Article

Induced plant resistance as a pest management tactic on piercing sucking insects of sesame crop

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Abstract
Sesame, *Sesamum indicum* L. is the most oil seed crop of the world and also a major oil seed crop of Egypt. One of the major constraints in its production the damage caused by insect pests, particularly sucking insects which suck the cell sap from leaves, flowers and capsules. Impact of three levels of potassin-F, salicylic acid and combination between them on reduction infestation of Stink bug *Nezara viridula* L., Mirid bug *Creontiades* sp., Green peach aphid *Myzus persicae* (Sulzer), Leafhopper *Empoasca lybica* de Berg and Whitefly *Bemisia tabaci* (Gennadius) of sesame crop cultivar Shandawil 3 was carried out during 2010-2011 crop season at Experimental farm, Faculty of Agriculture, Suez Canal University, Ismailia, Egypt. Also, the impacts of potassin-F and salicylic acid on yield production of sesame were studied. Results indicated that percent of reduction of infestation by *N. viridula*, *M. persicae*, *Creontiades* sp., *E. lybicae*, *B. tabaci* and phyllody disease were significantly higher at Level 2 (Potassin-F= 2.5 cm/l, Salicylic acid= 10^{-3} M and Potassin + Salicylic= 2.5 cm/l + 10^{-3} M) and consequently higher seed yield per plant were obtained.

Keywords *Sesamum indicum*; potassin-F; salicylic acid; induced resistance; piercing sucking insects.

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1 Introduction
Sesame (*Sesamum indicum* L.) is one of the important oil crops. It is cultivated in almost all tropical and sub tropical Asia and African countries for its highly nutritious and edible seeds (Iwo et al., 2002). In Egypt, sesame is considering a food crop rather than oilseed crops because most of its seeds consumed directly. It is clear that the increase in sesame production during last ten years was mainly due to the increase in its growing area, especially in newly reclaimed sandy soils.

Among various factors responsible for the low productivity levels of sesame, the insect pests associated with flowering phase usually inflicts very severe damage to the crop. The physical damage may be less than those of foliage pests, yet their impact on final yield is colossal.

Piercing sucking insects have great economic importance to sesame plants. They cause serious damage directly by sucking plant sap or indirectly by transmission of virus and mycoplasma diseases (El-Gindy, 2002). Stink bug *Nezara viridula* L., Mirid bug *Creontiades* sp., Green peach aphid *Myzus persicae* (Sulzer), Leafhopper *Empoasca lybica* de Berg and Whitefly *Bemisia tabaci* (Gennadius) are serious pests which suck the cell sap from leaves, flowers and capsules. Due to this curling of leaf margins downward, reddening of leaf margins, stunted growth of the plants, sickly appearance of the crop and subnormal growth of the leaf tissue occur. The peculiar yellow spots are found on upper surface of leaves affected by whitefly. Jassid and whitefly are also responsible to transmit phyllody and leaf curl diseases in sesame, respectively. Induced plant resistance is very important component of integrated pest management programs, including adequate inorganic fertilization kinds and amounts. Of all the nutrients that affect plant diseases and pests, potassium (K) is probably the most effective. It has been considered a key component of plant nutrition that significantly influences crop growth and some pests infestation. There are limited information about results of potassium fertilization on reduction population of piercing sucking insects of sesame. Potassium fertilizer is negatively associated with occurrence of *Aphis glycines* (Myers and Gratton, 2006) and leafhoppers and mites (Parihar and Upadhyay, 2001). Cotton aphid population density at seedling stage was suppressed by potassium fertilizers in proper rate (Ai et al., 2011). The high rates of potassium reduced the population density of some piercing sucking insects on cereal, legumes and maize plants (El-Gindy, 2002, 2006).

Inducible defenses play a major role in conferring disease resistance against plant pathogens (Maleck and Dietrich, 1999) and their effects on phytophagous insects can include increased toxicity, delay of larval development or increased attack by insect parasitoids (Baldwin and Preston, 1999). Inducible defenses are thought to compromise plant fitness less and may be more durable than constitutive defense mechanisms (Agrawal, 1998). The plant nutrient status in an indicator of host plant quality plays an important role in the population dynamics of many herbivores (Sarwar et al., 2011). Salicylic acid has been shown to have a positive effect on some species of plants with regards to expression of dormant genes. However, no work has yet been done to assess the level of insect attacks on the sesame plants treated with salicylic acid. Considering the fact that some substances in association with crops under particular conditions can induce the presence of both major and minor pests and diseases at different stages of development, the level of sucking insect infestations on sesame in association with salicylic acid under our prevalent conditions must be properly studied and understood. The concept of integrated pest management has taken centre stage in pest and diseases management on a wide range of crops. This approach includes an integration of cultural, biological, chemical and host plant resistance methods in controlling pests. Therefore, the purpose of this research was to investigate the impact of three levels of potassin-F fertilizer and salicylic acid on reduction densities and infestation of piercing sucking insects attacking sesame plants within two successive seasons, and to investigate the impact of these treatments on yield production of sesame crop. Finding out the effect of treatments on the pest load and damage can help update the control strategy of sucking insects on sesame.

2 Materials and Methods

2.1 Experimental design

This experiment was carried out at the Experimental farm, Faculty of Agriculture, Suez Canal University, Ismailia, Egypt during the growing seasons of sesame (2010 and 2011). The soil texture of experimental site was sandy soil (94.5% sand, 2.5% silt and 3.0% clay) with pH of 7.8.

Seeds of cultivar of sesame namely (Shandawil 3) were purchased from the Agriculture Research Center, Giza, Egypt. These seeds were treated with Rizolex-T (3 g/kg seeds) before planting to prevent rot infection. A randomized complete block experimental design was used and each experimental unit measuring an area of 3.5 × 4 m^2. Three treatments were used at three levels and control.

Table 1 Potassin-F and salicylic treatment levels used in the present study.

Levels	Treatments		
	Potassin –F (P) (0 N: 8P: 30K)	Salicylic Acid (S)	*P + S
Control	0.0	0.0	0.0
Level 1	1cm/l	10^{-2} M	1cm/l + 10^{-2} M
Level 2	2.5 cm/l	10^{-3} M	2.5 cm/l + 10^{-3} M
Level 3	4 cm/l	10^{-4} M	4 cm/l +10^{-4} M

***** P= Potassin- F foliar application, S= Salicylic foliar application.

2.2 Sampling of studied insects

2.2.1 Jassid and aphid

25 sesame leaves were sampled weekly from each plot early in the morning from three different levels of the plant. The upper and lower surfaces of the randomly chosen sesame leaves were carefully examined using lens (5×) to count all individuals of *Empoasca lybica* and *Myzus persicae* and the data were recorded (El-Zahi et al., 2012).

2.2.2 Whitefly

25 sesame leaves were randomly chosen from each plot and picked up weekly from the levels mentioned above. The chosen leaves were transmitted to the laboratory in paper bags where binocular-microscope was used to count the immature stages of *B. tabaci* (nymphs and pupae). The duration of sampling as mentioned before.

2.2.3 Stink and mirid bugs

Sampling methods were made directly in the field on five randomly selected plants from each plot. All stages were recorded. The reduction percentage of insect infestations was calculated for the seasons of 2010 and 2011.

2.3 Treatments

Sesame plants were sprayed with three levels of potassin–F and salicylic acid separately and together. Potassin-F (P) was purchased from the Agriculture Research Center, Giza and Salicylic acid (S) was initially dissolved in a few drops of dimethylsulfoxide and the final volume was reached using water. The concentrations of (S) with a surfactant triton 0.1% and concentrations of (P) were sprayed twice on the whole foliage of sesame (after 30 days from sowing and at the initiation of flowering stage). One set served as control was sprayed with water only. The plants were sprayed with hand spray bottles10 liter capacity.

2.4 Effect of potassin-F fertilizer (P) and salicylic acid (S) on sesame production

Some parameters were measured as follows: no. of capsule/ plant, capsule weight, no. of seed/capsule, weight of 1000 seed and seed yield/plant of sesame (Dhurve, 2008).

1- Number of capsule per plant: the number of capsule on plant was counted and expressed as capsule per plant. Observation was made on 10 randomly selected plants per treatment.

2- Capsule weight: weight of 25 randomly selected capsules from each treatment was measured before the harvest using an electronic balance.

3- Number of seeds per capsule: the number of seeds in a capsule was counted and expressed as seeds per capsule. Observation was made on 10 randomly selected plants per treatment.

4- Weight of 1000 seeds: the observation was made by weighing 1000 dried seeds drawn randomly from each treatment using an electronic balance.

5- Seed yield per plant: after maturation, the capsules from ten plants from each treatment were removed and recorded. The seeds were separated and weight using an electronic balance and expressed in grams per plant. Each treatment was replicated four times.

2.5 Statistical analysis

Data obtained in all presented experiments were subjected to analysis of variance (ANOVA) and correlation coefficient with the honestly significant difference value calculated as Tukey's statistic at $\alpha = 0.05$ (SAS Institute, 2002).

3 Results

Results from Fig. 1 showed five piercing sucking insects attacked sesame during growing season 2010/2011 and phyllody and healthy plant of sesame. Data presented in Fig. 2 and 3 showed the effect of three levels of potassin-F, salicylic acid and the combination between them on population density of some piercing sucking insects and the mean number of phyllody disease for sesame cultvar shandawil 3, during the growing season of 2010 and 2011. Data in Fig. 2 and 3 revealed that the three levels of all treatments led to reduction of population density of jassid (*Empoasca lybica*), aphid (*Myzus persicae*), stink bug (*Nezara virdula*), whitefly (*Bemesia tabaci*), mirid bug (*Creontiades* sp.) and the mean number of phyllody disease. Also, data in Fig. 2 and 3 indicated that Level 2= (Potassin-F= 2.5 cm/l, Salicylic acid= 10^{-3} M and Potassin + Salicylic= 2.5 cm/l + 10^{-3} M) was the more affect on reduction of population density than level 1 and level 3. Moreover, the combination of potassin-F and salicylic acid in level 2 was the most suitable treatment to reduce population of insects and phyllody disease.

The relationship between the reduction of infestation, % and the three levels of treatments potassin-F, salicylic acid and the combination between them for the growing seasons of sesame, 2010 and 2011 were computed as a coefficient of determination based on the simple linear regression Fig. 4 and 5.

Data presented in Fig. 4 indicated that level 2 of treatments (P= 2.5 cm/l, S= 10^{-3} M and P+S= 2.5 cm/l + 10^{-3} M) gave high reduction of infestation for the following insects, *B. tabaci*, *N. viridula*, and *M. persicae*. The coefficient of determination (R^2) was 0.993, 0.931 and 0.1, respectively. Whenever, level 1 of treatments (P= 1 cm/l, S= 10^{-2} M and P+S= 1 cm/l + 10^{-2} M) gave high reduction of infestation of *E. lybica* and *Creontiades* sp. R^2 was 0.923 and 0.750, respectively. Finally, the level 3 (P= 4 cm/l, S= 10^{-4} M and P+S= 4 cm/l + 10^{-4} M) gave high reduction of infestation only in phyllody disease at R^2 = 0.999.

Also, data presented in Fig. 5 showed that level 2 of treatments (P= 2.5 cm/l, S= 10^{-3} M and P+S= 2.5 cm/l + 10^{-3} M) gave high influence on the reduction of infestation,% for the following insects, *E. lybica*, *N. viridula*, *Creontiades* sp. and *M. persicae*. The coefficient of determination (R^2) was 0.993, 0.931, 0.1 and 0.964, respectively. While, level 3 of treatments (P= 4 cm/l, S= 10^{-4} M and P+S= 4 cm/l + 10^{-4} M) gave high reduction of infestation of *B. tabaci* and phyllody disease. Results further proved that R^2 for *B. tabaci* and phyllody disease in the infestation of reduction was very high at values of 0.964 and 0.750, respectively.

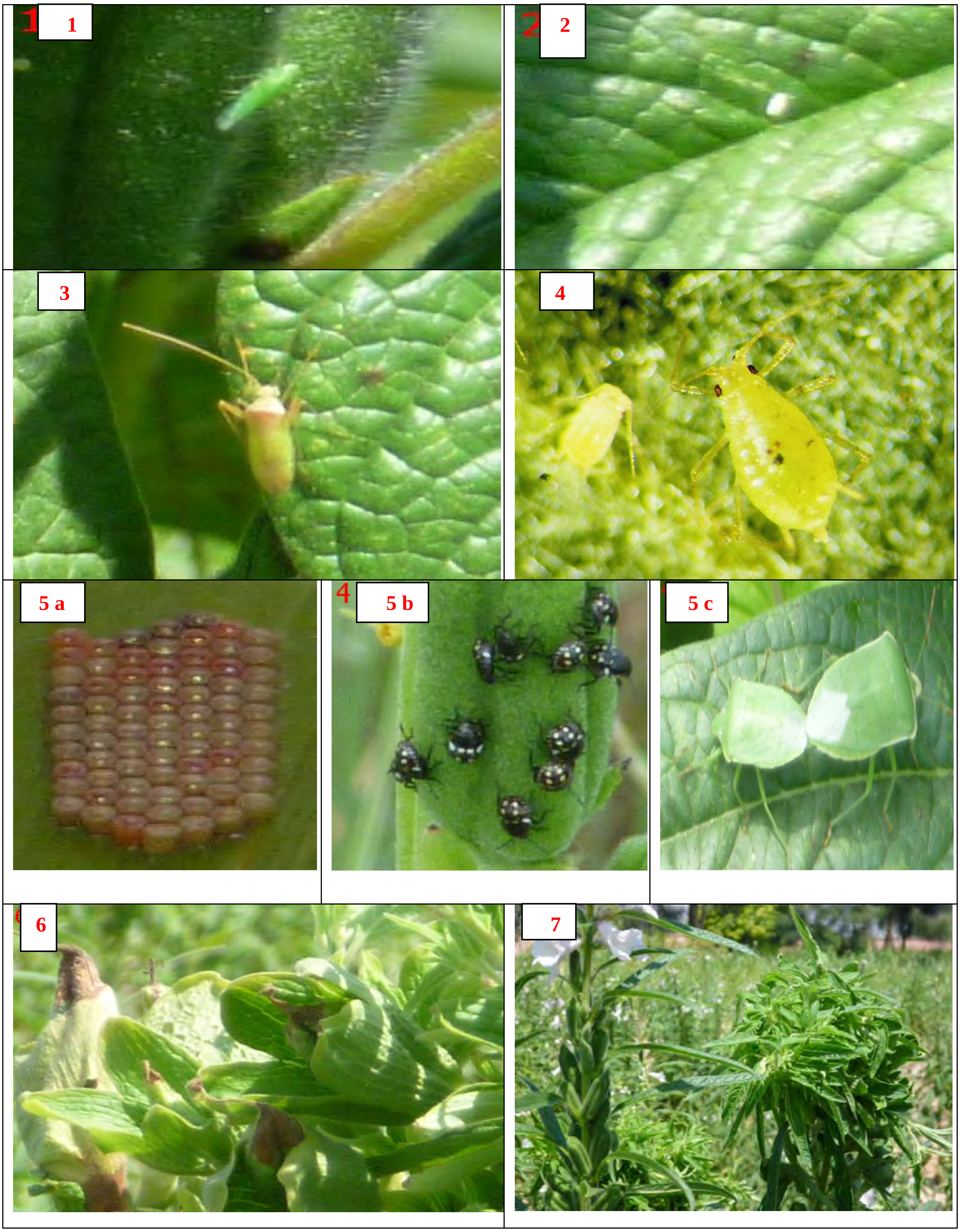

Fig. 1 Some piercing sucking insects attacked sesame during growing season 2010/2011, 1- *Empoasca lybica*, 2- *Bemesia tabaci*, 3- *Creontiades* sp., 4- *Myzus persicae*, 5a- *Nezara virdula* eggs, 5b- *N. virdula* nymphs, 5c, *N. viridula* adults, 6- phyllody disease, 7- phyllody and healthy plant of sesame.

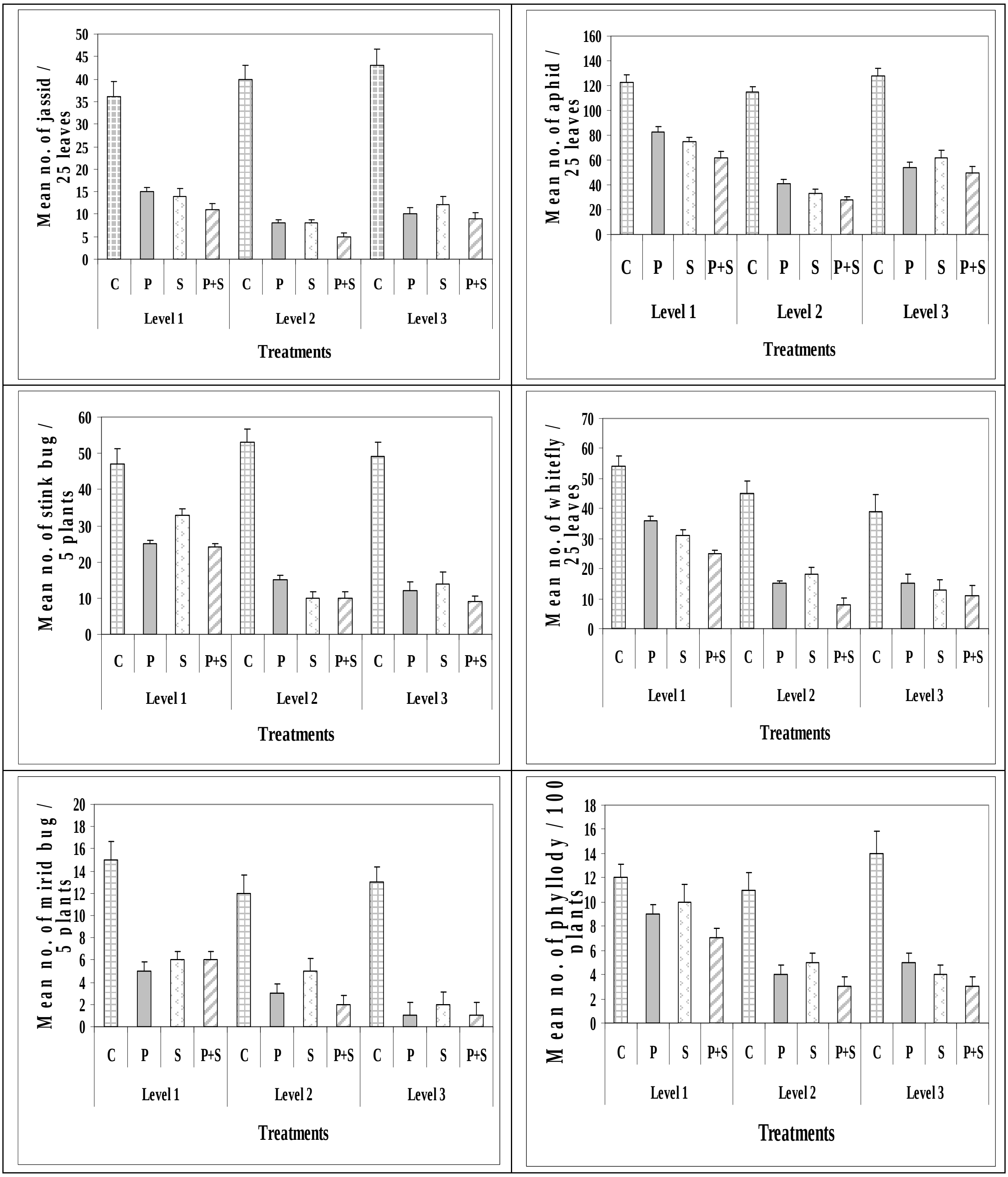

Fig. 2 Effect of three levels of potassin-F, Salicylic acid and the combination between them on the mean number of some piercing sucking insects which attack sesame and the mean number of phyllody disease during the growing season of 2010. C= Control, P= Potassin-F, S= Salicylic and P+S= Potassin-F + Salicylic; Level 1= (P= 1 cm/l, S= 10^{-2} M and P+S= 1 cm/l + 10^{-2} M); Level 2= (P= 2.5 cm/l, S= 10^{-3} M and P+S= 2.5 cm/l + 10^{-3} M); Level 3= (P= 4 cm/l, S= 10^{-4} M and P+S= 4 cm/l + 10^{-4} M).

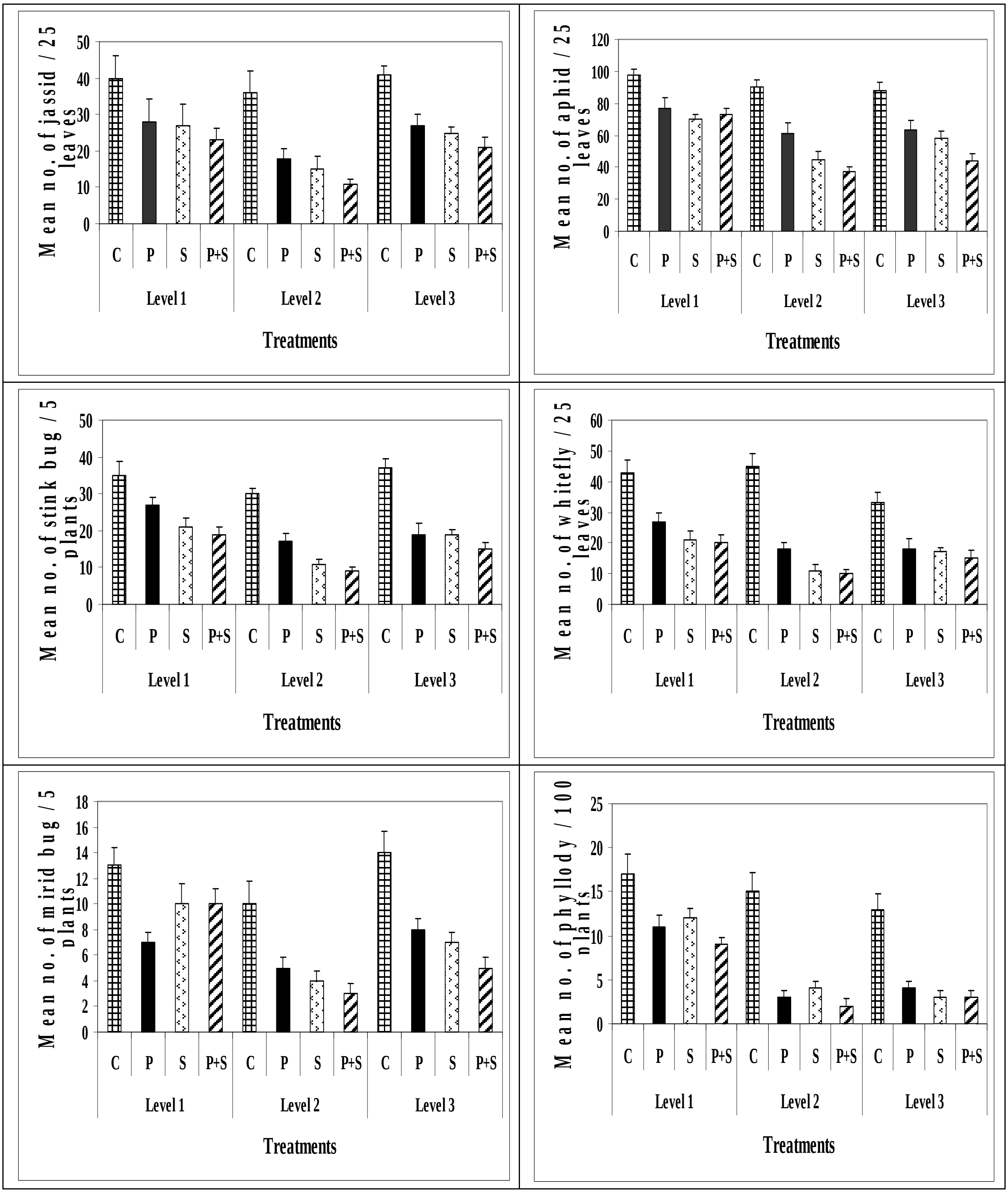

Fig. 3 Effect of three levels of potassin-F, Salicylic acid and the combination between them on the mean number of some piercing sucking insects which attack sesame and the mean number of phyllody disease during the growing season of 2011. C= Control, P= Potassin-F, S= Salicylic and P+S= Potassin-F + Salicylic; Level 1= (P= 1 cm/l, S= 10^{-2} M and P+S= 1 cm/l + 10^{-2} M); Level 2= (P= 2.5 cm/l, S= 10^{-3} M and P+S= 2.5 cm/l + 10^{-3} M); Level 3= (P= 4 cm/l, S= 10^{-4} M and P+S= 4 cm/l + 10^{-4} M).

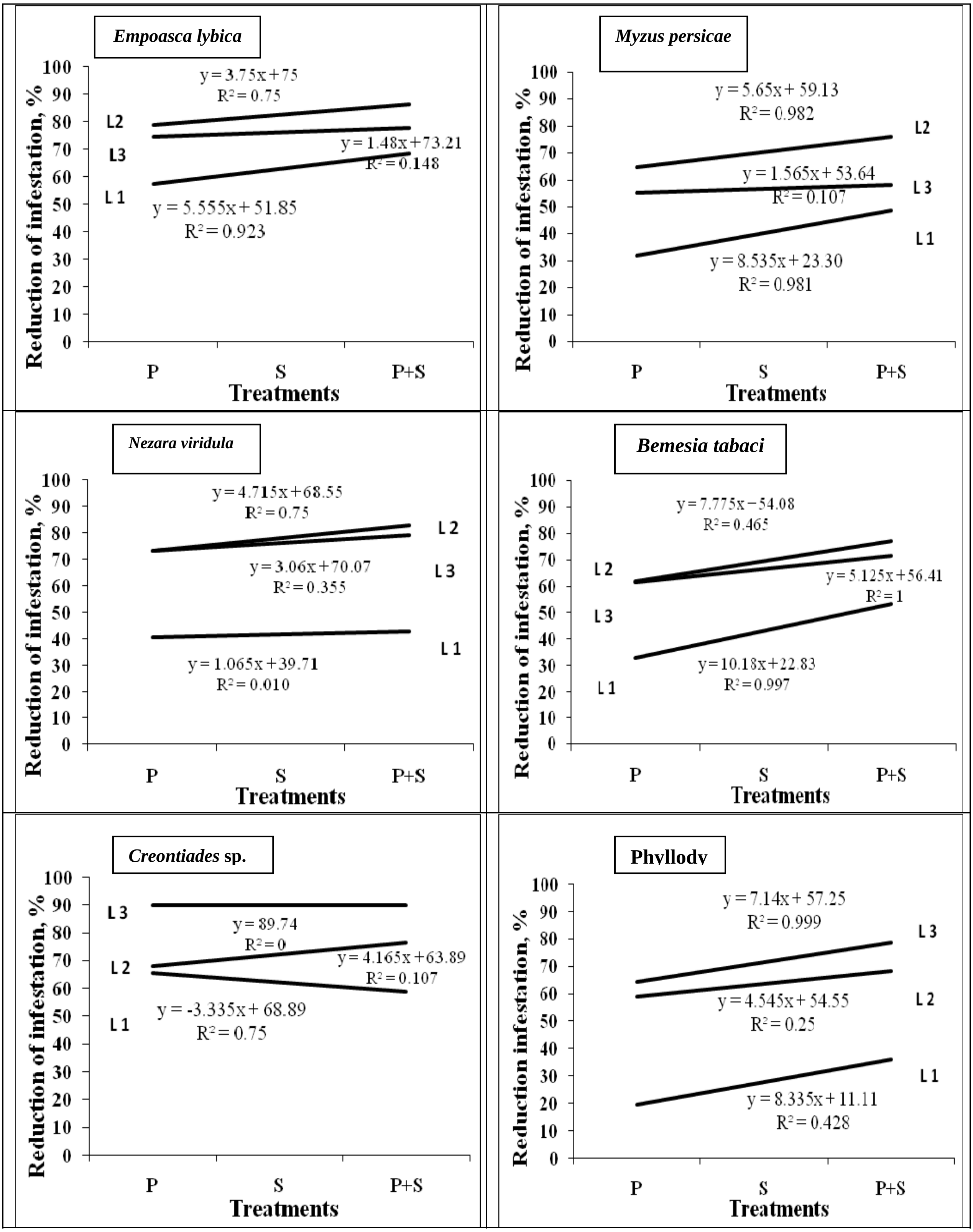

Fig. 4 Relationship between reduction of infestation, % and different levels of potassin-F, salicylic acid and the combination between them in sesame during growing season of 2010.

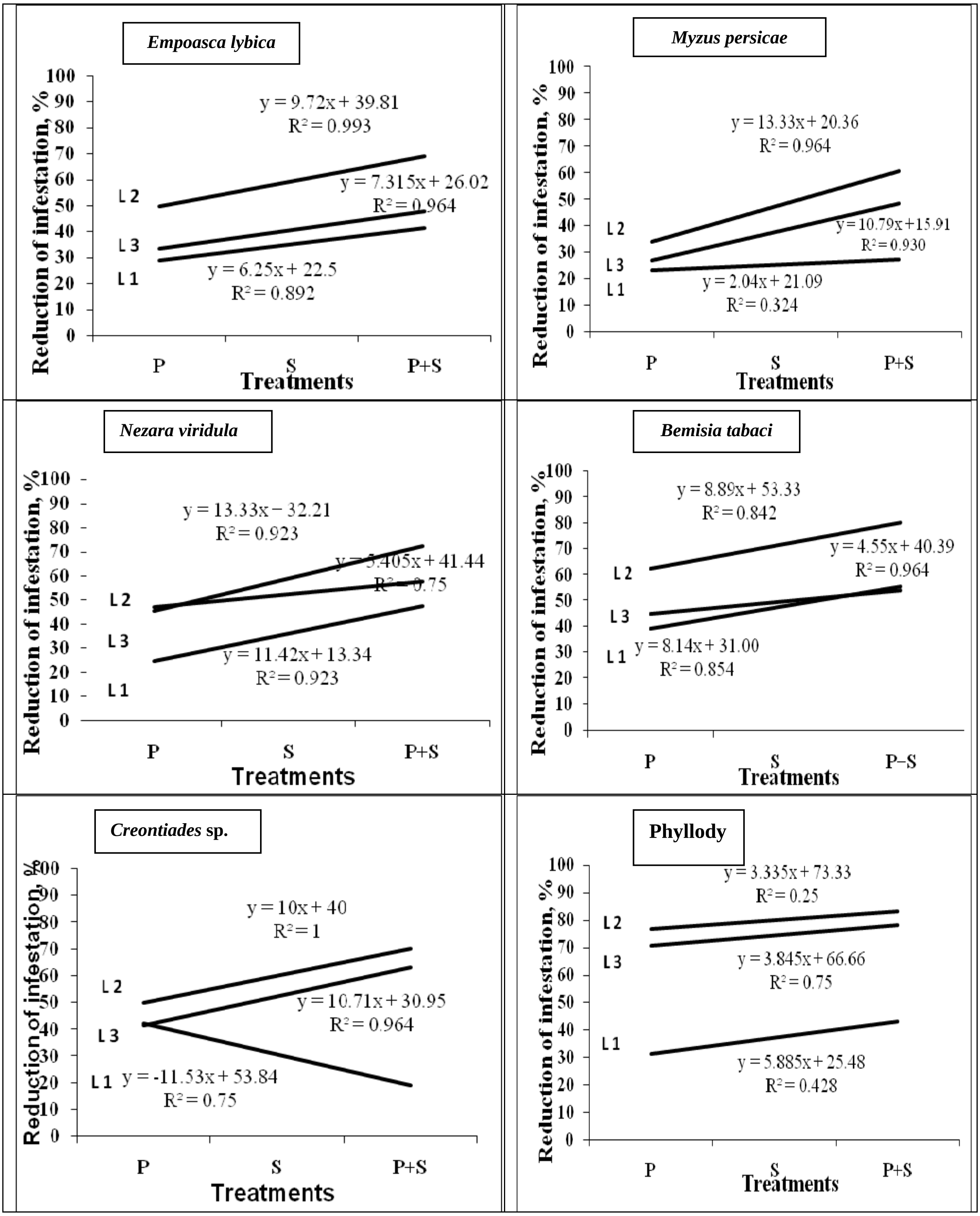

Fig. 5 Relationship between reduction of infestation, % and different levels of potassin-F, salicylic acid and the combination between them in sesame during growing season of 2011.

Results in Table 2 showed the influence of potassin-F, salicylic acid and the combination between them on number of capsule/ plant, capsule weight, number of seed/capsule, weight of 1000 seed and seed yield (g)/ plant of sesame. Data showed significant differences in some quantitative parameters either in 2010 or 2011. Number of capsule/ plant, capsule weight (g) and seed yield (g)/ plant in all treatments were significantly higher compared to control in both growing seasons. In 2010 season (df= 4,35; F= 1.315; P≤ 0.0009), (df= 4,35; F= 6.381; P≤ 0.0001), (df= 4,35; F= 2.793; P≤ 0.0166), respectively. While in 2011 season (df= 4,35; F= 6.440; P≤ 0.0000), (df= 4,35; F= 4.234; P≤ 0.0013), (df= 4,35; F= 8.432; P≤ 0.0000), respectively. Number of seed/ capsule was insignificant compared to control in both seasons. It was (df= 4,35; F= 1.315; P≤ 0.2701), (df= 4,35; F= 1.917; P≤ 0.0878), respectively. On the other hand, weight of 1000 seed was not significant in 2010 season (df= 4,35; F= 2.271; P≤ 0.0445), and it was significant in 2011 season (df= 4,35; F= 2.708; P≤ 0.0194).

The correlation coefficient (r) between seed yield (g)/ plant which produced from sesame plants treated with different levels of potassin, salicylic and the combination between them and reduction of infestation of different piercing sucking insects and phyllody disease was calculated of both studied seasons and presented in Table 3. Data in this Table showed greatest direct effect on seed yield (g)/ plant produced from sesame plants treated with potassin, with reduction of infestation of *M. persicae*, *E. lybica*, *B. tabaci* and *N. viridula* in 2011 season. It was 0.961, 0.522, 0.956 and 0.918, respectively. Also, results showed direct effect on seed yield (g)/ plant produced from sesame plants treated with salicylic, with reduction of infestation *M. persicae*, *E. lybica* and *N. viridula* in 2010 season. It was 0.971, 0.642 and 0.988, respectively. And it was 0.537 with *Creontiades* sp. in 2011 season. The strength of a relationship between seed yield (g)/ plant and reduction of phyllody disease was high in both growing seasons of sesame especially with combined treatment (potassin + salicylic). It was (0.581) in 2010 and (0.841) in 2011, respectively.

On the other hand, most of negative correlation has been recorded between seed yield (g)/ plant produced from sesame plants treated with combined levels of potassin and salicylic and reduction infestation of *M. persicae*, *E. lybica*, *N. viridula* and *Creontiades* sp.

Table 2 Influence of potassin-F, salicylic acid and the combination between them on no. of capsule/ plant, capsule weight, no. of seed/capsule, weight of 1000 seed and seed yield/plant of sesame.

Treatments		No. of capsule/ plant		Capsule weight (g)		No. of seed/capsule		Weight of 1000 seed		Seed yield (g)/plant	
		2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Control (0)		68.50 c	67.25 c	1.83 c	1.85 c	62.50 a	63.00 a	4.45 a	4.50 b	19.05 b	19.06 d
Potassin-F	L1**	71.25 bc	71.75 bc	1.91 bc	2.07 abc	64.25 a	60.25 a	4.46 a	4.47 b	21.81 ab	19.26 cd
	L2	77.75 abc	84.00 ab	2.00 abc	2.15 ab	68.00 a	61.00 a	4.51 a	4.52 b	23.85 ab	23.12 bcd
	L3	7 7.75 abc	78.75 abc	2.08 ab	2.14 ab	66.00 a	62.50 a	4.47 a	4.57 ab	23.28 ab	22.54 bcd
Salicylic	L1	78.75 abc	75.75 abc	1.98 abc	1.99 bc	63.75 a	64.50 a	4.51 a	4.60 ab	22.53 ab	22.59 bcd
	L2	81.75 a	87.75 a	2.05 ab	2.27 a	69.00 a	68.75 a	4.52 a	4.77 a	25.53 a	28.82 a
	L3	81.25 a	81.50 ab	2.12 a	2.08 abc	70.00 a	68.25 a	4.58 a	4.65 ab	25.98 a	25.86 a
Potassin-F + Salicylic	L1	77.25 abc	79.00 abc	2.05 ab	1.96 bc	65.00 a	62.75 a	4.57 a	4.60 ab	22.99 ab	22.83 bcd
	L2	81.75 a	86.50 a	2.16 a	2.15 ab	63.25 a	64.75 a	4.50 a	4.57 ab	23.26 ab	25.59 ab
	L3	79.75 ab	83.00 ab	2.10 ab	2.02 abc	64.00 a	63.50 a	4.53 a	4.57 ab	23.23 ab	24.08 abc
LSD 0.5	-	**6.056**	**7.381**	**0.114**	**0.166**	**6.507**	**6.131**	**0.083**	**0.147**	**3.319**	**2.931**

*Means followed by the same letter in a column are not statistically different by Tukey's HSD (P=0.05)
****** Level 1= (P= 1 cm/l, S= 10^{-2} M and P+S= 1 cm/l + 10^{-2} M); Level 2= (P= 2.5 cm/l, S= 10^{-3} M and P+S= 2.5 cm/l + 10^{-3} M); Level 3= (P= 4 cm/l, S= 10^{-4} M and P+S= 4 cm/l + 10^{-4} M).

Table 3 Correlation coefficient (r) between seed yield (g)/plant produced from sesame plants treated with different levels of potassin-F, salicylic acid and the combination between them and reduction infestation of different piercing sucking insects and phyllody disease.

Seed yield (g)/plant	*M. persicae*		*E. lybica*		*B. tabaci*		*N. viridula*		*Creontiades sp.*		Phyllody disease	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Potassin-F	0.606	0.961	0.485	0.522	0.671	0.956	-0.949	0.918	-0.966	-0.986	-0.068	0.036
Salicylic	0.971	0.687	0.624	0.466	0.369	0.828	0.988	0.750	-0.039	0.537	0.150	-0.461
Potassin + Salicylic	-0.598	0.207	-0.547	0.281	0.561	0.281	-0.330	-0.047	-0.827	0.281	0.581	0.841

4 Discussion

In the present study, we applied potassin-F which consists of (0 Nitrogen: 8 Phosphorus: 30 Potassium). It is well known that, potassium plays an important physiological roles including building up of resistance to insect pests by influencing tissue of cell structures and biochemical processes. 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 and pathogens as well as their subsequent growth and development the plant (Amtmann et al., 2008). A thicker cuticle in plants can be considered as a first line of defense to disease and insect attack and increases the resistance to insect feeding, especially against sucking insects (Khattab, 2007).

Several studies conclusively indicate that phosphate is effective in controlling some important plant diseases caused by pathogens. Action of phosphate anion is based on two mechanisms: the first is a direct toxic action on the pathogen and the second in indirect action due to phosphite anion activates plant defence responses (Cook et al., 2009; Avila et al., 2012).

Salicylic acid (SA), is a plant phenolic, is widely distributed throughout the plant kingdom. It is a hormone-like substance, which plays an important role in the regulation many aspects of plant growth and development (Raskin, 1992). However, it is especially famous for its ability to induce systemic acquired resistance (SAR) in plants (Ryals et al., 1996) i.e. resistance in induced but also uninduced distal leaves of the same plant.

Piercing sucking insects play an important role in reducing the production of sesame yield. The present results revealed that sesame plants at the studied location was infested with Stink bug *Nezara viridula* L., Mirid bug *Creontiades* sp., Green peach aphid *Myzus persicae* (Sulzer), Leafhopper *Empoasca lybica* de Berg and Whitefly *Bemisia tabaci* (Gennadius). These insects were recorded on sesame crop variety shandawil 3 during growing season of 2010 and 2011, Ismailia, Egypt (Mahmoud, 2012). Also, some of these pests were recorded on potato plants by Parihar et al. (1996) and Kuroli (2001). On the other hand, *M. percicae*, *A. gossypii*, *A. craccivora*, *B. tabaci* and *Empoasca* sp. populations were most at zero potassium fertilization in comparison with 100, 150 and 200 kg/feddan, respectively (El-Gindy et al., 2009). Also, phyllody disease plays a significant role in reducing yield of sesame. Leafhopper transmitted phytoplasma is the cause of phyllody disease (Akhtar et al., 2008; Akhtar et al., 2009), which can cause up to 80% yield loss with disease incidence of 61-80% (Kumar and Mishra, 1992).

Results in the present study confirmed significant effect of potassin-F fertilization on the insect infestations. These findings are in agreement with those reported by (Kindler and Staples, 1970) who found that increasing amount of potassium and phosphorus fertilizer, increased resistance against spotted alfalfa aphid in alfalfa, green bug in sorghum (Schwessing and Wilde, 1979). Data in presented study indicated that Salicylic acid had positive effects on plant growth, reduction infestation, % of *M. persicae*, *B. tabaci*, *E. lybica*, *Creontiades* sp., *N. viridula*, phyllody disease and yield components and hence could find roles to play in integrated pest management on sesame plants.

In general, treatment of potassin-F and salicylic acid separately and together, especially at the level 2 clearly caused significant decrease in population density and percentage of infestation of *N. viridula*, *Creontiades* sp., *M. persicae*, *E. lybica* and *B. tabaci*. Also, it caused reduction in the mean number of phyllody disease during 2010 and 2011 crop seasons of sesame. Moreover, it caused significant increase in the number of capsules on sesame stem, capsule weight (g), thousand seed wt (g) and seed yield/ plant (g). Therefore, using potassin-F fertilization and salicylic acid is so necessary for encouraging the defense system of plant to be more resistance or tolerant to insect injury caused by piercing sucking insects. Elden and Kenworkthy (1995) found that the optimum or higher levels of potassium nutrition have been implicated with decline in the incidence of disease and insect pests in several plant species.

In conclusion, potassin-F and salicylic acid provided good nutrition and resistance for the reduction of pest load and damage and consequently, enhanced seed yield of sesame cultivar (Shandawil 3) in the reclaimed land. Application of potassin-F (P) and salicylic acid (S) separately or combined at level 2 (P= 2.5 cm/l, S= 10^{-3} M and P+S= 2.5 cm/l + 10^{-3} M) provided the best nutrition for effective reduction of sesame pest load and damage with increased seed production. The findings of this study also recommended that even though application of potassin-F and salicylic acid at the level 2 (P= 2.5 cm/l, S= 10^{-3} M and P+S= 2.5 cm/l + 10^{-3} M) reduced pest load and increased the quantity and quality of sesame, higher seed yield could be enhanced through integrated pest management, especially if this rate is applied in conjunction with other cultural practices such as crop rotation, inter-cropping, planting date manipulation, plant spacing and biological control.

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