Relative toxicity of two natural compounds compared to abamectin against some soybean pests under period rates

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Abstract – A sustainable pest management in agro-ecosystems requires parallel assessments of pesticide and natural compounds to control target pests. In the present study, a semi-field experiment was conducted to evaluate the relative toxicity of abamectin (Abamax), humic acid, and Chitosan Nano-Particles (C.N.Ps) against four soybean pests: *Tetranychus urticae*, *Eutetranychus orientalis*, *Bemisia tabaci*, and *Phenacoccus solenopsis*. The experimental treatments were arranged in a split-plot design with three replicates, where treatments were assigned to main plots and pest populations under different periods in the subplots. The obtained results and graphs demonstrated that there were considerable differences between the total numbers of pests after different periods of treatment. Generally, *E. orientalis* recorded the minimum pest number at all. Different tested compounds demonstrated a considerable correlation between the densities of the pests. *T. urticae* exhibited a significant correlation with the other three pests (*E. orientalis*, *B. tabaci*, and *P. solenopsis*). *E. orientalis* did not correlate with *B. tabaci* and *P. solenopsis*. The humic acid recorded the best effect on *T. urticae* after 3 days with a reduction of 85.45% and *E. orientalis* after 7 days 65.55%. However, Chitosan Nano-Particles (C.N.Ps) was the best for *E. orientalis* after 14 days (mortality 74.36%). In contrast, abamectin (Abamax) had a general mean of reduction of 91.17% against *T. urticae*, whenever, these compounds are promising for controlling *T. urticae*, *E. orientalis*, *B. tabaci*, and *P. solenopsis*. These results may be a supporting method to overcome some soybean pests. The findings are discussed within the context of integrated management of soybean pests under semi-field conditions.

Keywords: soybean / *Tetranychus urticae* / *Eutetranychus orientalis* / *Bemisia tabaci* / *Phenacoccus solenopsis* / biplot / abamectin / humic acid / Chitosan Nano-Particles

Résumé – Ravageurs du soja : efficacité à différentes dates de 2 composés naturels comparés à l’abaméctine. La gestion durable des ravageurs dans les agro-écosystèmes nécessite des évaluations comparées des pesticides et des composés naturels pour contrôler les ravageurs cibles. Dans la présente étude, une expérience en semi-champ a été menée pour évaluer l’efficacité relative de l’abaméctine (Abamax), de l’acide humique et des nanoparticules de chitosan (C.N.Ps) contre quatre ravageurs du soja : *Tetranychus urticae*, *Eutetranychus orientalis*, *Bemisia tabaci* et *Phenacoccus solenopsis*. Le dispositif expérimental mis en place est un *split-plot*, avec trois répétitions ; les traitements ont été assignés aux blocs principaux et les populations de ravageurs à différentes périodes aux sous-blocs. Les résultats obtenus et les graphiques ont démontré qu’il y avait des différences considérables entre les nombres totaux de ravageurs après différentes périodes de traitement. En général, *E. orientalis* était le ravageur le moins présent. Les différents composés testés ont démontré une corrélation considérable entre les densités de ravageurs. *T. urticae* a montré une corrélation significative avec les trois autres ravageurs (*E. orientalis*, *B. tabaci*, et *P. solenopsis*). *E. orientalis* n’a pas présenté de corrélation avec *B. tabaci* et *P. solenopsis*. Les meilleures efficacités de l’acide humique sur *T. urticae* sont enregistrées après 3 jours avec une réduction de 85,45% et sur *E. orientalis* après 7 jours (65,55%). Cependant, les meilleurs résultats sur *E. orientalis* avec les nanoparticules de chitosan (C.N.Ps) ont été obtenus après 14 jours (mortalité de 74,36%). En revanche, l’abaméctine (Abamax) a réduit en moyenne de 91,17% *T. urticae*. Ces composés sont donc prometteurs pour lutter contre *T. urticae*, *E. orientalis*, *B. tabaci* et *P. solenopsis*. Ces résultats...
montront que les composés naturels testés pourraient constituer des méthodes de lutte alternatives sur certains ravageurs du soja. Les résultats sont discutés dans le contexte de la gestion intégrée des ravageurs du soja dans des conditions de semi-liberté.

**Mots clés** : soja / *Tetranychus urticae* / *Eutetranychus orientalis* / *Bemisia tabaci* / *Phenacoccus solenopsis* / biplot / abamectine / acide humique / nanoparticules de Chitosan

### 1 Introduction

Soybean (*Glycine max*) is considered an important oilseed crop that has grown in the world (60% of world oilseed production) (US Soybean Export Council, 2019). About 15 000 ha was sown soybean in Egypt, total production was 48 000 tons (FAO, 2018). Numerous kinds of pests attack soybean from seedling to mature stages such as spider mites, aphids, cotton leaf worms, and many other pests. Pests’ infestation can lead to yield losses from 20 to 50%. Therefore, the farmers use pesticides to protect their crops (Fikru and Massoud, 2003; Massoud et al., 2014).

Polyphagous pests are wide-ranged on many economic and important crops including soybean (Alakhdar et al., 2015). The two-spotted spider mite *Tetranychus urticae* Koch, and the oriental red mite *Eutetranychus orientalis* Klein are piercing-sucking pests’ infest soybean plant. This behavior of feeding leads to the appearance of characteristic yellow-chlorate spots on the leaves. Pale yellow streaks develop along the midrib and veins initially, which later progress to a grayish or silvery appearance of the leaves. In heavier infestations, mites feed and oviposit over the whole surface of the leaf, causing leaf fall and appearance of the leaves. Pale yellow streaks develop along the midrib and veins initially, which later progress to a grayish or silvery appearance of the leaves. Therefore, the knowledge of the relationship between these pests under different treatments, obtainable through correlation coefficient, was detected to measure only the degree (intensity) and nature (direction) of association (Golkar et al., 2011). The problem gets complicated in selection studies especially when there is a negative interaction between the primary trait of the experiments and the other traits (De Leon et al., 2016) or treatments. Recently, GGE (Genotype plus Environment) biplot method was developed by Yan (2014) to use different types of biplot graphs created to discuss the effects of applied treatment on one or all target traits at the same time, allowing the user to assess entire two-way data (Gabriel, 1971). Assessments are usually performed over PC1 and PC2 (the first two principal components) axes calculated from the data of rows and columns from a two-dimensional array produced by the combination of treatment and traits datasets (Akcura and Kokten, 2017).

In Egypt, no reference was found considering the technique of treatment by pest (TP)-biplot graph. Therefore, the objective of the current work was to:

1. Evaluate the efficacy of using natural compounds such as humic acid, and Chitosan Nano-particles, compared to an acaricide Abamectin: Abamax, after different treatment periods against target pests, *Tetranychus urticae* and *Eutetranychus orientalis* and non-target pests, *Bemisia tabaci*, and *Phenacoccus solenopsis*.
2. Study the interrelationships among pests infestations’ using the (TP)-biplot technique.

### 2 Materials and methods

A semi-field experiment was conducted at an experimental farm known as Plant Protection Research Institute, Agricultural Research Center (ARC), Giza, Egypt during the 2nd week of June in the two successive summer seasons of 2019 and 2020 on soybean. Crawford variety was kindly provided by Field Crops Research Institute (FCRI) to study the effect of three compounds – a commercial insecticide (Abamectin: Abamax), an organic compound (humic acid), and a nano-materials (Chitosan Nano-Particles) – after periods (3, 7 and 14 days of spraying) to reduce the populations’ density of *Tetranychus urticae*, *Eutetranychus orientalis*, *Bemisia tabaci*, and *Phenacoccus solenopsis*.
The performance of the number of each pest under the tested treatments (Tab. 1) was obtained.

## 2.3 Statistical analysis

Data on individual pests was carried out on the mean values over three replications. At first, the analysis of variance was applied, and then a combined analysis of variance was computed over two seasons according to Sendecor and Cochran (1981). Before running the combined analysis, Levene (1960) test was used to satisfy the assumption of homogeneity of variances. The mean comparison was done using the least significant differences test at a 5% level of probability. The number of pests data was transformed according to \((x + 1)^{1/2}\) and was applied to detect statistical differences among pests numbers. The transformed data analysis can modify the coefficient of variation (C.V.%). Correlations among different pests’ data were subjected, according to Sendecor and Cochran (1989), to reveal the relationship among soybean pests. When \(F\) was significant \((P < 0.05)\) for the levels of symptoms analysis was performed. The genotype by trait (GGT) biplot, which is an application of the GGE biplot used to study the genotype by trait data (Yan and Rajcan, 2002). The biplot method was employed to display the treatment by trait (TT) two-way data in the biplot graph and denoted as treatment-pest (TP)-biplot graph according to Akcura and Kokten (2017), using GenStat software (18.0 version) by ICARDA.

## 3 Results and discussion

### 3.1 Efficacy of compounds against different pests

Reduction percentages were calculated for each treatment, showing the effect of sprayed compounds (humic acid, C.N.Ps., and abamectin) against movable stages of different pests \((T. urticae, E. orientalis, B. tabaci, and P. solenopsis)\) after 3, 7, and 14 days of treatment under natural conditions (Fig. 1). All compounds indicated a decrease in the number of mites/insects remedied, a pre-spray sample was taken and the treatment was carried out with all tested compounds. Ten leaves were taken from each replicate and the number of each pest, all movable stages of Tetranychus urticae, Eutetranychus orientalis, Bemisia tabaci, and Phenacoccus solenopsis, was counted before treatment and after 3, 7, and 14 days post-treatment by the aid of a stereomicroscope in acarology lab. at PPRI (Alakhdar, 2020). The reduction percentages were calculated for each treatment, according to the Henderson and Tilton formula (Henderson and Tilton, 1955):
compared with control treatment after different periods. Hence, the formula of Henderson and Tilton (1955) was used to calculate the percentage of pest population reductions using the mean population pre- and post-spraying in treated and untreated controls. Results indicated that humic acid had a mortality percentage for T. urticae (85.45, 84.4, and 80.5%) and E. orientalis (63.91, 65.55, and 57.89%) after 3, 7, and 14 days of treatment, respectively. The highest effect of humic acid was obtained for T. urticae after a different period and followed by P. solenopsis (73.43%) after 3 days. Meanwhile, it had the lowest effectual impact on B. tabaci (35.6 and 48.26%) after 3 and 7 days of treatment, respectively. C.N.Ps revealed the highest mortality effect only on T. urticae, recording 75.3 and 74.36% after 7 and 14 days, respectively. However, C.N.Ps revealed the highest mortality effect on E. orientalis under different treatments, recording 75.3, 74.63, and 71.86% after 14, 7, and 3 days, respectively. Moreover, abamectin had an efficacy on T. urticae recording values above 90% (96.1, 91.52, and 85.9% after 3, 7, and 14 days, respectively) and for E. orientalis and P. solenopsis (85.6 and 85.5) after 3 days, respectively followed by B. tabaci (88.70) after 14 days. Therefore, all three spraying compounds (humic acid, C.N.Ps., and abamectin) had the highest mortality effects against T. urticae after different periods except for C.N.Ps treatment after 3 days. However, B. tabaci had the lowest motility effect for humic acid after 3 and 7 days (Tab. 2).

The three spraying compounds (humic acid, C.N.Ps., and abamectin) indicated a reduction in the mean number of pests under study in variance responses. There is a good match between our results and Prabhat and Poehling (2007) who reported heavy reduction percentages on the three nymphal stages of B. tabaci treated with abamectin within 24 h post-application, while the first instars being most susceptible. Kenneth et al. (2002) indicated that the mortality from abamectin residues was not significantly greater than the control at one day after application, but it was significantly greater than the control after 3, 7, and 14 days of treatment. Few studies recorded the effect of acaricides against E. orientalis, Alhewairini found that the populations of E. orientalis reduced to 76.68 and 78.52 after one-week exposure to the recommended dose (RD) of abamectin under field and laboratory conditions (Márquez et al., 2006; Alhewairini, 2018). The increase of the mean reduction in the population of T. urticae and E. orientalis may due to the specialty of abamectin: Abamax, as acaricide has efficacy on all stages of mites. Whenever its effect on P. solenopsis decreased over time as most of the insecticides used are mixed abamectin with another formula (Rezk et al., 2019).

Particular attention is paid to humic acid, as an organic compound that usually provides plants with a balanced source of nutrients that can influence the composition and physiology of plants. Apart from that, it might have provided some growth-promoting substances, vitamins and these probably have increased the plant resistance to pests or made the plants less palatable to the pest. It emerged superior in minimizing the whitefly 75% compared with other used compounds (Chatterjee et al., 2013). On other the hand, Panda et al. (2005) reviewed the lowest population of sucking pests, jassids, and thrips in chilli. The mechanisms for decreasing pest attacks may be due to the differential availability of mineral nutrients in plants, which might have enhanced the induced resistance development and subsequently helped in escaping sucking-piercing pest infestation. Furthermore, organic treatments reduced the incidence of sucking pest as whitefly and leafhopper that organic amendments comparatively increased the total phenols in the plants and also the activity of the enzymes like polyphenol oxidase and peroxidase, which might be responsible for the reduced pest incidence (Ravi et al., 2006). Consequently, more researches are needed on the mode of action and compatibility of tested compounds with bio- and organic-origin agents (Alakhdar et al., 2020). A similar approach is used for two tetranychid mites, Tetranychus urticae (Koch) and Tetranychus cinnabarinus, and their eggs and immature stages on dry beans (Phaseolus vulgaris L.). It was found that Chitosan Nano-Particles (C.N.Ps) is potent against T. urticae (Alakhdar, 2020). Other studies carried on C.N.Ps to evaluate its insecticidal effect on other pests, and Zhang and Tan (2003) reported that Chitosan exhibited different insecticidal activity to various aphids ranged between 93 and 99% for Hyalopterus pruni (Goffroy)
on flowers, while (Rabea et al., 2005) tested the insecticidal activities of Chitosan Nano-Particles against larvae of the cotton leafworm Spodoptera littoralis (Boisduval) (Lepidoptera: Noctuidae). The same trends were also observed against Aphis gossypii; the mean number of eggs/female of A. gossypii was significantly decreased to 20.9 and 28.9 eggs/female compared with 97.3 and 90.3 of the non-treated controls, under laboratory and semi-field conditions, respectively (Sahab et al., 2015).

3.2 Combined analysis and mean performance

Variances homogeneity for the studied number of pests in each mite/insect was confirmed according to the Levene (1960) test, which allowed the combined analysis. Accordingly, the mean variability for different treatments on each pest over the two seasons 2019 and 2020 were presented in Tables 3 and 4. Results showed that years affected significantly both T. urticae and E. orientalis. As well, significant differences among the different compound treatments for all pests except E. orientalis were obtained. Each of T. urticae, B. tabaci, and P. solenopsis revealed highly significant differences. Our results are in harmony with Sabbour (2016) and Alakhdar (2020) who reported that spray Chitosan Nano-Particles compounds had a high effect on pests’ number on soybean. Concerning periods, highly significant differences were detected for all pests, which demonstrated the existence of a high effect of different periods. The results in this experiment

| Treatments/Pests | Period/days | T. urticae | E. orientalis | B. tabaci | P. Solenopsis |
|------------------|-------------|------------|--------------|-----------|--------------|
| Humic acid       | T1 BT       | 195        | 38           | 152       | 177          |
|                  | T2 3        | 32         | 10           | 72        | 110          | 73.43        |
|                  | T3 7        | 38         | 6            | 98        | 199          | 60.65        |
|                  | T4 14       | 58         | 8            | 167       | 261          | 55.36        |
|                  | Mean        | 83.45      | 62.45        | 46.41     | 63.15        |
| C.N.Ps           | T5 BT       | 208        | 39           | 122       | 127          |
|                  | T6 3        | 72         | 8            | 57        | 91           | 69.36        |
|                  | T7 7        | 64         | 5            | 59        | 135          | 62.79        |
|                  | T8 14       | 69         | 5            | 52        | 138          | 67.1         |
|                  | Mean        | 73.0       | 72.75        | 61.79     | 66.63        |
| Abamectin        | T9 BT       | 151        | 38           | 109       | 139          |
|                  | T10 3       | 24         | 4            | 28        | 75.7         | 47           | 85.5         |
|                  | T11 7       | 16         | 4            | 28        | 79.47        | 88           | 77.84        |
|                  | T12 14      | 9          | 6            | 30        | 88.8         | 214          | 53.39        |
|                  | Mean        | 91.17      | 77           | 81.32     | 72.24        |

BT = before treatment; c = count of motile stages.
T1: before spraying humic acid; T2: 3 days after spraying humic acid; T3: 7 days after spraying humic acid; T4: 14 days after spraying humic acid; T5: before spraying C.N.Ps; T6: 3 days after spraying C.N.Ps; T7: 7 after spraying C.N.Ps; T8: 14 days after spraying C.N.Ps; T9: before spraying abamectin; T10: 3 days after spraying abamectin; T11: 7 days after spraying abamectin; T12: 14 days after spraying abamectin.

Table 2. Reduction percentages % according to Henderson and Tilton’s formula as the effect of different treatment under natural conditions.

| Treatments/Pests | Period/days | T. urticae | E. orientalis | B. tabaci | P. Solenopsis |
|------------------|-------------|------------|--------------|-----------|--------------|
| Humic acid       | T1 BT       | 195        | 38           | 152       | 177          |
|                  | T2 3        | 32         | 10           | 72        | 110          | 73.43        |
|                  | T3 7        | 38         | 6            | 98        | 199          | 60.65        |
|                  | T4 14       | 58         | 8            | 167       | 261          | 55.36        |
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|                  | T7 7        | 64         | 5            | 59        | 135          | 62.79        |
|                  | T8 14       | 69         | 5            | 52        | 138          | 67.1         |
|                  | Mean        | 73.0       | 72.75        | 61.79     | 66.63        |
| Abamectin        | T9 BT       | 151        | 38           | 109       | 139          |
|                  | T10 3       | 24         | 4            | 28        | 75.7         | 47           | 85.5         |
|                  | T11 7       | 16         | 4            | 28        | 79.47        | 88           | 77.84        |
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BT = before treatment; c = count of motile stages.
T1: before spraying humic acid; T2: 3 days after spraying humic acid; T3: 7 days after spraying humic acid; T4: 14 days after spraying humic acid; T5: before spraying C.N.Ps; T6: 3 days after spraying C.N.Ps; T7: 7 after spraying C.N.Ps; T8: 14 days after spraying C.N.Ps; T9: before spraying abamectin; T10: 3 days after spraying abamectin; T11: 7 days after spraying abamectin; T12: 14 days after spraying abamectin.

Table 3. Mean squares combined analysis of variance for a different number of pests under spray compounds and Periods rates.

| S.O.V.               | d.f. | T. urticae | E. orientalis | B. tabaci | P. Solenopsis |
|----------------------|------|------------|--------------|-----------|--------------|
| Year (Y)             | 1    | 300.125*   | 34.72**      | 115.01    | 144.50       |
| Error                | 4    | 113.49     | 4.31         | 347.97    | 1008.11      |
| Spray compound (Sc)  | 2    | 2444.68**  | 2.06*        | 1217.93** | 24110.18**   |
| Sc * Y               | 2    | 117.54     | 0.22         | 42.18     | 344.54       |
| Error                | 8    | 47.86      | 3.47         | 52.66     | 779.69       |
| Periods (P)          | 3    | 1192.83**  | 5.72**       | 281.50**  | 2212.65**    |
| P * Sc               | 6    | 980.9**    | 0.83         | 389.63**  | 2154.05**    |
| P * Y                | 3    | 179.90*    | 0.76         | 72.76     | 375.46       |
| Error                | 42   | 60.69      | 0.54         | 46.41     | 258.18       |

* and **: Significant at 5 and 1% probability levels, respectively.
Table 4. Simple correlation coefficients among studied pests in the soybean field (n = 144).

| Trait     | T. urticae | E. orientalis | B. tabaci |
|-----------|------------|---------------|-----------|
| E. orientalis | 0.494**    | 0.000         |           |
| B. tabaci   | 0.383**    | 0.009         | 0.952     |
| P. solenopsis | 0.224     | 0.064         | 0.436**   |

Cell Contents: Pearson correlation

* and **: Significant and high significant at probability levels 0.05 and 0.01, respectively.

are in agreement with the results of other researchers such as Ekin (2019) and in terms of the interaction between spray compound treatments and periods, there were highly significant differences for all the traits except E. orientalis.

3.3 Effect of tested compounds and periods rates

Figure 2 illustrated the effect of tested compounds on the studied pests on soybean over two seasons. Meanwhile, the analysis showed that this data wasn’t subjected to normal distribution. Then data of the number of pests trait was transformed according to \((x + 1)^{1/2}\) and reanalyzed for modifying analysis and coefficient of variation (C.V.).

The above results on soybean, the 1st compound (humic acid) recorded the best effect for T. urticae and E. orientalis, meanwhile, 2nd (Chitosan Nano-Particles) was the best for B. tabaci and P. solenopsis. Whenever E. orientalis recorded the minimum number at all. These results agreed with Ekin (2019).

3.4 Interaction effect of spray compounds and periods

Figure 3 represents the significant effects of the interaction between sprayed compounds and periods on the number of mites/insects. Data revealed that the humic compound had effects on T. urticae and E. orientalis mites, Chitosan nano-particles (C.N.Ps) decreased E. orientalis and abamectin compound had effects on each from T. urticae, E. orientalis, and B. tabaci pests. It could be noticed that the combination in the application of humic acid, C.N.Ps, and abamectin may reduce pests’ infestation in soybean plants when applied at this stage of plant growth. This time is accurate to manage pests understudy meanwhile keep their abundance under Economic Threshold (Alakhdar et al., 2015; Czepak et al., 2018; Abd El-Razzik, 2018; Mesbah et al., 2019).

3.5 Correlation between pests in the soybean field

Generally, many pests were noted in the soybean field. Adequate knowledge of the relationship that exists between these pests is essential for the identification of infestation in soybeans. The correlation coefficients among all pairs of studied pests of soybean over the two seasons are given in Table 4. The results showed that there was a highly significant positive correlation between T. urticae and each of B. tabaci (0.474**) and P. solenopsis (0.323**). As well as, mealybugs, P. solenopsis had a highly significant positive correlation with the whitefly, B. tabaci. Meanwhile, Eutetranychus (0.302**) had only a significant positive association with E. orientalis. On the other hand, E. orientalis exhibited an insignificant correlation with B. tabaci and P. solenopsis. A significant correlation between these pests indicated that the simultaneous infestation of these pests is possible. These findings indicate that the efficiency of spraying compounds for each pest would be accompanied by a high effect of another pest.

3.6 Treatment pest biplot (combined data)

Generally, the biplot graphs, according to (Yan et al., 2000; Yan, 2002; Yan and Rajcan, 2002; Yan and Tinker, 2005), can be used to compare genotypes in different environments (GE), genotypes based on multiple traits (GT) or treatment based on multiple traits (TT). The current study depended on the estimation of biplot polygon and vector graphs to study the effects of the used treatments (T) on the studied pests (P) in one graph which is termed as (TP)-biplot graph. This method that uses a combination of treatment and pest datasets is similar to the method of comparing treatments on multiple traits (Yan, 2002; Akcura and Kokten, 2017). The mean values of the effects of three compounds and four dates of accounting numbers of (mite-insects)/each pest (representing 12 factorial treatment combinations) were graphically summarized as shown in the polygon view (Fig. 4). The (TP)-biplot graph gives an overall picture of the interrelationships among factorial treatment and all pests simultaneously.

The treatment × pest (TP)-biplot model is generated according to Yan and Rajcan (2002). The polygon (which-won-where) view of the treatment × pest (TP)-biplot graph is a good tool to interpret the behavior pattern of treatment toward pest provided. Then, the biplot should explain a sufficient amount of the total variation. The principle components (PC) analysis based on (TP)-biplot method together explained that there is about 94.22% of the observed variation for the measured pests on soybean across studied treatments (spraying compounds by period treatments). The first and second principle components (PC) explained 76.29% and 17.92%, respectively, and the cumulative variance of the first two PCA was found 94.22%. The first two PC’s reflected more than 60% of the total variation. Therefore, it achieved the goodness of fit for the biplot model.

The polygon-view of the (TP)-biplot graph in Figure 4 indicated which spraying compound by period treatment combinations had the best values for which pests and correlated pests by mega-environment. Mega-environment identification is among the most important objectives of multi-environment statistical trials. The (TP)-biplot showed the variation of the twelve treatments in terms of four pests, treatments as bests ones for single or multiple pests, and grouped the twelve treatments based on pests that make them potential performances. On the right part of the graph (with the
relatively highest pest number), showing which treatments had the best values for the efficiency of pests. Four treatments T9, T11, T10, and T12 were the highest performing efficiency treatment for all pests (recording lowest insect number). The vertex treatment T11 (Abamectin: Abamax spraying compound after 7 days) on the right of the graph (positive part I) had the best, especially for *P. solenopsis* as the nearest pest for this treatment and *B. tabaci*. T10 (Abamectin: Abamax spraying compound after 3 days) and T12 (Abamectin: Abamax spraying compound after 14 days) which were middle between all pests (*T. urticae*, *E. orientalis*, *B. tabaci*, and *P. solenopsis*) recorded the best effective ones on pests. Meanwhile, T9 (before spraying Chitosan Nano-Particles compound), the best treatment has obtained for all pests, especially *T. urticae*. Then, the results of all treatments in the right part of the graph (T11, T12, T9, and T10) revealed that the abamectin effect with the highest insect number for all pests, especially *P. solenopsis* and *B. tabaci*. Therefore, this similarity established a strong correlation between *P. solenopsis* and *B. tabaci* pests in treatment results (as shown in Fig. 4).

The left part of the graph revealed the relatively lowest pest number. Regarding treatments, T2 (humic acid spraying compound after 3 days) and T3 (humic acid spraying compound after 7 days) were the vertex treatment on the left
part of the graph for the *E. orientalis* mite. Therefore, T2 and T3 (humic acid spraying compound after 3 and 7 days) recorded the best treatments for *E. orientalis* with a similar effect was obtained. *T. urticae*, showing the strong correlation between *E. orientalis* and *T. urticae* results as shown in (TP)-biplot graph (Fig. 4) and Table 4. Therefore, all treatments on the negative part of the graph recorded the lowest number of pests, then, it was considered as the best treatment and had a good effect for all pests (Yan and Hunt, 2002; Yan and Rajcan, 2002).

The (TP)-biplot graph displayed the relationship among the four pests on soybean. Also, traits with longer vectors are more responsive to the treatment combinations and traits with shorter vectors are less responsive to the treatment combinations as well as those located at the biplot center are not responsive at all (Yan and Hunt, 2002; Yan and Rajcan, 2002; Yan and Frégeau-Reid, 2008). Then, the ideal test trait (pest) effectively discriminates treatments and represents their grouping which can be classified as pests with low treatment discrimination that should be selected as test trait number of insects/mites. In addition to the results of the traditional method of analyzing data, biplot provides more information on the effectiveness of the treatments with the view of identifying the ideal (best) one or pest. Most of the above findings can be verified from the original correlation coefficients.

### 4 Conclusion

The present study revealed the reduction of chemical pesticides through judicious application of bio and organic compounds, Chitosan Nano-Particles (C.N.Ps), and humic acid was tested. Abamectin (Abamax) is a recommended pesticide compared to these natural compounds against *T. urticae*, *E. orientalis*, *B. tabaci*, and *P. solenopsis* on soybean crops. The obtained results demonstrated that there were considerable differences between the total numbers of these pests after different periods. There was a highly significant correlation between these pests indicated that simultaneous infestation of these pests is possible. These findings indicate that the efficiency of spraying these compounds for each pest would be accompanied by a high effect on another pest. Based on the modified treatment-by-pest biplot analysis, it was concluded that the treatments (three spraying compounds by four-period interactions) were identified as effective treatments for pests and these treatments would be considered as key during the selection. Biplot method of treatment × pest (TP) together established a significant correlation between *P. solenopsis* and *B. tabaci* pests in treatment and a significant correlation between *E. orientalis* and *T. urticae* results as shown in the (TP)-biplot graph. Treatments on the negative part of the graph recorded the lowest number of pests, then, it was considered as the best treatment and had a good effect on all pests. As similar other results were shown. Then, the biplot graph gave a conclusion for all treatments of all pests.

### References

Abd El-Razzik MI. 2018. Seasonal fluctuation of the cotton mealybugs, *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) and its natural enemies on mulberry trees in Egypt. *Egypt J Plant Protect Res Inst* 1(1): 74–83.
traits using multivariate analyses in safflower (Carthamus tinctorius L.). Ann Biol Res 2(3): 162–169.

Henderson CF, Tilton EW. 1955. Tests with acaricides against the brown wheat mite. J Econ Entomol 48: 157–161.

Kenneth WC, Edwin EL, Peter BS. 2002. Compatibility of acaricide residues with Phytoseiulus persimilis and their effects on Tetranychus urticae. Am Soc Horticult Sci 37(6): 906–909. https://doi.org/10.21273/HORTSCI.37.6.906.

Kumari S, Anuradha Ch, Anuradha K, Gireesh N. 2015. Comparative toxicities of novel and conventional acaricides against different stages of Tetranychus urticae Koch (Acari: Tetranychidae). J Saudi Soc Agric Sci 16(2): 191–196. https://doi.org/10.1016/j.jsass.2015.06.003.

Lasota JA, Dybas RA. 1990. Abamectin as a pesticide for agricultural use. Acta Leidensia 59: 217–225.

Levene H. 1960. Robust tests for equality of variances. Ingram Olkin, Harold Hotel ling, Italia, Stanford, Univ. Press, pp. 278–292.

Márquez A, Won E, García E, Olivero J. 2006. Efficacy assay of different phytosanitary chemicals for the control of Eutetranychus orientalis (Klein) (Oriental Spider Mite) on fine lemon and Valencia-Late orange crops. IOBC/WPRS Bull 29: 305–310.

Massoud AH, Derbalah AS, El-Shshtaway HF, Sleem M. 2014. Insecticidal, persistence, and removal of chlorpyrifos-methyl after application against cotton leafworm in soybeans. J Mater Environ Sci 5(5): 1398–1405. https://doi.org/10.3923/jest.2014.294.304.

Mesbah III, Khalafalla EME, Eissa GM, Fatma H, Khattab MA. 2019. Susceptibility of some soybean varieties to certain piercing-sucking insects under the field conditions of North Delta. Egypt J Agric Res 97(1): 159–165. https://dx.doi.org/10.21608/ejr.2019.68613.

Moghadam SG, Ahadiyat A, Edward A. 2016. Ueckermann species composition of tetranychid mites (Acari: Trombidiiformes: Prostigmata: Tetranychidae) in main landscapes of Tehran Province, Iran. Biologia 71(10): 1151–1166. https://doi.org/10.1515/biolog-2016-0138.

Panda S, Samal MK, Patnaik HP. 2005. Effect of oilcake-based vermicompost on the incidence of sucking insect pests and fruit yield in chilli. J Appl Zool Res 16(2): 184–185. https://dx.doi.org/10.19026/rjees.5.5645.

Prabhath K, Poehling HM. 2007. Effects of azadirachtin, abamectin, and spinosad on sweet-potato whitefly (Homoptera: Aleyrodidae) on tomato plants under laboratory and greenhouse conditions in the humid tropics. J Econ Entomol 100(2): 411–20. https://doi.org/10.1603/0022-0493(2007)100[411:EOAAAS]2.0.CO;2.

Rabea EI, Badawy MEI, Rogge TM, et al. 2005. Insecticidal and fungicidal activity of new synthesized Chitosan derivatives. P Man Sci 61: 951–960. https://doi.org/10.1002/pms.1085.

Ravi N, Dhandatani N, Sathiah N, Murugan M. 2006. Insecticidal and modelling ecological niche of Tetranychus urticae Koch (Acarina: Tetranychidae) population in Tomato (Lycopersicon: esculentum Mill.). J Saudi Soc Agric Sci 16(2): 191–196. https://doi.org/10.1016/j.jsass.2015.06.003.

Sabour MM. 2016. Observations of the effect of Chitosan and its nano compositions against the locust Schistocerca gregaria (Orthoptera: Acrididae). Int J Chem Tech Res 9(6): 270–276.

Sahab AF, Waly AI, Sabbour MM, Nawar LS. 2015. Synthesis, antifungal, and insecticidal potential of Chitosan (CS)-g-poly (acrylic acid) (PAA) nanoparticles against some seed-borne fungi.
and insects of soybean. *Int J Chem Tech Res* 8(2): 589–598. https://doi.org/10.13140/RG.2.1.1198.8325.

Sendecor GW, Cochran WG. 1981. Statistical methods, 7th ed. Iowa, USA: Iowa State Univ. Press.

Sendecor GW, Cochran WG. 1989. Statistical methods, 8th ed. Iowa State University Press.

US Soybean Export Council. 2019. How the global oilseed and grain trade works. Maine, US: Soyatech, LLC, Southwest Harbor. https://ussec.org/.

Xu S, Zhang L, McLaughlin NB, Chen Q, Liu J. 2015. Effect of synthetic and natural water-absorbing soil amendment soil physical properties under potato production in a semi-arid region. *Soil Tillage Res* 148: 31–39. https://doi.org/10.1016/j.still.2014.10.002.

Yan W. 2002. Singular value partitioning in biplot analysis of multi-environment trial data. *Agron J* 94: 990–996. https://doi.org/10.2134/agronj2002.0990.

Yan W. 2014. Crop variety trials: Data management and analysis. Hoboken, New Jersey, USA: Wiley-Blackwell, 349 p.

Yan W, Frégeau-Reid J. 2008. Breeding line selection is based on multiple traits. *Crop Sci* 48: 417–423. https://doi.org/10.2135/cropsci2007.05.0254.

Yan W, Hunt L. 2002. Biplot analysis of diallel data. *Crop Sci* 42: 21–30. https://doi.org/10.2135/cropsci2002.0021.

Yan W, Rajcan I. 2002. Biplot analysis of test sites and trait relations of soybean in Ontario. *Crop Sci* 42: 11–20. https://doi.org/10.2135/cropsci2002.0011.

Yan W, Tinker NA. 2005. An integrated system of biplot analysis for displaying, interpreting, and exploring genotype by environment interactions. *Crop Sci* 45: 1004–1016. https://doi.org/10.2135/cropsci2004.0076.

Yan W, Hunt LA, Sheng Q, Szlavnics Z. 2000. Cultivar evaluation and mega-environment investigation based on the GGE biplot. *Crop Sci* 40: 597–605. https://doi.org/10.2135/cropsci2000.403597x.

Zhang M, Tan T. 2003. Insecticidal and fungicidal activities of Chitosan and Oligo-Chitosan. Beijing, China: Department of Biochemical Engineering, Beijing University of Chemical Technology, pp. 391–400. https://doi.org/10.1177%2F0883911503039019.

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