Wheat-Sugar Beet Productivty and Land Equivalent Ratio under Intercropping System with Mineral, Nano Npk and Bio Npk Application

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ABSTRACT: Two field experiments were carried out during seasons at 2020/2021 and 2021/2022 in Etay El-Baroud, Research Station, El Beheira Governorate, Agriculture Research Center (ARC), Giza, Egypt to study the effect of intercropping two densities of wheat [25% (D1) and 12.50% (D2) with sugar beet as well as sugar beet and wheat in pure stands under eight fertilizer types {100% NPK (T1), 75% NPK + nano-fertilizer of NPK (T2), 75% NPK +bio-fertilizer of NPK (T3), 50% NPK +nano-fertilizer of NPK (T4), 50% NPK +bio-fertilizer of NPK (T5), nano- fertilizer of NPK only, bio-fertilizer of NPK only (T7) and nano- fertilizer of NPK + bio-fertilizer of NPK (T8)}, on sugar beet and wheat. The experiments were designed as split plot design. Results indicated that sowing in pure stand (D3) followed by grown sugar beet under plant density 12.50% of wheat (D2) recorded the highest values of yield and quality of sugar beet in both seasons. All studied characters of sugar beet achieved the highest values with 75% NPK + bio-fertilizer (T3) treatment in both seasons. Top, root and sugar yields/ fed in both season, and sucrose% in 2021/2022 seasons were significantly affected by the interaction between intercropping densities and fertilizer types. The highest values for these characters were obtaned when sowing sugar beet in pure stand (D3) followed by grown under intercropping density 12.50% of wheat (D2) and application of 75% NPK + bio-fertilizer (T3). Sowing wheat in a monoculture crop (D4) recorded the highest values of Plant height (cm), Number of spike/ m2, Grain weight / m2 (g), 1000-grain weight (g) and Grain yield in tons as well as straw yield in tons / fed., followed by grown wheat in intercropping density 25% (D1) in both seasons. Wheat fertilized with 75% NPK + bio-fertilizer (T3) recorded the highest values for all characters in both seasons. Sowing wheat in pure stand (D4), followed by intercropping density 25% (D1) with application of 75% NPK + bio-fertilizer (T3) achieved the highest values of all studied wheat characters in both seasons. LER and K achieved the highest values by using intercropping density 12.50% of wheat with sugar beet and application of 75% NPK + bio-fertilizer, which reached 1.403 and 1.415 as well as 6.602 and 7.124 in the first and second seasons, respectively.

Keywords: intercropping, sugar beet, wheat, nano-fertilizer, bio-fertilizer, yield, efficiency, Land equivalent ratio (*LER).*

INTRODUCTION

The sugar beet crop is the second sugar crop after sugar cane in Egypt. Egypt imports 300 thousand tons of sugar every year narrow the shortage gap. Sugar beet is cultivated in 121 countries, the total production of sugar beet in the world is 270 million tons from an area of 7.9 million hectares (FAO, 2019). The area of sugar beet in Egypt is 720,000 fed and the yield is 14,409,160 tons (Ministry of Agriculture and Land Reclamation 2021).

Wheat is the number onegrain crop in Egypt and the main ingredient for bread flour in Egypt. Egypt imports from 5 to 5.5 million tons annually. The area of wheat in Egypt was estimated at about (3,353,151 acres), which produced 9,342,538 tons (FAO, 2019).

Intercropping is one of the solutions and a major pillar to reduce imports of sugar and wheat. Thus, there is a need to maximize production per unit area to accelerate productivity gains, which may encourage a reduction in the expected food security gap. Intercropping is a component of permaculture, a more productive system than different crops separately (Kumar *et al*., 2014). intercropping wheat with sugar beets by reducing the density of wheat reduced competition between

growers and increased production per unit area (Gomaa *et al*., 2019).

The main elements (N, P and K) are the basis of plant nutrition. On the other hand, the production of mineral fertilizers is expensive. In addition, most of the energy for fertilizer production is provided by non-renewable fossil fuel consumption, which cause problems for the environment (Akbari *et al*., 2011 and Mir *et al.,* 2015).

The application of nano-fertilizers and nitrogen-fixing bio-fertilizers and the increase in the activity of phosphorus and potassium in the soil led to a decrease in the use of chemical fertilizers and the provision of high-quality products free of agricultural chemicals harmful to human safety (Mahfouz and Sharaf El-Din, 2007). Spraying with nano-fertilizers increases the efficiency of nutrient consumption (Rezaei and Abbasi, 2014). The highest values of Guar Plan vegetative growth, yield, oil yield, chlorophyll content, and NPK ratios were recorded with bio-fertilizer treatment plus two-thirds of the recommended dose of mineral fertilizer (Gendy *et al*., 2013).

The aim of this study was to study the effect of intercropping densities of wheat with sugar beet, nano and bio fertilizers (NPK) and their interaction on yield and quality of sugar beet and yield of wheat.

MATERIALS AND METHODS

Two field experiments were carried out at Etay El-Baroud Experimental station in El-Beheira Governorate, Agriculture Research Center, Egypt during 2020/2021 and 2021/2022 seasons to study the effect of two intercropping densities of wheat and the monoculture of both crops as follow:

1- Density 1 (D1) = 100% sugar beet + 25% wheat (15 kg of wheat grain in rows on the width of sugar beet ridge).

2- Density 1 (D2) = 100% sugar beet + 12.50% wheat (7.50 kg of wheat grain in rows on the width of sugar beet ridge).

3- Sugar beet in a monoculture crop (D3) (35000 plant/fed).

4- Wheat in a monoculture crop (D4) (60 kg of wheat grain/fed).

And eight treatments of fertilization as follow:

T1: 100% mineral NPK [215 kg N /fed (urea 46.50%) + 125 kg P/fed (super phosphate15%) + 62.50 kg K/fed (potassium sulphate 50 %)].

T2: 75% mineral NPK [161 kg N /fed (urea 46.50%) + 93.25 kg P/fed (super phosphate 15%) + 46.88 kg K/fed (potassium sulphate 50 %)] + Nano NPK (2 g/liter from three elements were add three time) for D1. Whereas, [145 kg N /fed (urea 46.50%) + 84 kg P/fed (super phosphate15%) + 42 kg K/fed (potassium sulphate 50%)] + Nano NPK (by rate 2 g/liter of distilled water from N, P and K were add at spayed three time after the first, second and third irrigations).

T3: 75% Mineral + bio NPK. Azobacterin (800g/fed) + Phosphorine (800 g/fed) + Potassiummag (800 g/fed). Turning the three types on sand in a shady place and scattering its mixed with sand and after planting and immediately before irrigating.

T4: 50% mineral + Nano NPK. [107 kg N /fed (urea 46.50%) + 62.50 kg P/fed (super phosphate15%) + 31.25 kg K/fed (potassium sulphate 50%)] + Nano NPK (2g/liter sprayed three times.

T5: 50% mineral NPK + Bio NPK.

T6: Nano NPK only.

T7: Bio NPK.

T8: Nano NPK + bio NPK.

The experimental design was a split-plot design with four replications. The two densities of wheat and the monoculture crops were allocated in the main plots, whereas the eight fertilizers treatments were distributed at random in the sub-plots. The number of ridges in each sub- plot was 3 ridges (120 cm width), the length of ridge was 3 m (plot area was 10.80 m2 = 1/388.89 of fed). All the other culture Practices p were done according to the recommendation of the Ministry of Agriculture and Land Reclamation. Sugar beet was planted in 14th and 16th of October 2020 whereas wheat was planted in15th and 17th of November 2021, respectively.

The fertilizer Super phosphate (15%) was applied during soil preparation, while urea (46.50 % N) was done in two equal doses before the first and second irrigation, and potassium sulphate (50 % K_2O) was applied before the first irrigation.

Table (1). Physical and chemical analysis of experimental soil during 2020/2021 and 2021/2022 seasons.

Soil properties	Soil texture	Sand %	Silt %	Clay%	PH	Organic matter%	Available N (ppm)	Available P (ppm)	Available K (ppm)	EC (m mhos) cm^{-1} (1;5)
2020/021	Clay	7.09	32.50	61.41	7.71	1.99	1.50	0.39	278.86	1.93
2021/022	Clay	8.59	31.80	59.61	7.79	2.07	1.52	0.38	286.79	1.61

2- Nano- fertilizer: the nano-fertilizers of NPK were obtained from (Bio-nano-technology Company Factory Al-Nubaria Alexandria Desert Road, the rate of 2 g / liter in distilled water. It was foliar sprayed three times after the first, second and third irrigations.

3- Bio-fertilizer: bio-fertilizer of Nitrogen, Phosphorous and Potassium were obtained by Azobacterin (800g/fed), Phosphorine (800 g/fed) and Potassiummag (800 g/fed), respectively. The three types of Bio and immediately before irrigating.

The studied Characters:

A- Sugar beet:

Yield characters: Root yield (ton/fed) and top yield (ton/fed) were estimated from whole plot and sugar yield (ton/fed): was calculated from root yield (tons/ fed) x sucrose%.

Quality characters:

1-Total soluble solids percentage (T.S.S. %) of roots were measured in juice of fresh root using hand refractometer according to (A.O.A.C., 1990).

2- Sucrose % was measured by hand saccharemeter according to Le-Docte (1972).

3- Juice purity %, was calculated according to Carruthers and Oldfield (1961) as follows: Juice purity% $= \frac{\text{Sucrose\%}}{\text{T.S.S.\%}} \text{x} 100$

B- Wheat:

Yield and yield components: Number of spikes/ m^2, 1000- grain weight (g) and Grain yield as well as straw yield in tons / fed.

C- Yield and yield advantages:

c.1. Land equivalent ratio (LER):

LER is the sum of fractions of the intercropped yield related to their monoculture crop yields. It is usually assumed that the same level of management must be the same for intercropping as for mono cropping. It was determined according to Willey and Soiree (1972).

$$\text{LER} = \frac{\text{Yab}}{\text{Yaa}} + \frac{\text{Yba}}{\text{Ybb}}$$

Where: Yab = yield of crop (a) intercropped with crop (b),Yba = yield of crop (b) intercropped with crop (a), Yaa = yield of crop (a) as a monoculture crop and Ybb = yield of crop (b) as a monoculture crop.

c.2. Relative crowding coefficient (K):

The relative crowding coefficient (K) is a measure of the relative dominance of one species over the other in a mixture (Banike et al., 2006). K was determined according to the following formula for species (a) in mixture with species (b).

$\text{Kab} = \frac{\text{YabxZba}}{(\text{Yaa}-\text{Yab})\text{xZab}}$ and $\text{Kba} = \frac{\text{YbaxZab}}{(\text{Ybb}-\text{Yba})\text{xZba}}$

$K = \text{Kab x Kba}$

Where: Zab=sown proportion of crop (a) in combination with crop (b) and Zba=sown proportion of crop (b) in combination with crop (a). When the values of LER and K were greater than1, there is a yield advantage; when LER and K were equal to 1, there is no yield advantage; and, when it is less than 1, there is a disadvantage (Dhima et al., 2007).

c.3. Aggressivity: (Agg):

It gives simple measure of how much relative yield increase in species (a) greater than for species (b) which is often used to determine the competitive relationship between two crops used in mixed cropping (Willey, 1979). The aggressivity was formulated as follows:

$$\text{Aa} = \frac{\text{Yab}}{(\text{Yaa}-\text{Yab})\text{xZab}} - \frac{\text{Yba}}{(\text{Ybb}-\text{Yba})\text{xZba}}$$

$$\text{Ab} = \frac{\text{Yba}}{(\text{Ybb}-\text{Yba})\text{xZba}} - \frac{\text{Yab}}{(\text{Yaa}-\text{Yab})\text{xZab}}$$

If Aggressivity value = zero it indicates that the component species are equality-for any other situation, both species will have the same numerical value, but the sing of the dominant species will be positive and the dominated will be negative.

3.2. Statistical analysis:

The obtained data were analyzed according to Snedecor and Cochron (1967). The treatments means were compared by using the least significant differences (L.S.D.) at 5% of probability, where it was computed using CoStat V 6.4 (2005) program.

RESULTS AND DISCUSSION

A: Sugar beet:

Data presented in Table (2) revealed that yield and yield components characters of sugar beet were significantly intercropping densities of wheat with sugar beet in both seasons. The highest values of these traits were recorded by growing sugar beet in a monoculture crop, followed by growing sugar beet under intercropping density 12.50% (D2) in the two growing seasons. Whereas, the lowest values were recorded by growing sugar beet under intercropping density 25% of wheat. Results of sugar beet yields/fed i.e. top, root and sugar yields/fed as the same trend as yield components characters in both seasons. The highest values of top, root and sugar yields /fed in the first season, and second season, resulted when sugar beet was grown in a monoculture crop, followed by growing sugar beet under intercropping density 12.50% (D2). Whereas, the lowest values of these characters in the first and second season, respectively were recorded by growing sugar beet under intercropping density 25% of wheat. These results were due to that increasing seeding rate of wheat lead to decrease of sugar beet traits. So, these traits of sugar beet were affected by inter-specific competition between sugar beet and wheat Plants for light, which led to increase shading especially at higher wheat plants density. Similar results were recorded by Heba *et al.* (2016) and Gomaa *et al.* (2019).

Data presented in Table (2) revealed that quality characters of sugar beet i.e. total soluble solids % and sucrose % were significantly affected intercropping densities in both seasons, while purity % was not significantly affected. Also,

chemical characters were increased by decreasing seeding rate of wheat compared with sugar beet in Pure stand in both seasons. These results are due to intra and inter competitive Saban *et al.* (2008) they found that intercropping improve the economic status of growers and sugar industry.

As shown in Table (2) sugar beet yield components were affected by fertilizer treatments in both seasons. Results of sugar beet yields/fed i.e. root and sugar yields/fed toke the same trend of yield components characters in both seasons. The highest values of root and sugar yields/fed in the first and second seasons, respectively were recorded when sugar beet plants were fertilized with75%NPK + bio-fertilizer (Azobacterin, Phosphorine and Potassiummag) (T3). This result may be due to that bio-fertilizing with mineral fertilizer, reduces mineral and makes nutrients available to the plant slowly during the growing season. Valizadeh and Milic (2016) found that a balanced fertilization strategy with macro and micronutrients in plant nutrition is very imperative for crop production. Top yield (ton/fed) was increased when sugar beet plants were fertilized of 100% mineral NPK in the first and second seasons, respectively. These results due to complete dose of NPK fertilizer increased growth traits than fruiting. These findings agreed with (Ouda, 2007). While the lowest values of root and sugar yields/fed were recorded when sugar beet plants Were fertilized with bio fertilizer only (T7), nano- fertilizer only (T6) and Nano + bio NPK together (T8) in both seasons, respectively. But T8 treatment was the best. Bio-fertilizers widely used as an alternative to chemical fertilizers, fertilizer producers have introduced new types of nanotechnology-based fertilizers, bio-fertilizers consisting of environmentally friendly microorganisms provide nutrients to the plant, improve soil fertility and crop productivity, nanoparticles provided the advantage of efficient loading due to their large surface area (Ghormade *et al.,* 2011, Jakiene *et al*., 2015).

For total soluble solids %, sucrose % and purity % were significantly affected by fertilizer treatments in both seasons as shown in Table (2). These characters behaved the same direction as sugar beet yields per fed in both seasons. These characters increased by application of bio-fertilizer with NPK mineral fertilizer compared to NPK mineral fertilizer alone in both seasons. These results due to that excessive NPK fertilizer increase impurities in quality traits. Quality traits (TSS, sucrose%, purity and recoverable sugar percentage were decreased with increasing N in combination with bio-fertilizer (Bassal *et al*., 2001).

Yield and its components were significantly affected by the interaction in both seasons as shown in Table (3). Growing sugar beet alone achieved the highest values with most fertilizer treatments from T1 to T5, followed by growing sugar beet under intercropping density 12.50% with 75% NPK +bio-fertilizer (T3), for root yield and sugar yield/fed in both seasons, respectively. While the lowest values were recorded by growing sugar beet under intercropping density 25% (D1) with bio-fertilizer only (T7), followed by nano-fertilizer only (T6) in both seasons, respectively. These results were due to inter and intera specific competitive. Similar results were obtained by (Gomaa *et al*., 2019).

The sugar beet quality traits weren't significantly affect by interaction except sucrose% in the second season as shown in Table (3). When the percentage of NPK mineral fertilizer decreased from T1 to T5 sucrose% increased, so the highest value was (19.06%) when sugar beet plants were fertilized with 50% NPK + bio-fertilizer (F5) under intercropping density 12.50% wheat (D2). While the lowest values (16.57 and 16.52%) Were recorded when sugar beet plants were fertilized with 100% NPK (T1) and 75% NPK + nano-fertilizer (T2) under intercropping density 25% wheat (D1), respectively.

Table (2). Effects of intercropping densities, fertilizer treatments and their interaction on yield and yield components of sugar beet as well as its quality characters during 2019/2020 and 2020/2021 growing seasons.

Treatments	Top yield (ton/ fed)		Root yield (ton/fed)		Sugar yield (ton/ fed)		TSS (%)		Sucrose (%)		Purity (%)	
	Seasons											
	2020/21	2021/22	2020/21	2021/22	2020/21	2021/22	2020/21	2021/22	2020/21	2021/22	2020/21	2021/22
A- Intercropping densities of wheat (D)												
25% density (D1)	5.954c	5.885c	22.478c	22.751c	2.215c	2.238c	20.61b	20.17b	17.90b	17.52c	86.85	86.60
12.50% density (D2)	6.689b	6.632b	23.926b	24.031b	2.391b	2.403b	21.39a	20.59a	18.50a	17.88a	86.15	86.88
Sugar beet alone (D3)	12.358a	12.057a	29.330a	29.209a	3.335a	3.350a	20.71b	20.40a	17.99b	17.79a	86.86	86.99
L.S.D. at 5%	0.553	0.445	0.166	0.248	0.036	0.041	0.21	0.24	0.16	0.13	Ns	Ns
B- Fertilizer treatments												
T1(100%NPK)	12.304a	12.089a	30.313a	30.840a	3.435c	3.453c	20.83bcd	19.86e	17.21f	16.83e	83.62d	84.86de
T2(75%NPK+nano-fertilizer)	11.731b	11.198b	30.108b	30.164b	3.376d	3.330d	20.55d	20.22d	17.19f	16.79e	88.67b	83.36e
T3(75%NPK+bio-fertilizer)	11.781b	11.556b	30.593a	30.971a	3.784a	3.806a	21.15a	20.67a	18.82b	18.43b	86.42c	89.22ab
T4(50%NPK+nano-fertilizer)	10.702c	10.468c	28.885d	29.330c	3.324e	3.336d	20.76cd	20.45bcb	17.94e	17.56d	90.40a	85.89cd
T5(50%NPK +bio-fertilizer)	10.618c	10.317c	29.231c	30.025b	3.626b	3.726b	21.26a	21.03a	19.21a	18.40a	87.38bc	89.52a
T6(nano-fertilizer only)	3.252d	3.285e	17.722f	17.027e	1.206g	1.189f	20.56d	20.32cd	17.96e	17.47d	86.75c	86.49abc
T7(bio-fertilizer only)	2.646e	2.752f	17.041g	16.588f	1.115h	1.155g	21.13ab	20.44bc	18.46c	18.04c	87.07bc	87.25bc
T8(nano+ bio-fertilizer)	3.637d	3.863d	18.177e	17.696d	1.312f	1.312e	20.99abc	20.33cd	18.27d	17.88c	83.62d	87.95abc
L. S. D. at 5%	0.420	0.416	0.211	0.266	0.044	0.045	0.38	0.36	0.25	0.14	1.73	84.86de
Interaction (A x B)	*	*	*	*	*	*	ns	ns	ns	*	ns	ns

* and ns : significant difference, not significant difference at 5 % level of probability, respectively.

Table (3). The interaction between intercropping densities and fertilizer treatments on yield and yield components of sugar beet as well as its quality characters during 2019/2020 and 2020/2021 growing seasons.

	Treatments	Top yield (ton/fed)		Root yield (ton/fed)		Sugar yield (ton/fed)		Sucrose%
		2020/21	2021/22	2020/21	2021/22	2020/21	2021/22	2021/22
25% density (D1)	T1(100%NPK)	8.957	8.844	27.117	27.761	4.596	4.601	16.57
	T2(75%NPK+Nano-fertilizer	8.690	8.410	26.903	27.187	4.555	4.491	16.52
	T3(75%NPK+Bio-fertilizer)	8.264	8.144	27.744	27.937	5.179	5.079	18.18
	T4(50%NPK+nano- fertilizer	7.920	7.583	25.701	26.211	4.544	4.537	17.31
	T5(50%NPK +bio-fertilizer)	7.544	7.480	26.051	26.897	4.937	4.995	18.57
	T6(nano- fertilizer only)	2.023	2.111	15.513	15.263	2.746	2.644	17.32
	T7(bio-fertilizer only)	1.730	1.920	14.981	14.880	2.757	2.681	18.02
	T8(nano+ bio fertilizer)	2.507	2.587	15.810	15.871	2.848	2.798	17.63
12.50% density(D2)	T1(100%NPK)	9.694	9.631	28.944	29.583	5.103	5.050	17.07
	T2(75%NPK+nano- fertilizer	9.527	8.920	28.471	28.887	5.014	4.919	17.03
	T3(75%NPK+bio-fertilizer)	9.461	9.357	29.084	29.691	5.596	5.543	18.67
	T4(50%NPK+nano- fertilizer	8.133	7.898	27.297	28.011	5.012	4.983	17.79
	T5(50%NPK +bio-fertilizer)	8.584	7.620	27.611	28.667	5.420	5.464	19.06
	T6(nano- fertilizer only)	2.804	3.334	16.667	15.768	3.063	2.761	17.51
	T7(bio-fertilizer only)	2.260	2.460	16.083	15.250	2.972	2.716	17.81
	T8(nano+ bio fertilizer)	3.050	3.834	17.251	16.387	3.224	2.969	18.12
Sugar beet alone(D3)	T1(100%NPK)	18.261	17.793	34.878	35.177	5.943	5.931	16.86
	T2(75%NPK+nano- fertilizer	16.977	16.264	34.607	34.417	5.890	5.785	16.81
	T3(75%NPK+bio-fertilizer)	17.617	17.167	34.951	35.284	6.518	6.510	18.45
	T4(50%NPK+nano- fertilizer	16.054	15.924	33.657	33.767	5.981	5.933	17.57
	T5(50%NPK +bio-fertilizer)	15.727	15.850	34.031	34.510	6.480	6.502	18.84
	T6(nano- fertilizer only)	4.930	4.410	20.987	20.050	3.734	3.527	17.59
	T7(bio-fertilizer only)	3.947	3.877	20.060	19.634	3.709	3.589	18.28
	T8(nano+ bio fertilizer)	5.354	5.168	21.470	20.831	3.886	3.729	17.90
L.S.D. at 5%		0.602	0.597	0.302	0.324	0.063	0.154	0.61

B- Wheat

Results in Table (4) revealed that Wheat yield and its components characters were significantly affected by intercropping densities of wheat with sugar beet in both seasons. The highest values of these characters were achieved by growing wheat in a monoculture crop, followed by growing wheat in intercropping density 25% with sugar beet (D1) in the two growing seasons. Whereas, the lowest values were resulted by growing wheat in intercropping density 12.50 % with sugar beet (D2) in both seasons, respectively. studied four intercropping densities of wheat with sugar beet i.e. (6.25%, 12.50%, 25% and 50% gain per fed from seeding rate of fed which was it 60 Kg/fed, as well as along with two solid checks of both crops. Wheat characters were reached the maximum in pure stands and reduced by reducing the intercropping percentages of wheat with sugar beet (Gomaa *et al*., 2019). Similar results were obtained by Heba *et al.* (2016).

Results in Table (4) revealed that Wheat yield and its components characters were significantly affected by fertilizer treatments. 100% mineral NPK (T1) recorded the highest straw yield. Gomaa *et. al.* (2021) found that 100% NPK achieved the highest values for plant height, straw yield and biological yield/fed. Application of 75% NPK + bio-fertilizer (T3) resulted the highest values of wheat traits i.e. number of spikes /m^2, 1000-grain wheat and grain yield /fed in both seasons, respectively. This result may be due to bio-fertilizer with mineral fertilizer, makes nutrients available to the plant slowly during the growing season. Valizadeh and Milic (2016) found that a balanced fertilization strategy with macro and micronutrients in plant nutrition is very imperative for crop production. While the lowest values were recorded when wheat plants were fertilized by bio only (T7), nano- fertilizer only (T6) and both together (T8) for all characters in both seasons, respectively. Gomaa *et al*. (2021) found that bio-fertilizers (Mycorrhiza + Microben + Potassiummag) only gave the lowest values.

Results in Table (5) showed that yield and it's components of wheat were significantly affected by interaction between intercropping densities and fertilizer treatments in the first and second seasons. Sowing wheat as a monoculture crop attained the highest values with all fertilizer treatments. Except 1000-grain weight which was the highest by growing wheat in intercropping density 25% with sugar beet (D1) and fertilized with 50% NPK + bio-fertilizer (T5). These results may be due to the competition between plants of different species is less than the competition between plants of the same species, that is, intra and inter competition. Similar results were obtained by Gomaa *et al*. (2019). While the lowest values were recorded when growing wheat in intercropping density 12.50% (D1) with bio-fertilizer only (T7), followed by nano- fertilizer only (T6) in both seasons, respectively. Grain yields of wheat and barley and seed yield of faba bean reached the maximum in the pure stand and reduced by reducing intercropping percentage of the three companion crops (Heba *et al*., 2016).

Table (4). Effects of intercropping densities, fertilizer treatments and their interaction on yield and its components of wheat in both seasons.

Treatments	Number of spikes /m^2		1000- grain weight (g)		Grain yield/fed (ton)		Straw yield /fed (ton)	
	Seasons							
	2020/21	2021/22	2020/21	2021/22	2020/21	2021/22	2020/21	2021/22
A- Intercropping densities of wheat (D)								
25% density (D1)	183.85b	181.56b	65.76a	59.86a	1.622b	1.553b	2.097b	2.034b
12.50% density (D2)	173.31c	170.89c	64.69b	59.11b	1.576c	1.533b	1.828c	1.824b
Wheat alone (D4)	293.38a	288.71a	61.28c	58.67c	2.808a	2.733a	3.568a	3.388a
L.S.D. at 5%	5.00	1.65	1.12	0.34	0.032	0.096	0.147	0.214
B- Fertilizer treatments (T)								
T1(100%NPK)	256.24a	252.46a	64.21abc	59.40bc	2.511a	2.431a	3.337a	3.230a
T2(75%NPK+nano- fertilizer)	238.24b	230.39b	64.07abc	59.04bc	2.433b	2.357b	3.166ab	3.042ab
T3(75%NPK+bio-fertilizer)	257.85a	253.58a	64.72a	60.20a	2.526a	2.446a	3.116b	2.976b
T4(50%NPK+nano- fertilizer)	220.28d	211.48c	63.88bcd	59.08bc	2.284d	2.194c	2.795c	2.715c
T5(50%NPK +bio-fertilizer)	231.85c	228.59b	64.53ab	59.64ab	2.326c	2.297c	2.715c	2.628c
T6(nano- fertilizer only)	173.76f	171.46e	63.13d	58.72bc	1.333f	1.288e	1.566e	1.528e
T7(bio-fertilizer only)	171.48f	169.66e	63.10d	58.47c	1.193g	1.142f	1.375e	1.409e
T8(nano+ bio fertilizer)	185.09e	182.11d	63.60cd	59.16ab	1.410e	1.362d	1.914d	1.794d
L. S. D. at 5%	3.30	4.63	0.86	0.65	0.061	0.072	0.208	0.187
Interaction (A x B)	*	*	*	*	*	*	*	*

* and ns : significant difference, not significant difference at 5 % level of probability, respectively.

Table (5). The interaction between intercropping densities and fertilizer treatments on yield and its components of wheat in both seasons.

	Treatments	Number of spikes/ m^2		1000-grain weight(g)		Grain yield/fed (ton)		Straw yield /fed (ton)	
		2020/21	2021/22	2020/21	2021/22	2020/21	2021/22	2020/21	2021/22
25% density (D1)	T1(100%NPK)	220.83	218.22	65.14	59.55	2.043	1.963	2.747	2.514
	T2(75%NPK+nano- fertilizer	204.17	199.78	65.45	59.45	1.984	1.893	2.650	2.420
	T3(75%NPK+bio-fertilizer)	223.89	219.41	66.27	60.41	2.067	1.974	2.531	2.403
	T4(50%NPK+nano- fertilizer	188.33	190.00	65.77	60.05	1.823	1.753	2.067	2.107
	T5(50%NPK +bio-fertilizer)	195.55	191.44	66.60	60.43	1.883	1.841	2.087	2.014
	T6(nano- fertilizer only)	141.67	140.00	65.61	59.60	1.064	1.019	1.617	1.590
	T7(bio-fertilizer only)	137.22	136.11	65.44	59.50	0.931	0.902	1.313	1.474
	T8(nano+ bio fertilizer)	159.17	157.50	65.77	59.83	1.127	1.079	1.770	1.750
12.50% density(D2)	T1(100%NPK)	207.22	201.67	64.38	59.04	1.991	1.925	2.551	2.510
	T2(75%NPK+nano- fertilizer	193.89	187.22	64.15	58.74	1.907	1.861	2.347	2.443
	T3(75%NPK+bio-fertilizer)	208.00	202.44	64.61	60.28	2.003	1.954	2.293	2.314
	T4(50%NPK+nano- fertilizer	176.67	181.11	64.27	58.91	1.801	1.734	2.027	2.013
	T5(50%NPK +bio-fertilizer)	187.50	186.00	65.27	59.83	1.833	1.815	2.007	1.961
	T6(nano- fertilizer only)	133.78	133.55	64.94	58.94	1.048	1.009	1.013	0.984
	T7(bio-fertilizer only)	133.34	133.43	64.71	58.11	0.917	0.893	0.978	0.907
	T8(nano+ bio fertilizer)	146.11	141.67	65.10	59.05	1.106	1.069	1.410	1.457
Wheat alone (D4)	T1(100%NPK)	340.66	337.50	63.11	59.61	3.497	3.405	4.713	4.667
	T2(75%NPK+nano- fertilizer	316.67	308.33	62.61	58.94	3.407	3.317	4.501	4.257
	T3(75%NPK+bio-fertilizer)	341.67	338.89	63.27	59.84	3.507	3.410	4.523	4.211
	T4(50%NPK+nano- fertilizer	295.84	293.34	61.61	58.28	3.227	3.094	4.291	4.024
	T5(50%NPK +bio-fertilizer)	312.50	304.17	61.72	58.66	3.263	3.234	4.052	3.910
	T6(nano- fertilizer only)	245.84	240.84	58.83	57.61	1.888	1.836	2.067	2.010
	T7(bio-fertilizer only)	243.89	239.44	59.16	57.79	1.679	1.632	1.833	1.847
	T8(nano+ bio fertilizer)	250.00	247.17	59.94	58.61	1.997	1.938	2.563	2.174
	L.S.D. at 5%	4.73	6.64	1.24	0.93	0.087	0.103	0.298	0.269

C- Yield and yield advantages.

1- Land equivalent ratio (LER):

Results in Table (6) showed that intercropping densities of wheat with sugar beet and fertilizer sources, exceeded land usage than unit in all treatments in both seasons. Best results in both seasons were obtained by using intercropping density 12.50% of wheat with sugar beet (D2) and application of 75% NPK + bio-fertilizer (T3) fertilizer treatment which recorded 1.403 and 1.415 in the first and second seasons, respectively. In all fertilizer treatments, sugar beet during the two intercropping density with wheat produced higher yields than 0.50% in both crops in all intercropping systems in both seasons. This result indicated that wheat with sugar beet is a good component where its yields exceeded the expected yield. Similar results were recorded by Heba *et al.* (2016) and Gomaa *et al.* (2019).

2- Relative crowding coefficient (RCC):

Results in Table (6) indicated that all intercropping treatments were exceeded than unity in both seasons. The best results were achieved by the treatment including intercropping density 12.50% of wheat with sugar beet (D2) and application of 75% NPK + bio-fertilizer (T3) where K values reached 6.602 and 7.124 in the first and second seasons, respectively. It is quite evident form results that both components coefficient Ks and Kw exceeded unit in all treatments and Kw was more contributor for K than Ks in both seasons. This result indicates clearly that wheat was the better contributor in all treatments. Similar results were reported by Abou-Elela (2012).

3- Aggressivity (A):

Results in Table (6) showed that wheat was the dominant intercrop component and sugar beet was the dominated in all treatments in both seasons. Data revealed that "A" values of sugar beet were increased by increasing wheat percentage with sugar beet and the maximum values for "A" of sugar beet were achieved with intercropping 25% of wheat with sugar beet in both seasons. The present results indicate clearly that wheat the "overstory" intercrop has higher competitive abilities than sugar beet the "understory" component. These results are in line with the conclusion of Abou-Elela (2012) and Gomaa *et al*. (2019).

Table (6). Land equivalent ratio (LER), relative crowding coefficient (K) and Aggressivity (A) of intercropping densities of wheat with sugar beet and fertilizer sources in both seasons.

Treatment		LER			K			A		LER			K			A	
		Ls	Lw	LER	Ks	Kw	K	As	Aw	Ls	Lw	LER	Ks	Kw	K	As	Aw
		2020/2021								2021/2022							
25% wheat (D1)	T1	0.778	0.585	1.363	0.874	5.620	4.909	-1.949	+1.949	0.789	0.577	1.366	0.936	5.445	5.096	-1.896	+1.896
	T2	0.777	0.582	1.359	0.873	5.577	4.869	-1.940	+1.940	0.790	0.571	1.361	0.940	5.317	4.998	-1.866	+1.866
	T3	0.794	0.590	1.384	0.962	5.742	5.526	-1.955	+1.955	0.792	0.580	1.372	0.951	5.499	5.227	-1.905	+1.905
	T4	0.764	0.565	1.329	0.808	5.194	4.195	-1.870	+1.870	0.776	0.567	1.343	0.867	5.229	4.535	-1.863	+1.863
	T5	0.766	0.577	1.343	0.816	5.458	4.454	-1.928	+1.928	0.779	0.569	1.348	0.883	5.286	4.669	-1.872	+1.872
	T6	0.739	0.554	1.293	0.708	5.165	3.659	-1.894	+1.894	0.761	0.555	1.316	0.797	4.989	3.977	-1.823	+1.823
	T7	0.727	0.555	1.282	0.737	4.979	3.672	-1.839	+1.839	0.758	0.553	1.311	0.782	4.942	3.867	-1.816	+1.816
	T8	0.737	0.564	1.301	0.698	5.182	3.619	-1.901	+1.901	0.762	0.557	1.319	0.801	5.025	4.020	-1.831	+1.831
12.50% wheat (D2)	T1	0.830	0.569	1.399	0.603	10.697	6.449	-4.243	+4.243	0.841	0.565	1.406	0.654	10.524	6.879	-4.195	+4.195
	T2	0.823	0.560	1.383	0.573	10.286	5.899	-4.164	+4.164	0.839	0.561	1.400	0.646	10.341	6.676	-4.157	+4.157
	T3	0.832	0.571	1.403	0.613	10.775	6.602	-4.257	+4.257	0.842	0.573	1.415	0.656	10.858	7.124	-4.264	+4.264
	T4	0.811	0.558	1.369	0.531	10.219	5.421	-4.162	+4.162	0.830	0.560	1.390	0.601	10.316	6.205	-4.163	+4.163
	T5	0.812	0.562	1.374	0.532	10.371	5.513	-4.195	+4.195	0.831	0.561	1.392	0.606	10.349	6.275	-4.169	+4.169
	T6	0.794	0.555	1.349	0.477	10.094	4.813	-4.154	+4.154	0.786	0.540	1.326	0.455	9.871	4.493	-4.112	+4.112
	T7	0.802	0.546	1.348	0.501	9.737	4.867	-4.064	+4.064	0.777	0.547	1.324	0.431	9.777	4.203	-4.102	+4.102
	T8	0.803	0.556	1.359	0.505	10.049	5.078	-4.132	+4.132	0.787	0.552	1.339	0.456	9.953	4.536	-4.131	+4.131
Pure		1.00	1.00		1.00	1.00				1.00	1.00		1.00	1.00			

Where: A. Wheat density , D1 (25% wheat) , D2 (12.50% wheat) --- B. fertilizer sources, T1(100% mineral NPK), T2(75% mineral NPK + nano NPK), T3(75% mineral NPK + bio NPK), T4(50% mineral NPK + nano NPK), T5(50% mineral NPK + bio NPK), T6(nano NPK only), T7(Bio NPK only) and T8(Nano NPK + bio NPK).- Ls ═ Relative yield of sugar beet, Lw═ Relative yield of wheat and LER═ Land equivalent ratio. Ks ═ Relative yield of sugar beet, Kw═ Relative yield of wheat and K ═ Relative crowding coefficient. As ═ Aggressivity of sugar beet and Aw═ Aggressivity of wheat.

CONCLUSION.

It could be concluded that to obtain the maximum value of productivity, quality and LER of intercropping wheat with sugar is to intercrop 12.50% wheat density after 30 days from sowing date of sugar beet and fertilizer treatment of 75% NPK + bio-fertilizer.

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الملخص العربي

إنتاجية بنجر السكر والقمح ومعدل استغلال الارض تحت نظام التحميل مع تطبيق التسميد المعدني والنانوي والحيوي

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أقيمت تجربتين حقليتين خلال موسمين 2021/2020 و2022/2021 بمحطة بحوث إيتاي البارود – البحيرة –مركز البحوث الزراعية –الجيزة–مصر, لدراسة تأثر كثافتين من القمح وهي[25% (D1)و12,50%(D2)] مع بنجر السكر وكذلك زراعة بنجر السكر منفرد (D3) والقمح منفرد (D4), تحت ثمانية أنواع من الاسمدة {100%NPK (T1), 75% NPK + النانو(T2), 75% NPK + الحيوي(T3), 50% NPK + النانو(T4), 50% NPK + الحيوي (T5), النانو فقط (T6), الحيوي فقط (T7), والنانو + الحيوي معا (T8) على بنجر السكر والقمح. تضمنت التجربة 32 معاملة على الزراعة المحملة والمنفردة. أظهرت النتائج أعلى القيم للمحصول ومكوناته والجودة في بنجر السكر عندما زرع منفردا, يليها زراعة البنجر تحت كثافة 12,50%(D2) من القمح في كلا الموسمين. حققت اعلى القيم لكل صفات بنجر السكر بالمعاملة السمادية 75% NPK + الحيوي(T3) في كلا الموسمين. محصول العرش والجذور وكذلك السكر/ للفدان في الموسمين, ونسبة السكروز في موسم 2022/2021 تأثروا معنويا بالتفاعل, حيث كان أعلى القيم لهذه الصفات عند زراعة بنجر السكر منفردا يليه زراعتهُ تحت كثافة 12,50% (D2) من القمح مع تطبيق نظام التسميد 75% NPK + الحيوي (T3). كل الصفات المدروسة للقمح وهي عدد السنابل /م^2, وزن حبوب /م^2, وزن 1000حبة, ومصول الحبوب والتبن /للفدان تأثروا معنويا بكثافة التحميل في كلا الموسمين. زراعة القمح منفردا سجل اعلى القيم لهذه الصفات, يليه زراعهُ مع بنجر السكر بكثافة 25% (D1) في الموسمين. تسميد القمح بـ 75% NPK + الحيوي (T3) سجل أعلى القيم لكل صفات القمح في الموسمين. زراعة القمح منفردا يليه زراعتهُ مع بنجر السكر بكثافة 25% (D1) و استخدام معاملة السماد 75% NPK + الحيوي (T3) سجل اعلى القيم لصفات القمح في الموسمين. معدل استغلال الارض (LER) ومعامل الحشد النسبي (K) وصلوا لأعلى قيم بإستخدام كثافة التحميل للقمح 12,50% (D2) ومعاملة التسميد 75% NPK + الحيوي (T3), والتي كانت (1,403و1,415 وكذلك 6,602 و7,124 علي التوالي في كلا الموسمين. القمح كان المحصول السائد, وبنجر السكر كان المحصول المسود.