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Effect of Mineral and Nano-Nitrogen Fertilizers on Yield and Its Components of Soybean and Maize Hybrids under Intercropping System

El-Ghobashi, Y. E.[1*] and M. R. Ismail[2]

[1]Crop Intensification Res. Dep., Field Crops Res. Inst., ARC.
[2]Maize Res. Dep., Field Crops Res. Ins., ARC.

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ABSTRACT

Three hybrids of maize (SC-168, SC-176 and TWC-321) were the subject of a field experiment conducted at the El-Serw Agricultural Research Station, and four combinations of mineral and Nano-N fertilization (120 kg N/fed mineral as a control treatment, 50% N mineral + 50% N nano, 75% N mineral +25% N nano, and 50% N mineral + 100%N nano), on maize and soybean yields and its attributes as well as land use efficiency. The study applied in a split-plot design with three replications. The findings demonstrated that maize hybrids greatly impacted both seasons' yield and characteristics of both maize and soybean. Data revealed that SC-168 maize hybrid achieved the highest values for all characters except, plant height and LAI in both seasons, whereas soybean with SC-168 hybrids significantly increased seed yield and its attributes except, plant height compared with other hybrid in both seasons. Treatment of nitrogen fertilization 75% Mineral + 25% N Nano significantly increased all studied characters of both crops in both seasons. Results indicated that most characters of maize and soybean were significantly by the interaction between two factors under study, and maize SC-168 hybrid with 75% M + 25% N Nano gave the highest values for all yields and its attributes of maize hybrids and soybean in both seasons. Treatment of 75% M+ 25%N nano recorded the highest values for each of LER and RCC in both seasons. Results indicated that maize hybrids were the dominant crops whereas soybean was the dominated crop in both seasons.

Keywords: Intercropping; Nano-Nitrogen; Maize; Soybean.

INTRODUCTION

Consider crop intensification to overcome nitrogenous fertilizer shortages by intercropping some leguminous crops (soybeans) on grass-fed crops (maize). Soil fertility, maize variety, and nitrogen (N) fertilization all contributed to the highest maize (*Zea mays* L.) yield productivity (Ding *et al*., 2005). Maize plant development is strongly influenced by the availability of N in the soil as well as the efficiency with which N is utilized for bio mass production and yield (Sonnewald, 2012). It is the most widely planted cereal crop in the world (FAO, 2013). It is a significant summer/autumn crop grown throughout Egypt for both grain and green fodder. The demand for mineral N fertilizers required for maize growth and development has prompted farmers to reduce N fertilizer rates, particularly N, which is the most frequent limiting factor of intensive agriculture production and is extremely expensive for many farmers (Montanez and Margarita, 2013). Furthermore, large losses of reactive N to the environment are still common in agricultural systems (Hussein and Abu-Baker, 2018) through nitrate transport to ground water or surface waters and nitrous gas emissions to the atmosphere (Davidson *et al.*, 2014). The use of a large amount of nitrogenous nitrogen fertilizer raises the production costs of the grass crop. (Hussein *et al.*, 2015) and (Montanez and Margarita, 2013). As a result, using nano-nitrogen in proportion to mineral nitrogen fertilizers reduces production costs and increases maize yield and components, according to (Hasaneen *et al.*, 2016). Intercropping maize on soybean fields boosts both crop productivity (125:140%), according to (Metwally *et al.*, 2005), because it reduces qualitative competition between the two crops for lighting and different soil elements. Because maize takes up half of the land and soybeans take up the other half. Legume crop with a deep root system Maize is a four-carbon crop with superficial roots. It absorbs nutrients from the soil's surface layer, and soybeans are a three-carbon leguminous crop with deep roots (Metwally, *et al.*, 2005). It absorbs nutrients from the soil's depths. The goal of this study was to see how partial replacement of Nano-Nitrogen with mineral nitrogen affected yield and component of soybean intercropped with three maize hybrids to maximize land use and farmer income.

MATERIALS AND METHODS

A field experiment was conducted at El-Serw Agricultural Research Station in Damietta Governorate, Egypt, over two cropping seasons 2019 and 2020 to investigate the effect of four N treatments on growth, yield, and yield components of three maize hybrids and intercropping with soybean (Giza 21). In both seasons, clover was the preceding winter crop.

Experimental Design and Treatments:

Each experiment featured 12 treatments consisting of three maize hybrids and four N fertilizers treatments, which were as follows:

Hybrid maize: The three maize hybrids SC-168, SC-176, and TWC-321 were intercropped with soybeans for the study. 2 ridges maize: 2 ridges soybean in addition to pure stands of both crops as advised.

*** Corresponding author.**
E-mail address: dryasser809@gmail.com
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- N fertilizer treatments:

Nano fertilizer was made by coating nitrogen, which comes from urea, with nano-chitosan, where nitrogen constitutes 20% and chitosan 80% of the fertilizer used for the experiment fertilization

N1: Conventional urea (CU) as recommended 120 kg mineral N/fed.

N2: 50% CU + 50% Nano-N/fed.

N3: 75% CU + 25% Nano-N/fed.

N4: Nano-N Fertilizers Each liter of fertilizer is archived from 20% nitrogen (sourced from urea) + 80% chitosan is the mineral nitrogen carrier nanomaterial. Nano-N Fertilizers at rate 2.650 L/fed, it considered as 100% Nano-N /fed.

A randomized complete blocks design (RCBD) with three replications was utilized in a split-plot arrangement with maize hybrids as main plots and nitrogen fertilizer treatments as sub-plots. The plot size was 16.8 m2 (4 × 4.20), with six ridges measuring 4 m in length and 4.20 m in breadth.

The experimental site's soil was clayed. Table 1 shows the mechanical and chemical examinations of the soil (0-30 cm) performed using the procedures recommended by Black (1965).

Table 1. The physical and chemical soil properties at the experimental locations throughout the course of two seasons.

Growing season	Particle size distribution%				OM %	$CaCO_3$ %	CEC meq /100g soil	pH	EC dSm^{-1}	IWEC*
	Sand	Silt	Clay	Texture class						
1st	11.88	21.33	66.85	Clayey	0.88	1.44	43.80	7.50	3.75	1.65
2nd	11.78	22.25	65.93	Clayey	0.89	1.35	42.30	7.80	3.44	1.60

Growing season	Cations and anions in the soil water extract (1:5), meq/100 g soil								NPK available ppm		
	Cations				Anions				N	P	K
	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}			
1st	3.00	2.79	11.30	0.25	---	1.43	12.11	3.80	32	9.03	480
2nd	3.15	2.73	11.42	0.33	---	1.55	12.15	3.75	33	8.40	470

IWEC, Irrigation water electrical conductivity, dSm^{-1}

Intercropping pattern of soybean with maize cultivars:

Soybean (Giza 21) was planted before maize by 21 days of sowing maize by using 2 ridges soybean: 2 ridges maize in alternating. Soybean was planted at two sides of ridges and leaving two plants /hill at 20 cm apart to give (60000 plants/fed); 50% plant density of its pure stand. Maize was planted on one side and leaving one plant/hill at 25 cm apart to give (12000 plants/fed); 50% of its pure stand. In mono-agriculture, both crops were planted as recommended for each crop. The competitive connections were estimated using solid cultures of both crops.

Crop management practices:

During soil preparation, phosphorus fertilizer was applied at a rate of 200 kg (P_2O_5)/fed (feed in the form of calcium monophosphate (15% P_2O_5). Soil and foliar application were used for conventional and nano urea fertilizers, respectively, which were applied in two equal doses, before the 1st and 2nd irrigations. The foliar solutions volume was to 200 L/fed using knapsack sprayer. Product name of nano urea is nitrogen conjugated to chitosan nanoparticles, its Polymer. Trade name of nano urea is Nitrogen loaded on nano chitosan, Chemical formula ($C_6H_{11}NO_4$) n. **Bulletin (2016 and 2018**). Chemical composition;

Nano Chitosan 80% + Nitrogen 20% (Source of Nitrogen is Urea). Nano was produced by NanoFab Technology Company, Egypt. It is created using the ionic gelation process. All agronomic methods were kept normal and consistent throughout all treatments.

Data Collected:

At harvest, 10 guarded plants were chosen at random from each treatment to measure maize and soybean growth.

Maize characters: Plant height (cm), Stem diameter (cm), Number of green leaves/plant, Leaf area of topmost ears (cm^2), Ear length (cm), Ear diameter (cm), Number of rows/ear grain weight (g), 100-grain weight (g), and grain yield (ardab/fed) were measured on a whole-plot basis and corrected to 15.5% moisture content.

Soybean characters: On the whole plot, soybean parameters such as plant height (cm), number of branches/plant, number of pods/plant, seed weight/plant (g), 100 seed weight (g), and seed yield (ton/fed) were recorded.

Competitive relationships:

Land equivalent ratio (LER): The ratio of land required for solitary cropping to that required for intercropping at the same management level to provide an equivalent yield (Willey 1979). It is determined as follows: LER = (Yab/Yaa) + (Yba/Ybb), where Yaa represents pure stand yield of crop a (maize), Ybb represents pure stand yield of crop b (soybean), Yab represents intercrop yield of crop a (maize), and Yba represents intercrop yield of crop b (soybean).

Aggressivity (Ag): According to Mc-Gilchrist, (1965), Ag is a comparison of how much relative yield increase for the intercropped crop (a) on crop (b) with the projected crop to determine which of the two crops prevailed in yield.

For crop (a).

Aab = (Yab/Yaa x Zab) – (Yba/Ybb × Zba),

and for crop (b).

Aba = (Yba/Ybb x Zba) – (Yab/Yaa × Zab).

Where Yaa and Ybb are yields of a and b as sole crops, while Yab and Yba are yields of a and b as intercrops. The sown proportions of a and b are represented by Zab and Zba, respectively. If Aab = 0, both crops are equally competitive; if Aab is positive, crop an is dominant; if Aab is negative, crop b is dominating, (Willey, 1979).

Relative crowding coefficient (RCC): RCC, or relative crowding coefficient by dividing the coefficient (K) for the first crop (Kab) by the coefficient (K) for the second crop (Kba), it was estimated as follows:

Kab =Yab x Zba/ (Yaa – Yab) x Zab and also, Kba = Yba x Zab/ (Ybb – Yba) x Zba

where;

Z_{ab} = the area ratio of the crop (a) when intercropping

Z_{ba} = the area ratio of the crop (b) when intercropping

Then, relative crowding coefficient (K) was evaluated as follows:

RCC = Kab x Kba

Finally, all obtained data were subjected to analysis of variance and treatment means were compared by L.S.D test at the 5 % level of probability in the two experimented seasons according to Gomez and Gomez, (1984).

RESULTS AND DISCUSSION

A- Maize growth characters:

Hybrids Traits Growth Characters Varietal diverse:

Table 2 shows that the differences between the maize hybrids under study were substantial for all of the variables investigated in both seasons. In both seasons, the TWC-321 was the tallest hybrid, while the SC-176 was the smallest. Furthermore, in both seasons, the SC-168 had the greatest values for stem diameter and number of green leaves/plants. These findings are consistent with those of (Abdel-Galil *et al.*, 2014) and (El-Ghobashi *et al.*, 2018) These findings were related to genetic make-up, whereas the TWC-321 reported the best value of Leaf area of uppermost ear in both seasons. These findings are consistent with those of (Lamlom *et al.*, 2015), (Gomaa *et al.*, 2018).

Table 2. Growth yield of maize hybrids as affected by intercropping with soybean.

Maize hybrids	Plant height (cm)		Stem diameter (cm)		No. - of green leaves/plant		Leaf area of topmost ear (cm^2)	
	2019	2020	2019	2020	2019	2020	2019	2020
SC-168	286.78	278.19	4.36	4.65	14.08	13.97	721.50	755.90
SC-176	277.72	270.17	4.00	4.44	13.81	13.36	695.93	729.50
TWC-321	296.45	300.97	3.77	4.48	13.21	10.45	734.07	792.15
LSD 0.05 (A)	6.84	4.24	0.07	0.05	0.23	0.49	20.62	18.35
Solid SC- 168	265.67	271.11	3.93	4.36	13.10	12.67	6847.14	6926.15
Solid SC- 176	261.67	262.22	3.51	4.35	13.00	12.33	4934.02	6063.11
Solid TWC- 321	283.22	287.78	3.31	4.28	11.34	10.89	4723.07	4746.92

Effect of N nano- mineral fertilization:

The results in Table 3 demonstrated that nitrogen fertilisation in the form of nano-mineral fertilisation had a substantial effect on the examined variables, namely plant height, stem diameter, number of green leaves/plant, and ear leaf area/plant, in both seasons. The greatest values of all the examined features were obtained by applying a 75% N mineral + 25% N nano treatment in both seasons, followed by a 50% N mineral + 50% N nano treatment, followed by a control. In both seasons, the lowest results were obtained using 100% nano fertilizer. The chemical composition, surface coverage, size, reactivity, and, most critically, the dose at which they are effective affect the efficiency of NPs (Khodakovskaya *et al.*, 2012). Increases in these characteristics due to partial replacement of conventional urea with nano urea might be attributable to nano fertilisation increasing nutrient availability to the developing plant (Hediat and Salama, 2012) and reducing traditional N losses. Nano-fertilizers have a higher surface and reactive area because of the extremely small or lowest particle size, which provides more sites to promote different metabolic processes in the plant system, resulting in more photosynthesis and eventually more growth and yield (Qureshi *et al.*, 2018). These findings are consistent with those obtained by Manikandan and Subramanian (2016), who discovered that nanozeourea (nitrogen coated with nano Zeolite) treatment consistently outperformed conventional urea in terms of maize growth, yield, quality, and nutrient uptake. According to Goma *et al.* (2017), the application of mineral fertilizer in the soil combined with foliar application of nano- fertilizer resulted in the highest value of maize plant height.

Table 3. Effect of sources of N fertilizer on growth characters of maize.

Traits	Plant height (cm)		Stem diameter (cm)		No.of green leaves/plant		Leaf area of topmost ear (cm^2)	
N. source fertilizer	2019	2020	2019	2020	2019	2020	2019	2020
100 % M	251.33	277.00	3.92	4.58	13.26	12.37	672.96	735.07
50% M+50% N	307.00	288.30	4.20	4.72	14.04	12.89	778.70	846.24
75% M+25% N	339.89	311.81	4.47	4.93	14.92	13.47	885.17	879.60
100 % N	249.70	255.33	3.57	3.86	12.56	11.37	531.84	575.90
LSD 0.05 (B)	7.02	6.13	0.07	0.07	0.31	0.32	47.82	38.86

Interaction effects:

Results presented in Table 4 indicate that the interaction between N nano-mineral fertilizers and maize hybrids significantly influenced plant height, stem diameter, number of green leaves, and Leaf area of topmost ear for both seasons, except for number of green leaves in first season Table 4. Fertilized SC-168 hybrid with 25% mineral along with 75% nano fertilizer recorded the highest values of stem diameter in both seasons, number of green leaves/plants in second seasons and Leaf area of topmost ear for first season. For plant height trait, the fertilized SC-176 and TWC-321 with 25% mineral along with 75% nano fertilizer recorded the best value for this trait in first and second season, respectively. On the other hand, 100% nano-urea with TWC-321 hybrid yielded the lowest values for plant height and stem diameter in the first season, as well as the number of green leaves in the second season. In both seasons, the SC-176 fertilized with 100% nano-urea had the lowest value for plant height, stem diameter, and ear leaf area/plant. Depending on the properties of the NPs, nanoparticles can cause a variety of morphological and physiological changes. The chemical composition, surface covering, size, reactivity, and, most importantly, the dose at which they are effective determine the efficiency of NPs. According to Auffan *et al*. (2009), unlike macronutrients, nanomaterials have unique properties such as surface effect, volume effect, and quantum size effect, among others. The magnitude of increased growth variables was greatest with low concentrations of 10% nano-NPK. In used genotypes, adding K2SO4 nanoparticles at a low level resulted in the highest shoot dry weight, relative yield, root length, and root dry weight (El-Sharkawy *et al.*, 2017).

Table 4. Interaction effect of maize hybrids and sources of N fertilizer on growth characters of maize.

Treatments		Plant height (cm)		Stem diameter (cm)		No.of green leaves/plant		Leaf area of topmost ear (cm^2)	
		2019	2020	2019	2020	2019	2020	2019	2020
SC-168	100 % M	261.45	268.89	4.32	4.71	13.66	13.67	637.00	707.20
	50% M+50% N	291.56	287.78	4.55	4.85	14.46	14.33	786.06	877.50
	75% M+25% N	342.67	306.11	4.84	5.15	15.40	15.56	896.16	829.83
	100 % N	251.44	250.00	3.73	3.89	12.80	12.33	566.80	609.26
SC-176	100 % M	257.78	262.11	3.78	4.48	13.47	13.22	646.53	728.86
	50% M+50% N	310.67	273.78	4.07	4.67	14.11	13.78	784.33	812.76
	75 %M+25% N	351.67	306.55	4.54	4.79	15.07	14.33	866.66	853.80
	100 % N	265.67	238.22	3.60	3.84	12.57	12.11	486.20	522.60
TWC-321	100 % M	234.78	300.00	3.67	4.56	12.65	10.22	735.36	769.16
	50% M+50% N	318.78	303.33	3.97	4.63	13.57	10.56	765.70	848.46
	75 %M+25% N	325.33	322.78	4.04	4.85	14.29	11.33	892.70	955.16
	100 % N	232.00	277.78	3.38	3.86	12.32	9.67	542.53	595.83
LSD 0.05 A x B		20.86	18.81	18.21	0.12	N.S	0.55	73.25	67.31

Effect of maize hybrids on yield and yield components:

The hybrid SC-168 had the highest values of the studied traits (number of rows/ears, ear length, ear diameter, ear grain weight, 100-grain weight, and grain yield/fed) in both seasons, according to the results in Table 5. Show that, the performance differences between hybrids are primarily due to genetic differences. Differences in the genetic constituents of different maize hybrids may be based on differences in ear length and size, especially since there was a positive and highly correlated relationship between ear fill, ear length, and ear circumference and grain weight/ear circumference (Paudel, 2009). Grain yield/fed followed the same pattern as maize yield components such as ear length, ear diameter, ear grain weight, and 100-grain weight. Variations in growth, grain yield, and its components among maize in this study could be attributed to genetic differences. These findings agreed with those of Lamlom *et al.* (2015), Gomaa *et al.* (2017).

Table 5. Effect of maize hybrids on yield and yield components in both seasons.

Traits	Ear length (cm)		Ear diameter (cm)		No of rows/ear		Ear grain weight (g)		100-grain weight (g)		Grain yield (ardab/fed)	
Maize variety	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**
SC- 168	25.21	22.92	6.64	5.74	16.25	16.28	154.78	164.61	29.81	32.81	13.97	14.93
SC- 176	21.74	22.17	6.21	5.56	15.86	15.94	145.95	154.31	24.25	30.61	12.60	13.39
TWC- 321	19.00	16.83	5.99	5.31	15.24	13.31	127.26	129.78	22.10	27.75	10.07	10.99
LSD 0.05 (A)	0.53	0.79	0.18	0.12	0.61	0.37	1.70	6.06	0.73	0.75	0.88	0.66
Solid SC-168	21.89	20.22	6.22	5.88	14.44	15.11	142.78	147.78	28.21	29.33	23.48	24.58
Solid SC-176	18.33	17.89	5.15	5.66	14.00	14.33	131.44	121.78	23.24	26.56	21.70	22.78
Solid TWC-321	16.08	16.00	5.10	5.42	13.65	12.67	124.33	107.52	20.89	25.67	19.27	20.05

Effect of N nano- mineral fertilization on maize yield and yield components:

Results recorded in Table 6 show clearly that N nano-mineral fertilization had significantly influenced on number of rows/ear, ear length, ear diameter, ear grain wt., 100-grain wt. and grain yield/fed of maize in both seasons.

The highest values of all the studied traits were recorded with 75% mineral + 25% nano fertilization, followed by 50% mineral +50% nano and then 100% mineral (control). Meanwhile the lowest values for these characters were achieved by 100% nano urea. Mahmood zadeh *et al.* (2013) reported that significant increase in all growth variables determined at optimum concentrations of Nano solution. The contributory effect of foliar applied fertilizer in this work may be attributed to the fact that the foliar applied fertilizer provides a quicker response and release of some nutrients than soil applied fertilizers but cannot completely replace soil fertilization in maize (Liang and Silberbush, 2002).

Table 6. Effect of sources of N fertilizer on yield and yield components of maize in both seasons.

N source fertilizer	Ear length (cm)		Ear diameter (cm)		No of rows/ear		Ear grain weight (g)		100-grain weight (g)		Grain yield (ardab/fed)	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
100 % M	21.13	19.82	6.36	5.39	15.49	14.81	130.44	141.04	24.67	28.93	11.96	12.86
50% M+50% N	23.87	21.52	6.42	5.68	16.18	15.89	151.34	148.30	26.88	31.37	13.25	14.12
75% M+25% N	25.14	23.48	6.64	6.25	17.71	16.33	165.64	183.52	28.87	33.85	15.55	16.45
100 % N	17.79	17.74	5.71	4.83	13.76	13.67	123.23	125.41	21.13	27.41	8.09	8.99
LSD 0.05 (B)	0.33	0.26	0.08	0.11	0.33	0.39	2.95	4.32	0.36	0.47	0.49	0.45

Grain yield/fed behaved the same trend of yield components characters in both seasons, where application 75% N mineral along with 25% nano fertilization increased grain yield by compared to conventional fertilization. However, separately applied nano fertilization decreased grain yield/fed significantly in both seasons. At nano scale physical and chemical properties are differing than bulk material (Nel *et al.* 2006). If fertilizers use as nano form, it increases the availability of elements, may prevent fixation and increased absorption and uptake through different plant parts (Hussein *et* *al*. 2015). Foliar applied fertilizers provide a quicker response and are more effective for some nutrients than soil applied fertilizers (Oluwafemi and Funsho, 2015). Results herein accordance with those obtained by Manikandan and Subramanian (2016). However, nano fertilizer efficiency depended on size and rate of nanoparticles. Similar results were reported by Mahmood zadeh *et al.* (2013).

Interaction effect of maize hybrids and sources of N fertilizer:

Data presented in Table 7 revealed that ear length, 100-grain wt., and grain yield/fed in both season, ear diameter, no. of rows/ear, ear grain wt. in one season out of two and No of rows/ear in second season were significantly affected by the interaction between maize hybrids and N nano-mineral fertilization.

Data revealed that SC-168 when fertilized by 75% N mineral + 25% N nano achieved the highest values for all the studied trait in both season except for ear grain wt. in second season. In addition to that, the best value achieved by the SC-176 when fertilized by 75% N mineral of its recommended + 25% N nano for ear grain wt. in second season. Opposite trend of these characters were obtained with the maize hybrid TWC-321 fertilized by nano fertilization only in both seasons. This reduction under 100 % nano fertilizer may be attributed increased toxicity due to high concentration of N nano. This results accordance with those obtained by Khodakovskaya *et al.* (2012) and Mahmood zadeh *et al*. (2013). Nanoparticles cause significant increase in all growth variables determined at optimum concentrations of nano solution.

Table 7. Interaction effect of maize hybrids and sources of N fertilizer on yield and yield components of maize.

Treatments		Ear length (cm)		Ear diameter (cm)		No of rows/ear		Ear grain weight(g)		100-grain weight(g)		Grain yield (ardab/fed)	
		2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
SC-168	100 % M	25.15	22.22	6.75	5.58	16.26	15.89	149.00	156.67	29.00	31.11	12.68	13.68
	50%M+50% N	26.67	24.00	6.52	5.89	16.67	17.22	164.34	172.56	31.89	34.00	15.69	16.63
	75% M+25% N	27.47	25.89	6.85	6.45	17.81	17.67	176.11	196.67	34.46	37.00	18.66	19.66
	100 % N	21.56	19.56	6.45	5.02	14.26	14.33	129.67	132.56	23.89	29.11	8.85	9.75
SC-176	100 % M	19.91	20.89	6.23	5.36	15.64	15.33	121.89	141.11	23.19	28.00	13.90	14.83
	50% M+50% N	24.118	23.00	6.47	5.71	16.30	16.78	158.96	143.89	26.22	32.67	13.17	13.84
	75% M+25% N	25.23	25.44	6.59	6.25	17.74	17.33	175.27	201.67	27.43	34.56	15.05	15.82
	100 % N	17.66	19.33	5.56	4.93	13.77	14.33	127.70	130.55	20.17	27.22	8.30	9.08
TWC-321	100 % M	18.34	16.33	6.11	5.25	14.57	13.22	120.43	125.33	21.82	27.67	9.30	10.08
	50% M+50% N	20.77	17.56	6.27	5.44	15.56	13.67	130.73	128.44	22.53	27.45	10.89	11.88
	75%M+25% N	22.73	19.11	6.47	6.03	17.58	14.00	145.54	152.22	24.72	30.00	12.95	13.86
	100 % N	14.14	14.33	5.11	4.52	13.23	12.33	112.32	113.11	19.33	25.89	7.12	8.14
LSD 0.05 A x B		0.58	0.44	0.14	N.S	N.S	0.67	5.11	7.49	0.63	0.81	0.85	0.78

B- Soybean characters

Effect of maize hybrids:

Data presented in Table 8 display the studied characters of soybean i.e., plant height, number of branches/plant, no. pods/plant, seed weight/plant, 100- seed weight and seed yield. The highest soybean plants were recorded by maize hybrid TWC-321 followed by SC-176 and the lowest of plant height was showed with SC-168 followed by SC-176 followed by TWC- 321 in both seasons El-Shamy *et al.* (2015). The best values for other studied traits were obtained under the maize hybrid SC-168 in both seasons El-Ghobashi *et al*. (2020). Intercropping soybean with maize hybrid SC-168 has given the best values for all the studied traits in both seasons than those intercropped with maize hybrid SC-176 and TWC-321, respectively. These results may be attributed to the TWC-321 hybrid which is the highest plant and highest LAI compared with other maize varieties. Increased shading effect on soybean plants may be due to differences among leaf inclination and height of the maize hybrids can result in differences in trans mission of radiation to the other component in the intercropping system. Similar results were obtained by Abdel- Galil *et al.* (2014 a and b).

Table 8. Effect of maize hybrids on yield and yield components of soybean.

Maize hybrids	Plant height (cm)		No. of branches/plant		No. pods /plant		Seed weight/plant		100 seed weight (g)		Seed yield (Ton/fed)	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
SC-168	109.00	106.33	2.83	3.00	35.26	37.77	11.70	12.36	15.55	16.39	0.661	0.714
SC-176	113.92	112.58	2.76	2.92	32.53	35.79	11.33	11.70	15.26	15.92	0.631	0.662
TWC- 321	116.50	114.92	2.57	2.74	29.63	31.10	10.74	11.00	14.65	15.42	0.547	0.597
LSD 0.05 (A)	3.10	2.99	0.19	0.13	1.84	1.06	0.03	0.53	0.54	0.31	0.120	0.130
Solid soybean	114.33	124.00	3.56	4.05	36.42	37.00	11.29	11.67	19.44	18.67	1.31	1.36

Effect of N nano-mineral fertilization:

According to Table 9, different fertilization treatments significantly influenced plant height, number of branches/plant, number of pods/plant, seed weight/plant, 100 seed weight, and seed yield in both seasons. The 75% N mineral + 25% N nano treatment clearly recorded the highest values for all the studied traits in both seasons. While 50% N mineral + 50% N nano came in second, 100% N mineral came in third, and 100% N nano came in last. The increase in these traits may be due to the combination of nano and mineral fertilization at different % ages of its recommended could be attributed to nano fertilization increasing nutrient availability to the growing plant (Hediat and Salama, 2012) and reducing conventional N losses (Wu and Liu, 2008; and Iqbal *et al.,* 2013). As a result, meristematic activity, cell elongation stimulation, and soybean production increased. When soil application of fertilizers is not readily available or when plants are unable to absorb them directly from the soil, foliar fertilizer application is an effective way of reforming soil nutrient deficiencies (Oluwafemi and Funsho, 2015). These findings could be attributed to foliar N nano fertilization, which could be used to supplement soil applied fertilizers but cannot replace soil fertilization in the case of maize (Liang and Silberbush, 2002). Furthermore, nano materials are causing significant improvements in plants by increasing growth and thus dry weight, leaf area, and growth rate (Hasaneen *et al.,* 2016). While high concentrations of nano urea had a negative impact on soybean plant growth, yield, and attributes. The properties of nano particles cause a variety of morphological and physiological changes. These findings are consistent with those of El-Sharkawy *et al*. (2017), who discovered that low levels of nano particles resulted in the highest shoot dry weight, relative yield, root length, and root dry weight in used genotypes.

Table 9. Effect of sources of N fertilizer on yield and yield component of soybean.

N source fertilizer	Plant height (cm)		No. of branches/plant		No. of pods /plant		Seed weight/plant (g)		100 seed weight (g)		Seed yield (Ton/fed)	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
100 % M	107.78	109.89	2.39	2.42	28.93	32.22	9.47	9.70	15.30	15.96	0.583	0.645
50% M+50% N	117.45	115.55	3.04	3.51	35.13	38.70	12.81	13.63	15.95	16.85	0.669	0.723
75% M+25% N	128.44	125.00	3.93	3.90	43.69	44.80	15.19	15.42	16.33	17.62	0.749	0.782
100 % N	94.89	94.66	1.53	1.70	22.15	23.41	7.57	8.01	13.03	13.24	0.451	0.480
LSD 0.05 (B)	2.88	3.26	0.35	0.16	2.55	2.11	0.53	0.49	0.51	0.38	0.086	0.037

Interaction effect of maize hybrids and sources of N fertilizer on soybean:

Data in Table 10 showed that No. of pods/plant, seed weight/plant, 100 seed weight and seed yield were significantly affected by the interaction between maize hybrids and N nano-mineral fertilization treatments in both seasons, while plant height and number of branches/plant were insignificantly affected in both seasons. Data revealed that the highest values were recorded by application 75% mineral + 25% nano and intercropping soybean with single hybrids compared to three ways cross. On the other hand, intercropping soybean with TWC-321 that received 100% nano recorded the lowest values for the respective characters. These results could be attributed to intercropping soybean with single hybrids positively interacted with 75% mineral + 25% nano to achieve better basic growth recourses and reduced inter specific competition among maize and soybean plants for soybean growth and development compared with the other treatments. While high concentrations of nano urea had a negative impact on soybean plant growth, yield, and other characteristics. The properties of nanoparticles cause a variety of morphological and physiological changes. The chemical composition, surface covering, size, reactivity, and, most importantly, the dose at which they are effective determine the efficiency of NPs (Khodakovskaya *et al*., 2012). In used genotypes, adding K2SO4 nano particles at a low level resulted in the highest shoot dry weight, relative yield, root length, and root dry weight (El-Sharkawy *et al.,* 2017). Emara et al. (2018), on the other hand, discovered that foliar application of the Nano fertilizer Lithovit at (5g/L water) resulted in higher productivity of Egyptian cotton variety (Giza 86) compared to control and Lithovit at (2.5g/L water).

Table 10. Interaction effect of maize hybrids and sources of N fertilizer on yield and yield components of soybean.

Treatments		Plant height (cm)		No. of branches/plant		No. pods /plant		Seeds weight/plant		100 seed weight (g)		Seed yield (Ton/fed)	
		2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
SC- 168	100 % M	100.00	105.00	2.49	2.55	32.00	33.51	9.95	10.21	15.57	16.69	0.612	0.707
	50% M+50% N	116.67	110.33	3.14	3.66	38.00	43.52	13.25	14.34	16.52	17.10	0.737	0.790
	75% M+25% N	124.33	115.67	4.11	3.86	46.60	49.01	15.75	16.17	16.37	17.88	0.827	0.817
	100 % N	95.00	94.33	1.58	1.91	24.46	25.05	7.86	8.73	13.74	13.91	0.470	0.543
SC-176	100 % M	107.67	115.33	2.42	2.48	27.00	34.31	9.58	9.57	15.76	16.11	0.617	0.637
	50% M+%50 N	115.00	117.00	3.10	3.53	34.73	39.99	12.85	13.66	15.53	16.86	0.692	0.747
	75%M+25% N	131.00	127.67	3.94	4.05	45.46	44.70	15.16	15.54	16.72	17.72	0.773	0.810
	100 % N	92.00	95.33	1.61	1.60	22.92	24.19	7.75	8.04	13.03	13.03	0.442	0.453
TWC-321	100 % M	115.67	114.33	2.26	2.24	27.80	28.85	8.87	9.33	14.57	15.07	0.520	0.590
	50% M+50% N	120.67	119.33	2.90	3.33	32.66	32.59	12.32	12.88	15.81	16.60	0.580	0.633
	25% M+75% N	130.00	131.67	3.74	3.80	39.00	40.70	14.65	14.55	15.91	17.26	0.647	0.720
	100 % N	97.67	94.33	1.40	1.60	19.06	22.27	7.11	7.26	12.33	12.77	0.440	0.443
LSD 0.05 A x B		N.S	N.S	N.S	N.S	4.42	3.65	0.91	0.86	0.88	0.67	0.075	0.063

Competitive relationships:

Land equivalent ratio (LER):

In Table 11 indicate that all the values of LER which obtained, in 2019 and 2020 seasons exceeded the unit, except treatments that received 100% N nano fertilizer irrespective maize variety and intercropping soybean and TWC- 321 Hiebsch (1980), along with 100% mineral N in both seasons. LER ranged from 0.70 and 0.71 due to intercropping soybean with TWC- 321 under 100 % N nano fertilizer to 1.42 and 1.40 due to intercropping soybean with SC- 168 these results agree with Grookston, and Hill, (1979). Soybean and TWC-321 that received 75% mineral N +25% Nano-N. That indicated that intercropping soybean with maize increased total yields of both crops, that is achieved highest LER compared with sole culture.

Aggressivity (Ag):

As shown in Table 11, the results show that the value of aggressivity of maize was positive for all treatments, whereas the value of aggressivity of intercropped soybean was negative for all treatments in both seasons. These findings support El-Edward *et al*. (1985) findings that maize plants were dominant, whereas soybean plants were dominant. In general, intercropping soybean with TWC-321 hybrid and 100% mineral fertilization yielded the highest negative values, while intercropping soybean with SC-176 hybrid and 100% nano urea yielded the lowest negative values. Similarly, Takim (2012) and Saudy (2015) discovered that maize was the dominant crop, while soybean was the dominant one Metwally *et al*. (2005).

Relative crowding coefficient (RCC)

Results in Table 11 showed that the intercropping soybean with maize SC-168 and SC-176 under mineral N fertilizer alone or in combinations with Nano urea and/or TWC-321 along with applied mineral + Nano urea fertilizer achieved yield advantageous in both seasons. The best yield advantage was achieved with maize SC-168 that received 75% mineral N + 25% Nano-N, in same time the lowest value of (K) 0.30 and 0.33 was produced when intercropping soybean with TWC-321 and applied 100% Nano-N fertilizer in 2019 and 2020 seasons. It is quite evident from the results that maize coefficient (Km) over than soybean coefficient (Ks) in all treatments. This result indicates clearly that maize was more competitive than soybean (Ahmed *et al*., 1999).

Table 11. Land equivalent ratio (LER), aggressivity (Ag) and relative crowding coefficient (RCC) of intercropping soybean with maize as affected by maize hybrids and N fertilizer rate in both seasons.

Character		Land equivalent ratio (LER)			Aggressivity (A)		Relative crowding Coefficient (RCC)			Land equivalent ratio (LER)			Aggressivity (A)		Relative crowding Coefficient (RCC)		
Treatments		L m	L s	LER	Ag/m	Ag/s	K m	K s	K	L m	L s	LER	Ag/m	Ag/s	K m	K s	K
		2019 season								2020 season							
SC-168	100 % M	0.54	0.47	1.01	+0.14	-0.14	1.17	0.88	1.03	0.56	0.52	1.07	+0.08	-0.08	1.26	1.07	1.35
	50% M+50% N	0.67	0.56	1.23	+0.21	-0.21	2.01	1.29	2.60	0.68	0.58	1.26	+0.20	-0.20	2.09	1.37	2.87
	75% M+25% N	0.79	0.63	1.42	+0.32	-0.32	3.87	1.72	6.67	0.80	0.60	1.40	+0.40	-0.40	4.00	1.49	5.96
	100 % N	0.38	0.36	0.74	+0.03	-0.03	0.60	0.56	0.34	0.40	0.40	0.79	+0.01	-0.01	0.66	0.66	0.43
SC-176	100 % M	0.64	0.47	1.11	+0.34	-0.34	1.78	0.89	1.59	0.65	0.47	1.12	+0.37	-0.37	1.87	0.88	1.63
	50% M+50% N	0.61	0.53	1.14	+0.15	-0.15	1.54	1.13	1.74	0.61	0.55	1.15	+0.12	-0.12	1.55	1.21	1.87
	75% M+25% N	0.69	0.59	1.28	+0.20	-0.20	2.26	1.45	3.28	0.69	0.59	1.29	+0.20	-0.20	2.27	1.46	3.32
	100 % N	0.38	0.34	0.72	+0.09	-0.09	0.62	0.51	0.32	0.40	0.33	0.73	+0.13	-0.13	0.66	0.50	0.33
TWC-321	100 % M	0.48	0.40	0.88	+0.17	-0.17	0.93	0.66	0.62	0.50	0.43	0.93	+0.14	-0.14	1.01	0.76	0.77
	50 %M+50 %N	0.57	0.44	1.01	+0.24	-0.24	1.30	0.80	1.04	0.59	0.46	1.06	+0.26	-0.26	1.45	0.86	1.26
	25% M+75% N	0.67	0.50	1.17	+0.35	-0.35	2.05	0.98	2.01	0.69	0.53	1.22	+0.33	-0.33	2.24	1.12	2.50
	100 % N	0.37	0.34	0.71	+0.03	-0.03	0.59	0.51	0.30	0.40	0.32	0.72	+0.12	-0.12	0.68	0.48	0.33

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تأثير التسميد المعدني والنانو النيتروجيني على المحصول ومكوناته لفول الصويا والذرة الشامية تحت نظام التحميل

ياسر السيد الغباشى و محمد رضا إسماعيل

[١]قسم بحوث التكثيف المحصولى، معهد بحوث المحاصيل الحقلية، مركز البحوث الزراعية، مصر

[٢]قسم بحوث الذرة الشامية، معهد بحوث المحاصيل الحقلية، مركز البحوث الزراعية، مصر

الملخص

أقيمت تجربة حقلية بمحطة بحوث السرو الزراعية خلال موسمي ٢٠١٩-٢٠٢٠ لدراسة تأثير ثلاثة أصناف هجن من الذرة الشامية (هجين فردى١٦٨ اصفر، هجين فردى ابيض ١٧٦، هجين ثلاثي ابيض ٣٢١، وأربع معاملات من التسميد الآزوتى المعدني والنانو (١٢٠كجم آزوت معدني/فدان كمعاملة كونترول، ٥٠% آزوت معدني + ٥٠% ازوت نانو، ٧٥% آزوت معدني +٢٥% آزوت نانو و١٠٠% آزوت نانو، وهي عبارة عن ٢,٦٥٠لتر/فدان) على المحصول ومكوناته لفول الصويا والذرة الشامية تحت نظام التحميل.استخدم تصميم القطع المنشقة في ثلاث مكررات ويمكن تلخيص أهم النتائج كالاتي: أثرت هجن الذرة الشامية معنويا على المحصول ومكوناته لكلا من الذرة الشامية وفول الصويا في كلا الموسمين واظهرت النتائج ان هجين فردى ١٦٨ للذرة الشامية حقق أعلى القيم لكل صفات الذرة الشامية ماعدا صفتي طول النبات ومساحة ورقة الكوز خلال موسمي الزراعة، وزادت صفات المحصول ومكوناته لفول الصويا معنويا ماعدا صفة طول النبات مقارنة بهجن الذرة الشامية الأخرى خلال موسمي الزراعة. أدت المعاملة ٧٥% ازوت معدني ٢٥% ازوت نانو الى زيادة معنوية لكل الصفات المدروسة لكلا المحصولين خلال موسمي الزراعة. أشارت النتائج الى ان معظم صفات الذرة الشامية وفول الصويا قد تأثرت معنويا بالتفاعل بين عاملي الدراسة. وحقق التفاعل بين هجين فردى ١٦٨ والتسميد ٧٥% ازوت معدني + ٢٥% ازوت نانو أعلى القيم لكل صفات المحصول ومكوناته لكلا من الذرة الشامية وفول الصويا، كما سجلت قيم معامل استغلال الأرض ومعامل الحشد النسبي أعلى القيم عند تسميد هجين فردى ١٦٨ بمعاملة التسميد ٧٥% ازوت معدني +٢٥% ازوت نانو خلال موسمي الزراعة، كما أشارت النتائج أن الذرة الشامية هي المحصول السائد بينما فول الصويا هو المسود خلال موسمي الزراعة.