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Influence of Potassium Fertilization on Certain Homopterous Insects Infestation and Relationship with Chemical Constituents and Cell Thickness of Maize Plants

Ola I. M. Hegab* and M. A. M. Hegab

Plant Prot. Dept., Fac. Agric., Zagazig Univ., Egypt

ABSTRACT

The present work was conducted during 2017 and 2018 seasons in Diarb-Nigm district at Sharhia Governorate, Egypt to study the effect of four rates of potassium fertilization (0, 24 , 48 , 72 Kg. K2o / fed.) on maize infestation with certain piercing-sucking insects such as aphids, *Rhopalosiphum maidis* and *R. padi*, leafhoppers and planthoppers , *Empoasca decipiens, E.decedens, Balclutha hortensis, Cicadulina chinai, C. bipunctella , Sogatella vibix and S. furicefera* and relationship with the chemical components and epidermal cells thickness of maize plant leaves. The results showed significant differences in the population density of the aforementioned insects of the tested rates of potassium fertilization, whereas, the highest mean numbers of their insects were recorded at the rate of F1(zero Kg. K2o /fed.), while the least mean numbers of the aforementioned insects occurred at the rate of F4(72 Kg. K2o / fed.). In addition, the results of some chemical analyses revealed that a positive relationship between total protein, carbohydrates contents, k values and the epidermal cell thickness and aforementioned rates of potassium fertilization. While, a reverse relationship was recorded between pH values and potassium fertilization. Also, the fertilization influenced significantly on six amino acids; aspartic, glutamic , glycine , alanine , isoleucine and leucine, which affected the attractive of these insect species, which may explain the decreasing in numbers of the insects by increasing the rates of fertilization. According to these results, the potassium fertilization should be recommended as effective factor in the integrated pests control program.

Keywords: Maize, piercing-sucking insects, potassium fertilization, cell thickness, chemical components

INTRODUCTION

Maize (*Zea mays* L.) is one of the three important major crops in the worlds. It infested with certain piercing-sucking insects such as aphids, leafhoppers and planthoppers that fed on plant sap and caused a large damages of crops. The fertilization may have an impact on the infestation with the aforementioned insects considering of some chemical composition of plants such as amino acids, carbohydrate and protein contents. These insects feed on the phloem that provides carbohydrates and nitrogenous compounds and moves in the phloem primarily in the form of free amino acids (Montllor, 1991 and Wilkinson and Douglas, 2003). Amino acids as a source of nitrogen, essential amino acids must be taken from the plant and these are a limiting factor for aphid growth and there is evidence that plant amino acid composition is related with aphid resistance (Chiozza *et al.*, 2010). Fertilizers not only improve crop yield, but also influence crop susceptibility for insect infestation depending on the type of fertilizer and pest species (Wooldbridge and Harrison,1968 and Kogan,1994). Embden (1973) reported that the essential amino acids in the plant sap are essential for growth and reproduction of aphids. Willings and Dixon (1987) reported that phloem feeders adversely effect of both growth and amino-Nitrogen profile of their host plants. Bi *et al.* (2001) reported that the potassium has been considered a key component of plant nutrition that significantly influences crop growth and some pests infestation. Choudhary *et al.* (2001) studied the incidence of *Lipaphis erysimi* and *Myzus persicae* on brassica species at three NPK levels and reported that increasing the fertilizer level resulted in increased aphid incidence in all cultivars, except Ethiopian mustard,which was highly resistant to aphid at all fertilizer levels. Amtmann *et al.* (2008) suggested that potassium nutrition has a profound effect on the profile and distribution of primary metabolites in plant tissues, which in turn could affect the attractiveness of plant for insects as well as their subsequent growth and development and the same author explained that the relationship between potassium deficiency and increased insect attack. Potassium deficiency results in reduced synthesis of proteins, starch, and cellulose, and increased accumulation of lower molecular weight compounds such as amino acids, nitrate, soluble sugars, and organic acids. These lower weight molecular compounds are more easily utilized as nutrient sources by sucking insects. Thus in other words, potassium deficiency on its own may not correlate with higher insect attack, but the subsequent impact of Potassium deficiency on plants, makes plants more readily attacked by sucking insects. These results explained by Walter and Difonzo (2007) who reported that low potassium fertility was associated with high foliar levels of the amino acid serine and higher aphid infestations. Low potassium rate in soil was associated with increased aphid populations in the soybean fields (Bruulsema *et al.*, 2010).

This study aim to examine the association between the infestation with aphids, leafhoppers and planthoppers and potassium fertilization rates, in order to determine the appropriate role of plant nutrition with potassium fertilization in the management of these insect pests.

* **Corresponding author.**
E-mail address: drolahegab@gmail.com
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MATERIALS AND METHODS

Experimental Design

Field experiments were carried out at Diarb-Nigm district, Sharkia Governorate, Egypt during 2017 and 2018 seasons. An area of about 900 m^2 was chosen for this investigation and divided into tweleve replicates and each replicate was 60m^2. The experiment was laid out in a randomized complete block design with three replicates for each potassium treatment. Maize *(Zea mays* L. Balady variety) was sown on the second week of May during the two successive seasons. Spaces of one meter were left between plots. All plots were kept without any insecticide treatments. The normal agricultural practices were followed in due time. Phosphorus was added to all plots before sowing at a rate of 200 Kg. P/fed. as super phosphate (15% p_2o_2). Nitrogen fertilizer was added at a rate of 238 Kg. N/fed. in the form of urea (46.5%N) in three equal splits portions 15, 30 and 45 days after sowing. Potassium fertilizer was applied as potassium sulfate (48%K_2o) at rates of 0, 24, 48 and 72 Kg. / K_2o /Fed. in the two equal portions after 15 and 45 days of sowing.

Sampling started when the age of maize plants reached about 30 days and continued at weekly intervals throughout the period of growth until the harvest on the second week of September in both seasons of 2017 and 2018.

Two sampling procedures were used as follows:

a) Plant Sample

Weekly sample of 10 leaves and 5 tiller tissues tassels of maize plant were taken randomly from each replicate. These leaves were kept in paper bags and transferred to the laboratory for inspection. The number of individuals of aphids were counted using a hand lens, recorded and identified according to Hegab *et al*. (1987).

b)Sweeping Net

A sweeping net was used and each sample consisted of 50 double strokes taken randomly from the field. In case of maize plants, spaces of 1 m were left for walking between plots. Collected leafhopper and planthopper insects were transferred to plastic sacs containing pieces of cotton saturated with ether for anesthetizing collected insects. The plastic sacs were tied by rubber bands and taken to the laboratory for inspection and identification according to Nielson (1968) and Hegab *et al*. (1989).

Chemical Analyses and Anatomical Studies

Chemical analyses of the maize plants were carried out in the Central Laboratory, Faculty of Agriculture, Zagazig University. To confirm the relationship between certain chemical constituents of fertilized maize plants and the infestation with aphid, leafhopper and planthopper insects, plant leaves were taken at random at the start of flowering in the second season after adding the second portion of potassium fertilization to determine the total protein, carbohydrate contents and potassium contents according to(Dubois *et al*., 1956 , Jackson , 1970 and Bremner and Mulvaney, 1982 ,) and estimated pH values in the plants sap by using pH meter according to the method of AOAC(1970). To assay amino acids using the amino acids analyzer T-339 (Microtechna , Praha) according to Lasheen *et al*. (1970). As well as, the anatomical studies were carried out only in the second season, the epidermal cell thickness was measured by planimeter. (Saeed, 1992).

Statistical Analysis

All data were analyzed statistically by ANOVA technique and simple correlation values (r), partial regression (b) and explained variance (E.V. %) were calculated using CoStat, Computer Program (2005).

RESULTS AND DISCSSION

Effect of potassium fertilization rates on certain piercing-sucking species infestation

The obtained results in Tables (1and 2) showed that the two species of aphids, *Rhopalosiphum padi* (Linnaeus) and *Rhopalosiphum maidis* (Fitch) were surveyed by plant samples. Five species of leafhoppers, *Empoasca decipiens* (Paoli), *Empoasca decedens* (Paoli), *Balclutha hortensis* (Lindberg), *Cicadulina chinai* (Ghauri), *Cicadulina bibunctalla zea* and two species of planthoppers, *Segatella vibix* (Haupt) and *Segatella furcifera* (Horv) were collected by sweeping net on maize plants.

The results in Table 1 showed that the average numbers of different piercing- sucking insect pests on the maize plant according to four rates of potassium fertilization during the first season of 2017. The highest average number of aphids, leafhoppers and planthoppers were recorded with zero Kg. K_2o/fed. and represented by 446.33, 102.72 and 42.08 individuals, respectively and decreased gradually to reach to the lowest average number of the aforementioned insects with 72 Kg. K_2o/fed. And represented by 301.67 ,44.00 and 25.78 individuals, successively .

Table 1. The average number of different piercing- sucking insect pests on the maize plant according to four rates of potassium fertilization during the first season of 2017

	Insects species	Potassium fertilization rates (Kg / feddan)				F	L.S.D
		0 Kg. K_2o	24 Kg .K_2o	48 Kg .K_2o	72 Kg .K_2o		
Aphids	*Rhopalosiphum maidis*	226.00	199.00	182.33	164.00	**	13.09
	Rhopalosiphum padi	220.33	197.33	154.33	137.67	**	15.48
	Total	446.33	396.33	336.66	301.67	**	8.46
Leafhoppers	*Empoasca decipiens*	21.11	15.69	11.64	7.83	**	1.79
	Empoasca decedens	20.22	17.25	11.42	8.28	**	0.59
	Balclutha hortensis	22.33	19.47	15.25	10.25	**	0.46
	Cicadulina chinai	21.67	17.47	14.19	9.83	**	0.44
	Ccadulina. bibunctalla zea	17.39	14.25	11.39	7.81	**	0.36
	Total	102.72	84.13	63.89	44.00		4.05
Planthoppers	*Segatella vibix*	21.69	18.81	14.83	15.78	**	5.30
	Segatella furcifera	20.39	16.05	12.58	10.00	**	0.33
	Total	42.08	34.86	27.41	25.78	**	3.17

**** = Highly significant at 0.01 level of probability.**

The obtained results in Table(2) appeared that, in the second season of 2018 the highest mean numbers of aphids, leafhoppers and planthoppers on the fertilized maize plant occurred with the zeroKg. k_2o /fed. and represented by 593.00,120.78and 45.31 individuals. While, the lowest average numbers of tested insects were recorded with72 Kg. k_2o/fed. and represented by 394.02 56.49 and 22.53 individuals, successively. It could be noticed that the population of all tested insects differed highly significantly with all rates of potassium fertilization and the rates of 24 Kg. k_2o/ fed. and 48 Kg. k_2o/fed. seemed to be moderately susceptible to all tested insects infestation in the two investigated seasons.

It could be concluded that the reducing in the average numbers of all tested insects, aphids ,leafhoppers and planthoppers related with the increasing of the potassium fertilization rates during the two successive seasons 2017 and 2018.

These results are in agreement with those obtained by Parihar and Upadhyay (2001) and Myers and Gratton (2006) found that the populations of leafhoppers and aphids had significantly high peak abundance with the rate of population increase in the low K treatment. Bruulsema *et al.* (2010) mentioned that the low K in the soil was associated with the high population of aphids, which observed on the zero/K treatment. Hegab (2015) reported that the potassium fertilization had a great reduce effect of the incidence of piercing and sucking insects. Shah (2017) who recorded that Potassium had been considered a key component of plant nutrition that significantly influenced of crop growth and the infestation of some insect pests.

Table 2. The average number of different piercing- sucking insect pests on the maize plant according to four rates of potassium fertilization during 2018 season

	Insects species	Potassium fertilization rates (Kg / feddan)				F	L.S.D
		0 Kg. K_2o	24 Kg .K_2o	48 Kg .K_2o	72 Kg .K_2o		
Aphids	*Rhopalosiphum maidis*	314.00	249.67	219.00	199.02	**	1.81
	Rhopalosiphum padi	279.00	253.67	221.33	195.00	**	1.31
	Total	593.00	503.34	440.33	394.02	**	7.23
Leafhoppers	*Empoasca decipiens*	26.64	19.86	18.03	12.25	**	1.32
	Empoasca decedens	22.14	21.11	14.86	11.03	**	0.79
	Balclutha hortensis	25.14	22.53	16.42	11.83	**	0.80
	Cicadulina chinai	24.33	19.97	16.03	11.19	**	0.83
	Ccadulina. bibunctalla zea	22.53	18.33	14.14	10.19	**	0.61
	Total	120.78	101.80	79.48	56.49	**	6.29
Planthoppers	*Segatella vibix*	23.14	19.08	16.28	11.39	**	0.43
	Segatella furcifera	22.17	17.67	14.11	11.14	**	0.57
	Total	45.31	36.75	30.39	22.53	**	4.99

**** = Highly significant at 0.01 level of probability**

Effect of potassium fertilization on some chemical constituents and the thickness of plant epidermal cells and its relation with certain piercing-sucking species infestation

a)Relationship between potassium fertilization treatments, plant chemical constituents, and the mean number of piercing-sucking insect pests

Results given in Table (3) indicated that the highest average number of the tested insect pests, aphids, leafhoppers and planthoppers recorded with zero Kg. k_2o/fed. and represented by 593.0, 120.7and 45.3 individuals and coincide with the lowest percentages of plant chemical constituents, 8.6% total protein, 51.3% total carbohydrate, 0.9% K and 4.6 pH value, successively .On the other hand, the lowest average number of the tested insect pests occurred with 72 Kg. k_2o/fed. and represented by 394.02 56.49 and 22.53 individuals, successively with 10.4% total protein, 63.1% total carbohydrate, 3.1% K and 4.2 pH value ,respectively.

Table 3. Effect of different potassium fertilization rates on the total mean numbers of aphids, leafhoppers and planthoppers infesting maize plants with four rates of potassium fertilization at Sharkia Governorate, Egypt during 2018 season

Potassium fertilization Kg / feddan	Protein %	Carbohydrate %	K %	pH	Total of mean number of aphids	Total of mean number of leafhoppers	Total of mean number of planthoppers
0 Kg. K_2o	8.6	51.3	0.9	4.6	593.0	120.7	45.3
24 Kg .K_2o	8.8	58.9	2.6	4.5	503.3	101.8	36.7
48 Kg. K_2o	9.5	61.8	3.0	4.3	440.3	79.4	30.3
72Kg. K_2o	10.4	63.1	3.1	4.2	394.0	56.4	22.5
F .test	**	**	**	*	**	**	**
L.S.D	0.04	0.08	0.90	0.01	3.98	2.99	1.02

*** = Significant at 0.05 level of probability. ** = Highly significant at 0.01 level of probability.**

Generally, the obtained results revealed that a positive relationship between potassium fertilization rates and protein, carbohydrate contents and potassium percentage in fertilized maize plants. While it was negatively related with pH values. Statistical analysis revealed that there were highly significant differences between the potassium fertilization rates and the chemical constituents in one hand and on the other hand with the average number of tested insect pests. Hegab (2015) mentioned that total free amino acids, soluble proteins and sugars were responsible for susceptibility of the host plants to aphid and leafhopper insects infestation.

b) Effect of potassium fertilization on the thickness of epidermal cells and the tested insect pests

Data in Table (4) illustrated that the highest average numbers of aphids, leafhoppers and planthoppers decreased from 593.0, 120.7and 45.3 individuals with zero Kg. k_2o/fed. to 394.0 56.4 and 22.5 individuals with72 Kg. k_2o/fed. , successively coincide with the increasing of the thickness of epidermal cells from 5.0 micron with zero Kg. k_2o/fed. to 6.6 micron with72 Kg. k_2o/fedden .

Table 4. Total numbers of certain piercing and sucking insect species as influenced by potassium sulfate fertilization and its relation with the thickness of leaves epidermal cells of fertilized maize plants during 2018 season

Potassium fertilization Kg / feddan	Epidermal cell thickness /micron	%of epidermal cell thickness increasing	Mean number of aphids	%of mean number of aphids decreasing	Mean number of leafhoppers	%of mean number of leafhoppers decreasing	Mean number of planthoppers	%of mean number of planthoppers decreasing
0 Kg. K_2o	5.0	00.0	593.0	00.0	120.7	00.0	45.3	00.0
24 Kg .K_2o	5.6	11.2	503.3	15.1	101.8	15.7	36.7	18.8
48 Kg. K_2o	5.8	15.0	440.3	25.7	79.4	34.2	30.3	32.9
72Kg. K_2o	6.6	31.7	394.0	33.5	56.4	53.2	22.5	50.2

From the previous results, it could be concluded that the using potassium fertilization caused considerable increase in the thickness of plant epidermal cells and suppressed the ability of mouthpart insects for piercing-sucking and feeding which caused a great reduction in the population density of these insect pests. Therefore, the potassium fertilization could be recommended for suppression the populations of these insects such as aphid species, leafhoppers and planthoppers. These results are in agreement with the findings of Amtmann *et al.* (2008) suggested that potassium from soil might effect of number of physiological, metabolic and hormonal processes in plant tissues and these processes are important for plants susceptibility to resistant the pathogens and insects.

c) Effect of different rates of potassium fertilization on the mean values of amino acids of maize plants leaves and its correlation with certain homopterous insect infestation

The obtained results of chemical analysis of maize leaves appeared that, there were seventeen amino acids occurred in Table (5).It was showed that there were a highly negative correlation between glutamic acid and average number of the aforementioned insects. While, there were a positive correlation between aspartic, glycine, alanine, isoleucine, leucine, and the average number of the tested insect pests.

Aspartic, glutamic, glycine and alanine are nonessential amino acid that were correlated with the aforementioned insects in most comparisons. For essential amino acids, leucine and isoleucine were correlated with attractive of these insects.

These results are in agreement with those of Brodbeck *et al.* (1990) recorded that glutamine plus asparagine were the amino acids most highly correlated with host selection. These compounds are the predominant amino acid in xylem fluid. Strong correlation between leafhopper abundances and concentrations of amino acids. Eleftherianos *et al.* (2006) found that the mean total amino acid concentration correlated with the reproduction of *R. padi.* Walter and Difonzo (2007) reported that low potassium fertility was associated with high levels of aphid infestations. Chiozza *et al.,* (2010) measured the ratio of 17 common amino acids in the sap and noted that aphids are dependent on soluble amino acids for their nutrition and that potassium deficiency can cause increased concentration of such amino acids in plant tissue.

Table 5. Simple correlation coefficient (r) between the amino acids and the average numbers of aphid, leafhopper and planthopper insects and in fertilized maize.

Amino acids	Simple correlation coefficient (r)		
	Aphids(r_1)	Leafhoppers (r_2)	Planthoppers(r_3)
Aspartic	0.989	0.946	0.965
Threonine	0.166	-0.013	0.227
Serine	0.085	-0.095	0.154
Glutamic	-0.822	-0.759	-0.784
Proline	-0.470	-0.524	-0.409
Glycine	0.638	0.773	0.614
Alanine	0.789	0.660	0.754
Cystine	-0.442	-0.509	-0.380
Valine	0.403	0.227	0.447
Methionine	0.136	0.288	0.111
Isoleucine	0.875	0.764	0.820
Leucine	0.928	0.833	0.876
Tyrosine	-0.061	-0.206	0.016
Phenylalanine	-0.026	-0.094	0.04
Histidine	-0.354	-0.275	-0.303
Lysine	-0.141	-0.026	-0.203
Arginine	-0.549	-0.47	-0.49

**** = Highly significant at 0.01 level of probability. * = Significant at 0.05 level of probability. N.S. = Non significant between treatments**

The values of partial regression coefficients between the population of these insects and the values of amino acid were recorded in Table 6.

Results in Table(6) showed that the values of explained variance by the different rates of potassium fertilization indicating that the considered factors had played a conspicuous role for detecting the infestation of tested insects during the investigated season.

Table 6. Partial regression (b) and explained variance (E.V%)between each of amino acid concentration and the average number of the tested piercing- sucking insect pests according to different potassium fertilization rates in maize plant

Amino acids	Partial regression coefficient (b)			Explained variance (%)		
	Aphids (b_1)	Leafhoppers (b_2)	Planthoppers (b_3)	Aphids	Leafhoppers	Planthoppers
Aspartic	107.8**	33.2**	11.90**	0.977	0.896	0.931
Threonine	22.4	-0.58	0.5	0.028	0.001	0.001
Serine	22.5	-78.2	-1.2	0.007	0.009	0.002
Glutamic	-1053.1**	-317.7**	-107.5**	0.676	0.576	0.549
Proline	-380.1	-138.5	-48.6	0.221	0.275	0.282
Glycine	921.3*	364.6**	115.6**	0.407	0.597	0.500
Alanine	436.8**	19.4*	42.7*	0.622	0.436	0.465
Cystine	-726.2	-235.9	-952.7	0.196	0.259	0.261
Valine	185.3	34.1	14.1	0.162	0.052	0.074
Methionine	181.6	125.9	29.6	0.018	0.083	0.038
Isoleucine	433.9**	123.9**	44.8**	0.765	0.584	0.636
Leucine	911.5**	267.2**	94.7**	0.861	0.693	0.725
Tyrosine	-51.5	-57.1	-17.1	0.004	0.042	0.032
Phenylalanine	-10.4	-12.3	-5.0	0.001	0.009	0.012
Histidine	-702.7	-177.9	-37.4	0.126	0.075	0.020
Lysine	-37.4	-2.2	-.899	0.020	0.001	0.001
Arginine	-460.6	-409.1	-158.6	0.301	0.221	0.277

**** = Highly significant at 0.01 level of probability. * = Significant at 0.05 level of probability. N.S. = Non significant between treatments**

Generally, these results indicated that the availability of potassium in the soil and leaves of plants affects the quality of the plant, as it provides some physiological processes such as cell division, carbohydrate formation, sugars translocation and nitrate reduction, which effected of amino acids formation, in addition to that it plays an important role in increasing the thickness of the epidermis in plants, which prevents the infestation of piercing and sucking insects such as, aphids, leafhoppers and planthoppers which fed on plant sap. Also,the fertilization influenced significantly on six amino acids, aspartic, glutamic, glycine , alanine , isoleucine and leucine which affected the attractive and preference of these insect species.

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تأثير التسميد البوتاسى على الإصابة ببعض الحشرات المتشابهة الاجنحه وعلاقته بالتركيب الكيماوى وسمك البشرة فى نباتات الذرة

علا ابراهيم محمد حجاب ومحمد على مرسى حجاب

قسم وقاية النبات ـ كلية الزراعة ــ جامعة الزقازيق ــ مصر

إجريت تلك الدراسة خلال موسمى 2017و2018 فى منطقة ديرب نجم ـ محافظة الشرقية ـ مصر لدراسة تأثير أربع معدلات من التسميد البوتاسى (صفر ،24 ،48، 72 كجم / k_2o /فدان) على متوسط تعداد بعض الحشرات الثاقبة الماصة مثل المن *Rhopalosiphum maidis* and *R. padi* ونطاطات الأوراق ونطاطات النباتات *Empoasca decedens, E. decipiens,* وعلاقتها بالمكونات الكيميائية وسمك طبقة البشرة فى نباتات الذرة. أوضحت *Balclutha hortensis, Cicadulina chinai, C. bipunctella , Sogatella vibix* and *S. furicefera* النتائج إن هناك إختلافات معنوية فى كثافة المجموع للحشرات سالفة الذكر عند المعدلات المختبرة من التسميد البوتاسى ، حيث سجل أعلى متوسط تعداد من الحشرات عند المعدل F1(صفر كجم / k_2o /فدان) بينما وجد أقل تعداد من تلك الحشرات عند معدل F4 (72 كجم / k_2o /فدان).بالإضافة إلى ذلك تشير نتائج التحليل الكيماوى إلى إن هناك علاقة موجبة بين محتوى البروتين الكلى، محتوى الكربوهيدرات الكليه ، قيم البوتاسيوم وسمك طبقة البشرة والمعدلات السالفة الذكر من التسميد البوتاسى، بينما سجلت علاقة عكسية بين قيم pH والتسميد البوتاسى ،وأيضا اثر التسميد بشكل كبير على ستة أحماض أمينية وهم الأسبارتيك ، الجلوتاميك، الجلايسين، الالانين، أيسولوسين و ليسين والتي أثرت على جانبية هذه الأنواع الحشرية ، والتى يمكن أن تفسر لنا إنخفاض تعداد تلك الحشرات مع زيادة معدلات التسميد ، ووفقا لهذة النتائج ينصح بإستخدام التسميد البوتاسى كعامل مؤثر فى برنامج المكافحة المتكاملة لتلك الافات.