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Full Length Article

Influence of Maize Planting Methods and Nitrogen Fertilization Rates on Mealybug Infestations, Growth Characteristics and Eventual Yield of Maize

Moustafa M.S. Bakry[1*], Yani Maharani[2], Nawal Al-Hoshani[3] and Rania Ali El Hadi Mohamed[3]
[1]*Department of Scale Insects and Mealybugs Research, Plant Protection Research Institute, Agricultural Research Center, Giza, Egypt*
[2]*Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Padjadjaran, West Java, Indonesia*
[3]*Department of Biology, College of Sciences, Princess Nourah Bint Abdulrahman University, Riyadh 11617, Saudi Arabia*
[*]For correspondence: md.md_sabry@yahoo.com
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Abstract

Nitrogen fertilization is known to increase crop productivity but improper application can make plant tissues softer and more susceptible to pests such as mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae). The attack of this pest can cause the plant to dry out and even dies. The objective of this study was to investigate the impact of maize planting methods (Ridge & raised bed) and nitrogen fertilization rates (90 & 150 kg N/ fed.) on *P. solenopsis* infestations, growth characteristics and eventual yield of maize. The study was conducted on Single-Hybrid 168 Yellow maize cultivar, in Luxor Governorate, Egypt during the 2021–2022 seasons and various nitrogen fertilization rates were applied to examine their effects on the different parameters studied. The findings revealed that the amount of nitrogen fertilizer applied to maize plants significantly affected the infestation of *P. solenopsis* on vegetative growth and maize production. Low doses of fertilizer reduced the infestation of *P. solenopsis* but this led to a lack of maximum maize vegetative phase, which had a negative impact on the final yield by 10.49 and 10.56% as compared with higher doses. As well, the ridge pattern cultivation pattern has a positive influence on plant vegetative growth but is not supportive for plant attributes. Moreover, the resulting yield, and its component attributes in the plants cultivated using the raised bed method and fertilized were significantly higher compared to the different tested treatments. It can be concluded that the best method in supporting the growth and production of maize crops is to use the raised bed method by paying attention to the schedule of fertilizer application to avoid mealybug infestation. The results offer valuable recommendations to farmers for determining the optimal planting method and dosage of fertilizers in the cultivation of maize crops and pest free.

Keywords: Crop productivity; Nitrogen fertilization; *Phenacoccus solenopsis;* Planting methods; Sucking insect

Introduction

In Egypt, maize (*Zea mays* L.) is deemed one of the best-known cereal crops in summer for human and animal nutrition. It is the third largest cereal crop after rice and wheat and is known as the "queen of cereals" (El-Ezz and Haffez 2019). Although maize is essentially used for the production of carbohydrates, it has become increasingly important in recent years as a source of vegetable oils (Prudhvi and Mehta 2021).

Maize is vulnerable to attack by numerous piercing-sucking insect pests (Naroz *et al*. 2021). Among these pests, the mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae), is one of the most serious pests that infest maize plants (Nabil *et al*. 2015; El-Mageed *et al*. 2020). It is a small sap-sucking insect that causes severe damage to maize plants. All stages of this pest are found on all plant parts, including the leaves, branches, cobs and roots (Aheer *et al*. 2009). The appearance and aggregation of *P. solenopsis* bodies on the damaged plant parts is a symptom of an infestation's occurrence (Shah *et al*. 2015). Plants infested by *P. solenopsis* during their vegetative phase exhibit features of distorted shoots, crinkled and stunted plants that dry completely in severe cases (Babasaheb and Suroshe 2015). *P. solenopsis* excretes honeydew, which encourages the development of black sooty mould (Arif *et al*. 2012), which also delaying photosynthesis process and causes chlorosis spots, malformation, pits, and death in infested of plants (Ibrahim *et al*. 2015).

Different factors influence maize productivity; however, agronomic practices are the primary determinants of perfect growth and eventual yield. These include selecting an appropriate planting method and nitrogen fertilizer rates to provide plants with the best possible conditions for growth and development, as well as reducing insect infestations during critical growth periods (El-Rouby *et al*. 2021). Nitrogen is a vital mineral element for plant development and growth and is used by plants (Srivastava and Singh 1999). It is also essential for insect herbivore reproduction, growth, fertility, and survival (Joern and Behmer 1997). Fertilizers are regarded as a means to enhance crop productivity as they provide a steady source of nutrients. The nature of these inputs can affect pest populations depending on the fertilizer type, the plant being cultivated and the species of insects involved (Ali *et al*. 2013). Despite the higher cost of the fertilizer, numerous studies have found that balanced fertilizer is an essential part of crop administration in order to achieve a perfect crop yield (Cui *et al*. 2010). Heavy use of nitrogen fertilizers scarcely influences insects directly, but can modify the physiological, biochemical, and morphological properties of host plants and plays a main role in insect population size (Simpson and Simpson 1990). Increased nitrogen fertilizer use encourages the crop infestation by insects by decreasing plant resistance (Ge *et al*. 2003). Application of nitrogen fertilizer to the soil can modify the level of nitrogen in the diet of phloem-feeding insects, which in turn can impact their population growth (Godfrey *et al*. 1999) and improves plant nutritional condition and direct pest defence methods (Chen and Ruberson 2008), as well reduced evaporation and increased transpiration (Vinay *et al*. 2008). There is a positive relationship between optimum nitrogen fertilization and the growth rate of maize crop (Moghazy 2021).

The influence of agronomic practices on *P. solenopsis* populations has not been studied. Hence, the ultimate goal of this research was to assess the potential influence of maize planting method and nitrogen fertilizer levels and their interactions on the population abundance of the pest when applied to the Single-Hybrid 168 Yellow maize cultivar in Luxor Governorate, Egypt. Understanding these pest parameters is very important in pest abundance, distribution, and development. So, the ultimate goal is to assist farmers in learning the appropriate agronomic practices for the maize crop to reduce *P. solenopsis* infestation in maize plants.

Materials and Methods

Experimental layout

The experiment was conducted in a private maize field (25º21'48" N, 32º32'26" E) during two growing seasons (2021 and 2022) in Esna district, Luxor Governorate, Egypt, to study the effect of different planting methods and nitrogen fertilization levels on the vegetative growth attributes of maize, eventual yield and *P. solenopsis* infestation rates. The maize plants (Single-Hybrid 168 Yellow maize cultivar) were planted over an area of about one feddan (4200 m^2), including experimental units. The experiment was carried out in a split-plot design with four replicates (plots). Each experimental plot area was 42 m^2, *i.e*., (6 m × 7 m) = 0.01 feddan. The main plots represented two different planting methods (ridge and raised bed), whereas the split plots comprised two nitrogen fertilization levels (90 and 150 kg N/fed).

The tested factors and their treatments

Planting patterns were two. First one, Ridge-furrow system (75 cm width), and the second method, Furrow irrigated raised bed system (150 cm width), with maize planted on the two edges to help reduce irrigation requirements and the shortage of water supply, as shown in Fig. 1.

The nitrogen fertilizer was applied in the form of urea (46.5% N) at different rates of 90 and 150 kg N/ fed in two equal doses. The first dose was added before the first irrigation, while the second one in addition to potassium fertilizer (potassium sulphate 48% K_2O) at a rate of 50 kg K/ fed was applied before the second irrigation. The experiment had four treatments, and each treatment included four replicates, totaling 16 units. The maize plants were cultivated on the proper date (first week of June per season). All the other agronomic practices were carried out based on the recommendation of the Egyptian Ministry of Agriculture without using any control measures against any insect pest.

Population abundance of the *P. solenopsis* infesting maize plants

The sampling date was determined from the beginning of the infestation of *P. solenopsis* that could be detected in the study area. *P. solenopsis* infestation started 15 days after emergence and continued sampling up to crop maturity. Forty maize plants were randomly selected from each treatment at weekly intervals (10 plants from each plot, nearly 10 cm long of maize leaf) and the total number of *P. solenopsis* was recorded.

The samples of leaves were collected randomly from the different directions of the plants per plot. The collected leaves were transferred in polyethylene bags to the laboratory for examination. The number of total *P. solenopsis* per sample on the two surfaces of leaves was recorded and counted in each examined time period plus or minus (±) the standard error (SE), which was applied to indicate the population estimates. This was executed in all of the studied plots. *P. solenopsis* individuals were maintained in tubes containing 90% alcohol until they were for identification. Mealybug samples identify at Plant Protection Research Institute, Dokki, Giza, Egypt.

Vegetative growth measurements, yield and its components of maize plants

At maturity, 10 plants were randomly harvested from each

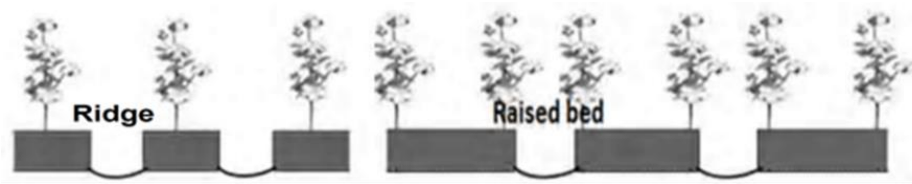

Fig. 1: Ridge and Raised bed planting patterns of maize

plot to register the following attributes: Plant height (cm) - stem diameter (cm) - No. of green leaves/plant - ear length (cm) - ear weight (g) - Grain yield (ton/fed), was calculated in all the tested plots.

Percentages of decrease or increase in the examined measurements

Planting methods: The percentage decrease or increase in the examined measurements was calculated resulting from the planting by the ridge pattern (R) compared to that for the raised bed method (P) was computed using the following formula:

$$\% \text{ Decrease or increase} = [(R-P) / R] \times 100$$

R: average of a given estimation in plots that are planted with the ridge pattern. P: average of the same variable in plots that are planted with the raised bed pattern

Nitrogen fertilizer levels: The percentage of increase or reduction in the tested traits caused by the added 90 kg N/ fed for the plants compared to that for the added plants by 150 kg N/ fed was computed using the following formula:

$$\% \text{ Increase or decrease} = [(A-B) / A] \times 100$$

A: average of a given estimation of the lower treatments (90 kg N/ fed) and B: average of the same variable across the higher treatments (150 kg N/ fed).

Statistical analysis

The data was statistically assessed as a split-plot design, with four replicates and were compared using the LSD test at a 5% level of probability, which was analysist on a computer (SPSS Program software 1999).

Results

Population abundance of mealybug, *P. solenopsis* attacking maize plants

The total number of *P. solenopsis* was monitored on maize plants during the period from the third week of June 2021–2022 to the time of yield harvest across every season. The seasonal occurrence of pest had three peaks per season, which took place in the third week of July, the second week of August and the first week of September in all the studied treatments. In addition, the total alive numbers of *P. solenopsis* through the first season were higher as average (102.40 ± 6.32 individuals) as compared to the second season (as average of 99.40 ± 5.82 individuals per sample) (Table 1).

The analysis of variance mentioned the presence of extremely significant variations in the population densities of *P. solenopsis* in the different inspection periods over every season in all studied treatments when the comparisons were completed for every treatment severally. Moreover, the interactions between planting methods, nitrogen levels, and examination dates had a very significant impact on the average *P. solenopsis* count. The L.S.D. values were (26.22 and 18.52), respectively through the two seasons, respectively, in Table 1.

Data in Table 2 showed that the maize plants grown using the ridge method increased the population size of *P. solenopsis* by an average of (114.39 ± 12.34 and 110.87 ± 11.53 individuals per sample) as compared to the plants grown using raised bed (90.40 ± 9.42 and 87.94 ± 9.17 individuals per sample), during the two seasons, respectively. Similarly, the numbers of *P. solenopsis* on maize plants cultivated using the ridge pattern method increased by 20.97 and 20.68%, respectively, when compared to the planted plots using the raised bed mode during the (2021 and 2022) seasons.

Statistical inspection of the data revealed that there were real differences in the mean counts of *P. solenopsis* between the two planting during the two seasons 11.85 and 5.11, respectively.

Concerning the nitrogen fertilizer levels, the application of nitrogen at a rate of 150 kg N/fed. increased the number of *P. solenopsis* by an average of (131.39 ± 14.07 and 123.62 ± 13.03 individuals per sample), as compared with the fertilization by 90 kg N/fed. (73.40 ± 7.69 and 75.19 ± 7.69 individuals per sample), across the two seasons, respectively. Furthermore, the counts of *P. solenopsis* were increased considerably by 44.13 and 39.18% on the maize plants in the plots that were fertilized at a rate of 150 kg N/fed., when compared to fertilized plots by 90 kg N/fed., throughout the two seasons, respectively. The different nitrogen fertilizer levels had an extremely important impact on the mean counts of *P. solenopsis* (L.S.D. values were 12.13 and 6.23) during two seasons, respectively (Table 2).

Highest pest population densities were obtained on maize plants planted using the ridge method and fertilized

Table 1: Weekly number (mean ± SE) of *P. solenopsis* individuals per sample as influenced by planting methods and nitrogen fertilizer levels in maize plants during the two growing seasons (2021 and 2022).

Sampling date (in weeks)		First growing season (2021)					Second growing season (2022)				
		Planting method (Ridge) (M_1)		Planting method (Bed) (M_2)		Average	Planting method (Ridge) (M_1)		Planting method (Bed) (M_2)		Average
		90 kg N/fed.	150 kg N/fed.	90 kg N/fed.	150 kg N/fed.		90 kg N/fed.	150 kg N/fed.	90 kg N/fed.	150 kg N/fed.	
June	3rd	2.33 ± 0.33	4.00 ± 0.58	2.67 ± 0.33	3.00 ± 0.58	3.00 ± 0.28	2.67 ± 0.33	3.33 ± 0.33	2.00 ± 0.58	2.66 ± 0.33	2.67 ± 0.22
	4th	11.00 ± 1.15	20.67 ± 3.18	10.67 ± 0.88	15.67 ± 2.03	14.50 ± 1.50	11.00 ± 1.15	18.00 ± 2.31	9.33 ± 0.88	14.67 ± 2.03	13.25 ± 1.24
July	1st	25.67 ± 2.91	47.67 ± 6.64	20.33 ± 1.45	34.33 ± 4.63	32.00 ± 3.63	23.33 ± 2.40	45.33 ± 6.06	19.33 ± 2.40	34.00 ± 3.46	30.50 ± 3.47
	2nd	44.00 ± 6.35	80.33 ± 9.84	38.67 ± 1.33	59.00 ± 4.93	55.50 ± 5.58	45.71 ± 6.50	77.78 ± 9.56	39.53 ± 1.52	57.68 ± 4.84	55.17 ± 5.16
	3rd	91.00 ± 3.21	176.67 ± 16.90	73.67 ± 1.86	103.00 ± 4.58	111.08 ±12.44	94.33 ± 3.48	166.67 ± 13.02	74.00 ± 2.08	101.00 ± 4.58	109.00±10.92
	4th	81.00 ± 3.21	115.67 ± 5.36	54.67 ± 1.76	106.00 ± 3.46	89.33 ± 7.31	81.33 ± 3.48	111.33 ± 4.81	55.33 ± 2.91	99.00 ± 3.79	86.75 ± 6.55
Aug.	1st	36.67 ± 3.33	164.00 ± 20.23	85.67 ± 9.24	125.00 ± 9.81	102.83 ± 15.16	84.67 ± 4.67	157.00 ± 19.66	86.00 ± 9.24	119.33 ± 9.82	111.75±10.31
	2nd	127.67 ± 3.93	244.00 ± 14.00	117.33 ± 4.06	170.67 ± 7.22	164.92 ± 15.45	130.33 ± 3.18	196.67 ± 8.82	105.33 ± 7.86	167.05 ±7.08	149.85±10.92
	3rd	115.00 ± 1.73	202.67 ± 8.17	105.33 ± 2.91	165.33 ± 9.26	147.08 ±12.18	118.00 ±2.00	195.00 ± 7.64	106.00 ± 2.31	160.00 ± 8.66	144.75±10.93
	4th	150.00 ± 8.08	280.67 ± 9.33	123.00 ± 1.53	218.00 ± 8.08	192.92 ±18.77	134.67 ± 7.86	261.67 ± 1.67	104.00 ± 7.02	210.33 ± 7.31	177.67±18.91
Sept.	1st	166.67 ± 3.53	293.67 ± 6.01	104.33 ± 6.17	226.00 ± 8.33	197.67 ±21.32	163.33 ± 7.26	276.00 ± 8.33	136.00 ± 6.23	202.67 ± 8.97	194.50±16.27
	2nd	96.33 ± 12.41	168.00 ± 20.23	78.00 ± 5.29	129.33 ± 17.90	117.92 ± 12.17	99.33 ± 10.35	163.33 ± 18.78	79.00 ± 5.57	126.33 ± 16.46	117.00±11.19
General average		78.94 ± 8.98	149.83 ± 16.07	67.86 ± 6.88	112.94 ± 21.21	102.40 ± 6.32	82.39 ± 8.48	139.34 ± 14.71	67.99 ± 7.08	107.89 ± 11.49	99.40 ± 5.82
L.S.D. at 0.05 level		15.52 **	24.80 **	41.16 **	21.17 **	16.48 **	14.68 **	27.07 **	14.76 **	18.15 **	12.64 **
L.S.D between (Planting methods, nitrogen levels and inspected dates) at 0.05 level = 26.22 **									18.52 **		

M = Planting method; M_1 = ridge; M_2 = raised bed; N = Nitrogen fertilization levels; N_1 = 90 kg N/ fed.; N_2 = 150 kg N/ fed

Table 2: Averages of *P. solenopsis* individuals per sample and measurements of vegetative growth of the maize plants as affected by planting methods and N fertilizer rates during the two growing seasons (2021 and 2022). Each value is the mean of the four different replicates ± SE

Treatment		Mean number of individuals per sample ± SE		Means of vegetative growth ± SE					
				Plant height (cm)		Stem diameter (cm)		No. of green leaves/ plant	
		2021 Season	2022 Season	2021 Season	2022 Season	2021 Season	2022 Season	2021 Season	2022 Season
M	M_1	114.39 ± 12.34 (+20.97%)	110.87±11.53 (+20.68%)	245.83 ±1.92 (+5.19%)	250.17 ±2.09 (+5.26%)	3.52 ±0.03 (+4.49%)	3.33±0.02(+4.15%)	14.50 ±0.29 (+2.30%)	15.50 ± 0.29 (+2.15%)
	M_2	90.40 ± 9.42	87.94 ± 9.17	233.08 ± 0.65	237.00 ± 1.15	3.37 ± 0.04	3.20 ± 0.03	14.17 ± 0.33	15.17 ± 0.33
L.S.D. at 0.05 level		11.85 *	5.11 **	10.78 *	9.96*	N.S.	0.13 *	N.S.	N.S.
N	N_1	73.40 ± 7.69	75.19 ± 7.69	227.67 ± 1.67	231.67 ± 1.67	3.28 ± 0.01	3.11 ± 0.01	13.50 ± 0.29	14.50 ± 0.29
	N_2	131.39 ± 14.07 (+44.13%)	123.62±13.03 (+39.18%)	251.25±1.13(+10.36%)	255.50±1.26(+10.29%)	3.62±0.04(+10.41%)	3.42±0.04(+9.80%)	15.17±0.33 (+12.35%)	16.17±0.33(+11.49%)
L.S.D. at 0.05 level		12.13 **	6.23 **	5.32 **	4.56 **	0.03 **	0.10 **	1.03 **	1.02*
M_1	N_1	78.94 ± 8.98 (+14.04%)	82.39 ± 8.48 (+17.48%)	231.33 ±2.40 (+3.17%)	235.33 ±2.40 (+3.12%)	3.32 ±0.04 (+2.53%)	3.13±0.02(+1.38%)	13.67 ±0.32 (+2.44%)	14.67 ± 0.33 (+2.27%)
	N_2	149.83 ± 16.07 (+24.62%)	139.34±14.71 (+22.57%)	260.33 ±2.60 (+6.98%)	265.00 ±2.89 (+7.17%)	3.73 ±0.03 (+6.23%)	3.53±0.03(+6.60%)	15.33 ±0.33 (+2.17%)	16.33 ± 0.28 +2.04%)
M_2	N_1	67.86 ± 6.88	67.99 ± 7.08	224.00 ± 1.15	228.00 ± 1.13	3.23 ± 0.02	3.09 ± 0.01	13.33 ± 0.30	14.33 ± 0.30
	N_2	112.94 ± 21.21	107.89 ± 11.49	242.17 ± 1.30	246.00 ± 1.15	3.50 ± 0.06	3.30 ± 0.06	15.00 ± 0.58	16.00 ± 0.56
General average		102.40 ± 6.32	99.40 ± 5.82	239.46 ± 4.21	243.58 ± 4.29	3.45 ± 0.06	3.26 ± 0.05	14.33 ± 0.31	15.33 ± 0.30
L.S.D. at 0.05 level		17.15 **	8.81 *	7.52 *	6.44 *	N.S.	N.S.	N.S.	N.S.

M = Planting method; M_1 = ridge; M_2 = raised bed; N = Nitrogen fertilization levels; N_1 = 90 kg N/ fed.; N_2 = 150 kg N/ fed

with 150 kg (N/fed.) with an average of (149.83 ± 16.07 and 139.34 ± 14.71 individuals per sample) when compared to the other tested treatments, respectively (Table 2). However, the plants cultivated using the raised bed method and fertilized with 90 kg (N/fed.) had lower population densities of pest, with an average of (67.86 ± 6.88 and 67.99 ± 7.08 individuals per sample) than the other studied treatments during the two seasons, respectively. The interaction influences of cultivating methods and nitrogen fertilizer levels had an extremely significant effect on *P. solenopsis* population estimates across two seasons. The L.S.D. values were (17.15 and 8.81), respectively (Table 2).

Over the two seasons, the counts of *P. solenopsis* were increased by 24.62 and 22.57% for the maize plants that planted using the ridge method and fertilized with 150 kg (N/fed) compared to cultivated plots using the raised bed method and fertilized with 150 kg (N/fed) over the two seasons, respectively. Moreover, there was an important increase in the number of *P. solenopsis* by 14.04 and 17.48% in the plants that were cultivated at ridge pattern and fertilized with 90 kg (N/fed) compared to planted treatments at the raised bed method, which received the same level of nitrogen fertilizer, over the two seasons, respectively (Table 2).

The binary influences of planting methods and nitrogen fertilizer levels on maize vegetative growth attributes and eventual yield and its components

Plant height: The data in Table 2 showed that the height of plants was affected by cultivation patterns and nitrogen fertilizer levels over the two studied seasons. Results demonstrated that the maize plants grown using the ridge method increased in the plant height by an average of (245.83 ± 1.92 and 250.17 ± 2.09 cm) as compared with the plants planted using the raised bed (233.08 ± 0.65 and 237.00 ± 1.15), through the two seasons, respectively. Also, the plant height was increased by 5.19 and 5.26% in plots planted using the ridge model as compared to plots using the raised bed way, during the two seasons, respectively. The plant height between the two grown methods of maize plants had significant variations. The L.S.D. values were (10.78 and 9.96) for the two seasons, respectively.

The influence of various levels of nitrogen on maize indicated that nitrogen application promoted the height of the plant; the use of 150 kg N/fed produced an increase in this attribute with an average (251.25 ± 1.13 and 255.50 ± 1.26 cm) than that of the fertilizer by 90 kg N/fed (227.67 ± 1.67 and 231.67 ± 1.67 cm), over the two seasons, respectively. It increased by 10.36 and 10.29% in the plots that were fertilized at a rate of 150 kg N/fed, when compared to fertilized plots by 90 kg N/fed, respectively. As well, there are there were very significant differences between different nitrogen fertilizer levels in the plant height (L.S.D. values of 5.32 and 4.56) in both seasons, respectively.

It was obvious that the highest rates of the plant height were noticed in the plants planted using the ridge way and fertilized with 150 kg N/fed, with an average of (260.33 ± 2.60 and 265.00 ± 2.89 cm), compared to the studied treatments, across the two seasons, respectively. However, the least rate of plant height (224.00 ± 1.15 and 228.00 ± 1.13 cm) was recorded in the plots planted using raised bed pattern and fertilized with 90 kg N/fed than in the other tested treatments, through the two seasons, respectively (Table 2). The combined effects of planting methods and nitrogen fertilizer levels had significant differences on plant heights (L.S.D. values; 7.52 and 6.44), during the two seasons, respectively (Table 2).

The plant height was increased by 6.98 and 7.17% for the plants that were cultivated using the ridge pattern and fertilized with 150 kg (N/fed.) compared to the planted plots using the raised bed way and fertilized with 150 kg (N/fed.) over the two seasons, respectively. Furthermore, there was a clear increase in plant height by 3.17 and 3.12% in the plants that were planted at the ridge method and fertilized with 90 kg (N/fed.) as compared to cultivated treatments at the raised bed pattern**,** which applied the same rate of nitrogen fertilizer during the two seasons, respectively (Table 2).

Stem diameter: As regarding in Table (2), the results showed that the maize plants planted using the raised bed method had smaller in diameters of maize stem with an average of (3.37 ± 0.04 and 3.20 ± 0.03 cm) than the plants cultivated using the ridge way (3.52 ± 0.03 and 3.33 ± 0.02), over the two seasons, respectively. As well, the stem diameter was increased by 4.49 and 4.15% in plots planted using the ridge model than that of the plots using the raised bed way, through the two seasons, respectively. Moreover, no there were any differences in stem diameter between the two cultivation methods during the first season, while, there were significant variations in second season (L.S.D. value was 0.13). Lima *et al*. (2010) mentioned that insect activity decreased plant biomass. According to our results, the plant height and stem diameter decreased.

The application of 90 kg N/fed of plant obtained an decrease in stem diameter with an average (3.28 ± 0.01 and 3.11 ± 0.01 cm) than that of the adding fertilizer by 150 kg N/fed (3.62 ± 0.04 and 3.42 ± 0.04 cm), during the two seasons, respectively. It decreased by (10.41 and 9.80%) in the two seasons, respectively. In addition, the nitrogen fertilizer levels had extremely significant differences in the stem diameter (L.S.D. values; 0.03 and 0.10) in both two seasons, respectively.

It was obvious that the minimum stem diameter (3.23 ± 0.02 and 3.09 ± 0.01 cm) were observed in the plants grown using the raised bed pattern and that utilized 90 kg N/fed, as compared to the different treatments, through the both seasons, respectively. While, the maximum value of this attribute (3.73 ± 0.03 and 3.53 ± 0.03 cm) was recorded in the plants planted using the ridge method and fertilized with 150 kg N/fed, than that of the tested other treatments, for the two seasons, respectively (Table 2). In addition, the combined impact of these factors on stem diameter had no variations in the two seasons (Table 2).

The stem diameter was increased by 6.23 and 6.60% for the plants that were planted using the ridge way that were fertilized with 150 kg (N/fed) than that of the cultivated plants using the raised bed way and used the same level of nitrogen fertilizer during the both seasons, respectively. There was obvious increase in stem diameter by 2.53 and 1.38% in the plants that were cultivated at the ridge way and fertilized with 90 kg (N/fed.) than that of the planted plots at the raised bed way and fertilized with the same rate of nitrogen fertilizer during the two seasons, respectively (Table 2).

Number of green leaves per plant: Data appeared that the maize plants cultivated using the raised bed way exhibited fewer leaves per plant, as an average was (14.17 ± 0.33 and 15.17 ± 0.33 leaves/plant) compared to the plants grown using the ridge method (14.50 ± 0.29 and 15.50 ± 0.29 leaves/plant) during the two seasons, respectively (Table 2). The reduction in the number of leaves per plant was greater in the plots planted using the raised bed (2.30 and 2.15%) than in the plots cultivated using the ridge way, for the two seasons, respectively. Moreover, no variations in the number of leaves per plant between different planting methods during the two seasons, respectively.

Results showed that the adding of 150 kg N/fed to plants produced to a obvious increase in leaves no. per plant with an average (15.17 ± 0.33 and 16.17 ± 0.33 leaves/plant) compared to fertilized plants by 90 kg N/fed (13.50 ± 0.29 and 14.50 ± 0.29 leaves/plant), during the two seasons, respectively. It increased by (12.35 and 11.49%) over the two seasons, respectively. As well, the nitrogen fertilizer levels had important variances in the number of leaves per plant (L.S.D. values of 1.03 and 1.02) across the two seasons, respectively.

The data mentioned that the plants that planted using the ridge pattern and that utilized 150 kg N/fed had produced greater leaves (15.33 ± 0.33 and 16.33 ± 0.28 leaves/plant) than that of the different other treatments, during the two seasons, respectively. However, the minimum number of leaves (13.33 ± 0.30 and 14.33 ± 0.30 leaves/plant) was observed in the plants planted using the raised bed pattern and fertilized with 90 kg N/fed, as compared to the studied other treatments, through the two seasons, respectively (Table 2). As well, all the combined interactions of the tested factors had an unimportant effect on this attribute.

In addition, the number of leaves per plant was clearly increased by (2.44 and 2.27%) for the plants that were

Table 3: Averages of maize yield and its components as influenced by planting methods and N fertilizer rates during the two growing seasons (2021 and 2022). Each value is the mean of the four different replicates ± SE

Treatment		Ear length (cm)		Ear weight (g).		Grain yield (ton/fed)	
		2021 Season	2022 Season	2021 Season	2022 Season	2021 Season	2022 Season
M	M_1	20.43 ± 0.07	21.27 ± 0.06	259.50 ± 1.80	267.50 ± 1.80	2.50 ± 0.02	2.59 ± 0.04
	M_2	21.62 ± 0.04 (+5.79%)	22.52 ± 0.08 (+5.91%)	271.83 ± 2.05 (+4.75%)	279.50 ± 2.08 (+4.49%)	2.62 ± 0.03 (+4.97%)	2.76 ± 0.03 (+6.32%)
L.S.D. at 0.05 level		0.31 **	1.34 **	12.19 *	11.85 *	0.05 **	0.16 *
N	N_1	19.93 ± 0.12	20.77 ± 0.21	252.00 ± 1.89	259.08 ± 1.82	2.43 ± 0.04	2.54 ± 0.04
	N_2	22.12 ± 0.17 (+10.95%)	23.02 ± 0.18 (+10.80%)	279.33 ± 1.86 (+10.85%)	287.92 ± 2.05 (+11.13%)	2.69 ± 0.02 (+10.49%)	2.81 ± 0.02 (+10.56%)
L.S.D. at 0.05 level		0.83 **	0.13 **	6.86 **	7.57 **	0.07 **	0.07 **
M_1	N_1	19.40 ± 0.31	20.20 ± 0.31	249.67 ± 1.45	257.17 ± 1.59	2.42 ± 0.02	2.51 ± 0.05
	N_2	21.47 ± 0.29	22.3 ± 0.32	269.33 ± 4.06	277.83 ± 4.34	2.58 ± 0.03	2.68 ± 0.03
M_2	N_1	20.47 ± 0.09 (+5.50%)	21.35 ± 0.13(+5.76%)	254.33 ± 2.33 (+1.87%)	261.00 ± 2.06 (+1.49%)	2.45 ± 0.04 (+1.29%)	2.57 ± 0.04 (+2.64%)
	N_2	22.77 ± 0.08 (+6.06%)	23.70 ± 0.06 (+6.12%)	289.33 ± 1.76 (+7.43%)	298.00 ± 2.08 (+7.26%)	2.80 ± 0.02 (+8.41%)	2.94 ± 0.02 (+9.76%)
General average		21.03 ± 0.39	21.90 ± 0.40	265.67 ± 4.80	273.50 ± 5.00	2.56 ± 0.05	2.67 ± 0.05
L.S.D. at 0.05 level		N.S.	N.S.	9.71 *	10.84 *	0.10 *	0.10 *

M = Planting method; M_1 = ridge; M_2 = raised bed; N = Nitrogen fertilization levels; N_1 = 90 kg N/ fed.; N_2 = 150 kg N/ fed.

cultivated using the ridge method that were fertilized with 90 kg (N/fed.) than in the planted plants at the raised bed method and fertilized with the same level of nitrogen fertilizer during both seasons, respectively. Furthermore, for the two seasons, there was an important increase in this parameter by 2.17 and 2.04% in the plants that were cultivated at the ridge way and fertilized with 150 kg (N/fed) compared to the planted plots using the raised bed method and fertilized with the same rate of nitrogen fertilizer, respectively (Table 2).

Maize resulting Yield and its components

Ear length: According to Table 3, the maize plants grown in the ridge had a shorter mean length of ear with an average of (20.43 ± 0.07 and 21.27 ± 0.06 cm), as compared to (21.62 ± 0.04 and 22.52 ± 0.08 cm) in the plants that were grown in the raised bed method, during the two seasons, respectively (Table 3). The increase in the ear length in the maize plants was greater in the plants cultivated using the raised bed method (5.79 and 5.91%) than in the plants planted using the ridge method, through the two seasons, respectively.

Moreover, there are highly significant variations in the length of the ear between planting ways (L.S.D. values were 0.31 and 1.34) for the two seasons, respectively. The data revealed that the application of 150 kg N/fed to plants increased the length of the cob, with an average (22.12 ± 0.17 and 23.02 ± 0.18 cm) compared to fertilized plants by 90 kg N/fed (19.93 ± 0.12 and 20.77 ± 0.21 cm), over the two seasons, respectively. It increased by (10.95 and 10.80%) for the two seasons, respectively. Likewise, the nitrogen fertilizer rates had highly significant variations in the length of the cob (L.S.D. values of 0.83 and 0.13) across the two seasons, respectively.

The data revealed that the minimum ear length (cm) values were noticed in the plants cultivated using the ridge pattern and fertilized with 90 kg N/fed, with an average (19.40 ± 0.31 and 20.20 ± 0.31) than that of the other treatments, during the two seasons, respectively (Table 3). However, the maximum length of ear was detected in the plants that were planted using the raised bed pattern and that utilized 150 kg N/fed, being (22.77 ± 0.08 and 23.70 ± 0.06 cm) compared to the other treatments during the two seasons, respectively (Table 3). The length of the ear was insignificantly impacted by the interaction between the tested binary factors every season.

The ear length in plants planted using the raised bed method and fertilized with 150 kg (N/fed) was increased by 6.06 and 6.12% compared to plants planted using the ridge method and fertilized with the same rate of nitrogen fertilizer. As well, over both seasons, there was a greater increase in this attribute by (5.50 and 5.76%) in the plots that were planted using the raised bed method and fertilized with 90 kg (N/fed) as compared to the plots that were cultivated using the ridge method and fertilized with the same level of nitrogen fertilizer, respectively (Table 3).

Ear weight: Data in Table (3) appeared to show that the ear weight of the maize plants planted using the ridge method had a smaller average weight of ear, being (259.50 ± 1.80 and 267.50 ± 1.80 g) than the plants planted using the raised bed method (271.83 ± 2.05 and 279.50 ± 2.08), during the two seasons, respectively. As well, the cob weight of the plants cultivated using the raised bed way increased by about (4.75 and 4.49%) of their weight as compared to the plants cultivated using the ridge way, through the two growing seasons, respectively. Over the two seasons, there were significant variances in the weight of the ear among the different planting methods (L.S.D. values were 12.19 and 11.85), respectively.

These results revealed that the use of 150 kg N/fed led to an increase in the weight of the ear with an average (279.33 ± 1.86 and 287.92 ± 2.05 g) than that of the fertilizer by 90 kg N/fed (252.00 ± 1.89 and 259.08 ± 1.82 g), over the two seasons, respectively. It increased by 10.85 and 11.13% in the plots that were fertilized at a level of 150 kg N/fed, when compared to fertilized plants by 90 kg N/fed, respectively. During the two seasons, there were extremely significant differences in the ear weight between the different nitrogen fertilizer rates (L.S.D values were 6.86 and 7.57), respectively.

These results mentioned that the plants planted using the raised bed method and fertilized with 150 kg (N/fed.)

exhibited the greatest ear weight with an average of (289.33 ± 1.76 and 298.00 ± 2.08 g) during the two seasons, respectively. Furthermore, the lowest ear weight was observed in the plants cultivated using the ridge way and fertilized with 90 kg N/fed, being (249.67 ± 1.45 and 257.17 ± 1.59 g) as compared to the other treatments, during the two seasons, respectively (Table, 3). As well, the combined interaction between the tested binary factors (planting methods and nitrogen fertilizer rates) had a substantial effect on ear weight for the two seasons (L.S.D. values were 9.71 and 10.84), respectively.

It is obvious that the ear weight of the plants cultivated using the raised bed method and fertilized with 150 kg (N/fed) was increased by 7.43 and 7.26% more than that of the plants planted using the ridge method and fertilized with the same level of nitrogen fertilizer over the two seasons, respectively. Furthermore, there was a significant increase in this characteristic by (1.87 and 1.49%) in the plants that were cultivated using the raised bed way and fertilized with 90 kg (N/fed) as compared to the plants that were planted using the ridge way and fertilized with the same rate of nitrogen fertilizer, across the two seasons, respectively (Table 3).

Grain Yield: Data gained in Table (3) showed that the plants cultivated using the raised bed method had a higher grain yield with an average weight of (2.62 ± 0.03 and 2.76 ± 0.03 ton/fed.) than the plants cultivated using the ridge way (2.50 ± 0.02 and 2.59 ± 0.04 ton/fed.) for the two seasons, respectively. Likewise, the weight of grain yield from the plants planted using the raised bed pattern increased by about (4.97 and 6.32%) of their weight as compared to the plants cultivated using the ridge method over the two growing seasons, respectively. There was significant variance in the weight of grain yield per feddan between the cultivating methods (L.S.D. values of 0.05 and 0.16) during the two seasons, respectively.

The application of 90 kg N/fed had lower grain yields (average weight was 2.43 ± 0.04 and 2.54 ± 0.04 ton/fed) compared to the fertilized plants that received 150 kg N/fed with an average of (2.69 ± 0.02 and 2.81 ± 0.02) through the two seasons, respectively. The increment in the average weight of grain yield in fertilized plants at a rate of 150 kg N/fed was by (10.49 and 10.56%) than in the fertilized plants at a rate of 90 kg N/fed, for the two seasons, respectively. As well, the impact of nitrogen fertilizer rates had a very significant influence on grain yield (L.S.D. value was 0.07) each season.

The results mentioned that the plants that were planted using the raised bed method and that added 150 kg N/fed exhibited the greatest weight of grain yield (2.80 ± 0.02 and 2.94 ± 0.02 g) through the two seasons, respectively. However, the plants planted using the ridge method and fertilized with 90 kg N/fed produced the least weight of grain yield (2.42 ± 0.02 and 2.51 ± 0.05 g) than the other treatments over the two seasons, respectively. Moreover, the grain yield during the two seasons was significantly influenced by the interaction between the estimated binary factors (L.S.D. value was 0.01) every season (Table 3).

As well as, grain yield increased by (8.41 and 9.76%) in plants planted using the raised bed pattern and fertilized with 150 kg (N/fed), as compared to plants cultivated using the ridge method and fertilized with the same rate of nitrogen fertilizer, during the two seasons, respectively. Similarity, there was an increase in the grain yield (1.29 and 2.64%) in the plants that were planted using the raised bed pattern and fertilized with 90 kg (N/fed.) compared to the plants that were cultivated using the ridge pattern and fertilized with the same rate of nitrogen fertilizer over the two seasons, respectively (Table 3).

Discussion

The aforementioned results are in agreement with earlier literature findings which mentioned that the seasonal occurrence of *P. solenopsis* had three peaks per season. The same results were mentioned by Bakry and Fathipour (2023) in Luxor, Egypt, recorded three peaks of *P. solenopsis* per season on okra plants. The population densities of *P. solenopsis* may be increased as a result of the moisture available at the ridge method because it requires large amounts of water. In contrast, the raised bed pattern saves a large amount of water.

The results mentioned above are consistent with earlier findings that suggest mealybugs prefer nitrogen-rich succulent tissues for feeding. Also, more nitrogen content in host plants increased the survival, longevity, fecundity, and hatchability of sucking insect pests, as does the hatching capacity of their eggs (Dogar *et al.* 2018). Over fertilization and watering can lead to problems with these pests (Goble *et al.* 2012). This increase resulting from the ridge planting method is leading due to the competition on the light and solar energy between the plants, which push plants to grow up for acquiring enough light. These findings are consistent with results from Sarjamei *et al.* (2014) and Mohamed (2015) that show an increase in plant height due to competition for light and solar energy between plants.

These results are in agreement with those of Moghazy (2021) who mentioned that the application of nitrogen fertilizer rates led to the plant height increased from 253 to 265.5 cm when nitrogen rate increased from 90 to 150 kg N/ fed. Proper application of nitrogen fertilizers will also have a positive influence on plant height and stem diameter (Abdelmula and Sabiel 2007). These results agree with that obtained by Adesoji *et al.* (2013) mentioned that the increase in maize growth might be as a result of nitrogen influences that lead to increase cell expansion, cell division and increase in size of all its morphological parts (*i.e.*, leaves numbers/plant). Kaur and Vashisht (2015) discovered that the number of leaves per plant was 13.9 with 150 kg N ha^{-1} and 12.3 with no N adding.

The application of fertilizers in accordance with the raised bed planting method produced higher ear length (2.9%) in 2011 and (2.5%) in 2012 compared to ridge planting method. In this critique, Gadallah and Gabra (2015) found that increasing nitrogen fertilizer levels from 90 to 120 kg N/fed led to an increase in plant height, ear diameter, ear length, and grain yield per fed of maize. Similarly, Rashwan and Zen El-Dein (2017) reported that cob diameter increased with higher nitrogen levels, with the highest values observed at 120 kg/fed and the lowest at 80 kg/fed. These results are agreement with Mohamed (2015) mentioned that the raised bed cultivating method produced significantly higher grain yield (tonfed^{-1}) (6.5%) in 2011 and (16.7%) in 2012 compared to ridge method. Nitrogen is an element that plays an important role in plant growth and development. The presence of nitrogen in the soil structure significantly increases and improves yield and quality by playing an important role in the biochemical and physiological functions of plants (Leghari *et al*. 2016).

Conclusion

Based on the results obtained during the two-year growing season, it can be concluded that the mealybug population is higher at high doses of fertilizer application. The ridge pattern cultivation pattern has a positive influence on plant vegetative growth but is not supportive for plant attributes. Moreover, the resulting yield, and its component attributes in the plants cultivated using the raised bed method and fertilized were significantly higher compared to the different tested treatments. The best method in supporting the growth and production of maize crops is to use the raised bed method by paying attention to the schedule of fertilizer application to avoid mealybug infestation.

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Author Contributions

MMSB designed the experiment, data collection, wrote the paper and performing data analysis. YM revising the first draft of the manuscript and revising the final manuscript and Interpretation of the results.NAlH and RAEH revising the final manuscript. All authors agreed the final manuscript.

Conflicts of Interest

The authors declare that they have no conflict of interest.

Data Availability

All relevant data are within the paper and its supporting information files.

Ethics Approvals

Not applicable in this paper.

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