 120-cm terraces (beds) at 20-cm distance between hills, (T2): solid onion (5 rows) on beds, (T3): intercropping one row of onion in the middle of the two rows of sugar beet representing 20% of the solid planting of onions; (T4): intercropping two rows of onion in the middle of the two rows of sugar beet representing 40% of the solid planting of onions; (T5): intercropping three rows of onion in the middle of the two rows of sugar beet representing 60% of the solid planting of onions and (T6): intercropping four rows of onion in the middle of the two rows of sugar beet representing 80% of the solid planting of onions. Solid and intercropped onions were grown at 10-cm apart within row and 15-cm between rows. Solid onion was used only for competition relationships. Intercropped sugar beet was sown on both sides of 120 cm terraces at 20 cm distance between hills. Onion cultivar "Giza 20" and sugar beet "Sarah Hs0061" multigerm cultivar were used as planting material. The source of planting material was onion research department and sugar crops research institute, respectively. The preceding summer crop was rice (Sakha 101). The experiments were carried out in clay loam soil. Soil analysis of the experimental site (0-30 cm depth) is presented in Table 1 according to standard methods described by **Piper (1950) and Jackson (1973**). DTPA-extractable Fe, Mn and Zn were measured in soil. The sample of soil was taken before planting.

The studied patterns were arranged in a randomized complete block design with three replications. The area of experimental plot was16.8 m^2, which consisted of 4 terraces (3.5 m long×1.2 m width). Onion seedlings were planted with 1st post-planting irrigation of sugar beet. Planting date of sugar beet was 20th November and 25th November in 2018/2019 and 2019/2020 seasons, respectively. Meanwhile, onion transplanting was done on 15th and 20th of December in 2018/2019 and 2019/2020 seasons, respectively. Sugar beet and onion plants were harvested on 15th and 17th of May and 20th and 22th May in the 1st and 2nd seasons, respectively. Other agronomic practices were applied according to the technical recommendations of sugar beet and onion crops. The meteorological data during the two seasons was obtained from the following website:https://power. larc. nasa.gov/data-access- viewer/. The data are presented in Table 2.

Harvest Measurements

At harvest, the following traits were determined on five sugar beet plants from each plot: Root length (cm), root diameter (cm), root fresh weight/plant (g) and top fresh weight/plant (g). Root and top fresh yields/fad., were recorded on the basis of plot area and then converted to ton/fad. Quality traits [(Total soluble solids (%) (TSS %), sucrose (%) and purity (%)] were measured at Sugar Crops Research Institute, Agricultural Research Center, Giza, Egypt. Sucrose (%) was measured in fresh samples of sugar beet root using saccharometer according to the method described by **AOAC (1995).** Sugar yield/ fad., was calculated as follows:

Sugar yield/fad = root yield/fad × sucrose (%) × purity (%)

At harvest, five onion plants were randomly taken as replicates from each treatment to estimate the following traits: Plant height (cm), number of leaves/plant, bulb diameter (cm), bulb weight/plant (g), fresh plants weight at 150 and 180 (g) days. Onion yield (ton)/ fad was determined on the basis of plot and then converted to fad. Bulbing ratio was measured at 150 and 180 days as following:

Bulbing ratio: it was estimated as a ration of the greatest diameter of bulb to the minimum neck bulb diameter according to **Mann (1952).**

Disease incidence (%) of sugar beet was calculated as follow:

Disease incidence (%) = No. of infected roots/total roots x 100.

Table 1. The physical and chemical analyses of the soil site after rice

physical analysis		Chemical analysis	
Sand (%)	59.1	**pH 1:2.5**	7.8
Silt (%)	20.0	**E.C. (ds/m)**	1.1
Clay (%)	20.9	**Calcium carbonate (%)**	7.5
Soil texture	Clay loam	**Macro and micronutrients**	
		Nitrogen (ppm)	10.1
		Phosphorous (ppm)	23.9
		Potassium (ppm)	30.4
		Magnesium (ppm)	26.2
		Sodium (ppm)	105.3
		Iron (ppm)	18.9
		Mn (ppm)	13.6
		Zn (ppm)	1.1
		Cu (ppm)	1.2

Table 2. Monthly mean of the meteorological data of the experimental site in 2018 and 2019 seasons

	First season		
Season and month	**Temperature (C°)**	**Relative humidity (%)**	**Rainfall (mm)**
2018-11	24.46	50.93	0.55
2018-12	19.96	55.90	4.79
2019-01	14.92	61.48	7.87
2019-02	12.10	49.81	1.51
2019-03	13.71	53.83	9.98
2019-04	15.95	52.20	7.16
2019-05	19.75	44.19	2.23
	Second season		
2019-11	24.96	54.09	36.42
2019-12	21.09	53.28	0.79
2020-01	15.09	61.61	19.85
2020-02	12.46	66.83	11.15
2020-03	13.87	63.37	6.20
2020-04	16.55	56.90	13.05
2020-05	19.21	54.27	4.05

Competitive Indices Analysis

Competitive relationship

Land Equivalent Ratio (LER)

It was determined according to **Mead and Willey (1980)** equation as follows:

LER = (Yab/Yaa) + (Yba/Ybb),

Where:

Yaa = solid yield of crop a (sugar beet), Ybb = solid yield of crop b (onion), Yab = intercrop yield of crop a (sugar beet), Yba = intercrop yield of crop b (onion).

Relative crowding coefficient (K)

It was estimated by multiplying the coefficient for the sugar beet (K_{ab}) by the coefficient of the onion crop (K_{ba}), **Dewit (1960)** according to the following equation of:

$$K = K_{ab} \ x \ K_{ba}$$

$$K_{ab} = \frac{Y_{ab} \ x \ Z_{ba}}{(Y_{aa} - Y_{ab}) \ x \ Z_{ab}}$$

$$K_{ba} = \frac{Y_{ba} \ x \ Z_{ab}}{(Y_{bb} - Y_{ba}) \ x \ Z_{ba}}$$

Where:

Z_{ab} = the area ratio of intercropped sugar beet crop

Z_{ba} = the area ratio of intercropped onion crop

Aggressivety

It means a comparison of how much relative yield increase for the intercropped crop (a) on crop (b) with the expected crop to find out which of the two crops dominated in yield according to **Mc-Gilchrist (1960)**.

Ag for sugar beet=(Yab/(Yaa x Zab)- (Yba/(Ybb x Zba)

Ag for onion=(Yba/(Ybb xZba)-(Yab/ (Yaa x Zab)

If the aggressivity value reaches zero, it means that both crops have the same competitive ability, and the value of aggressiveness is the same for both crops, but one of the values is positive and the other is negative. The higher the value of the aggressiveness, the larger the difference between the actual yield and the yield expected.

Economic Evaluation

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

Total return/fad. (LE) = (Price of sugar beet yield × productivity) + (price of onion yield × productivity).

Net return/fad. (LE) = total return – (fixed costs of sugar beet + variable costs of onion).

The average of sugar beet and onion price and costs were presented by **Bulletin of Statistical Cost Production and Net Return (2018)** and the market price. The local prices were LE 625 of one ton of sugar beet roots, LE 74 of one ton of tops and LE 2039 of one ton of onion, this price can be decreased to LE 1000 for low quality onion.

Statistical Analysis

Data were analyzed according to **Snedecor and Cochran (1988)**. Treatment means were compared using Least Significant Differences (LSD) test at 0.05 level of probability (**Waller** and **Duncan**, **1969**). Statistical analysis was performed by using analysis of variance technique using MSTAT-C statistical package (**Freed, 1991**).

RESULTS AND DISCUSSION

Effect of Different Onion Plant Densities on Sugar Beet Yield and Traits

Results in Table 3 show that the studied intercropping systems significantly affected root diameter , top fresh weight / plant and

Table 3. The studied sugar beet harvest and quality traits as affected by densities of onion in 2018/2019 season

Treatment	Harvest traits							Quality traits		
	Root length (cm)	Root diameter (cm)	Top fresh weight/ plant (kg)	Root fresh weight (kg)	Root yield/fad. (ton)	Top fresh weight / fad. (ton)	Sugar yield/ fad. (ton)	TSS (%)	Sucrose (%)	Purity (%)
(T1) Solid sugar beet	41.0	9.80	1.31	1.05	32.51	16.95	4.66	20.5	14.6	71.2
(T3) one row onion intercropped with sugar beet	39.2	9.50	1.13	0.94	31.91	14.22	4.77	20.3	15.5	76.3
(T4) 2 rows of onion intercropped with **sugar beet**	37.7	9.20	1.10	0.90	31.27	12.65	4.68	19.6	15.2	77.5
(T5) 3 rows of onion i**ntercroppe**d **with sugar beet**	37.4	8.90	0.96	0.85	30.55	12.53	4.64	20.3	15.2	74.8
(T6) 4 rows of onion intercropped with sugar beet	35.9	8.65	0.94	0.83	29.28	13.15	4.39	19.3	15.0	77.7
Mean	38.24	9.21	1.088	0.914	31.11	13.90	4.69	20	15.1	75.5
LSD at (0.05)	NS	0.72	0.06	NS	NS	0.96	NS	NS	NS	2.68

top yield per fad. Also, there was significant difference in yield/fad., in 1st season. The results cleared that the solid planting of sugar beet recorded the highest value for each of root diameter, top fresh weight/plant and top yield per fad, and the lowest percentage of purity. Insignificant differences were noticed among T1, T3 and T4 as well as among T4, T5 and T6 in root diameter. It can be noticed that increasing the density of onion intercropped with sugar beet to 4 rows (T6) caused a substantial reduction in sugar beet root diameter, top fresh weight/plant and top yield per fad. and root yield/fad., probably due to increasing the competition degree among plants for *i.e*., nutrients, carbon dioxide solar radiation and water. The results revealed that root length was insignificantly influenced by the applied intercropping patterns. Similar results were shown in the 2nd season, these results are similar to those obtained by **Azad and Alam (2004**) who reported that yield of sugar beet root has been reduced by intercropping with onion, compared to solid sugar beet and so, the results were in agreement with those found by **Abdel Motagally and Metwally (2014) and Masri and Safina (2015).** Sugar beet yield was decreased by increasing in onion rows number. Intercropping one or two rows of onion (T3 and T4) in intercropping treatments gave the highest values in this regard while, T6 gave the lowest value. These results agreed with **El-Shamy *et al*. (2015) and Abd Allah *et al*. (2020)** who conducted that intercropping two rows of onion with sugar beet significantly increased root, top and sugar yields/fad of sugar beet, compared to 3 and 4 rows of onion.

Effect of Different Onion Plant Densities on Quality Characters of Sugar Beet

The results in Tables 3 and 4 show that, there was insignificant difference in sucrose (%) and TSS (%) while there was significant difference in purity (%) character. T6 gave the highest values in sucrose (%)and purity (%) while T1 and T3 gave the highest TSS during both seasons, on other hand, T1 and T3 resulted in the lowest values for each of sucrose(%) and purity (%). These results may be due to the root's weight and size rather than the intercropping pattern effect. Quality traits maybe seemed to be associated with root weight and governed by the dilution theory. The higher root weight was, the less sucrose and purity percentage were obtained. These results were in line with those of **Abd Allah *et al.*** (**2020)** who conducted that the lowest values of sucrose and purity percentage achieved with the solid culture of sugar beet in both seasons, also these results may be due to, the influence of the meteorological condition which presented in Table 2.

Effect of Different Onion Plant Densities Intercropping on Sugar Yield

Although, there was insignificant difference in sugar yield among treatments, the results in Tables 3 and 4 show that, intercropping one row of onion with sugar beet (T3) gave the highest yield of sugar yield/fad., which were 4.77 and 4.57 ton/fad., in 1st and 2nd season, respectively followed by T4. On other hand, intercropping 4 rows of onion gave the lowest yield of sugar (4.36 and 4.12 ton/fad). These results were in accordance with **El-Shamy *et al*. (2015)** and **Abd Allah *et al*. (2020) who** conducted that intercropping two rows of onion with sugar beet increased sugar yields/fad of sugar beet as compared to other treatments.

Effect of Different Onion Plant Densities Intercropping with Sugar Beet on Onion Yield Components

The results in Tables 5 and 6 point that, there were significant differences in onion yield and its component. The results indicated that, solid onion (T2) recorded the

Table 4. The studied sugar beet harvest and quality traits as affected by densities of onion in 2019/2020 season.

Treatment	Harvest traits							Quality traits		
	Root length (cm)	Root diameter (cm)	Top fresh weight/ plant (kg)	Root fresh weight (kg)	Root yield/ fad. (ton)	Top yield/ Fad. (ton)	Sugar yield/ fad. (ton)	TSS (%)	Sucrose (%)	Purity (%)
(T1) Solid sugar beet	42.4	11.71	1.48	1.20	32.32	23.859	4.66	20.2	14.5	71.7
(T3) one row onion intercropped with sugar beet	41.6	11.48	1.27	1.09	30.23	22.004	4.77	20.3	15.5	76.3
(T4) 2 rows of onion intercropped with sugar beet	40.6	11.31	1.20	1.04	28.48	21.898	4.68	19.5	15.0	76.9
(T5) 3 rows of onion intercropped with sugar beet	40.0	10.90	1.11	0.95	27.39	20.906	4.27	19.5	15.6	80.0
(T6)4 rows of onion intercropped with sugar beet	38.5	10.55	1.09	0.93	25.80	20.800	4.12	18.3	16.0	87.4
Mean	40.62	11.19	1.23	1.04	28.84	21.893	4.62	19.5	15.2	78.4
LSD at (0.05)	NS	0.8	0.21	0.11	4.5	2.9	NS	NS	NS	3.5

Table 5. Yield and yield components as well as quality of onion as affected by densities of onion intercropped with sugar beet in 2018/2019 season

Plant density of onion	Plant height (cm)	No. of leaves/ plant	Bulb diameter at 150 days (cm)	Bulb diameter at 180 days (cm)	Fresh plant weight (g) at 150 days	Fresh plant weight (g) at 180 days	Growth rate	Bulb weight/ plant (g)	Bulbing ratio at 150 days	Bulbing ratio at 180 days	Onion yield (ton/ fad.)
(T2) Solid onion	95.6	11.0	4.13	5.30	152.3	185.6	0.43	105.3	1.6	2.6	15.78
(T3) one row onion intercropped with sugar beet	75.6	7.6	2.80	3.60	113.1	136.6	0.23	84.3	1.2	2.1	2.48
(T4) 2 rows of onion intercropped with **sugar beet**	86.5	7.3	2.80	3.42	101.0	117.0	0.13	63.2	1.2	1.9	3.72
(T5) 3 rows of onion intercropped **with sugar beet**	87.3	7.0	2.66	2.98	90.6	101.3	0.16	52.6	1.3	1.8	3.45
(T6)4 rows of onion intercropped **with sugar beet**	90.3	6.6	2.20	2.50	83.0	91.3	0.03	50.6	1.2	1.9	4.27
Mean	87.0	7.9	2.91	3.56	108	126.3	0.19	71.2	1.3	2.06	5.94
LSD at (0.05)	8.45	0.90	0.54	0.61	13.19	10.10	0.09	3.67	0.2	0.5	0.90

Table 6. **Yield and yield components as well as quality of onion as affected by densities of onion intercropped with sugar beet in 2019/2020 season**

Plant density of onion	Plant height (cm)	No. of leaves/ plant	Bulb diameter at 150 days (cm)	Bulb diameter at 180 days (cm)	Fresh plant weight(g) at 150 days	Fresh plant weight(g) at 180 days	Growth rate	Bulb weight/plant (g)	Bulbing ratio at 150 days	Bulbing ratio at 180 days	Onion yield (Ton/ fad.)
(T2) Solid onion	93.7	10.9	4.11	5.1	151.8	186.2	0.45	106.5	1.6	2.6	15.52
(T3) one row onion intercropped with sugar beet	76.0	7.9	2.90	3.9	115.1	140.1	0.15	87.3	1.2	2.1	2.32
(T4) 2 rows of onion intercropped with **sugar beet**	84.5	7.1	2.78	3.33	102.0	120.2	0.001	68.3	1.2	1.9	3.52
(T5) 3 rows of onion intercropped **with sugar beet**	86.0	6.8	2.70	2.9	81.2	91.5	0.09	55.4	1.3	1.8	3.67
(T6)4 rows of onion intercropped **with sugar beet**	89.3	6.5	2.0	2.2	75.1	83	0.05	52.8	1.2	1.9	4.0
Mean	85.9	7.8	2.89	3.48	105.0	124.2	0.14	74.06	1.3	2.06	5.806
LSD at (0.05)	6.5	0.8	0.19	0.8	16.0	14.2	0.03	4.5	0.5	0.7	1.02

highest value as compared with intercropping patterns in all characters in the two seasons. These results may attributed to the fact that intercropping onion with the sugar beet increased the competition on solar radiation and other nutrient compared to the solid culture and so the onion was the lowest in competition on solar radiation and other nutrient. These results were in agreement with **El-Shamy *et al*. (2015) and Abd Allah *et al*. (2020)** who said that solid onion gave the highest values as compared with intercropping treatments**.** Regarding intercropping treatment, the results indicated that plant height was increased by increasing number of rows of onion intercropped with sugar beet. The highest values of plant height (90.3 cm and 89.3cm) cm were obtained by intercropping four rows of onion with sugar beet in the two seasons respectively, while the shortest plants were obtained by decreasing onion plant density to one row (T3) intercropped with sugar beet (75.6 and 76) cm. These results are probably referred to the competition for light intercepted by foliage might be the cause to length onion height, these results were in accordance with those obtained by **El-Shamy *et al*. (2015) and Abd Allah *et al*. (2020)**. On other hand, number of leaves/plant, bulb diameter at 150 and 180 day, fresh plant weight at 150 and 180 day, growth rate and yield/plant were decreased by increasing number of rows of onion from one row to four rows. These results may be due to the high competition above ground for light intercepted by foliage and high competition for nutrient by sugar beet. Also, these results may be due to increasing in top size of sugar beet which increased by plant age progression of sugar beet which caused increasing in canopy on onion especially the rows neighboring to sugar beet leading to a reduction in photosynthesis process and ultimately decreased all yield components, these results are in agreement with **Dunn *et al*. (1999)** who showed that the onion is shallow-rooted bulbs and having a low canopy, so they do not compete with space and deep-rooted long duration crop. In regard to bulb diameter, there were increasing in bulb diameter during 150-180 day but the increasing differed among treatments because there was difference in fresh plant weight, which reverse on bulb diameter. These differences in foliage display and rooting patterns create the space dimension of intercropping, these results were similar with **El-Shamy *et al*. (2015) and Abd Allah *et al.* (2020).**

Effect of Different Onion Plant Densities Intercropping on Bulbing Ratio

The results in Tables 5 and 6 indicate that, there was significant difference among treatments in growth rate and bulbing ratio. Solid planting of onion recorded the highest values as compared to intercropping culture. Intercropping one row (T3) and two rows onion (T4) were higher in growth rate and bulbing ratio as compared with intercropping 3 (T5) and 4 rows onion (T6). These results may be attributed to decreasing in dry weigh which accumulate because increase in top size of sugar beet which increased with plant age progression which caused increasing in canopy on onion especially the rows besides sugar beet. Increasing the canopy on onion decreased photosynthesis which decreased accumulation dry weight as well as the onion have low canopy and do not compete with space and deep-rooted long duration crop. There was significant difference between treatments of bulb factor in 150 day and 180 days but this increasing was higher in T3 and T4 as compared to T5 and T6, These findings may be due to increasing bulb diameter as results of increasing photosynthesis and dry matter accumulation.

Effect of Different Onion Plant Densities Intercropping with Sugar Beet on Onion Yield/fad.

The results in Table 5 and 6 show that there was significant difference between cropping systems, of yield/fad. in the two seasons. Solid planting was the highest in yield/fad. (15.78 and 15.52) as compared with intercropping treatments because increasing component yield in solid culture. These results were in agreement with those found by **El-Shamy *et al*. (2015) and Abd Allah *et al*. (2020).** In regard to intercropping systems, intercropping four rows of onion with sugar beet gave the highest of this trait followed by intercropping two rows of onion, as compared with -yielding onion intercropped at one and three rows by 72.1%and 23.7% in the first season, corresponding to 72.4% and 13.6% in the second one, respectively. Although, yield components of onion intercropped with sugar beet were decreased by increasing number of rows, took the reverse direction, these results may be due to increasing rows number of onion intercropped with sugar beet. These results are similar with **El-Shamy *et al*. (2015) and Abd Allah *et al.* (2020).**

Effect of Different Onion Plant Densities on Root Rot (%) in Sugar Beet

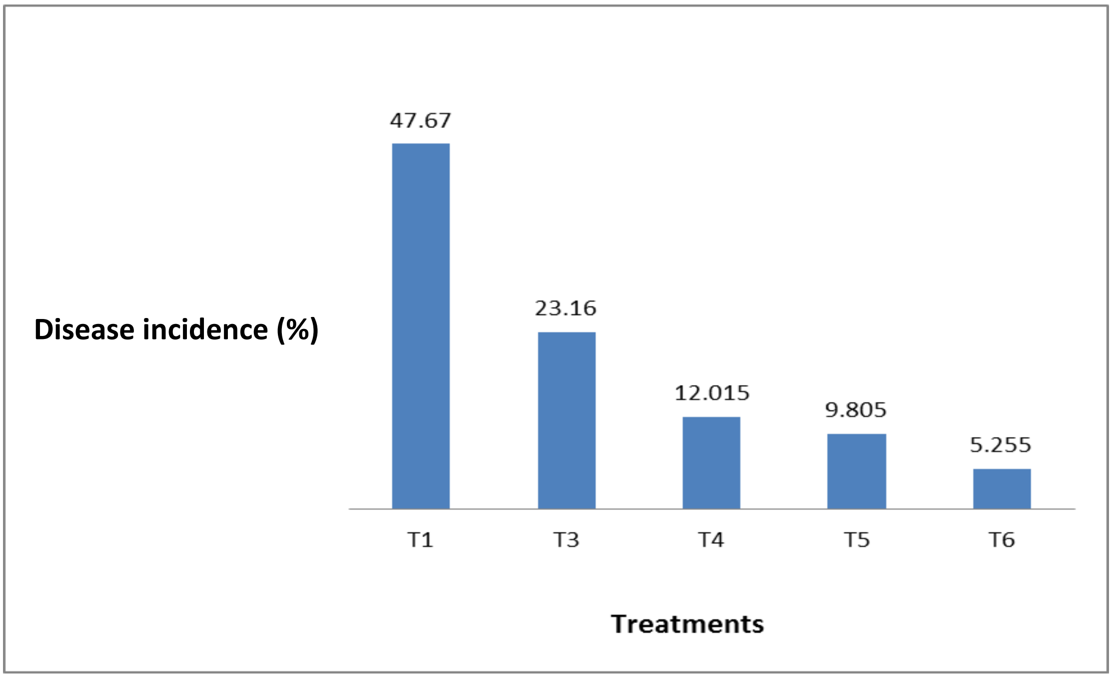
The obtained results in Table 7 show that there were significantly differences among treatments and so, it revealed that in general, sugar beet root rot was decreased in all intercropping treatments as compared with solid culture. Root rot (%) was decreased by increasing rows number of onion intercropping with sugar beet. These results may be due to onion root exudates consist of a variety of compounds, for example, *h*exahydro-3-(2-methylpropyl)-pyrrolo[1,2-a]pyrazine-1,4-dione, Nformyl-tyramine, dibutyl phthalate or hexahydro-3-(phenylmethyl)- pyrrolo[1,2-a] pyrazine-1,4-dione, which involved in inhibition of root-rot activity. The exudate compounds may likely have a complex interrelationship on resistance against root rot (**Li *et al*., 2018).** Increasing density of onion intercropped with sugar beet to four rows (T6) resulted in the lowest root rot disease incidence during the two growing seasons, it recorded (5.40 and 5.11%) compared with solid sugar beet treatment (50.23 and 45.11) during two growing seasons, respectively. On the contrary, decreasing the density of onion intercropped with sugar beet to one row gave 23.74% and 22.62% in two seasons comparing with solid sugar beet treatment. These results are in the same line with the main disease incidence under intercropping between onion and sugar beet during two growing season 2018/2019 and 2019/2020 as recorded in Fig 1.

These results may be due to focused on the less pathogen attacks, by the alteration of microenvironment and formation of “root wall” to restrict the spread of spores (**Gómez-Rodrıguez *et al.*, 2003; Gao *et al*., 2014**), or by the increase of soil microbial antagonism for pathogens (**Ren *et al*., 2008; Fengzhi and Xingang, 2009)**, or/ and by the direct inhibition of pathogens with root exudates from companied plants (**Ren *et al*., 2008; Hao *et al*., 2010; Gao *et al*., 2014; Yang *et al*., 2014)**.

Studies by **Ramert and Lennartsson (2002)** have indicated that intercropping reduces the proportion of susceptible host tissues and, therefore, impacting on the production, amount and efficiency of the disease inoculum and, therefore, limiting spread and development of the disease. In addition, intercropping increases the distance to be travelled by the disease inocula. Further, the onion plants may have created a physical barrier that intercepted or filtered the fungal propagules, thus effectively limiting dissemination of the

Table 7. Root rot disease (%) of sugar beet affected by densities of onion at 2018/2019 and 2019/2020 seasons

Treatment	Disease root rot incidence (%)		
	2018/2019 season	2019/2020 season	Average
(T1) Solid sugar beet	50.23a	45.11a	47.67
(T3) 1 row of onion intercropped with sugar beet	23.74b	22.62b	23.16
(T4) 2 rows of onion intercropped with sugar beet	12.88c	11.15c	12.015
(T5) 3 rows of onion intercropped with sugar beet	10.49c	9.12c	9.805
(T6) 4 rows of onion intercropped with sugar beet	5.40d	5.11d	5.255
Mean	20.548	18.622	19.58
LSD at 0.05	7.1	6.5	



T1= Solid sugar beet, **T3=** one row onion intercropped with sugar beet, **T4=** 2 rows of onion intercropped with sugar beet, **T5=** 3 rows of onion intercropped with sugar beet and **T6=**4 rows of onion intercropped with sugar beet

Fig. 1. Main average disease incidence (%) under intercropping between onion and sugar beet during two growing seasons 2018/2019 and 2019/2020

pathogen. **Song *et al.* (2007)** showed that intercropping has significant effects on microbiological and chemical properties in the rhizosphere, which may contribute to the yield enhancement by intercropping. These results may be due to focused on the less pathogen attacks, by the alteration of microenvironment and formation of “root wall” to restrict the spread of spores **(Gómez-Rodrıguez *et al.,* 2003; Gao *et al.,* 2014)**, or by the increase of soil microbial antagonism for pathogens **(Ren *et al.,* 2008; Fengzhi and Xingang, 2009)**, and/or by the direct inhibition of pathogens with root exudates from companied plants **(Ren *et al.,* 2008; Hao *et al.,* 2010; Gao *et al.,* 2014; Yang *et al.,* 2014).** These results mean that, intercropping may be method to reduce root rot (%) without using chemical methods.

Competitive Relationship

Effect of planting density of onion intercropped with sugar beet on land equivalent ratio (LER)

Land equivalent ratio (LER) was used to compare the yields in intercropping systems with the same crops in solid culture (**Mead and Willey, 1980**). Results listed in Table 8 reveal that the means of the relative yield of sugar beet were higher than those of the relative yield of onion indicating that relative yield positively correlated with plant density per unit area in the two seasons. Relative yield of sugar beet in T3 and T4 gave the highest value where, it gave (0.98 and 0.96) and (0.93 and 0,88) in the first and second seasons, respectively. Results recorded showed that all values of LER ratios of onion density intercropping with sugar beet were greater than 1.0 in all treatments as compared to solid culture. These results mean that intercropping gave advantages in land use efficiency which means the actual productivity of intercropping treatments was higher than solid culture in two seasons. The highest values of LER (1.19 and 1.10) were produced by intercropping two rows of onion (T4) with sugar beet in two season, respectively. Meanwhile, the lowest LER values were achieved by intercropping one row of onion with sugar beet (T3) in first season where it gave 1.13 while intercropping 4 rows of onion with sugar beet gave the lowest value in second season, it gave 1.05. This may be due to decreasing plant density of intercropped onion from four to one and two rows could be decreased intra and interspecific competition between two spices crops for basic growth resources, carbon dioxide, solar radiation and water and consequently formed suitable above and under-ground conditions for growth and development of both crops, so the final yield of two crops were increased which led to increase the value of LER. These results are in harmony with those obtained by **Abdel Motagally and Metwally (2014), El-Shamy *et al*. (2015), Masri and Safina (2015), Zohry *et al*. (2017) and Abd Allah *et al*. (2020)**.

Effect of planting density of onion intercropped with sugar beet on relative crowding coefficient (K):

Relative crowding coefficient (K) is the measure of the relative dominance of one species over the other in intercropping (**Dewit, 1960**). When the product of two coefficients (K sugar x K onion) is greater than one, there is a yield advantage, if the value of K is one there is no yield advantage and if less than one there is no yield advantage and the system has the disadvantage (**Khan *et al.,* 2001**). The results in Table 8 indicated that, (K) is greater than one: range (9.85-1.35) in the two seasons, that means all intercropping treatments have yield advantage. Average values of sugar beet exceeded those of onion indicating that sugar beet was a good competitor in all treatment and the dominant component, whereas onion was the un dominated (Table 8). The results showed higher values of the relative crowding coefficient (RCC) more than unity

Table 8. Effect of onion plant density intercropped with sugar beet on land equivalent ratio (LER), aggressivity (Agg) and relative crowding coefficient (K) in 2018 and 2019 seasons

Years	2018/2019								2019/2020							
Character	Land equivalent ratio			Aggressivity (Agg)		Relative crowding coefficient			Land equivalent ratio			Aggressivity (Agg)		Relative crowding coefficient		
Treatment	L sugar	L onion	LER	Sugar	Onion	Sugar	Onion	K	L sugar	L onion	LER	Sugar	Onion	Sugar	Onion	K
(T3) 1 row of onion intercropped with sugar beet	0.98	0.15	1.13	+0.20	-0.20	10.6	0.93	9.85	0.93	0.14	1.08	+0.19	-0.19	2.88	0.87	2.50
(T4) 2 rows of onion intercropped with sugar beet	0.96	0.23	1.19	+0.37	-0.37	10.0	0.77	7.75	0.88	0.22	1.10	+0.32	-0.32	2.96	0.73	2.16
(T5) 3 rows of onion intercropped with sugar beet	0.93	0.21	1.15	+0.57	-0.57	9.34	0.46	4.29	0.84	0.23	1.08	+0.45	-0.45	3.33	0.51	1.69
(T6)4 rows of onion intercropped with sugar beet	0.90	0.27	1.17	+0.57	-0.57	7.05	0.46	3.24	0.79	0.25	1.05	+0.48	-0.48	3.16	0.43	1.35
Mean	0.94	0.21	1.16	0.42	-0.42	9.26	0.65	6.28	0.86	0.21	1.07	0.36	-0.36	3.08	0.635	1.93
Solid sugar beet	1.0	-	1.0						1.0	-	1.0					

L: relative yield, LER: Land equivalent ratio, K: relative crowding coefficient for T3 and T4 intercropping patterns (one and two rows of onion in the middle of the two rows of sugar beet), while T6 recorded the lowest value. This pointed to clear yield advantage owing to intercropping one and two rows of onion with sugar beet. These results are in line with those obtained by by **Abdel Motagally and Metwally (2014) and Abd Allah *et al*. (2020).**

Effect of planting density of onion intercropped with sugar beet on aggressivety

The results in Table 8 show that, there was difference among intercropping treatments, the aggressivety between crops increased by increasing in rows number of onion intercropping with sugar beet. Sugar beet was the more aggressiveness, but onion was the lowest aggressivety. It was positive with sugar beet while aggressivety was negative with onion. These results may be due to competition degree between sugar beet and onion on nutrients, carbon dioxide, solar radiation and water where the onion have low canopy and low competition for space and deep-rooted long duration crop. Intercropping one row or two with sugar beet was the lowest value of aggressiveness while 4 rows with sugar beet was the highest value. Results are in accordance with those obtained by **Abdel Motagally and Metwally (2014), El-Shamy *et al*. (2015), Masri and Safina (2015), Zohry *et al*. (2017) and Abd Allah *et al*. (2020).**

Effect of planting density of onion intercropped with sugar beet on total and net return

The evaluation of different intercropping treatments was made for the two seasons as a total return and net return of the two components comparative with solid sugar beet as the main crop as shown in Table 9. The results showed that, all intercropping treatment gave the higher total return and net return as compared to solid culture of sugar beet and so total and net returns differed by intercropping treatments. The results revealed that T4 had the highest value for each of total and net returns amounted to LE. 28081 and 18071 respectively in the first season, corresponding to 26602 LE and 16592 in the second season. On the other hand, the lowest values of gross total return 26065 and 25253 LE/fad., were obtained by intercropping one row of onion (T3) with sugar beet in first and second seasons, respectively. Meanwhile, the lowest value of net return was16523 in T3 in first season and 14882 LE/fad in T6 in second season . These results indicated that the best onion intercropping density that positively ensures high productivity and net return was two rows of onion intercropping with sugar beet. These results are in harmony with those obtained by **El-Shamy *et al.* (2015)** who reported benefit of intercropping onion with sugar beet on productivity of both crops. The greatest benefit of intercropping was increasing grower profits (A**bdel Motagally and Metwally, 2014; Masri and Safina, 2015; Zohry *et al*., 2017**).

Conclusion

Results showed that intercropping two rows of onion with sugar beet gave the highest net return, LER, as well as, decreasing in root rot (%) compared to the solid culture of sugar beet in both seasons. Yield components of intercropped onion was decreased by increasing in rows number of onion but onion yield/ fad. took reverse way. In general, intercropping onion with sugar beet played an important role in decreasing root rot (%) of sugar beet. Increasing No. rows of onion decreased root rot (%). As result of intercropping onion with sugar beet, root rot (%) decreased, this led to decrease in losses root, this led to root yield in intercropping treatments was nearly of solid. Although the rate of infection with root rot decreased with the increase in the number of onion rows, (T4) two rows of onion gave the highest advantage yield as compared with all intercropped systems.

Table 9. Effect of onion plant densities intercropped with sugar beet on total return, costs and net return in 2018 and 2019 seasons

	2018/2019							2019/2020						
Character	**Total return**			**Costs**			**Net**	**Total return**			**Costs**			**Net**
Treatment	**Sugar**	**Onion**	**Total**	**Sugar**	**Onion**	**total**	**Net**	**Sugar**	**Onion**	**Total**	**Sugar**	**Onion**	**Total**	**Net**
(T3) one row onion intercropped with sugar beet	21000	5064	26065	9075	467	9542	16523	20523	4730	25253	9075	467	9542	15711
(T4) 2 rows of onion intercropped with **sugar beet**	20484	7597	28081	9075	935	10010	18071	19425	7177	26602	9075	935	10010	16592
(T5) 3 rows of onion intercropped with sugar beet	20026	7034	27061	9075	1402	10477	16584	18667	7483	26150	9075	1402	10477	15673
(T6) 4 rows of onion intercropped with sugar beet	19276	8722	27999	9075	1868	10943	17056	17669	8156	25825	9075	1868	10943	14882
Solid sugar	21578	-	21578	9075	-	9075	12503	21970			9075	-	9075	12895
Mean	20472	7104	26156	9075	1168	10009	16147	19650	6886	25957	9075	1168	10009	15150

Under the conditions of the present work, it can be recommended to grow sugar beet on both sides of 120-cm terraces at 20 cm apart between hills, and to intercrop two rows of onions in the middle of beet rows at a distance of 15 cm between rows and 10 cm between the hills, in order to obtain the highest value of land equivalent ratio and the highest net income for the farmer with a low incidence of sugar beet root rot without using chemical methods.

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الملخص العربي

تأثير الكثافة النباتية للبصل المحمل مع بنجر السكر على الصفات الإنتاجية وأعفان الجذور لبنجر السكر

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اقيمت هذه الدراسة في المزرعة التجريبية - كفر الحمام، محافظة الشرقية، مصر خلال الموسمين 2019/2018 و2020/2019 لدراسة تأثير كثافات البصل المحمل مع بنجر السكر على إنتاجية كلًا المحصولين، دلائل التنافس، صافي العائد الإقتصادى ونسبة الإصابة بأعفان جذور بنجر السكر. نفذت التجربة بتصميم القطاعات الكاملة العشوائية في ثلاث مكررات. تضمنت التجربة 6 معاملات، صف واحد، اثنان، ثلاثة وأربعة صفوف من البصل محملًا مع بنجر السكر بالاضافه الى زراعه كلا من بنجر السُكَّر والبصل منفرداً، تفوق بنجر السكر المنفرد معنويًا في قطر الجذروأعطى أدنى قيمه للنسبة المئوية للنقاوة فى موسمي الزراعة، كما تفوق بنجر السُكَّر المنفرد فى جميع الصفات تحت الدراسه خلال موسم واحد بالمقارنه ببنجر السكر المنفرد. فيما يتعلق بالبصل أوضحت النتائج أن الزراعة المنفردة للبصل حققت أعلى قيمة في جميع الصفات يليها تحميل سطرين من البصل مع بنجر السكر، كذلك اظهرت النتائج ان مكونات محصول البصل المحمل نقصت بزيادة عدد سطور البصل المحمل مع بنجر السكر، أعطي تحميل سطرين من البصل مع بنجر السُكَّر أعلي مُعدل لكفاءة استغلال الأرض وصافي العائد النقدي في الموسمين، بينما أعطى تحميل أربعة سطور من البصل أقل مُعدل لكفاءة استغلال الأرض واقل صافي في العائد النقدي. أدى تحميل البصل دوراً مُهماً فى تقليل نسبة الإصابة بأعفان جذور البنجر. نوصي بزراعة سطرين من البصل تحميلًا على بنجر السكر والزراعة على مصاطب 120 سم حيث يتم زراعة بنجر السكر علي جانبي المصطبة ويتم زراعة سطرين من البصل علي ظهر المصطبة 10 سم بين الجور و15 سم بين السطرين وذلك يعطى أعلى معدل لاستغلال الأرض وأعلي صافى دخل للمزارع مع انخفاض الإصابة بأعفان الجذور في البنجر بدون استخدام طرق كيمائية.

الكلمات الاسترشادية: المحاصيل المحملة، البصل، بنجر السكر، نسبة المكافئ الارضي، صافي العائد، نسبة الاصابة باعقان الجذور.

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