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Effect of bio-fertilizers and N-levels on yield and other agronomic traits of some corn hybrids under Assiut conditions, Egypt

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Abstract

This investigation was carried out at the Agricultural Experimental Farm, Faculty of Agricultural, Al-Azhar University, Assiut, Egypt. Two field experiments were conducted during 2020 and 2021 summer seasons to study the effect of inoculation by bio-fertilizers in order to reducing N fertilization rates of some maize hybrids grown under Assiut governorate conditions. Each experiment was designed in a randomized complete block design (RCBD) in split –split plots design with three replications. The obtained results showed that the plant height, height of the 1st ear, ear length, number of rows/ear and grain yield (ton/feddan) (feddan = 4200 m² = 0.420 hectares = 1.037 acres) were significantly affected by the maize hybrids, bio-inoculation and N-fertilizer rates, except ear length was not affected by the maize hybrids in both seasons. Results indicated that. Hybrids and bio-fertilizers (H × bio) interaction was significantly difference for all studied traits in both seasons, except for plant height and height of the 1st ear in both seasons. Hybrids and N-fertilizer rates (H × N) interaction was significantly difference for all studied traits in both seasons, except for plant height in both seasons and ear length in only 2020 season. Bio-fertilizers and N-fertilizer rates (Bio × N) interaction was significantly difference for all studied traits in both seasons, except for both plant height and ear height in both seasons and ear length in only 2021 season. Moreover, the results indicated interaction among hybrid type, inoculation with bio-fertilizers and applied nitrogen fertilizer rates (H × Bio × N) was non-significant for most studied traits except for number of rows/ear and grain yield in both seasons.

Keywords: bio-fertilizers, hybrids, corn, phosphorus, potassium fertilizers.

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1. Introduction

Maize (*Zea mays* L.) is one of the most important and necessary cereal crops in the world which used as food for human and feed for animal. Maize is the third plant in crop production after wheat and rice (Majnoon, 2006). USDA reported that in February 2023, 201.12 and 0.93 million hectares of land were covered by maize and produced 1,151.36 and 7.44 million metric tons with yield of 5.72 and 8.00 metric tons per hectare of maize grain in the world and Egypt, respectively. There is a gap between production and consumption of maize in Egypt estimated by around 45%. This gap is compensated by importation, which put a burden on the country's budget. While average imports reached 9.58 million tons representing 58.88% of total local consumption for the same period. Stats reflect the critical roe maize food security plays, as Egypt imports around 59% of local consumption (Shady *et al*., 2020). Therefore, any attempts for raising maize production are considered a matter of utmost importance. Bio-fertilizers are produced from microorganisms and used as a vaccine. These bio-fertilizers could be considered the most reliable tools to reduce the rate of chemical fertilizers applied for all crops and all types of soil, and hence decreasing environmental pollution. It used as an alternative to the use of mineral fertilizers, which have an impact on environmental pollution. Therefore, the research was conducted to study the effect of bio-fertilizers in reducing N fertilization rates of some maize hybrids. Nitrogen fertilizer is an important factor in increasing growth, yield and yield components of maize crop. Growth stages of maize plant is influenced by nitrogen amounts and by its increasing which sequentially increased the dry matter accumulation in corn (Alizadeh *et al*., 2007). Many investigators reported that growth attributes and grain yield were positively affected by increasing N-fertilizer rate. El-Nagar (2003) reported that mineral nitrogen up to 130 kg N/feddan, to significant increase in plant weight, ear height, ear length, seed index, number of rows/ear, number of grains /row and grain yield/feddan, compared with other nitrogen rates (60 and 100 kg N/feddan). Moreover, due to the recent increase in fertilizer prices, in addition to the environmental pollution resulting from the addition of nitrogenous fertilizers, researcher aimed to provide alternative methods for chemical fertilizers, which is to rely on biological and organic fertilizers, sustainable management and the inoculation with N2-fixing bacteria are the alternatives to reduce fertilization cost and the environmental impacts with N fertilizers. Furthermore, the aim target of this investigation was to study the effect of some biofertilizers, various levels of nitrogen, and their interactions on growth, yield and quality traits of some corn hybrids under Assiut conditions, Egypt.

2. Materials and methods

2.1 Experimental site and treatments description

Two field experiments were carried out during the summer seasons of 2020 and 2021 at the Agricultural Experimental Farm, Faculty of Agriculture, Al-Azhar University, Assiut, Egypt. Field experiments were designed in a randomized complete block design (RCBD) in split –split plots design with three replications. Since, yellow maize hybrids (Giza-SC168 (H1), High Tec-SC2066 (H2) and Pioneer-SC3062 (H3) were placed in the main plots. While five levels of bio-fertilizers (without biofertilizers (Bio-0)., Biogen (Bio-1), Cerialein (Bio-2), Microben (Bio-3) and Nitroben (Bio-4) and three levels of nitrogen fertilizer (80 Kg N/feddan (N1), 100 Kg N/feddan (N2) and 120 Kg N/feddan (N3) were distributed randomly in the sub and sub-sub plots, respectively. Each sub-sub plot consisted of five ridges with 3.5 meter length and 70 cm width (10.5 m^2). The physical and chemical analyses of experimental soil used during the two seasons (2020 and 2021) were demonstrated in Table (1). Agronomic practices were followed as usually done for the maize crop in the Assiut region. Phosphorus and potassium fertilizers were applied prior to land preparation at the rate of 30 kg P_2O_5/feddan and 24 kg K_2O in the form of super phosphate (15.5% P_2O_5) and potassium sulfate (48% K_2O), respectively. Seeds of maize were sown on the 8th of June and harvested on the 6th of October in both seasons, respectively. Floating irrigation was followed in both seasons. The average temperatures were recorded during two experimental seasons (Table 2).

Table (1): Some physical and chemical characteristics of the experimental soils.

Character	2020	2021
Clay	49.60	49.40
Silt	24.20	24.10
Sand	26.20	26.50
Texture	Clay	Clay
pH (1:2.5)	7.50	7.74
ECe (dS m^{-1})	0.40	0.68
$CaCO_3$ (%)	2.36	2.66
Cations (meq 100 g $soil^{-1}$)		
Ca^{2+}	0.53	0.71
Mg^{2+}	0.00	0.07
Na^+	0.75	0.94
K^+	0.11	0.08
Anions (meq 100 g $soil^{-1}$)		
Cl^-	0.59	0.61
HCO_3^-	0.33	0.29
SO_4^{2-}	0.40	0.51
Available N (ppm)	20.0	22.50
Available P (ppm)	0.20	0.31
Available K (ppm)	0.20	0.51

Table (2): Monthly temperature at Assiut during 2020 and 2021 maize grown seasons.

Season	2020			2021		
Temperature / Month	Maximum °C	Minimum °C	Mean °C	Maximum °C	Minimum °C	Mean °C
May	38.10	22.0	30.00	35.50	19.50	27.50
June	39.00	24.90	31.95	38.60	22.50	30.55
July	38.90	25.20	31.95	38.50	23.90	31.20
August	38.90	25.00	31.50	38.40	24.00	31.20
September	35.40	22.20	28.80	37.80	23.30	30.55
October	33.60	19.30	26.45	34.60	20.50	27.55

2.2 Data recorded and studied traits

Maize individuals' plants from 1 m^2 were chosen at random from the middle of each plot in the two seasons, while the following data of traits were recorded:

A. Vegetative growth traits:

- Plant height (cm): It measured from the soil surface to the base of the tassel of ten plants randomly taken from each plot.
- Height of the 1st ear (cm): calculated from the soil surface to the base of the upper node – bearing ear of ten plants randomly taken from each plot.

B. Yield traits:

- Ear length (cm): It computed from the base to the tip of the ear and recorded in centimeters at the time of harvesting of ten plants randomly taken from each plot and averaged as ear length.
- Number of rows /ear: Number of rows per ear of ten plants randomly taken from each plot were counted and averaged as number of rows/ear.
- Grain yield (ton/feddan): It was measured by multiplying of grain weight of the harvested one m^2 by a factor of 10.5 and calculated to ton /feddan.

2.3 Analytical procedures

2.3.1 Soil analysis

The air-dried soil samples were ground and sieved through a 2 mm pore sieve. Soil texture was determined using the pipette method. The physical and chemical analyses of experimental soil used during the two seasons (2020 and 2021) were determined by Soil and Water Lab at Land Laboratory for Scientific Analyzes and Consulting, Faculty of Agriculture, Assiut University, Egypt according to Piper (1950), Jackson (1973), and Klute (1986).

2.3.2 Statistical analysis

All obtained data were subjected to statistical analysis of variance and treatment means were compared for significant differences using the LSD at *p*

= 0.05. The MSTAT-C computer program was used to perform all the analysis of variance with the procedure outlined by Steel and Torrie (1997).

3. Results and Discussion

3.1 Vegetative growth traits

3.1.1 Plant height at harvest (cm)

The demonstrated data in Table (3) stated that main values of plant height significantly affected by hybrids, inoculation with bio-fertilizers and applied mineral N-fertilizer rates in both seasons. The presented data in Table (3) showed significant (P<0.05) differences were observed between the three maize hybrids on the plant height. The H3 (SC 3062) recoded the maximum value of plant height (266.4 and 276.1 cm) while, H1 (SC 168) recorded the minimum value (236.3 and 244.0 cm) in the 1st and 2nd seasons, respectively. Also, H3 (SC 3062) significantly increased plant height by (17.00% and 13.15%) over H1 (SC 168).

The obtained data proved that H3 (SC 3062) gave the highest plant height all over the other hybrids. The variation in plant height might be due to its genetically governed characteristics or through plant densities as well as through environmental conditions. Mamudu *et al*. (2017) found that the tallest plant was observed in Obatanpa maize variety at 10 WAP and 8 WAP during the minor and major seasons, respectively. This observation confirms the work done by Awadalla *et al*. (2018), Abd El-Maksoud and Sarhan (2008), Hoshang *et al*. (2011), and Baqa *et al.* (2014) have reported similar results. Likely, data show that main values of plant height significantly affected by inoculation with bio-fertilizers. The tallest plant height values were obtained (263.8 and 275.2 cm) due to the inoculation with Microben (Bio-4) while, the minimum plant height values were recorded (242.9 and 250.9 cm) due to the control without bio-fertilizer (Bio-0). Inoculation with Microben bio-fertilizer (Bio-4) significantly increased plant height by (8.60 and 9.68%) over the un-inoculation (Bio-0). Hoshang *et al*. (2011) found that inoculation with Azotobacter, Azospirillum and Azospirillum had the highest plant height (212.4 cm). Concerning, the effect of nitrogen fertilizer rates, results in Table 3 revealed that plant height was significantly increased by increasing nitrogen levels. Application 120 kg/feddan, gave the tallest plant values (266.4 and 276.1). Meanwhile, the minimum values were 236.2 and 244.0 cm. Increasing of mineral N-fertilizer significantly increased plant height by 12.78 and 13.15% in both seasons. The increase in plant height due to increasing nitrogen fertilizer rates may be attributed to the fact that higher levels of nitrogen fertilizer promote vegetative growth in the maize. In this respect, Mamudu *et al*. (2017) found that the tallest plant height was produced with the application rate of 90 kg N/ha and the shortest being the application rate of 0kgN/ha. These results agree with those obtained by Nawab and Anjum (2017), and Abd- Elhady *et al*. (2017). Regarding the 1st and 2nd order interactions, results in Table (3) indicated that insignificant difference between hybrids and bio-fertilizers (H × Bio), (H × N), (Bio × N), and (H × Bio × N) in both seasons under the study.

Table (3): Effect of maize hybrids, bio-fertilizers and N-fertilization rates and their interactions on plant height (cm) in the 2020 and 2021 summer seasons.

Hybrid	N-fertilizer rate	Un-inoculated Bio-0	Biogen Bio-1	Cerialin Bio-2	Microben Bio-3	Nitroben Bio-4	Mean
2020 season							
H1 (SC168)	(N1) 80	217.0	223.7	221.7	228.0	225.3	223.1
	(N2) 100	230.7	243.7	237.7	249.0	246.0	241.4
	(N3) 120	233.3	244.3	243.0	253.7	246.7	244.2
Mean		227.0	237.2	234.1	243.6	239.3	236.3
H2 (SC2066)	(N1) 80	234.3	244.7	244.3	248.7	246.7	243.7
	(N2) 100	250.7	259.3	253.0	271.0	262.7	259.3
	(N3) 120	251.3	262.0	254.7	276.0	266.0	262.0
Mean		245.4	255.3	250.7	265.2	258.5	255.0
H3 (SC3062)	(N1) 80	243.3	252.3	250.6	259.7	256.7	252.5
	(N2) 100	261.0	268.3	265.7	282.3	273.7	270.2
	(N3) 120	264.0	270.3	267.0	306.0	275.3	276.5
Mean		256.1	263.6	261.1	282.7	268.6	266.4
Main effects	(N1) 80	227.0	237.2	234.1	243.6	239.3	236.2
	(N2) 100	245.4	255.3	250.7	265.2	258.5	255.0
	(N3) 120	256.1	263.6	261.1	282.7	268.6	266.4
Mean		242.9	252.1	248.6	263.8	255.5	
2021 season							
H1 (SC168)	(N1) 80	225.5	231.2	228.4	237.3	233.4	231.2
	(N2) 100	238.0	251.8	245.4	258.1	253.8	249.4
	(N3) 120	240.2	251.6	249.9	262.1	253.6	251.5
Mean		234.6	244.9	241.2	252.5	246.9	244.0
H2 (SC2066)	(N1) 80	242.9	252.8	250.2	259.0	255.9	252.2
	(N2) 100	258.4	267.8	259.7	282.2	270.9	267.8
	(N3) 120	258.5	270.6	262.5	289.8	273.5	271.0
Mean		253.3	263.7	257.5	277.0	266.8	263.7
H3 (SC3062)	(N1) 80	252.5	261.6	256.5	271.8	266.9	261.9
	(N2) 100	269.5	278.0	273.3	295.7	283.5	280.0
	(N3) 120	272.7	279.2	275.2	320.2	285.0	286.5
Mean		264.9	272.9	268.3	295.9	278.5	276.1
Main effects	(N1) 80	234.6	244.9	241.2	252.5	246.9	244.0
	(N2) 100	253.3	263.7	257.5	277.0	266.8	263.7
	(N3) 120	264.9	272.9	268.3	295.9	278.5	276.1
Mean		250.9	260.5	255.7	275.2	264.1	
L.S.D at p= 0.05		2020			2021		
A(Hybrids.)		3.98			6.18		
B (Bio-fert.)		8.03			10.45		
AB		n.s			n.s		
C (Nitrogen)		5.41			5.63		
AC		n.s			n.s		
BC		n.s			n.s		
ABC		n.s			n.s		

3.1.2 Height of the 1st ear (cm)

The presented data in Table (4) showed that height of the 1st ear was significantly (P<0.05) affected by maize hybrids in both seasons. The H1 (SC 168) recoded the maximum value of the height of the 1st ear (112.4 and 118.2 cm) while, H2 (SC 2066) recorded the minimum values (109.0 and 114.5 cm) in the 1st and 2nd seasons, respectively. Also, obtained results shown that values of the height of the 1st ear of SC 3062 hybrid (H3) was intermediate between those (H1 and H2) in both seasons. Similar results were in agreement with Karasui (2012) who found that the first ear heights of maize cultivars were significantly different, and the highest value (144.1 cm) was obtained from LG 2687 cultivar. The first ear heights of the other two cultivars were low and similar. The obtained data in Table (4) showed significant (P<0.05) differences were observed for the inoculation with bio-fertilizers on the heights of the 1st ear. The maximum values of the height of 1st ear (115.7 and 120.5 cm) were obtained due to the inoculation of Microben (Bio-4) while, the minimum plant height values (106.4 and 112.3 cm) were due to the control (without bio-fertilizer) in Bio-0. The increasing percentage of height of 1st ear due to Microben inoculation reached (8.74 and 7.30%) in comparison to the un-inoculation in the 1st and 2nd seasons, respectively. This might be attributed to that ear are basically affected by the genetic makeup of the plant and the growing conditions. The research findings are coordinated with Li *et al.* (2018) and Wei *et al.* (2018). Concerning, the effect of nitrogen fertilizer rates, results in Table (4), revealed that heights of the 1st ear were significantly affected by nitrogen levels. The maximum values heights of the 1st ear were recorded at N1 (80 kg /feddan) rate in both seasons. The increase in heights of the 1st ear due to different nitrogen fertilizer rates may be explanation that nitrogen as a main constituent of protein and protoplasm, stimulates and increase cell division and elongation. Karasui (2012) found that the first ear height in term of nitrogen levels ranged between 132.3 and 134.7 cm. Similar results were in agreement with Nawab and Anjum (2017). Results recorded in Table (4) indicate that the interaction effect between hybrids and bio-fertilization (H × Bio) on heights of the 1st ear was no significant in the 1st and 2nd seasons. Regarding to the interaction effects of (H × N), SC 168 hybrid treated with 120 kg mineral N-fertilizer gave the maximum heights of the 1st ear (117.3 and 123.7 cm) in the 1st and 2nd seasons. Karasui (2012) found that the interaction effects of cultivar and nitrogen fertilizer on first ear height were also significant, and the highest value (152.8 cm) was produced by the 150 kg N ha^{-1} and LG 2687 cultivar while the lowest value was produced by 300 kg N ha^{-1} and 34M43 Pioneer cultivar. Similar results were in agreement with Turgut (1998) and El-Nagar (2003). Regarding the 2nd interaction effects of (Bio × N), results indicated that there are no significantly differences on first ear height between treatments in both seasons. Regarding the 1st order interactions (H × Bio) and (Bio × N) and order interaction (H × Bio × N) had insignificantly effect on first ear height in both seasons.

Table (4): Effect of maize hybrids, bio-fertilizers and N-fertilization rates and their interactions on height of the 1st ear (cm) in the 2020 and 2021 summer seasons.

Hybrid	N-fertilizer rate	Un-inoculated Bio-0	Biogen Bio-1	Cerialin Bio-2	Microben Bio-3	Nitroben Bio-4	Mean
2020 season							
H1 (SC168)	(N1) 80	95.7	104.0	101.7	110.3	108.3	104.0
	(N2) 100	111.7	115.0	113.7	120.7	118.3	115.9
	(N3) 120	112.3	117.0	114.3	123.7	119.0	117.3
Mean		106.6	112.0	109.9	118.2	115.2	112.4
H2 (SC2066)	(N1) 80	101.0	102.7	102.3	105.3	103.7	103.0
	(N2) 100	105.7	112.0	108.7	115.7	114.3	111.3
	(N3) 120	107.0	113.3	109.3	119.3	114.7	112.7
Mean		104.6	109.4	106.8	113.4	110.9	109.0
H3 (SC3062)	(N1) 80	103.0	106.0	103.7	107.7	107.0	105.5
	(N2) 100	109.0	113.3	112.3	117.7	115.0	113.5
	(N3) 120	111.7	114.3	113.0	121.3	116.7	115.4
Mean		107.9	111.2	109.7	115.6	112.9	111.4
Main effects	(N1) 80	106.6	112.0	109.9	118.2	115.2	112.4
	(N2) 100	104.6	109.4	106.8	113.4	110.9	109.0
	(N3) 120	107.9	111.2	109.7	115.6	112.9	111.5
Mean		106.4	110.9	108.8	115.7	113.0	
2021 season							
H1 (SC168)	(N1) 80	98.9	110.3	107.1	114.0	112.8	108.6
	(N2) 100	119.8	122.3	118.2	127.1	124.0	122.3
	(N3) 120	120.1	123.7	119.5	128.2	126.8	123.7
Mean		112.9	118.8	114.9	123.1	121.2	118.2
H2 (SC2066)	(N1) 80	105.8	109.4	108.8	108.2	107.4	107.9
	(N2) 100	109.9	117.6	113.5	122.1	121.5	116.9
	(N3) 120	113.8	119.7	113.0	123.8	122.8	118.6
Mean		109.9	115.6	111.8	118.0	117.3	114.5
H3 (SC3062)	(N1) 80	110.3	110.5	110.1	113.4	110.8	111.0
	(N2) 100	113.9	118.5	116.8	121.2	119.8	118.0
	(N3) 120	118.4	117.7	115.6	126.7	123.1	120.3
Mean		114.2	115.6	114.2	120.4	117.9	116.5
Main effects	(N1) 80	112.9	118.8	114.9	123.1	121.2	118.2
	(N2) 100	109.9	115.6	111.8	118.0	117.3	114.5
	(N3) 120	114.2	115.6	114.2	120.4	117.9	116.5
Mean		112.3	116.6	113.6	120.5	118.8	
L.S.D at *p*= 0.05		2020			2021		
A(Hybrids.)		0.620			0.888		
B (Bio-fert.)		2.146			3.001		
AB		n.s			n.s		
C (Nitrogen)		1.232			1.713		
AC		2.133			2.967		
BC		n.s			n.s		
ABC		n.s			n.s		

3.2 Yield traits

3.2.1 Ear length (cm)

The ear length of maize Table (5) was significantly affected by the type of hybrid in the 2nd season; however, it recorded insignificant effect in the 1st season. H3 SC 3062 gave the longest ear (22.64 cm) as compared with the other hybrids. Mukhtar *et al.* (2012) found that, maximum ear length (22.25 cm) was recorded for YH-1898 which was statistically at par with YH-1850 (22.0 cm), minimum value (20.75 cm) was recorded for Yusafwala hybrid which was statistically similar to FH 793. These results come in the same line with Mohamed (2004), Rahman *et al*. (2007), Abd El-Maksoud and Sarhan (2008), Baqa *et al.* (2014), Mamudu *et al.* (2017), and Adhikari *et al.* (2021). The recorded data in Table (5) showed clearly that inoculation with bio-fertilizers significantly affected ear length in both seasons. Inoculation with Microben bio-fertilizer gave the tallest ear (23.11 and 23.06 cm) in both seasons, respectively, while the shortest ear lengths (20.51 and 21.17 cm) were recorded as a result from control treatment (Bio-0) in both seasons, respectively. The increase percentages in ear length due to inoculation Microben were (12.67 and 8.92%) in both seasons, respectively. Results in Table (5) showed clearly that there was a significant effect of nitrogen fertilizer levels on ear length (cm) in 2020 and 2021 seasons. Application nitrogen fertilizer at the rate of 120 kg N/feddan gave the tallest ear length (21.80 and 22.64 cm) in both seasons, respectively. However, N-application at a rate of 80 kg/feddan gave the shortest ear (21.80 and 21.92 cm) in both seasons, respectively. The increase percentage in ear length due to 120 kg N/feddan over 80 kg N/feddan was (3.28 %) in the 2nd season. Similar results were obtained by Badawi *et al.* (2012) who indicated that the highest level of nitrogen fertilizer (130 kg N/feddan) produced the highest values of ear length (cm), in both seasons. Baffoe (2014) and Sharifi and Taghizadeh (2009) had the same conclusion. Results in Table (5) indicated that the interaction between hybrid type and bio-fertilization (H × Bio) was significant for ear length in two seasons. The tallest ear lengths (23.45 and 24.00) were obtained as a result from the interaction between (H1 × Bio3) and (H3 × Bio-3) in the 1st and 2nd seasons, respectively. Concerning, the 1st interaction (H3 × N3), results indicated that fertilization SC 3062 hybrid with 120 kg gave the longest ear length (22.93 and 23.13 cm) in both seasons as compared with other interaction treatments in 2020 and 2021 seasons, respectively. Ahmed Amal *et al.* (2016) showed clearly that application (120 kg N/feddan and (60 kg N + 10 tons organic matter/feddan) + Azoto + Pseudo) yielded the highest significant value ear length. El-Nagar (2003) had a similar finding. Also, results in Table (5) showed that the interaction between bio-inoculation and nitrogen fertilizer levels (Bio × N) was significant in the 1st season and insignificant in the 2nd season. In the 1st season, inoculation maize seeds with

Microben (Bio-3) and applied mineral N fertilizer rate of 80 (Bio-3 × N1) gave the longest ear length (23.11) in the 1st season. Meanwhile, differences in the 2nd season were not affected. Results in Table (5) indicated that the 2nd order interaction among hybrid type, inoculation with bio-fertilizers and applied nitrogen fertilizer rates (H × Bio × N) was non-significant on ear length in both seasons.

Table (5): Effect of maize hybrids, bio-fertilizers and N-fertilization rates and their interactions on ear length (cm) in the 2020 and 2021 summer seasons.

Hybrid	N-fertilizer rate	Un-inoculated Bio-0	Biogen Bio-1	Cerialin Bio-2	Microben Bio-3	Nitroben Bio-4	Mean
2020 season							
H1	(N1) 80	19.53	19.97	19.60	21.10	20.40	20.12
(SC168)	(N2) 100	21.30	22.07	22.03	24.53	22.63	22.51
	(N3) 120	21.40	22.17	22.47	24.73	23.07	22.77
Mean		20.74	21.40	21.37	23.45	22.03	21.80
H2	(N1) 80	19.33	19.67	19.67	20.00	20.00	19.73
(SC2066)	(N2) 100	20.67	22.67	21.67	24.00	23.00	22.40
	(N3) 120	21.00	23.00	22.00	24.33	23.33	22.73
Mean		20.33	21.78	21.11	22.78	22.11	21.62
H3 (SC3062)	(N1) 80	19.33	20.00	19.67	20.00	20.00	19.80
	(N2) 100	21.00	22.67	21.67	24.33	23.67	22.67
	(N3) 120	21.00	23.00	22.00	25.00	23.67	22.93
Mean		20.44	21.89	21.12	23.11	22.45	21.80
Main	(N1) 80	20.74	21.40	21.37	23.45	22.03	21.80
effects	(N2) 100	20.33	21.78	21.11	22.78	22.11	21.62
	(N3) 120	20.44	21.89	21.12	23.11	22.45	21.80
Mean		20.51	21.69	21.20	23.11	22.20	
2021 season							
H1	(N1) 80	19.67	21.34	21.00	21.67	21.67	21.07
(SC168)	(N2) 100	21.17	22.34	22.00	22.50	22.00	22.00
	(N3) 120	21.67	22.67	22.13	23.67	23.33	22.69
Mean		20.83	22.11	21.71	22.62	22.33	21.92
H2	(N1) 80	20.34	21.33	21.00	21.67	21.33	21.13
(SC2066)	(N2) 100	21.33	22.00	22.00	22.50	22.67	22.10
	(N3) 120	21.67	23.00	22.67	23.50	23.00	22.77
Mean		21.11	22.11	21.89	22.56	22.33	22.00
H3	(N1) 80	21.00	22.67	21.67	23.67	22.00	22.20
(SC3062)	(N2) 100	21.33	23.00	22.00	24.00	22.67	22.60
	(N3) 120	22.33	23.33	22.33	24.33	23.33	23.13
Mean		21.55	23.00	22.00	24.00	22.67	22.64
Main	(N1) 80	20.83	22.11	21.71	22.62	22.33	21.92
effects	(N2) 100	21.11	22.11	21.89	22.56	22.33	22.00
	(N3) 120	21.55	23.00	22.00	24.00	22.67	22.64
Mean		21.17	22.41	21.86	23.06	22.45	
L.S.D at p= 0.05		2020			2021		
A(Hybrids.)		n.s			0.163		
B (Bio-fert.)		0.190			0.249		
AB		0.329			0.431		
C (Nitrogen)		0.155			0.184		
AC		n.s			0.318		
BC		0.347			n.s		
ABC		n.s			n.s		

3.2.2 Number of rows/ear

The number of rows/ear were significantly affected by the type of hybrid in the 1st and 2nd seasons, SC 3062 hybrid gave the highest number of row/ear (15.33 and 15.42) in the 1st and 2nd seasons, respectively. On the other hand, SC 168 gave the lowest number of rows/ear (13.81 and 14.05) in the 1st and 2nd seasons, respectively. Also, SC 3062 hybrid exceeds SC 168 hybrid in number of rows/ear by (11.00 and 9.75%) in the 1st and 2nd seasons. Awadalla *et al.* (2018) showed that the maximum number of rows/ear was recorded for white S.C.10, while yellow T.W.368 scored the lowest one. Results in Table (6) showed clearly that there was a significant effect of inoculation with bio-fertilizer on number of rows/ear in 2020 and 2021 seasons. Microben inoculation gave the highest number of rows/ear (15.50 and 15.66) in the 1st and 2nd seasons, respectively. On the other hand, un-inoculation gave lowest number of row/ear (14.06 and 14.33) in the 1st and 2nd seasons, respectively. Also, SC 3062 hybrid exceeds SC 168 hybrid in number of rows/ear by 10.24 and 9.28% in the 1st and 2nd seasons, respectively. Hoshang *et al.* (2011) found that inoculation with Azotobacter, Azospirillum and Azospirillum had the highest number of rows per ear (14.5 rows). The obtained data showed clearly that there was a significant effect of nitrogen fertilizer levels on number of rows/ear in 2020 and 2021 seasons. Application nitrogen fertilizer at the rate of 120 kg N/feddan gave the highest number of rows/ear (15.33 and 15.42) as compared with all other nitrogen levels in both seasons, respectively. On the other hand, applied nitrogen fertilizer at the rate of 80 kg N/feddan gave the lowest number of rows/ear (13.81 and 14.05) in the 1st and 2nd seasons, respectively. Increasing mineral N-fertilizer significantly increased number of row/ear by 11.00 and 9.75% in both seasons. Badawi *et al*. (2012) indicated that the highest level of nitrogen fertilizer (130 kg N/fed) produced the highest values of number of rows/ear in both seasons number of ears/plant. Results indicate that the interaction effect, between hybrid type and bio-fertilization (H X Bio) was significant on number of rows/ear in two seasons. SC 3062 hybrid inoculated with Microben gave the highest number of row/ear (15.96 and 16.10) in the 1st and 2nd seasons, respectively. While the lowest number of rows/ear (13.46 and 13.80) were registered for SC 168 without any bio-fertilizer. Treating SC 3062 hybrid with Microben surpassed untreated SC 168 hybrid. So far, the SC 3062 hybrid with 120 kg (H3 × N3) gave the highest number of rows/ear by (15.90 and 16.01) in both seasons as compared with other interaction treatments in 2020 and 2021 seasons, respectively. El-Nagar (2003) reported that mineral nitrogen up to 130 kg N/fad., to significant increase in number of rows/ear compared with other nitrogen rates (60 and 100 kg N/feddan). Also, results in Table 6 show that the significant interaction between bio-fertilizer and nitrogen fertilizer levels (Bio × N) in both seasons. Incubation maize hybrids with Microben with combined fertilization of N at a rate of 120 kg/feddan, gave the highest number of rows/ear. Ahmed Amal *et al.* (2016) showed clearly that application (120 kg N/feddan and (60 kg N +10 tons organic matter/feddan) + Azoto + Pseudo) yielded the highest significant value from number of rows/ear. Results recorded in Table (6) indicated that the 2nd order interaction (H × Bio × N) among hybrid type, inoculation with bio-fertilizers and nitrogen fertilizer rates was significant on number of rows/ear by in both seasons. Also, inoculation hybrid SC 3062 with Microben combined with 120 kg N /feddan, recorded the maximum no of rows/ear (16.86 and 16.91) in both seasons, respectively.

Table (6): Effect of maize hybrids, bio-fertilizers and N-fertilization rates and their interactions on no. of rows/ear in the 2020 and 2021 summer seasons.

Hybrid	N-fertilizer rate	Un-inoculated Bio-0	Biogen Bio-1	Cerialin Bio-2	Microben Bio-3	Nitroben Bio-4	Mean
2020 season							
H1 (SC168)	(N1) 80	12.06	12.21	12.26	12.67	12.23	12.29
	(N2) 100	14.13	14.36	14.21	14.67	14.38	14.35
	(N3) 120	14.18	14.52	14.35	16.31	14.62	14.80
Mean		13.46	13.70	13.61	14.55	13.74	13.81
H2 (SC2066)	(N1) 80	14.33	14.13	14.42	14.41	14.32	14.32
	(N2) 100	14.21	16.21	14.38	16.71	16.33	15.57
	(N3) 120	14.36	16.37	14.61	16.82	16.64	15.76
Mean		14.30	15.57	14.47	15.98	15.76	15.22
H3 (SC3062)	(N1) 80	14.33	14.32	14.16	14.42	14.42	14.33
	(N2) 100	14.41	16.51	14.58	16.67	16.62	15.76
	(N3) 120	14.53	16.67	14.71	16.86	16.72	15.90
Mean		14.42	15.83	14.48	15.98	15.92	15.33
Main effects	(N1) 80	13.46	13.70	13.61	14.55	13.74	13.81
	(N2) 100	14.30	15.57	14.47	15.98	15.76	15.22
	(N3) 120	14.42	15.83	14.48	15.98	15.92	15.33
Mean		14.06	15.03	14.19	15.50	15.14	
2021 season							
H1 (SC168)	(N1) 80	12.67	12.76	12.31	12.82	12.26	12.56
	(N2) 100	14.32	14.63	14.53	14.85	14.32	14.53
	(N3) 120	14.41	14.72	14.68	16.67	14.72	15.04
Mean		13.80	14.04	13.84	14.78	13.77	14.05
H2 (SC2066)	(N1) 80	14.36	14.33	14.52	14.63	14.42	14.45
	(N2) 100	14.67	16.33	14.67	16.67	16.52	15.77
	(N3) 120	14.76	16.67	14.86	16.96	16.67	15.98
Mean		14.60	15.78	14.68	16.09	15.87	15.40
H3 (SC3062)	(N1) 80	14.41	14.36	14.26	14.63	14.53	14.44
	(N2) 100	14.63	16.33	14.67	16.76	16.67	15.81
	(N3) 120	14.72	16.72	14.86	16.91	16.83	16.01
Mean		14.59	15.80	14.60	16.10	16.01	15.42
Main effects	(N1) 80	13.80	14.04	13.84	14.78	13.77	14.05
	(N2) 100	14.60	15.78	14.68	16.09	15.87	15.40
	(N3) 120	14.59	15.80	14.60	16.10	16.01	15.42
Mean		14.33	15.21	14.37	15.66	15.22	
L.S.D at *p*= 0.05		2020			2021		
A(Hybrids.)		0.148			0.149		
B (Bio-fert.)		0.184			0.185		
AB		0.320			0.320		
C (Nitrogen)		0.148			0.148		
AC		0.257			0.257		
BC		0.331			0.332		
ABC		0.574			0.574		

3.2.3 Grain yield (ton/feddan)

The grain yield (ton/feddan) of maize as affected by hybrids, bio-inoculation, nitrogen fertilizer rates and their interaction effects in 2020 and 2021 seasons are presented in Table (7). The differences in grain yield/ feddan, among maize hybrids have been found significant. The grain yield/feddan, was significantly affected by the type of hybrid in the 1st and 2nd seasons, SC 3062 hybrid gave the maximum grain yield/feddan, (3.034 and 3.308 ton/feddan) in the 1st and 2nd seasons, respectively. On the other hand, SC 168 hybrid gave minimum grain yield/feddan, (2.378 and 2.614 ton/feddan) in the 1st and 2nd seasons, respectively. Also, SC 3062 hybrid exceeds SC 168 hybrid in grain yield/feddan, by 27.58 and 26.54% in the 1st season. The variation in grain yield/feddan could be partially attributed to the good climatic conditions recorded throughout growing as well as the maximum yield parameters. Njodi *et al.* (2019) showed that Sammaz 15 gave the highest values of growth and yield parameters compared with the others. This is in agreement with those reported by Hoshang *et al.* (2011), and Baqa *et al*. (2014). Results in Table (7) showed clearly that the grain yield/feddan, were significantly affected by the type of bio-inoculation in the 1st and 2nd seasons, Microben inoculation gave the highest grain yield/feddan, (3,300 and 3.510 ton/feddan) in the 1st and 2nd seasons, respectively. On the other hand, un-inoculated seed maize gave lowest grain yield/feddan, (2.290 and 2.570 ton/feddan) in the 1st and 2nd seasons, respectively. Also, SC 3062 hybrid exceeds SC 168 hybrid in grain yield/feddan, by 44.10 and 36.57% in the 1st and 2nd seasons, respectively. The same trend was reported by El-Kholy *et al.* (2005). Hoshang *et al.* (2011) found that inoculation with Azotobacter, Azospirillum and Azospirillum had the highest grain yield (10190 kg/ha). Results in Table (7) showed clearly that there was a significant effect of nitrogen fertilizer levels on grain yield/feddan, in 2020 and 2021 seasons. Application nitrogen fertilizer at the rate of 120 kg N/feddan gave the highest grain yield/feddan, (3.080 and 3.308 ton/feddan) as compared with all other nitrogen levels in both seasons, respectively. On the other hand, applied nitrogen fertilizer at the rate of 80 kg N/feddan gave the lowest grain yield/feddan, (2.378 and 2.612) in the 1st and 2nd seasons, respectively. Increasing mineral N-fertilizer significantly increased grain yield/feddan, by 29.52 and 26.64% in both seasons. Mamudu *et al*. (2017) found that increasing N-fertilization rates significantly increased grain yield/feddan. These results are in agreement with Sharifi and Taghizadeh (2009), Badawi *et al.* (2012), Kandil (2013), Modhej *et al*. (2014), Yasin (2016), and Awadalla *et al.* (2018). The recorded data in Table (7) indicate that the interaction between hybrid type and bio-inoculation (H × Bio) was significant on grain yield/feddan, in two seasons. SC 3062 hybrid inoculated with Microben gave the highest grain yield/feddan, (3.570 and 3.820 ton/feddan) in the 1st and 2nd seasons, respectively.

Table (7): Effect of maize hybrids, bio-fertilizers and N-fertilization rates and their interactions on grain yield (ton/feddan) in the 2020 and 2021 summer seasons.

Hybrid	N-fertilizer rate	Un-inoculated Bio-0	Biogen Bio-1	Cerialin Bio-2	Microben Bio-3	Nitroben Bio-4	Mean
2020 season							
H1 (SC168)	(N1) 80	1.333	1.572	1.422	1.779	1.721	1.565
	(N2) 100	2.240	2.532	2.476	3.454	3.107	2.762
	(N3) 120	2.311	2.607	2.506	3.515	3.101	2.808
Mean		1.960	2.240	2.130	2.920	2.640	2.378
H2 (SC2066)	(N1) 80	1.802	1.960	1.896	2.371	2.165	2.039
	(N2) 100	2.652	3.559	3.150	3.874	3.706	3.388
	(N3) 120	2.768	3.618	3.309	4.002	3.723	3.484
Mean		2.410	3.050	2.790	3.420	3.200	2.974
H3 (SC3062)	(N1) 80	1.834	2.192	2.089	2.430	3.047	2.318
	(N2) 100	2.687	3.585	3.238	4.107	3.017	3.327
	(N3) 120	2.999	3.670	3.378	4.184	3.061	3.458
Mean		2.510	3.150	2.900	3.570	3.040	3.034
Main effects	(N1) 80	.961	2.237	2.135	2.916	2.643	2.378
	(N2) 100	2.407	3.046	2.785	3.416	3.198	2.970
	(N3) 120	2.507	3.149	2.902	3.574	3.266	3.080
Mean		2.290	2.810	2.610	3.300	2.980	
2021 season							
H1 (SC168)	(N1) 80	1.518	1.838	1.713	1.992	1.950	1.802
	(N2) 100	2.482	2.865	2.711	3.619	3.246	2.985
	(N3) 120	2.564	2.911	2.792	3.665	3.315	3.049
Mean		2.190	2.540	2.410	3.090	2.840	2.614
H2 (SC2066)	(N1) 80	2.067	2.253	2.199	2.607	2.349	2.295
	(N2) 100	2.965	3.701	3.370	4.113	3.899	3.610
	(N3) 120	3.117	3.803	3.501	4.186	3.951	3.712
Mean		2.720	3.250	3.020	3.640	3.400	3.206
H3 (SC3062)	(N1) 80	2.162	2.390	2.300	2.660	2.439	2.390
	(N2) 100	3.069	3.761	3.456	4.301	3.998	3.717
	(N3) 120	3.147	3.870	3.548	4.485	4.042	3.818
Mean		2.790	3.340	3.100	3.820	3.490	3.308
Main effects	(N1) 80	2.188	2.538	2.405	3.092	2.837	2.612
	(N2) 100	2.716	3.252	3.023	3.635	3.400	3.205
	(N3) 120	2.792	3.340	3.101	3.815	3.493	3.308
Mean		2.570	3.040	2.840	3.510	3.240	

L.S.D at p= 0.05	2020	2021
A(Hybrids.)	0.051	0.054
B (Bio-fert.)	0.042	0.045
AB	0.073	0.078
C (Nitrogen)	0.030	0.031
AC	0.052	0.054
BC	0.068	0.070
ABC	0.117	0.122

On the other hand, the minimum values of grain yield/feddan, (1.960 and 2.190 ton/feddan) were obtained due to SC 168 hybrid without bio-fertilization. Also, treating SC 3062 hybrid with Microben surpassed untreated SC 168 hybrid. So far, the SC3062 hybrid with 120 kg (H3 × N3) gave the highest grain yield/plant by

3.458 and 3.818 ton/feddan in both seasons as compared with other interaction treatments in 2020 and 2021 seasons, respectively. On the other hand, the minimum values of grain yield/feddan, (1.565 and 1.802 ton/feddan) were obtained due to SC 168 hybrid without bio-fertilization. Also, SC 3062 hybrid exceeds SC 168 hybrid in grain yield/ fed., by (120.95 and 111.87%) in the 1st and 2nd seasons, respectively. In this respect, Abd Elhady *et al*. (2017) stated that plants treated with120 kg MN/feddan + 20 kg HA and 120 kg MN/feddan + 15 kg HA found that Maximum grain yield (3.76 ton/feddan) was obtained when plants were fertilized with 120 kg MN + 20 kg HA. Modhej *et al.* (2014) indicated that the maximum grain yield was obtained in DKC 6589 hybrid at 180 kg N ha^{-1}. Increase of nitrogen up to 260 kg N ha^{-1} led to the significant increase of grain yield of 640 hybrid, but in other hybrids, increase of nitrogen up to more than 180 kg N ha^{-1}, slightly decreased the grain yield. The optimum amount of nitrogen for Sc.704 hybrid was 180 kg N ha^{-1}. Similar findings obtained by Meena *et al.* (2013), El-Nagar (2003), and Yasin (2016). Also, the obtained data in Table (7) showed that interaction between bio-inoculation and nitrogen fertilizer levels (Bio × N) was significant in both seasons. Inoculation maize seeds with Microben combined with N-fertilizer at a rate of 120 kg (H3 × N3) gave the highest grain yield/feddan, (3.574 and 3.815 ton/feddan) in both seasons as compared with other interaction treatments in 2020 and 2021 seasons, respectively. On the other hand, the minimum values of grain yield/feddan, (1.961 and 2.188 ton/feddan) were obtained due to the fertilization with N-fertilizer at a rate of 80 kg/feddan, without bio-fertilizer (Bio-0). Also, SC 3062 hybrid exceeds SC 168 hybrid in grain yield/feddan, by 82.25 and 74.36% in the 1st and 2nd season, respectively. Increasing grain yield due to bio-inoculation may be due to yield attribute; plant height, ear height and ear length (El-Kholy *et al.*, 2005). Meena *et al*. (2013) stated that grain yield increased with increasing levels of nitrogen, and maximum grain yield of 4.3 Mg/ha was obtained by use of 150 kg N/ha with FYM at 5 ton/ha and Azotobacter inoculation. Results in Table (7) indicated that the 2nd order interaction (H × Bio × N) among hybrid type, bio-inoculation and nitrogen fertilizer rates was significant on grain yield/feddan, in both seasons. Treating SC 3062 hybrid with Microben combined with N-fertilization at a rate of 120 kg gave the highest grain yield/feddan, by 4.184 and 4.485 ton/feddan, in both seasons as compared with other interaction treatments in 2020 and 2021 seasons, respectively.

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