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Abundance and population density of the main insect pests infesting eggplant and their associated natural enemies under different planting dates and thermal stress condition

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Abstract
Climate has recently led to an impact on global food security, especially in developing countries in the Middle East Such as Egypt, due to the effective impact of global warming on both the production rate of cultivated crops and plant diversity. This study focus on the effect of eggplant growth under two different seasons a late summer plantation with two different planting dates and a nili plantation in order to study the relationship between planting dates as well as some of the climatic factors (temperatures and relative humidity) and heat stress conditions on the number of insect pests and their associated natural enemies. The data indicated that there are seven insect pests were surveyed in eggplant crop at the three different planting dates. There were significant differences in each of the three planting dates, in both the type of pests and in seasonal abundance of those pests. *Liromayza trifolii* appeared only on eggplant that was planted in a second period in a late of summer plantation, while, *Thrips tabaci* appeared only on a nili plantation dates. The highest general mean number of *Empoasca decipiens* was recorded in the first period in a late summer plantation 65.7 individual while, the highest mean number of *Bemisia tabaci* were recorded in a second period of late summer plantation dates 17.8. *Tetranychus urticae* Koch and *Nesidiocoris tenuis* recorded highest mean number in the first period of a late summer plantation dates 100.8 and 10.3 individual respectively meanwhile, *Pseudococcus longisspinus* recorded highest mean in nili plantation 23.7 individual. The 3rd planting time in nili plantation was the favorite time and had high quality rather than the other planting times, this is because it caused highest plant, high number of leaves and branches and the area of leaves was the highest.

Keywords: Eggplant, planting dates, climatic factors, *E. decipiens, L. trifolii, B. tabaci, T. urticae, P. longisspinus*

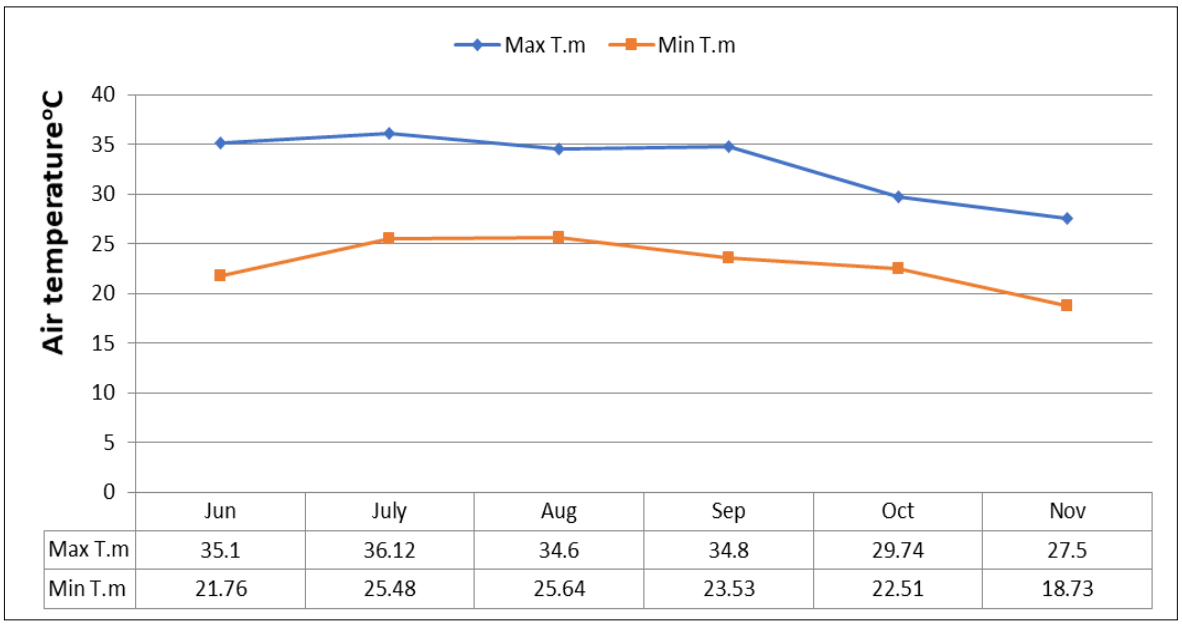
Introduction
Eggplant (*Solanum melanogena* L.) is one of the most important vegetable crops grown in Egypt, tropical and temperate regions (Al-Said and Kamal, 2005 [2]; Solieman *et al.*, 2012 [18] and Sadek *et al.*, 2013) [17]. Egypt is one of five countries from which ninety percent of eggplant production in the world comes (Kashyap *et al.*, 2003) [11]. Egypt produces about 1.2 million tons and in third place in its production, there are also some treatments that have been extracted from compounds from its tissues that are used in traditional medicine, as treatment for asthma, bronchitis, cholera and others is extracted from it. About 1.7 million hectares are allocated to growing eggplant in the world (FAO, 2010), but at the end of 21st century, temperature will increase between 3ºC – 4º C in Africa roughly 1.5 times the global mean response. This will result in significant yield losses (Kiprotich *et al.*, 2015) [13]. Since a rise in temperature has an impact on the number and quality of pests associated with crops, as well as affects production rates and vegetative measurements of plants therefore, the effect of planting dates and climatic factors affect the number of pests and their presence on eggplant plants can be used as one of the elements of integrated pest control (El-Khateeb *et al.*, 2001 [7]; Habashy and Saweeres, 2005 [9]; Baradaran *et al.*, 2007 [3] and Mubammad *et al.*, 2010) [15]. Therefore, this experiment aims to study the effect of eggplant growth at different planting dates on the number and diversity of pests and natural enemies associated with them, as well as the effect on the production rate and vegetative measurements of the plant.

Material and Methods
The field experiments
The experimental trail were conducted at El-Baramoun farm (30° 11′ N latitude and 28° 26′ E longitude) at Dakahlia Governorate Mansoura district during three different cultivation periods the first period in 6 Jun, the second period in 20 Jun (late summer plantation) and the last period on 4 Jul (nili plantation). An area of about ***700*** M^2 was divided into three plots for each of the different planting dates for eggplant crop. The name of cultivated variety is Nights night (black balady). The seedlings planted at a distance of 60cm between each seedling, on both sides of the line. Irrigation was done in the same days of transplanting. Potassium silicate was also added over the days of planting to help the seedlings retain water and increase the ability of the seedlings to withstand the rise in temperatures on the orbit of the experiment. The plants received the normal agricultural practices, with no insecticidal treatments. The following sampling techniques was visual examination used to survey the insect pests which infesting eggplant cultivar and their natural enemies and determination their seasonal abundance on eggplant crop grown under thermal stress conditions in the three planting periods.

Effect of temperature and relative humidity on the seasonal abundance of insect pests and their natural enemies:
The daily temperature and relative humidity values were obtained monthly from the Agricultural meteorological Journal of Dakahlia Governorate. The weekly average degrees of these weather factors were calculated to study these effects on the abundance of insect pests and their natural enemies of each period of planting.

Meteorological data

Plants were grown under high temperature conditions, since the air temperature rises to more than 36◦C for several successive days. Fig (1) shows the mean maximum and minimum temperature records during the late summer season of 2023 at Mansoura weather station according to the Central Laboratory for Agricultural Climate (CLAC).



	Jun	July	Aug	Sep	Oct	Nov
Max T.m	35.1	36.12	34.6	34.8	29.74	27.5
Min T.m	21.76	25.48	25.64	23.53	22.51	18.73

Fig 1: Monthly means of air temperature in El-Mansoura metrological station during 2023.

Data analysis

To reveal the apparent direct relationship between insect pests and natural enemies and between natural enemies and weather factors, statistical analysis was fulfilled. The correlation coefficient was obtained to describe the type of relationship among the studied variables were made with the Duncan's Multiple Range Test, by CoStat software statistical analysis system (Version 4.20, CoHort, USA, 1998-2004).

Results and discuss

Survey insect pests and natural enemies infesting eggplant crop at different planting dates in Dakahlia Governorate during season 2023.

A. Insect Pests

Seven insect pests were surveyed in eggplant crop at different planting dates (table 1 and Fig 2). The seasonal abundance of the major insect pests attacking eggplant at different date planting were detected in (Table 1and Fig 3), There were significant differences in each of the three planting dates, both in the type of pests and in seasonal abundance of those pests. Results indicated that *L. trifolii* appeared only on eggplant that was planted in the second period of late summer plantations, while thrips appeared only on the nili plantation dates. The highest general mean number of *E. decipiens* was recorded in first period of late summer plantations 65.7 individual while, the highest mean number of *B. tabaci* were recorded in second period of late summer plantations 17.8. *Tetranychus urticae* Koch and *N. tenuis* recorded highest mean in first period of late summer plantation100.8 and 10.3 individual respectively meanwhile, *P. longisspinus* recorded highest mean in nili plantation 23.7 individual. The heat stress conditions effect on the appeared of all insect pests at the different plantation dates.

B. Natural enemies

The data presented in (table 2 and Fig 3) indicated the seasonal abundance of four natural enemies associated with major insect pests attacking eggplant. The highest general mean number of *C. Carne* and *C. montrouzieri* was on the nili plantations it were 10.7 and 7.3 individual respectively while, *O. nubilalis* recorded highest mean in the first period of late summer plantation 7.2. *Coccinella undecimpunctata* recorded highest mean in both first period of late summer and nili plantation it was 4.7 individual.

Fig 2: Some different pictures from the study A) is *E. decipiens*, B) is *N. tenuis*, C) is *P. longisspinus*, D) semptoms of *T. urticae* and E) is *L. trifolii.*

These results are agreement with (Castañe *et al.* 2011) detected that adults and nymphs feed on plants and cause injury in the absence of prey. Feeding by *Nesidiocoris tenuis* affects plant growth and reduces the quality and quantity of yield. Host plants of *N. tenuis* include but are not limited to tomato, sweet pepper, cucumber, zucchini, yellow squash, sesame, tobacco, aubergine, and potato. (Biondi *et al*. 2016 [4], Kim *et al.* 2016) [12]. *Bemisia tabaci* (Genn.) and *Tetranychus urticae* Koch the most important pest were found on eggplant (Mona, Ammar and Rahouma, 2018) [14] Meanwhile the results disagreement with (Mona, Ammar and Rahouma, 2018) [14] mentioned that the mealy bug *Phenacoccus solenopsis* Tinsley its new insect pest of eggplant (*Solanum melanogena* L.) these pests are attacking a wide spectrum of economic plants, causing greet losses in their yield.

Tabl 1: Survey insect pests and natural enemies at different planting dates on eggplant during season 2023 in Dakahlia Governorate.

Sampling dats	*E. decipiens*			*B. tabaci*			*T.urticae*			*N. tenuis*			*P. longisspinus*			*L. trifolii*			*Th. tabaci*		
	Different planting dates																				
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
21/7/2023	5	-----	---	4	---	---	30	----	-----	8	-----	----	0	----	-----	--	---	---	---	---	---
28/7/2023	28	---	----	5	---	--	130	-----	-----	30	-----	----	0	-----	-----	--	---	---	---	---	---
3/8/2023	19	82	---	16	28	---	102	29	-----	15	3	----	0	0	-----	--	10	---	---	---	---
10/8	26	72	24	7	22	25	180	50	25	13	0	6	0	0	0	--	5	---	---	---	8
17/8	22	62	55	7	20	10	130	40	10	10	0	11	0	0	0	--	2	---	---	---	6
24/8	105	98	75	2	18	3	120	76	3	9	5	18	0	0	0	--	3	---	---	---	5
31/8	108	62	62	3	5	4	150	82	4	3	0	24	0	0	0	--	0	---	---	---	4
7/9/2023	130	110	104	11	39	37	200	120	37	12	9	30	0	0	0	--	0	---	---	---	0
14/9	110	44	20	0	19	25	110	40	25	4	0	8	0	0	8	--	0	---	---	---	0
21/9	98	40	12	2	11	16	70	14	16	3	4	2	15	0	42	--	0	---	---	---	0
28/9	169	43	11	26	45	20	90	9	20	16	3	8	42	3	67	--	0	---	---	---	0
5/10/2023	68	10	30	5	0	6	65	11	6	9	3	11	15	13	23	--	0	---	---	---	0
12/10	13	22	32	3	11	25	25	2	25	8	22	6	12	15	35	--	0	---	---	---	0
19/10	20	12	27	4	7	0	10	0	0	3	25	4	15	10	48	--	0	---	---	---	0
26/10	----	20	21	---	13	0	----	0	0	-----	20	4	----	14	58	--	3	---	---	---	0
2/11/2023	------	21	20	---	12	0	-----	0	0	-----	23	3	----	25	42	--	5	----	---	---	0
9/11	-----	-----	5	---	----	0	-----	----	0	-----	-----	2	----	-----	10	--	---	---	----	---	0
Total	921	648	498	95	250	137	1412	473	171	145	117	137	109	80	333	--	28	---	---	---	30
Mean	65.7	46.2	35.5	6.8	17.8	9.7	100.8	33.7	12.2	10.3	8.3	9.7	7.7	5.7	23.7	--	2	---	---	---	2.14

1st means the first period in late of summer plantation, 2nd means second period in late of summer plantation and 3rd means nili plantations.

Table 2: Population density of the main natural enemies associated with the main insect pests in eggplant under different planting dates during season 2023 in Dakahlia Governorate.

Sampling dates	*C. Carne*			*O. nubilalis*			*C.montrouzieri*			*C.undecimpunctata*		
	Different planting dates											
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
21/7	3	--	---	8	---	---	9	---	---	3	---	---
28/7	9	--	---	6	---	---	5	---	---	7	---	---
3/8/2023	7	5	---	2	4	---	4	3	---	4	5	---
10/8	3	11	11	3	0	2	1	0	0	0	8	11
17/8	4	4	26	2	2	5	4	3	0	4	9	3
24/8	2	13	20	3	2	2	2	4	1	13	1	4
31/8	4	14	18	15	2	10	4	3	3	2	2	2
7/9/2023	15	15	28	10	5	5	3	2	4	3	12	9
14/9	6	8	8	12	0	6	2	4	5	8	5	9
21/9	21	4	19	18	4	4	8	3	8	5	4	0
28/9	20	6	3	8	3	3	12	5	14	10	4	2
5/10/2023	6	10	3	3	0	0	8	2	15	7	0	5
12/10	0	2	6	5	0	0	7	8	10	0	2	4
19/10	4	13	3	7	0	0	5	16	11	0	3	0
26/10	---	20	4	---	0	0	---	17	18	---	3	5

2/11/2023	---	5	2	---	---	0	---	23	5	---	0	3
9/11	---	---	0	---	---	5	----	---	9	---	---	9
Total	104	130	151	102	22	42	74	93	103	66	58	66
Mean	7.04	9.28	10.7	7.2	1.5	3	5.3	6.6	7.3	4.7	4.14	4.71

1st means the first period in late of summer plantation, 2nd means second period in late of summer plantation and 3rd means nili plantations.

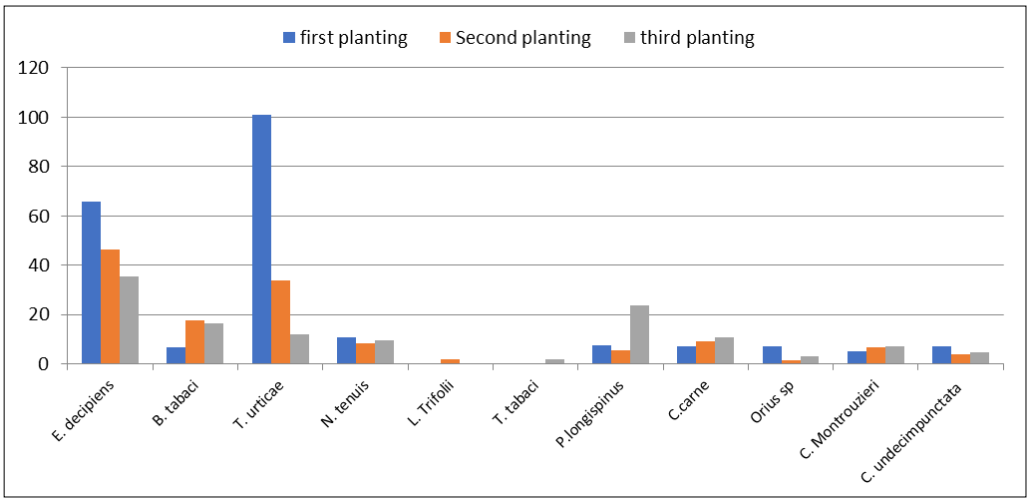


Fig 3: Relative abundance of the main insect pests and their natural enemies in different planting dates on eggplant crop at Mansoura district during season of 2023.

Effect of some weather factors on the population density of main insects infected eggplant crop planting at three different dates and their associated natural enemies.

Results estimated in Table (3) assured that the values of correlation coefficient between the average temperature, relative humidity and the population density of the main insects attacking eggplant plantation in different dates. In the first plantation dates, the relation between temperature parameters and population density of *E. decipiens, T. urticae* and *N. tenuis* cleared highly significant positive correlation during 2023 meanwhile, in the second period of late summer plantation dates there were highly significant positive correlation between temperature parameters and population density of *E. decipiens, B. tabaci* and *T. urticae* while, there were negative correlation between temperature parameters and the population density of *N. tenuis* and *P. longisspinus.* In nili plantation dates there were highly significant positive correlation between temperature parameters and population dates of *E. decipiens, B. tabaci* and *N. tenuis* also, there was significant positive correlation between temperature parameters and population density of *T. urticae.* The correlation coefficient between relative humidity and the population density of *E. decipiens, B. tabaci* and *T. urticae* was high in second period of late summer plantation dates while in nili plantation dates there were highly significant positive correlation between relative humidity and the population density of *E. decipiens, T. urticae* and *N. tenuis* during 2023 season at Mansoura district. These results are agreement with (Abou El-Saad 2016) [1] noted that the highest general mean number of *T. urticae* was recorded on the nili plantation followed by summer and early summer ones during the eggplant two growing seasons of 2014 and 2015. Max. and Min. temperatures gave highly significant and significant correlation values on the census of *T. urticae* through the three tested planting dates.

The date in Table (4) illustrated that there were significant positive correlation between population density of *C. Carne* and average temperature in the first period of late summer and nili plantation dates. Also there were positive correlations between *O. nubilalis, C. undecimpunctata* and average temperature in the second period of late summer plantation dates. In the other hand relative humidity had a significant negative correlation in the population density of *O. nubilalis* in the first and second period of late summer plantation dates while; relative humidity had a significant negative correlation in population density of *C. undecimpunctata* in the second period of late summer plantation dates. The relative humidity showed negative insignificant correlations with all natural enemies in the nili plantation date.

The relationship between main insects that infested eggplant crop and their associated natural enemies at different plantation dates

Data represented in Table (5) showed a highly significant relationship between *E. decipiens* and their natural enemies' *C. carne, O. nubilalis* and *C. undecimpunctata* in the first plantation date. It may be noticed that *C. carne, O. nubilalis* exerted highly significant effect on the numbers of *E. decipiens* on the first period of late summer plantation date. The data summarized in Table (5) indicated that *C. montrouzieri* had only highly significant effect on *P. longisspinus* numbers in the first plantation date while, in the second plantation date *O. nubilalis* and *C. undecimpunctata* exerted a highly positive significant effect on the population density of *E. decipiens, B. tabaci* and *p.longisspinus* meanwhile, *C. undecimpunctata* exerted highly significant effect on the numbers of *T.urticae* on the second plantation dates. In the third plantation dates there were a highly significant relationship between *P. longisspinus* population and the predators *O. nubilalis, C. montrouzieri* and *C. undecimpunctata*. Moreover, *C. carne* had a highly significant effect with *E. decipiens* and *B. tabaci* numbers in the nili plantation dates. Also *O. nubilalis* exerted a positive significant effect on the population density of *B. tabaci* in the nili plantation dates.

Table 3: Correlation Coefficient between the population densities of Main insects that infested the eggplant crop and weather factor during the different planting dates in 2023 season at Mansoura district.

Main insect	Simple correlation coefficient (r)			
	1st planting dates			
	Average Temperature		Average R.H.	
	r±S.E	P	r±S.E	P
E. decipiens	0.79±0.173	0.0006***	-0.50±0.24	0.0673 ns
B. tabaci	0.42±0.26	0.1320 ns	-0.41±0.26	0.1361 ns
T.urticae	0.80±0.17	0.0006***	-0.48±0.25	0.0771 ns
N. tenuis	0.54±0.24	0.0429*	-0.48±0.25	0.0776 ns
P. longisspinus	-0.19±0.28	0.5114 ns	-0.042±0.28	0.8851 ns
2nd planting dates				
E. decipiens	***0.86±0.146***	***0.0001*****	-0.59±0.23	0.0259*
B. tabaci	0.68±0.210	0.0071**	-0.62±0.22	0.0173*
T.urticae	0.81±0.16	0.0004***	-0.60±0.22	0.0211*
N. tenuis	-0.58±0.23	0.0295*	0.19±0.28	0.4981 ns
P. longisspinus	-0.67±0.21	0.0081**	0.44±0.25	01080 ns
L. trifolii	-0.034±0.28	0.9071 ns	0.37±0.26	0.1813 ns
3rd planting dates				
E. decipiens	0.70±0.20	0.0048**	-0.60±0.22	0.0206*
B. tabaci	0.69± 0.208	0.0062**	-0.48±0.25	0.0761 ns
T.urticae	0.59±0.231	0.0237*	-0.70±0.20	0.0052**
N. tenuis	0.83±0.16	0.0002***	-0.71±0.20	0.0038**
P. longisspinus	-0.34±0.27	0.2292 ns	0.104±0.28	0.7214 ns
T.tabaci	0.44±0.25	0.1096 ns	-0.10±0.28	0.7283 ns

r = correlation coefficient ns= insignificant * = significant with varied degree

Table 4: Correlation Coefficient between the population densities of natural enemies that associated with the main insects infested the eggplant crop and weather factor during the different planting dates in 2023 season at Mansoura district.

Natural enemies	Simple correlation coefficient (r)			
	1st planting dates			
	Average Temperature		Average R.H.	
	r±S.E	P	r±S.E	P
C. Carne	0.57±0.23	0.0326*	-0.51±0.24	0.0580 ns
O. nubilalis	0.43±0.26	0.1232 ns	-0.60±0.23	0.0221*
C.montrouzieri	-0.19±0.28	0.4956 ns	0.014±0.28	0.9603 ns
C.undecimpunctata	0.27±0.27	0.3351 ns	-0.15±0.28	0.6061 ns
2nd planting dates				
C. Carne	0.26±0.27	0.3575 ns	-0.19±0.28	0.4946 ns
O. nubilalis	0.74±0.191	0.0021**	-0.60**±0.22**	0.0213*
C.montrouzieri	-0.62±0.22	0.0160*	0.45**±0.25**	0.1053 ns
C.undecimpunctata	0.64±0.219	0.0121*	-0.55**±0.24**	0.0414*
3rd planting dates				
C. Carne	0.69±0.208	0.0063**	-0.45±0.25	0.1021 ns
O. nubilalis	0.48±0.25	0.0779 ns	-0.27±0.27	0.3428 ns
C.montrouzieri	-0.311±0.27	0.2783 ns	0.045±0.28	0.8782 ns
C.undecimpunctata	0.18±0.28	0.5182 ns	-009±0.28	0.7528 ns

r = correlation coefficient ns= insignificant * = significant with varied degree

Effect of different planting dates and the main insect pests associated in eggplant crop on some vegetative growth parameters and yield components:

Results presented in Table 6indicated that eggplant is a warm crop, it is adversely affected by photo thermal condition of late summer season in Egypt, high temperature (above 36ºC for several successive days), high relative humidity (more than 75%) and long photo period (from 12.5 to 14 h.). Accordingly, Table 6 clears that plant height, number of branches/plant, number of leaves, leaf area, fresh weight of leaves and dry weight of leaves. Where's they were significantly enhanced in all protected treatments. Generally, the treatments of planting time were more pronounced, especially the treatment of 3rd time.

Table 6: Effect of different planting dates and the main insect pests associated in eggplant crop on some vegetative growth parameters and yield components of eggplant in seasons 2023.

vegetative growth parameters and yield components	different planting dates			LSD at 0.05%
	1st planting time	2nd planting time	3rd planting time	
Plant height (cm)	65 b	66 b	71 a	1.76
No. of branches/plant	6.4 b	5.9 c	6.7 a	0.176
No. of leaves/plant	64.8 c	66.8 b	77.8 a	0.199
Leaf area cm^2	31.9 c	34.2 b	36.5 a	0.176
Fresh weight of leaves/ plant (g)	121.3 c	133.8 b	166.7 a	0.199
Dry weight of leaves/ plant (g)	15.23 c	16.54 b	19.88 a	0.019

Fruit weight (g)	133.2 b	124.6 c	148.9 a	0.720
No. of fruits/plant	8.54 b	7.39 c	8.67 a	0.017
Early yield /Plant (g)	176.0 b	159 c	179 a	1.153
Total /yield Plant (g)	105.0b	95.0 c	108.0 a	0.1997
Early yield /feddan (ton)	1.82 b	1.62 c	1.86 a	0.019
Total yield/ feddan (ton)	11.26 b	9.97 c	11.45 a	0.019

Also, Table (6) demonstrated that the 3rd planting time was the favorite time and had high quality rather than the other planting times, this is because it caused highest plant, high number of leaves and branches and the area of leaves was the highest, also. In addition, Table (6) showed that the 3rd planting time had the highest fruit weight, highest number of fruit, early yield of plant and highest total yield. Date of planting has an effective impact on yield and pest incidence as well as seasonal control (Hossain *et al*. 2002 [10] and Rahman *et al.*, 2011) [16]

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