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EFFECT OF INTERCROPPING PATTERNS AND NITROGEN FERTILIZER LEVELS ON PRODUCTIVITY OF INTERCROPPED SUGAR BEET AND SUNFLOWER

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ABSTRACT: Two field experiments were conducted during two winter successive seasons 2013/2014 and 2014/2015 at Gemmeza Research Station, El Gharbia Governorate, Egypt to study the effect of two patterns of mono cropping and intercropping *i.e.*: P1-Sunflower was planted in one row at the top of the terrace, 20 cm apart between hills one plant hill^{-1} (17500 plants fad.$^{-1}$) to achieve (100% sugar beet + 50% sunflower). P2- Sunflower was planted in one row at top of the terrace, 30 cm apart between hills one plant hill^{-1} (11666 plants fad.$^{-1}$) to achieve (100%sugar beet + 33.33% sunflower). P3- Sunflower was planted in one row at top of the terrace, 40 cm apart between hills one plant hill^{-1} (8315 plants fad.$^{-1}$) to achieve (100%sugar beet + 25% sunflower). In all intercropping patterns, sugar beet was planted at 20 cm a part on two sides of the terrace (35000 plants fad.$^{-1}$). The sole treatments of sugar beet and sunflower were grown at the recommended densities (35000 plants fad.$^{-1}$) 20 cm, one plant hill^{-1} in one side in ridge 60 cm wide, and three nitrogen fertilizer levels (80, 100 and 120 kg N fad.$^{-1}$) on yield and land use efficiency of sugar beet (*Beta vulgaris* L.) – sunflower (*Helianthus annuus* (L.) Merr.) intercropped. The results showed that**:** root length and diameter, top and root weights plant^{-1} and top, root and sugar yields fad.$^{-1}$, as well as purity, total soluble solids (%) (TSS%) and sucrose (%) of sugar beet were significantly increased by reducing sunflower plant density in intercropped with sugar beet from 50 to 33.3 and up to 25% of its pure stand in both seasons and their combined analysis. The reduction in root yield fad.$^{-1}$, of sugar beet were 8.64 and 4.58% for intercropping patterns which including 50.0 and 33.3% sunflower plant density of its pure stand in combined analysis, respectively, compared with 25.0%. Increasing N fertilizer levels from 80 up to 120 Kg N fad.$^{-1}$, significantly increased all aforementioned traits of sugar beet, expect quality traits behaved with opposite trend in both seasons and combined analysis. There was significant effect of relay intercropping patterns in most sunflower traits. Plant height and seed yield fad.$^{-1}$, of sunflower were significantly increased by increasing sunflower plant density with sugar beet from 25, 33.3 and up to 50%, whereas yield components showed opposite trend in both seasons as well combined analysis. All aforementioned traits of sunflower were significantly increased by increasing N fertilizer level from 80, 100 and up to 120Kg N fad.$^{-1}$, in both seasons and combined analysis. The highest value of Land Equivalent Ratio (LER) 1.50, Land Equivalent Coefficient (LEC) (0.53), Area Time Equivalent Ratio (ATER) (1.15) were obtained with intercropping planting pattern (100% sugar beet + 50% sunflower) at 120 Kg N fad.$^{-1}$, and the best yield advantage Relative Crowding Coefficient (RCC) was obtained with (100% sugar beet + 25% sunflower) at the same level of N fertilizer. The highest values of Monetary Advantage Index (MAI) (4750 LE) and gross profit (14252 LE) were showed with (100% sugar beet + 50% sunflower) under 120 Kg N fad^{-1}.

Key word: Sugar beet, sunflower, intercropping, nitrogen fertilizer, economic evaluation.

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INTRODUCTION

One of the main problems associated with the Egyptian agricultural system is the small area of cultivated land per farmer. In average, 42.9% of the farmers own or work in field area about one faddan (4200 m^2) (Ahmed *et al.*, 2009). This led to an increase need to maximize land usage to enhance farmer's income. The need to follow practices such as intercropping is a great importance in this context. Intercropping is growing two or more crops on the same spatial and temporal scales, for increasing productivity and profitability per unit area. Intercropping system is more productive than the sole (Umrani *et al*., 1984). The intercropping system greatly contributes to crop production by its effective utilization of resources compared to the monoculture cropping system (Zhang and Li, 2003). Currently, this system was interestingly increasing in low-input crop production systems and was being extensively investigated.

Sugar beet (*Beta vulgaris* L.) is an important crop, worldwide as source of sugar industry. In Egypt, it is the second sugar crop after sugar cane. Egyptian Government imports large amounts of sugar every year to contribute in reducing sugar deficiency gap. Increasing sugar yield per unit area had national interest and it can be achieved by adopting suitable cultural practices such as intercropping system. The area that allocated to sugar beet in Egypt had increased mostly in the recent years (16900 fad., at 1982 to 450000 fad., at 2012 season). Also, sugar beet production from sugar beet largely increased, since the cultivated area in Egypt is limited, the agriculture intensification had become urgent necessity to optimize the utilizing of unit area (Abdel Motagally and Metwally, 2014).

Sunflower (*Helianthus annuus* L. Merr.) is one of the most cultivated oil crops in the world. In recent years, the planted area has increased, sunflower high oil yield due to its ability to tolerate short periods of water deficit (Hattendorf *et al.,* 1988). The oil seeds are the second food stocks after the cereals in the world. Because they not only have enriched of fatty acids but also they are full of proteins. Of these oil seeds, the sunflower is the fourth annual crop as food oil. Sunflower having features such as suitable climate adaptation, soil, high quality of the oil, short growth duration, suitable oil cake, is considered as the most favorable oil productions (Tavakoli, 2013).

Plant density and nitrogen fertilizer level were the most important agronomic practices affected on sunflower yield and seed oil percentage (Bader and Rashed, 1988). Seed yield was positively correlated with plant density, but plant height, head diameter, 100-seed weight and seed yield plant^{-1} were decreased with increasing plant density (Allam and Galal, 1996).

Sugar beet-sunflower intercropping considerably increased monetary returns and produced positive impacts on the soil health and nutrition for the next crop (Stoyanov *et al*., 1997). The intercropping system like sugar beet with cereal crops or with oil seed crops could provide the farmer with high gross returns (Lal and Mukerji, 1998). Badraoui *et al*. (2003) cultivated wheat-sugar beet or sunflower in the irrigated regions of Morocco and recommended sugar beet and sunflower as companion crops. El-Dessougi *et al*. (2003) reported that grown sugar beet with oil seed crops produced higher monetary returns than other companion crops. Tichy *et al.* (2001) found that sugar beet + sunflower increased sunflower yield more than 5 tons ha^{-1} and sugar beet/sunflower intercropping was appeared as most successful companion crops with net benefits.

Nitrogen is the most limiting essential nutrient for sunflower and sugar beet production. It is the main driving force to produce large yields because nitrogen is vitally important and is required in large amounts. Shalaby (1995) reported that N fertilizer increased plant height, head diameter, seed yield plant^{-1}, and seed yield fad^{-1} of sunflower. Abd El-Wahed (1996) found that 60 kg N fad.$^{-1}$, adding to sunflower, resulted in maximum plant height, head diameter, seed yield plant^{-1}, weight of 100 seeds, seed yield fad^{-1}. The interaction between plant spacing and nitrogen rate significantly affected seed oil yield (Bader and Rashed, 1988).

Also, nitrogen is the most important fertilizer elements for sugar beet growth and yield (Badawi, 1989; El-Kassaby and Leilah, 1992). Increasing nitrogen rate up to120 kg N fad.$^{-1}$, significantly increased root length, root diameter as well as root, top and sugar yields fad.$^{-1}$, of sugar beet, but it resulted in marked reduction in TSS, juice purity and sucrose (%) (Sorour *et al*., 1992; El-Hannawy *et al.,* 1998).

The present investigation was planned to study the effect of intercropping patterns of sunflower- sugar beet and different N fertilizer levels on yield and its components of sunflower and sugar beet as well as quality traits of sugar beet and competitive relationships and monetary advantages.

MATERIALS AND METHODS

Two field experiments were carried out in Gemmeza Research Station, El-Gharbia Governorate, during two winter successive growing seasons 2013/2014 and 2014/2015 to study the effect of two planting patterns (sole cropping and intercropping) *i.e*.: P1-Sunflower was planted in one row at the top of the terrace, 20 cm apart between hills one plant hill^{-1} (17500 plants fad.$^{-1}$) to achieve (100% sugar beet + 50% sunflower). P2- Sunflower was planted in one row at top of the terrace, 30 cm apart between hills, one plant hill^{-1} (11666 plants fad.$^{-1}$) to achieve (100% sugar beet + 33.33% sunflower). P3- Sunflower was planted in one row at top of the terrace, 40 cm apart between hills one plant hill^{-1} (8315 plants fad.$^{-1}$) to achieve (100% sugar beet + 25% sunflower). In all intercropping patterns, sugar beet was planted at 20 cm a part on two sides of the ridge (35000 plants fad.$^{-1}$).

Sole treatments of sugar beet and sunflower were grown at the recommended densities (35000 plants fad.$^{-1}$) 20 cm, one plant hill^{-1} in one side in ridge 60 cm wide and three nitrogen fertilizer levels (80, 100 and 120 kg N fad^{-1}.) on yield and yield components as well as yield advantages of sugar beet (*Beta vulgaris* L.) cv. Kawemira and sunflower (*Helianthus annuus* L. Merr.) cv. Giza 102 in intercropping patterns.

Before sowing, the land was prepared and leveled with rotary plough to a depth of 15 cm. The soil was clay loam in texture had an average pH value of 8.1; 1.3% organic matter and had 37, 12 and 380 ppm available N, P and K, respectively (averaged over the two seasons for the upper 30 cm of soil depth).

Seeds of sugar beet and sunflower were sown on 11th and 15th November and 1st and 3rd March and harvested on 5th and 7th June and 23rd and 26th May in both seasons, for two crops in sole planting and intercropping system, respectively. After three weeks from planted in solid as well as intercropping planting, the plants were thinned to one plant per hill after 21 days for both crops.

The treatments were arranged in split-plot design with three replicates.

Nine treatments were applied *i.e.* combination of three planting patterns (25, 33.33 and 50% of sunflower pure stand) with sugar beet and three nitrogen fertilizer levels (80,100 and120 kg N fad^{-1}) in addition to pure stand of sunflower and sugar beet as recommended. Where, the planting patterns occupied the main plots in intercropped patterns. The nitrogen fertilizer levels were arranged in 1st order sub-plots. The field treatment *i.e.,* sub- plots included five terraces, 3.5 m long and 1.2 m width . Thus, the plot area was 21 m^2.

The solid culture did not included in the statistical analysis, but planted in purpose of estimating the competitive relationship and economic return. The preceding summer crop was maize (*Zea mays* L.) in both seasons.

Nitrogen fertilizer was applied to sole and intercropped sugar beet and sunflower in the form of urea (46% N) in four doses, 20% at the first irrigation, 30% at the second irrigation, 30% at the third irrigation of sugar beet while the last dose 20% was added after thinning sunflower. A basal dose of P and K corresponding to 30 kg P_2O_5 as super phosphate fertilizer (15.5% P_2O_5) and 24 kg K_2O as potassium sulfate (50% K_2O) fertilizer was uniformly broadcasted at the time of seedbed preparation. All the other practices were applied as recommended for each crop. The other agricultural practices were applied as recommended.

Data Recorded

Sugar beet

Ten guarded plants were randomly taken at harvest from the central ridge of each sub- plot to estimate: root length (cm), root diameter (cm), top and root fresh weight plant^{-1} (kg), top and root yields were determined on the whole plot basis then it were transferred to tons fad^{-1}.

Juice quality characteristics

Samples of fresh root were taken from each sub plot to determine:

1. Total soluble solids (%) (TSS %) measured by refract meter according to AOAC (1990).
2. Sucrose percentage was determined according to method describing by Le-Docte (1927).
3. Juice purity percentage was calculated according to the method describing by Carruthers and Old Field (1961).

$$\text{Purity (\%)} = \frac{\text{Sucrose}}{\text{TSS (\%)}} \times 100$$

4. Gross sugar yield (ton fad.$^{-1}$) = root yield (ton fad.$^{-1}$) × (sugar %)

Sunflower

Ten sunflower guarded plants were randomly taken at harvest from each sub-plot to estimate: plant height (cm), head diameter (cm), 100-seed weight (g) and seed yield plant^{-1} (g). Sunflower plants were harvest and threshed from each sub-plots to estimate the seed yield (kg fad.$^{-1}$).

Competitive Relationships and Economic Evaluations

Land use efficiency

In order to assess the land use efficiency, total land equivalent ratio (LER), land equivalent coefficient (LEC), area time equivalent ratio (ATER), relative crowding coefficient (RCC) and aggressivity were determined for each yield recorded per faddan *i.e.* root + seed. This was achieved for cropping systems.

Total Land equivalent ratio (Total LER)

Was suggested by (Monzon *et al*., 2014). It was determined according to do as the sums of yield relative *i.e.* intercrop yields relative to their solid yield. The total LER an accurate assessment of the biological efficiency of the intercropping situation, using the following equation to evaluate and compare the productivity of intercropping and mono cropping: Total LER = (Yab/Yaa) + (Yba/Ybb). Where, Yaa and Ybb are yields as sole crops of a (sugar beet) and b (sunflower) and Yab and Yba are yields as intercrops of a and b, respectively. Values of total LER greater than 1.0 are considered advantages. While, values of total LER less than 1.0 are considered disadvantages.

Land equivalent coefficient (LEC)

A measure of interaction concerned with the strength of relationship was calculated thus, LEC=La × Lb. Where, La= partial LER of main crop and Lb= partial LER of intercrop (Aditiloye *et al*., 1983). For a two- crop mixture the minimum expected productivity coefficient (PC) is 25% that is a yield advantage is obtained if LEC exceeds 0.25.

Area time equivalent ratio (ATER)

The ratio of number of hectare-days required in monoculture to the number of hectare-days used in the intercrop to produce identical quantities of each of the components, was calculated according to Hiebsch and McCollum (1987) as follows:

$$\text{ATER} = (\text{RYa} \times \text{ta}) + (\text{RYb} \times \text{tb})/\text{T or ATER} = \left(\frac{\text{Yab}}{\text{Yaa}} \times \text{ta}\right) + \left(\frac{\text{Yba}}{\text{Ybb}} \times \text{tb}\right)/\text{T}.$$

Where:

RY=Relative yield of crop (a) sugar beet or crop (b) sunflower *i.e.,* yield of intercrop/yield of main crop, t = duration (days) for species a or b and T = duration (days) of the intercropping system.

Relative crowding coefficient (RCC)

RCC was proposed according to De-Wit (1960). It assumes that mixture treatment forms a replacement crops. Each crop has its own coefficient (K) which gives a measure to indicate that crop has produced more, less or equal yield to that expected. It was calculated as follows:

$$K = K_a \text{ x } K_b$$

Where:

Ka for sugar beet, Kb for sunflower and K for the two crops were calculated as follows:

$K_a = Y_{ab} \times Z_{ba} / [(Y_{aa} - Y_{ab}) \times Z_{ab})]$, $K_b = Y_{ba} \times Z_{ab} / [(Y_{bb} - Y_{ba}) \times Z_{ba})]$

Where:

Zab = sown proportion of crop a (sugar beet) in a intercropping with b. Zba = sown proportion of crop b (sunflower) in b intercropping with a.

If a crop has a coefficient less than, equal to or greater than 1, it means it has produced less yield, the same yield or more yield than the expected, respectively.

Aggressivity (A)

Is another index represents a simple measure of how much the relative yield increase in crop a is greater than that of crop b in an intercropping system. It was calculated as: Aab=(Yab/Yaa xZab) – (Yba/Ybb × Zba). Where, Yaa and Ybb are yields as sole crops of a and b and Yab and Yba are yields as intercrops of a and b. Zab and Zba are the sown proportions of a and b, respectively. If Aab = 0, both crops are equally competitive, if Aab is positive, A is dominant, if Aab is negative a is dominated crop (Ghosh *et al*., 2006).

Economic evaluations

Monetary advantage index (MAI)

The price of sugar beet and sunflower were 370, 54 and 3605 LE in 1st season and 379, 57 and 3764 LE in 2nd season for root, top and seed yield per ton, respectively (Bulletin of Statistical Cost Production and Net Return, 2013/2014 and 2014/2015). It suggests that the economic assessment should be in terms of the value of land saved; this could probably be most assessed on the basis of the rentable value of this land. Monetary advantage index (MAI) was calculated according to the formula, suggested by Willey (1979).

MAI= [Value of combined intercrops × (LER–1)]/LER

Gross profit from each treatment was calculated in Egyptian pounds (LE) using the average market price of two seasons (Bulletin of Statistical Cost Production and Net Return, 2013/2014 and 2014/2015).

Statistical Analysis

The obtained data were statistically analyzed according to Steel *et al*. (1997), using "MSTAT-C" computer software package. Least significant differences was used for the comparison between means. Means having the same letters are not significantly different. A combined analysis was made for the data of the two seasons by using the Bartlett's test statistic for homogeneity of variance. In interaction tables capital and small letters were used for comparisons among means of rows and columns, respectively.

RESULTS AND DISCUSSION

Sugar Beet

Relay intercropping planting patterns effect

Results in Table 1 reveal that root length (cm), root diameter (cm), root weight plant^{-1} (kg), top fresh weight Plant^{-1} (kg), top fresh yield fad.$^{-1}$ (ton) and root yield fad.$^{-1}$ (ton) of sugar beet were significantly affected by intercropping patterns in both seasons as well as in combined analysis except, root weight plant^{-1}, where the differences among intercropping patterns did not reach the level of significant. Root length was significantly increased by decreasing sunflower plant density from 50 to 33.3 to 25% of its pure stand in both seasons. The highest values of aforementioned traits were recorded with P_3 (100% sugar beet + 25% sunflower) followed by P_2 (100% + 33.3%) and the lowest value was showed with P_1 (100% sugar beet + 50% sunflower) in both seasons and combined analysis. This results may be due to intra and inter-specific competition between sugar beet plants and sugar beet with sunflower plants for light, water and nutrients. Similar results were obtained by Sorour *et al*. (1992), El-Hannawy *et al.* (1998), Osman and Awed (2010) and Mohammed and Abd El-Zaher (2013).

Intercropping pattern P_3 (100% sugar beet+ 25% sunflower) surpassed in root yield fad^{-1} compared with P_1 and P_2 by 9.47 and 4.77%, respectively in their combined analysis. These results were in agreement with those obtained by Salama and Badawi (1996), Fahmi (1999) and Zhang and Li (2003).

Juice quality characteristics of sugar beet *i.e.* TSS (%), sucrose (%), purity (%) and gross sugar yield fad.$^{-1}$, were significantly decreased by increasing sunflower plant density from 25.0

Table 1. Root length (cm), root diameter (cm), root weight plant^{-1} (kg), top fresh weight plant^{-1} (kg), top fresh yield fad.$^{-1}$ (ton) and root yield fad.$^{-1}$ (ton) of sugar beet as affected by intercropping patterns and N fertilizer levels in both seasons and their combined analysis

Main effects and interaction	Root length (cm)			Roots diameter (cm)			Root weight plant^{-1} (kg)		
	2013/2014	2014/2015	Comb.	2013/2014	2014/2015	Comb.	2013/2014	2014/2015	Comb.
intercropping pattern (P)									
P_1 (100%sugar beet+ 50.00% sunflower)	24.17b	26.00b	25.08c	10.86c	12.09c	11.47c	0.660	0.700	0.680
P_2 (100% sugar beet+ 33.33% sunflower)	26.42a	27.33b	26.88b	12.61b	13.44b	13.03b	0.620	0.810	0.720
P_3 (100% sugar beet+ 25.00% sunflower)	27.98a	31.56a	29.77a	14.19a	16.11a	15.15a	0.710	0.770	0.740
F test	*	*	*	*	*	*	NS	NS	NS
N fertilizer level (kg fad.$^{-1}$) (N)									
N_1 80	24.66b	26.67b	25.66b	11.91b	12.98b	12.44b	0.450b	0.660b	0.550b
N_2 100	25.43b	28.33ab	26.88b	12.22b	13.78ab	13.00b	0.780a	0.740b	0.760a
N_3 120	28.48a	29.89a	29.18a	13.53a	14.89a	14.21a	0.760a	0.880a	0.820a
F. test	*	*	*	*	*	*	*	*	*
Interaction P × N	NS	NS	NS	NS	NS	NS	NS	NS	NS
Solid	29.27	32.47	30.87	17.33	16.29	16.81	0.79	0.82	0.81

Main effects and interaction	Top fresh weight plant^{-1} (kg)			Top fresh yield fad.$^{-1}$ (ton)			Root yield fad.$^{-1}$ (ton)		
	2013/2014	2014/2015	Comb.	2013/2014	2014/2015	Comb.	2013/2014	2014/2015	Comb.
intercropping pattern (P)									
P_1 (100%sugar beet+ 50.00% sunflower)	0.460c	0.530b	0.500c	12.15c	13.86c	13.00c	27.32b	28.01b	27.67c
P_2 (100% sugar beet+ 33.33% sunflower)	0.550b	0.610a	0.580b	13.82b	16.19b	15.00b	28.72ab	29.09ab	28.91b
P_3 (100% sugar beet+ 25.00% sunflower)	0.600a	0.660a	0.630a	15.35a	17.34a	16.34a	30.87a	29.72a	30.29a
F. test	*	*	*	*	*	*	*	*	*
N fertilizer level (kg fad.$^{-1}$) (N)									
N_1 80	0.460c	0.570	0.520c	12.00c	13.86c	12.93c	26.50b	26.42c	26.46c
N_2 100	0.540b	0.600	0.570b	13.73b	15.68b	14.70b	29.46a	29.20b	29.33b
N_3 120	0.610a	0.640	0.620a	15.59a	17.85a	16.72a	30.96a	31.21a	31.08a
F. test	*	NS	*	*	*	*	*	*	*
Interaction P × N	NS	NS	NS	NS	NS	NS	NS	NS	NS
Solid	0.54	0.68	0.61	11.65	13.90	12.78	32.21	32.89	32.55

NS and * meaning; Not significant and significant at 0.05 level, respectively.

to 33.3 up to 50.0% of its pure stand of sunflower in both seasons and combined analysis as shown in Table 2. The highest values of above traits were obtained from relay intercropping planting pattern P_3 (100% + 25%) followed by P_2 (100% + 33.3), while the lowest value was showed with P_1 (100% + 50%) sugar beet/ sunflower in both seasons and combined analysis. This reduction may be due to intra and inter competition between sugar beet and sunflower. Shading effect of sunflower plants on sugar beet plants reduces the process of photosynthesis, formation of sugar in the leaves and its transmission to roots. Similar results were obtained by Salama and Badawi (1996), Fahmi (1999), Mohammed and Abd El-Zaher (2013) and Zhang and Li (2003)

N fertilizer level effect

Results in Tables 1 and 2 reveal that all studied characters of sugar beet were significantly affected by N fertilizer level in both seasons and combined analysis except TSS% where the level of significant did not reach the level of significant during 2nd season and the combined.

The results in Tables 1 and 2 show that root length of sugar beet was significantly increased by increasing nitrogen level from 80, to 120 Kg N/fad., in both seasons and combined analysis. The increase reached about 4.75 and 13.71%, 4.50 and 14.22%, 38.18 and 49.09%, 9.61 and 19.23%, 13.68 and 29.31% as well as 10.84 and 17.46% for root length, root diameter, root weight plant^{-1}, top fresh weight plant^{-1}, top fresh yield fad^{-1} and root yield (ton) fad^{-1} due to application the 1st and 2nd N increment during the combined analysis, respectively. These results may be due to the role of N in activation the growth by stimulation effect for cell elongation, directly after division where nitrogen plans an important role in root length of sugar beet as well as for root diameter. The results coincided with Badawi (1989), Sorour *et al*. (1992), Shalaby (1995), Salama and Badawi (1996), El-Hannawy *et al.,* (1998), Fahmi (1999) and Neana (1999).

Concerning juice quality traits *i.e.,* TSS (%), sucrose (%) and purity (%) and gross sugar yield (ton fad.$^{-1}$) were significantly increased by increasing N fertilizer level from 80 to 100 Kg N fad^{-1} in both seasons and combined analysis as shown in Table 2. The gross sugar yield is an important yield parameter. The differences in root yield and sugar (%) between traits reflected the differences in sugar yield ton fad.$^{-1}$. The highest gross sugar yield (4.21 ton fad.$^{-1}$) was achieved at 100 Kg N fad.$^{-1}$ and followed by 120 Kg N fad.$^{-1}$ (3.94 ton fad.$^{-1}$) in the combined analysis. Similar results were obtained with Sorour *et al.* (1992) and El-Hannawy *et al.* (1998).

Interaction effect

The interaction effect between relay intercropping planting patterns sugar beet-sunflower and N fertilizer levels had no significantly effect on yield characteristics of sugar beet in both seasons and combined analysis as shown in Tables 1 and 2. While all juice quality traits of sugar beet were significantly affected except TSS% in the second season and combined analysis. This means that each of these factors act independently on their effect in these characteristics, consequently the results were excluded.

Sunflower

Intercropping planting patterns effect

Results in Table 3 reveal that plant height, head diameter, seed yield plant^{-1}, 100 seed weight and seed yield fad^{-1} were significantly affected by intercropping patterns in both seasons as well as combined analysis.

Results presented in Table 3 show marked and significant increase in plant height by increasing sunflower plant density from 25 to 33.3 to 50% of its pure stand (35,000 plants fad.$^{-1}$) when intercropped with sugar beet. This increase in sunflower plant height is mainly due to the increase in intra-specific competition on solar radiation at higher sunflower density and *vice versa*. Similar Results were obtained by Osman and Awed (2010) and Mohammed and Abd El-Zaher (2013). In contrary, traits *i.e*. head diameter, 100 seed weight and seed yield plant^{-1} behaved the opposite trend of plant height in both seasons as well as combined analysis. The reduction in these traits were 24.8 and 8.3%, 14.4 and 8.4 and 23.7 and 9.4% for head diameter, 100 seed weight and seed yield plant^{-1}, respectively, when intercropped sunflower with

Table 2. TSS%, Sucrose (%), purity (%) and Gross sugar yield (ton fad.$^{-1}$) of sugar beet as affected by intercropping patterns and N fertilizer levels and interaction in both seasons and their combined analysis

Main effects and interaction		TSS (%)			Sucrose (%)			Purity (%)			Gross sugar yield (ton fad.$^{-1}$)		
		2013/14	2014/15	Comb.	2013/14	2014/15	Comb.	2013/14	2014/15	Comb.	2013/14	2014/15	Comb.
Intercropping pattern (P)													
P_1 (100%sugar beet+ 50.00% sunflower)		17.07c	16.64	16.85	12.99b	13.13b	13.06b	76.10c	78.91b	77.50c	3.55b	3.67c	3.61b
P_2 (100% sugar beet+ 33.33% sunflower)		17.76b	16.81	17.28	13.64ab	13.35a	13.49ab	76.80b	79.42a	78.11b	3.89b	3.88b	3.89ab
P_3 (100% sugar beet+ 25.00% sunflower)		18.11a	17.11	17.60	14.59a	13.48a	14.03a	80.56a	78.78ab	79.67a	4.50a	4.00a	4.25a
F. test		*	NS	NS	*	*	*	*	*	*	*	*	*
N fertilizer level (kg fad.$^{-1}$) (N)													
N_1 80		17.63b	17.18a	17.40a	13.78a	13.46b	13.62a	78.16b	78.35c	78.25b	3.65c	3.56b	3.61b
N_2 100		18.50a	17.56a	18.03a	14.75a	13.87a	14.31a	79.73a	78.99b	79.36a	4.37a	4.05a	4.21a
N_3 120		16.81c	15.81a	16.31b	12.69b	12.63c	12.66b	75.49c	79.89a	77.69c	3.93b	3.95a	3.94ab
F. test		*	NS	*	*	*	*	*	*	*	*	*	*
Interaction between P and N													
Intercropping patterns													
Sugarbeet : sunflower	**80**	17.47b	17.17	17.32	12.85c	13.32c	13.09 b	73.55g	77.58g	75.57g	3.17c	3.39bc	3.28c
P_1 (100%+ 50.00%)	**100**	17.75b	17.33	17.54	13.40cb	14.17a	13.78a	75.49f	81.77b	78.63c	3.73bc	4.04b	3.89b
	120	16.00d	15.41	15.70	12.73c	11.90e	12.32e	79.56c	77.22h	78.39cd	3.74bc	3.58bc	3.66bc
Sugar beet : sunflower	**80**	18.20b	17.30	17.75	15.18a	13.47c	14.32b	83.41b	77.86f	80.63b	3.83bc	3.57bc	3.70bc
P_2 (100%+ 33.33%)	**100**	17.93b	17.70	17.82	13.57b	13.92b	13.74b	75.68f	78.64e	77.16e	4.00b	4.17a	4.09b
	120	17.14c	15.41	16.27	12.17c	12.66d	12.41d	71.00h	82.15a	76.58f	3.83bc	3.91b	3.87b
Sugar beet : sunflower	**80**	17.23c	17.07	17.15	13.31c	13.58b	13.44c	77.25d	79.55d	78.40cd	3.93bc	3.71bc	3.82b
P_3 (100%+ 25.00%)	**100**	19.81a	17.64	18.73	17.28a	13.51b	15.40b	87.23a	76.59i	81.91a	5.36a	3.94b	4.65a
	120	17.28bc	16.61	16.93	13.17c	13.35c	13.26d	76.22e	80.37c	78.29cd	4.22b	4.36a	4.29a
F. test		*	NS	NS	*	*	*	*	*	*	*	*	*
Solid		16.80	17.18	16.99	12.79	13.41	13.10	76.05	77.64	76.84	4.09	4.40	4.26

NS and * meaning; Not significant and significant at 0.05 level, respectively.

Table 3. Plant height (cm),head diameter (cm), seed yield plant^{-1} (g), 100 seed weight (g) and seed yield fad.$^{-1}$ (kg) of sunflower as affected by intercropping patterns and N fertilizer levels in both seasons and their combined analysis

Main effects and interaction	Plant height (cm)			Head diameter (cm)			Seed yield plant^{-1} (g)			100 seed weight (g)			Seed yield fad.$^{-1}$ (kg)		
	2013/14	2014/15	Comb.	2013/14	2014/15	Comb.	2013/14	2014/15	Comb.	2013/14	2014/15	Cozmb.	2013/14	2014/15	Comb.
Intercropping pattern (P)															
P_1 (100%sugar beet + 50.00% sunflower)	164.56a	159.00a	161.78a	10.51b	11.11bc	10.81c	42.44bc	43.33b	42.89c	4.89b	4.84c	4.86c	600.83a	590.56a	595.69a
P_2 (100% sugar beet + 33.33% sunflower)	155.78b	153.22b	154.50b	14.12a	12.27b	13.19b	44.00b	47.78a	45.89b	6.00a	5.54b	5.77b	360.76b	473.83b	417.30b
P_3 (100% sugar beet + 25.00% sunflower)	139.78c	162.56a	151.17b	14.26a	14.52a	14.39a	49.89a	50.33a	50.11a	6.31a	6.43a	6.37a	230.91c	360.31c	295.61c
F. test	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
N fertilizer level (kg fad.$^{-1}$) (N)															
N_1 80	150.11b	152.67b	151.39c	11.49b	11.48b	11.48b	43.00b	44.00c	43.50c	5.01b	5.03b	5.02b	327.26b	452.50bc	389.88c
N_2 100	151.33b	159.00a	155.17b	13.11a	12.81a	12.96a	45.11a	47.00b	46.06b	5.91a	5.76a	5.84a	420.53a	451.76b	436.14b
N_3 120	158.67a	163.11a	160.89a	14.29a	13.61a	13.95a	48.22a	50.44a	49.33a	6.29a	6.02a	6.15a	444.71a	520.44a	482.58a
F. test	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Interaction P × N	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Solid	155.00	162.00	158.50	15.30	15.70	15.50	50.00	51.00	50.50	6.07	6.29	6.18	1075.00	1100.00	1087.50

NS and * meaning; Not significant and significant at 0.05 level, respectively.

sugar beet at 50 and 33.3% plant density of its pure stand compared with 25% during combined analysis. These increases may be attributed to the less inter- specific competition under 25% plant density of sunflower with sugar beet compared with other intercropping patterns. It could be concluded that these traits were decreased by increasing sunflower plant density due to dense sowing lead to a severe competition among sunflower plants for nutrients, water supply and light. Similar results were obtained by Bader and Rashed (1988), Allam and Galal (1996), Al-Thabet (2006) and Osman and Awed (2010).

Results in Table 3 indicate that intercropping sunflower plant density at 50% with sugar beet (P_1) occupied the first rank in seed yield fad^{-1} which recorded 595.69 Kg, followed by 33.3% (P_2) it recorded 417.30 Kg fad^{-1} while 25% (P_3) produced the lowest seed yield (295.61 Kg fad^{-1}). The superiority in seed yield fad^{-1} of sunflower grown in intercropping pattern P_1 may be due to increase in number of plants fad^{-1} compared to P_3. Similar results were reported by Zhang and Li (2003).

N fertilizer levels effect

Results in Table 3 show that sunflower plant height, head diameter, 100 seed weight, seed yield plant^{-1} and seed yield (ton fad.$^{-1}$) were significantly increased by increasing nitrogen levels from 80 to 100 and up to 120 Kg N fad^{-1} by 2.5 and 6.3%, 12.9 and 21.5%, 5.9 and 13.4%, 16.3 and 22.5% as well as 11.9 and 23.8% due to 1st and 2nd N increment for aforementioned traits, respectively in combined analysis. The increase in plant height may be due to N encourage both meristematic activity and auxin production in plants and thus increase meristematic activity, cell elongation, metabolic processes in plants and in turn increases growth which resulting in the superiority of head diameter, 100 seed weight and seed yield plant^{-1} and consequently increased seed yield fad^{-1} of sunflower plants. These results are in harmony with those obtained by Abd El-Wahed (1996), Al-Thabet (2006) and Ail *et al*. (2014).

Interaction effect

plant height, head diameter, 100-seed weight, seed yield plant^{-1} and seed yield fad^{-1} were not significantly affected by the interaction between intercropping patterns and nitrogen fertilizer levels in both seasons and combined analysis as shown in Table 3.

Competitive Relationships and Monetary Advantage

Land equivalent ration (LER)

It is obvious from Table 4 that each N increment resulted in a significant increase in LER values which calculated on root and seed yields at all intercropping patterns whereas, results conclude that, intercropping pattern P_1 (100% sugar beet + 50% sunflower) and fertilized plants with 120 Kg N fad^{-1} recorded the highest LER (1.50) this means that land usage ratios significantly increased by 50% compared with sugar beet alone. The values of L_B of sugar beet were higher than those L_S of sunflower over all intercropping patterns. On the other hand, the lowest value (1.10) of LER was showed with ntercropping pattern P_3 (100% sugar beet + 25% sunflower) at 80 Kg N fad^{-1}. Similar results were obtained by Lal and Mukerji (1998) Tichy *et al*. (2001) Badraoui *et al*. (2003) and Abdel Motagally and Metwally (2014).

Land Equivalent Co-efficient (LEC)

It is obvious from Table 4 that, each N increment up to 120 kg fad.$^{-1}$ resulted in a significant increase in LEC values which calculated on root + seed yields at all intercropping patterns whereas, results conclude that, intercropping pattern P_1 (100% sugar beet + 50% sunflower) and fertilized sugar beet and sunflower plants with 120 Kg N fad^{-1} recorded the highest LEC value (0.53). On the other hand, the lowest value (0.20) of LEC was showed with intercropping pattern P_3 (100% sugar beet + 25% sunflower) at 80 Kg N fad^{-1}, in this case yield disadvantage. This means that all treatments had LEC values above 0.25 suggesting yield advantages and showed efficient utilization of land resource by growing both crops together and *vice versa*.

Area time equivalent ratio (ATER)

The highest area time equivalent ratio (1.15) was obtained with P_1 at 120 kg N fad.$^{-1}$ as average of two seasons. This value indicated

Table 4. Crop yield fad.$^{-1}$, land equivalent ration (LER), land equivalent coefficient (LEC), area time equivalent ratio (ATER), relative crowding coefficient (RCC), aggressivity (Agg.), monetary advantage index (MAI) and gross profit LE fad.$^{-1}$, of sugar beet (L_B) and sunflower (L_s) determined on (root + seed) yields basis of both components as affected by the interaction effect between intercropping patterns x N fertilizer levels (combined analysis)

Interaction between intercropping patterns and N fertilizer levels		Crop yield fad.$^{-1}$		LER			LEC	ATER	K			Agg.		MAI.	Gross profit LE fad^{-1}
		Sugar beet (ton)	Sunflower (Kg)	L_B	L_S	LER	L_B x L_S		K_B	K_S	RCC	A_B	A_S		
P_1 Sugarbeet + sunflower 100%+50%	80	25.06	563.33	0.77	0.51	1.28	0.39	0.98	1.65	2.09	3.44	-0.38	+0.38	2615	12043
	100	28.20	572.50	0.87	0.52	1.38	0-45	1.08	3.20	2.16	6.91	-0.27	+0.27	3678	13303
	120	29.74	651.25	0.91	0.59	1.50	0.53	1.15	5.21	2.88	15.03	-0.41	+0.41	4753	14252
P_2 Sugarbeet + sunflower 100%+33.33%	80	25.87	351.81	0.79	0.32	1.11	0.25	0.92	1.29	1.39	1.79	-0.21	+0.21	1168	11625
	100	29.71	441.43	0.91	0.4	1.31	0.36	1.08	3.48	1.98	6.90	-0.37	+0.37	3193	13478
	120	31.15	458.65	0.96	0.41	1.37	0.39	1.13	7.41	2.11	15.66	-0.37	+0.37	3821	14144
P_3 Sugarbeet + sunflower 100%+25%	80	28.44	254.50	0.87	0.23	1.10	0.20	0.97	1.73	1.19	2.06	-0.05	+0.05	1147	12285
	100	30.08	294.50	0.92	0.27	1.19	0.24	1.03	3.04	1.44	4.39	-0.17	+0.17	2088	13113
	120	32.36	337.83	0.99	0.30	1.30	0.29	1.12	42.57	1.75	74.51	-0.28	+0.28	3266	14209
Solid sugar beet		32.55	-	-	-	-		-	-	-	-	-	-	-	13039
Solid sunflower		-	1110	-	-	-		-	-	-	-	-	-	-	4090

that intercropping pattern was highly efficient in utilizing the growth resources than other pattern of both crops. Whereas, intercropping sunflower with sugar beet at 33.3% under 80 kg N fad.$^{-1}$ achieved the lowest value 0.92 as an average of the two successive seasons. These results are in harmony with those obtained by Mohammed and Abd El-Zaher (2013).

Relative crowding coefficient (RCC)

Results in Table 4 indicate that relative crowding coefficient (RCC) were more than one and this means that all treatments achieved yield advantages than solid planting of sugar beet or sunflower. The highest yield advantage for RCC (74.51) was recorded with (100% sugar beet + 25% sunflower) at 120 Kg N fad.$^{-1}$ and the lowest value of RCC (1.79) was showed by using (100% sugar beet + 33.33% sunflower) under 80 Kg N/fad^{-1}.

Aggressivity (Agg)

Results presented in Table 4 indicates the effect of intercropping patterns and N fertilization on aggressivity values (A) of sugar beet (A_B) and sunflower (A_S) calculated for roots + seeds yields . It is known that an aggressivity value of zero indicates that, both component crops are equally competitive. For any other situation, both crops will have the same numerical value by positive for the dominant crop and negative for the dominated one. The greater the numerical value, the larger the differences in competitive abilities. Results in Table 4 indicate that the component crops did not compete equally. Regardless intercropping pattern was a positive sign for sunflower and negative for sugar beet thereby that the sunflower was dominant while sugar beet was dominated of all intercropping patterns. This means that sunflower more aggressivity than sugar beet under different N fertilizer levels in this study. Aggressivity recorded the best value with minimum aggressivity (0.05) in P_3 at 80 kg N level. While the maximum values (0.41) were achieved with P_1 at 120 kg N level.

However, the negative sign for sugar beet and the positive one for sunflower may be due to the ability of the shorter component to compete with the taller component for available nutrients, especially N in this respect. This further, emphasizes that sunflower is able to acquired more resources than that sugar beet in the sugar beet-sunflower relay intercropping. These results are in line with the conclusion of Long *et al*. (2001), Ghosh *et al*. (2006) and Egbe (2010). However, Ghosh *et al*. (2004) further explained that because of the differences in canopy texture in height of sunflower and sugar beet, the two species not only competed for nutrient and water but also for sunlight. Our results indicate that, land use of the sugar beet/sunflower intercropping pattern was more efficient than sole cropping, which may be due to a more rational use of environmental resources in intercropping situations. Also Koji *et al*. (2016) suggest that intercropping is more useful cultivation system than double cropping to increase the annual soybean production.

Monetary advantage index (MAI*)*

Concerning monetary advantage index, results in Table 4 reveal that index of monetary advantage were positive in all treatments. 100% sugar beet +50% sunflower under 120 Kg N fad.$^{-1}$ gave the highest value (4753 LE) for monetary advantage index, while 100% sugar beet + 25% sunflower with adding 80 Kg N fad.$^{-1}$ gave the lowest value (1147 LE) for this characters similar trends were obtained by Stoyanov *et al*. (1997) and Tichy *et al*. (2001).

Gross profit

Results presented in Table 4 indicate that the maximum gross profit 14252 LE achieved with P_1 (50% + 100%) at 120 kg N fertilizer level and was at par with gross profit (14209 LE) produced by P_3 (25% + 100%) at the same level of N fertilizer. However, the lowest value 11625 LE was recorded when sugar beet intercropped with sunflower at 33.3% under 80 kg N level in combined analysis these results are in harmony with those obtained by Mohammed and Abd El-Zaher (2013).

Conclusion

It could be concluded that from this study intercropping sunflower at 25% plant density of its pure stand with 100% sugar beet achieve the highest root yield fad.$^{-1}$ (32.36 ton + 337.83 kg seed of sunflower) and gross profit 14209 LE at (120 Kg N fad) while the maximum sugar yield fad.$^{-1}$ (4.21 ton), sucrose (%) and purity (%) for sugar beet achieved at (100 Kg N fad.) in average of two seasons. The best land usage and monetary advantage index were recorded when intercropped sunflower at 50% + 100% sugar beet with 120Kg N fad.

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تأثير نظم التحميل ومستويات السماد النيتروجيني على إنتاجية بنجر السكر و دوار الشمس المحملين

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أقيمت تجربتين حقليتين بمحطة البحوث الزراعية بالجميزة محافظة الغربية خلال موسمي الزراعة ٢٠١٤/٢٠١٣ و٢٠١٥/٢٠١٤ لدراسة تأثير مستويات السماد النيتروجينى على إنتاجية بنجر السكر ودوار الشمس تحت نظم التحميل حيث زرع بنجر السكر على جانبي المصطبة (١٢٠سم عرض) والمسافة بين الجور ٢٠سم، نبات واحد فى الجورة بينما تم زراعة دوار الشمس فى سطر على ظهر المصطبة وعلى مسافة ٢٠و٣٠ و ٤٠سم بين الجور وترك نبات واحد في الجورة للوصول لثلاثة نظم تحميل (الأول ١٠٠% بنجر سكر + ٥٠% دوار شمس والثانى ١٠٠% بنجر سكر + ٣٣,٣٥ دوار شمس بينما الثالث ١٠٠% بنجر سكر + ٢٥% دوار شمس على الترتيب)، وفى حالة الزراعة المنفردة تم زراعة كلا المحصولين فى جور على مسافة ٢٠سم وعرض الخط ٦٠ سم للوصول بكثافة نباتية ٣٥ ألف نبات للفدان لكلا المحصولين، وقد استخدم تصميم القطع المنشقة فى ثلاث مكررات حيث كانت نظم التحميل في القطع الرئيسية بينما وزعت مستويات السماد النيتروجينى (٨٠- ١٠٠ -١٢٠ كجم ن/فدان) عشوائيا على القطع الشقية، وقد أظهرت النتائج: تأثرت صفات البنجر معنويا بالكثافة النباتية لدوار الشمس وكانت أعلى القيم لطول الجذر، قطر الجذور، وزن الجذر الغض للنبات، وزن العرش الغض للنبات ومحصول الجذور للفدان وذلك مع انخفاض نسبة الكثافة النباتية لدوار الشمس من ٥٠، ٣٣,٣٣ إلى ٢٥% فى كلا الموسمين، وانخفاض معنوي في محصول الجذور/للفدان لبنجر السكر بنسبة ٨,٦٤ و٤,٥٨% مع نظم التحميل المختلفة ١٠٠% بنجر سكر مع ٥٠ و٣٣,٣% دوار الشمس على التوالي وذلك بالمقارنة ٢٥%، أشارت النتائج إلى تفوق جميع صفات بنجر السكر مع زيادة مستويات السماد النيتروجينى ما عدا صفات الجودة في كلا الموسمين، أما بالنسبة لمحصول دوار الشمس فقد أظهرت النتائج وجود اختلافات معنوية لجميع الصفات لدوار الشمس تحت الدراسة مع الكثافة النباتية لدوار الشمس والتسميد النيتروجينى فى كلا الموسمين والتحليل التجميعي المشترك، تفوقت صفة ارتفاع النبات ومحصول البذور/فدان لدوار الشمس مع زيادة نسبة الكثافة النباتية لدوار الشمس من ٢٥ و ٣٣,٣ إلى ٥٠% في كلا الموسمين والتحليل التجميعي المشترك، أظهر التفاعل بين نظم التحميل والتسميد النيتروجينى تأثيرا غير معنوي على معظم صفات بنجر السكر ودوار الشمس المحملين، كان أعلى محصول من جذور البنجر (٣٢,٣٦ طن للفدان + ٣٣٧,٨٣ كجم بذور دوار الشمس) وإجمالى عائد تراوح ١٤٢٠٩ جنيه للفدان مع نظام التحميل الثالث (١٠٠% بنجر سكر + ٢٥% دوار الشمس) ومعامل بأعلى معدل سماد نيتروجينى (١٢٠ كجم ن للفدان)، بينما أعلى محصول السكر (٤٠٦٥ طن للفدان) ونسبة سكروز ونقاوة % مع نفس نظام التحميل +١٠٠ كجم ن للفدان، كانت أعلى قيمة لمعدل استغلال الأرض ١,٥٠ وإجمالى الدخل ١٤٢٥٢ جنيه للفدان مع نظام التحميل الأول ١٠٠% بنجر سكر + ٥٠% دوار الشمس +١٢٠ وحدة أزوت، أوضحت الدراسة طبقا لظروف التجربة أن أفضل نتيجة توصي بها عند استخدام نظام تحميل (١٠٠% بنجر سكر + ٢٥% دوار الشمس) مع معدل تسميد نيتروجينى ١٠٠ أو١٢٠كجم ن/فدان.

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