MANAGEMENT OF PEANUT CERCOSPORA LEAF SPOT USING RESISTANT CULTIVARS AND INDUCER RESISTANCE CHEMICALS

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ABSTRACT: Six cultivars of peanut i.e. Giza 5, Giza 6, R92, Ismailia 1, Gregory and Virginia, were evaluated for their susceptibility to the natural infection by Cercospora leaf spot during two successive growing seasons of 2016 and 2017. Generally, Ismailia 1, followed by R92 were the most resistant tested cvs., for the disease and produced the highest pod yield in both seasons. However, Gregory, followed by Virginia were the most susceptible ones recording the highest percentages of disease incidence and severity in tested both seasons. Induction of disease resistance was carried out using salicylic acid, nicotinic acid, butyric acid, ascorbic acid and bion which were applied at three concentrations, i.e. 2, 4 and 8 mM. The obtained results proved that bion and salicylic acid at 8 mM followed by ascorbic acid at the same conc., were the most effective inducers for minimizing disease incidence as well as disease severity and consequently increased the produced pod yield during both investigated seasons. Four plant growth regulators namely indole butaric acid (IBA), naphthalene acetic acid (NAA), gibberellic acid (GA3) and baclobtrazole were applied at three concentrations, i.e. 50, 100 and 200 ppm proved that naphthalene acetic acid and indole butaric acid at 200 ppm were the most effective inducers for minimizing disease incidence as well as severity and consequently increased the produced pod yield during both investigated seasons. Four sulfate mineral salts i.e., copper sulphate (CuSO₄), zinc sulphate (ZnSO₄), magnesium sulphate (MgSO₄) and manganese sulphate (MnSO₄) at three concentrations, i.e. 1, 2 and 4mM, were tested. Copper sulphate followed by magnesium sulphate gave the lowest percentages of disease incidence and severity without significant differences in between and consequently increased the produced pod yield. The effect of five silicate salts, i.e. calcium silicate (CaSiO₃), magnesium silicate (MgSiO₃), potassium silicate (K₂SiO₃) aluminum silicate (Al₂SiO₃) and seal-matreax (commercial compound) at four concentrations, i.e. 200, 400, 800 and1600 ppm were evaluated. Generally, calcium silicate followed by potassium silicate gave the lowest percentage of disease incidence and severity and increased the produced pod yield. Thus, there is a correlation between induced resistance and some biochemical changes in peanut leaf tissues including phenol contents (free, conjugate and total phenols) and oxidative enzyme activities, i.e., peroxidase and polyphenoloxidase.

Key words: Peanut, Cercospora leaf spot, cultivar reactions, induction, disease resistance, chemical inducers, plant growth regulators, sulfate salts, silicate salts, biochemical changes.

INTRODUCTION

Peanut (Arachis hypogaea L.) is one of the major sources of protein and oil in the world. It is, cultivated on 24 million hectares in over than100 countries (FAO, 2011). In Egypt peanut is one of the most crops for both exportation and locally consumption (Hilal et al., 1994). Peanut cultivated area in Egypt was around 156044 fad., produced around 3243848 ardab as mentioned by the yearly book 2017 of Economics and Statistics of the Economic Affairs Sectors,
Agriculture Ministry in Egypt. Leaf spots caused by the fungi *Cercospora arachidicola* S. Hori (telemorph = *Mycosphaerella arachidis* Deighton) and *Cercosporidium personatum* (Berk. and M.A. Curtis) Deighton (telemorph = *Mycosphaerella berkeleyi* Jenk.) are the most important foliar diseases of peanut worldwide (Lijun et al., 1999; Maninderpal, 2011). Yield losses near 50% may result from failure to control early leaf spot (Lijun et al., 1999). Yield losses in peanut cultivars are produced by diverse causes, mainly Cercospora leaf spots and the recognition of peanut genotypes being tolerant to them and simultaneously having higher production potentials should benefit growers and breeders to carry out the proper cultivar for sowing or for further breeding (Gaikpa et al., 2015). The cultivation of resistant and tolerant peanut cvs., does not only eliminate the crop losses caused by diseases, but also reduce costs related to fungicide spray and other control methods. The high expense associated with 8 to 10 fungicide sprayings during the crop cycle, is economically not feasible but serve as a challenge to develop resistance/tolerant cvs., against foliar diseases such as early leaf spot (*C. arachidicola*) and late leaf spot (*C. personatum*) (Alderman and Nutter, 1994; Ambang et al., 2011).

Wherever fungicidal applications cause hazards to human health and increase environmental pollution (García, 1993) therefore, alternatives, eco-friendly approaches for control of plant diseases are needed including induced resistance (Mandal et al., 2009). Induced disease resistance can be defined as the process of active resistance dependent on the host plants physical or chemical barriers activated by biotic or abiotic agents, (Meena et al., 2001; Walters et al., 2007). These responses include phytoalexin accumulation, phenols, lignifications and activation of many enzymes such as peroxidase, polyphenoloxidase, catalase and chitinase (Boller, 1991; Meena et al., 2001; Mahmoud et al., 2006; Hussein, 2011; Abdel Aal et al., 2012; Ibrahim et al., 2013).

The present investigation have been conducted to investigate the effectiveness of cultivar reactions and environmentally safe chemicals for management of peanut Cercospora leaf spot.

**MATERIALS AND METHODS**

**VARIETAL SUSCEPTIBILITY TO CERCOSPORA LEAF SPOTS**

This experiment was carried out under sprinkler irrigation system during the first week of May in a field at Ismailia Experimental Station (ARC), Ismailia Governorate Egypt. Six peanut cvs. *i.e.* Giza 5, Giza 6, R92, Ismailia 1, Gregory and Virginia were kindly obtained from the Oil Crops Research Department, Field Crops Research Institute, ARC. The six cvs were evaluated for their susceptibility to Cercospora leaf spot (Abdel Aal et al., 2019) during two successive growing seasons (2016 and 2017).

**DISEASE ASSESSMENT**

Percentages of disease incidence were calculated as follows:

\[
\text{Disease incidence (\%)} = \frac{\text{Number of infected leaves in the sample}}{\text{Total number of leaves in the sample}} \times 100
\]

Disease severity was assessed, three months after planting and before harvesting. One hundred leaves from each plot were randomly sampled to determine disease severity using (0-8) scale adopted by Ibrahim et al. (2013).

Pod yield was calculated as follows: Plants in individual plots were dug and inverted based on optimum maturity index. Pods were air-dried for three days then weighed as kg/plot (10.5m\(^2\)) at the end of the experimental periods and the expected pod weight (Ton/faddan), was calculated.

**INDUCTION OF CERCOSPORA LEAF SPOT BY DIFFERENT INDUCER RESISTANCE CHEMICALS (IRCS)**

The effectiveness of different chemical materials and concentrations were applied for induction of disease resistance against natural heavily infected by Cercospora leaf spot. The investigation was conducted in field conditions under sprinkler irrigation system in Ismailia Experimental Station (ARC), Ismailia Governorate, Egypt during 2016 and 2017 growing seasons. Different concentrations of inducers for each experiment were used as a foliar spray at 20 and
40 days after sowing to evaluate their effectiveness in managing Cercosporal leaf spot of peanut. Disease assessment and pod yield were recorded as previously mentioned. Five chemical inducers e.g. salicylic acid, nicotinic acid, butyric acid, ascorbic acid and bion were applied at three concentrations, i.e. 2, 4 and 8 mM for each. Four plant growth regulators namely indole butaric acid (IBA), naphthalene acetic acid (NAA), gibberellic acid (GA3) and baciobrazole each were applied at three concentrations, i.e. 50, 100 and 200 ppm and evaluated. Four sulfate mineral salts i.e., copper sulphate (CuSO₄), zinc sulphate (ZnSO₄), magnesium sulphate (MgSO₄) and manganese sulphate (MnSO₄) each at three concentrations i.e. 1, 2 and 4mM, were tested. Five silicate mineral salts, i.e. calcium silicate (CaSiO₃), magnesium silicate (MgSiO₃), potassium silicate (K₂SiO₃) aluminum silicate (Al₂SiO₃) and Seal-Matreax (commercial compound) at four concentrations, for each i.e. 200, 400, 800 and 1600 ppm were also evaluated.

Biochemical changes associated with induced resistance were evaluated to identify the probable mechanisms by which the tested chemical agents act as inducer disease resistance to Cercospora leaf spot. Thus, the activity of oxidative enzymes, i.e. peroxidase and polyphenol-oxidase as well as phenolic compounds were determined in the leaves of treated and untreated peanut plants with the inducer resistance chemicals.

Methods described by Tuzum et al. (1989) were followed for extraction of oxidative enzyme activities, i.e peroxidase and polyphenol oxidase. Peroxidase assay (based on oxidation of pyrogallol to purpurogallin in the presence of H₂O₂) was determined according to the method described by Allam and Hollis (1972). The activity of polyphenoloxidase (PPO) was measured as mentioned by Matta and Dimond (1963). Conjugated phenols, free and total ones using Folin and Ciocalteas reagent were determined as described by Snell and Snell (1953).

The obtained Results were statistically analyzed by analysis of variance (ANOVA) using MSTAT-C (1991). The least significant difference (LSD) test (0.05) was used to find out the significance of the means of various treatments (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Varietal Susceptibility to Cercospora Leaf Spots

Six cvs. of peanut (Table 1) were evaluated for their susceptibility to Cercospora leaf spot during 2016 and 2017 seasons under natural infection conditions, and sprinkler irrigation at Ismailia Governorate. Results presented show that, Ismailia 1, was the most resistant cv. where significantly recorded the lowest value for each of disease incidence and severity (18.3 and 10.7%) and (15.0 and 8.9%) in both seasons, respectively. However Gregory, followed by Virginia were the most susceptible cvs., recording the highest percentage for each of disease incidence and severity in both seasons. Pod production of peanut cultivars (Table 1) showed that R92 yielded the highest in both seasons, being (4.63 and 4.75 Kg/plot) respectively and (1.852 ton/fad., and 1.900 Ton/fad., respectively). However, cv. Giza5 produced the lowest pod yield in both growing seasons, being (2.85 and 3.12 Kg/plot) and (1.140 and 1.248 Ton/fad.) respectively.

The difference among the tested cvs., in their resistance and susceptibility to the disease, might be due to a given pathogen exhibited different reactions by the host due to their genome structures that master various biological and physiological behaviors (Knautf and Gorbet, 1990). The presence of genetic variability in crop plants have been described as essential in plant breeding where it encourage selection (Izge et al., 2005).

Induction of Resistance to Cercospora Leaf Spot by Different Chemicals

The effectiveness of different materials used for induction of disease resistance to peanut Cercospora leaf spot was investigated under sprinkler irrigation system under field conditions at Ismailia Experimental Station (ARC), Ismailia Governorate, during 2016 and 2017, growing seasons.

Induction by inducer resistance chemicals (IRCS)

Five IRCS, e.g. salicylic acid, nicotinic acid, butyric acid, ascorbic acid and bion were applied at
Table 1. Susceptibility of six peanut cvs. to Cercospora leaf spot and pod yield

| Peanut cvs. | Disease incidence and severity (%) | Peanut pod yield |  |
|-------------|------------------------------------|-----------------|---|
|             | 2016 DI (%) | 2017 DI (%) | 2016 DS (%) | 2017 DS (%) | 2016 Kg/plot (10.5m²) | 2017 Expected pod (ton/fad.) |
| Giza 5      | 39.3       | 40.0       | 23.8       | 20.5       | 2.85               | 3.12               |
| Giza 6      | 38.3       | 36.0       | 17.4       | 16.9       | 3.79               | 3.91               |
| R92         | 23         | 20.0       | 12.6       | 10.2       | 4.63               | 4.75               |
| Ismailia 1  | 18.3       | 15.0       | 10.7       | 8.9        | 4.03               | 4.11               |
| Gregory     | 58.3       | 55.0       | 34.9       | 31.4       | 3.45               | 3.63               |
| Virginia    | 52         | 49.0       | 29.1       | 26.8       | 3.65               | 3.97               |
| LSD 5%      | 5.3        | 4.9        | 1.5        | 1.4        | 0.78               | 0.58               |

DI = Disease incidence  DS = Disease severity

three concentrations, i.e. 2, 4 and 8 mM. Results presented in Tables 2 and 3 indicate that all tested chemical inducers and their concentrations significantly decreased incidence and severity of peanut Cercospora leaf spot and consequently increased the produced pod yield during both investigated seasons (2016 and 2017) if compared with the control. The obtained results proved that bion and salicylic acid, both at 8 mM, followed by ascorbic acid at 8 mM were the most effective for minimizing incidence and severity of the disease and, consequently increased the produced pod yield (Kg/plot) during both investigated seasons as the obtained yields for both seasons were (4.05 and 3.91), (3.85 and 3.92) and (3.76 and 3.61) respectively. However, butyric acid as well as nicotinic acid at 2 mM recorded the lowest reduction of both incidence and severity of the disease in both tested seasons.

The obtained results might be taken as a further support that such acids at special concentrations were clearly effective in enhancing yield production when applied as foliar spray. The improved performance of such acids might be one of the important agents implicated with the disease reaction leading to lower values of peanut Cercospora leaf spot. Induced disease resistance can be defined as the process of active resistance dependent on the host plants physical and/or chemical barriers activated by biotic or abiotic agents, (Meena et al., 2001; Walters et al., 2007). Some compounds, e.g., nicotinic acid, salicylic acid (SA), butyric acid have been shown to induce resistance in plants (Mahmoud et al., 2006; Mandal et al., 2009; Hussein, 2011; Khalifa et al., 2011; Abdel Aal et al., 2012; Ibrahim et al., 2013). They added that, induction of systemic resistance might sensitizes the plant to respond rapidly after infection. These responses include one or more of phytoalexin accumulation, phenols, lignifications and activation of many enzymes such as peroxidase, polyphenoloxidase, catalase and chitinase. Thus application of such antioxidants proved sufficient protection against peanut Cercospora leaf spot and most of such antioxidants increased pod yield.

There was significant effect of all examined IRCS at all their tested concentrations in reducing incidence and severity of the disease as well as consequently increased the total pod yield. Bion at the three concentrations studied followed by salicylic acid were the most effective ones during the two growing seasons in 2016 and 2017. Bion, activates various defense responses ranging from hypersensitive cell death (HR) of pathogen-attacked cells up to accumulation of reactive oxygen intermediates (ROI) like H₂O₂ and the expression of a number of pathogenesis-related genes (PR) genes, which together might control microbial pathogens (Sauerborn et al., 2001).

The effect of the different investigated IRCS on various biochemical changes, i.e. phenol contents and oxidative enzymes (peroxidase and polyphenol-oxidase) activities in peanut leaf plants, was studied.
Table 2. Effect of foliar spraying with some inducer resistance chemicals on incidence and severity of Cercospora leaf spot under field conditions during two successive seasons (2016 and 2017)

| IRCS         | Conc. (mM) | Disease incidence and severity (%) | 2016 | 2017 | DI   | DS   | DI   | DS   |
|--------------|------------|------------------------------------|------|------|------|------|------|------|
| Salicylic    | 2          | 30.15                              | 13.69| 26.42| 11.27|      |      |      |
|              | 4          | 26.27                              | 11.31| 23.19| 10.09|      |      |      |
|              | 8          | 20.49                              | 7.86 | 17.64| 7.12 |      |      |      |
| Nicotinic    | 2          | 38.76                              | 20.13| 37.68| 21.45|      |      |      |
|              | 4          | 35.19                              | 17.51| 34.93| 19.38|      |      |      |
|              | 8          | 26.63                              | 13.75| 29.88| 16.81|      |      |      |
| Butyric      | 2          | 43.19                              | 29.14| 46.27| 31.87|      |      |      |
|              | 4          | 39.42                              | 24.68| 41.90| 29.15|      |      |      |
|              | 8          | 33.16                              | 19.57| 32.75| 21.06|      |      |      |
| Ascorbic     | 2          | 28.71                              | 16.52| 27.34| 15.75|      |      |      |
|              | 4          | 26.80                              | 14.38| 25.50| 13.41|      |      |      |
|              | 8          | 20.13                              | 9.22 | 21.76| 10.73|      |      |      |
| Bion         | 2          | 25.84                              | 10.13| 26.92| 12.95|      |      |      |
|              | 4          | 18.33                              | 9.46 | 24.67| 10.31|      |      |      |
|              | 8          | 16.57                              | 6.97 | 19.31| 7.59 |      |      |      |
| Control      | -          | 68.69                              | 46.28| 73.14| 52.37|      |      |      |

LSD 0.05% for:
- Chemical inducers (A)
- Concentrations (B)
- Interactions (A) × (B)

Table 3. Effect of foliar spraying with some chemical inducers on peanut pod yield during two successive seasons (2016 and 2017)

| IRCS | Conc. (mM) | Peanut pod yield | Kg/ plot (10.5m²) | Expected pod (Ton/fad.) |
|------|------------|------------------|-------------------|-------------------------|
|      |            |                  | 2016              | 2017                    |
|      |            |                  | 2016              | 2017                    |
| Salicylic | 2 | 3.20 | 3.37 | 1.280 | 1.348 |
|         | 4 | 3.46 | 3.53 | 1.384 | 1.412 |
|         | 8 | 3.85 | 3.92 | 1.540 | 1.568 |
| Nicotinic | 2 | 2.91 | 2.74 | 1.164 | 1.096 |
|         | 4 | 3.08 | 2.96 | 1.232 | 1.184 |
|         | 8 | 3.17 | 3.07 | 1.268 | 1.228 |
| Butyric | 2 | 2.81 | 2.74 | 1.124 | 1.096 |
|         | 4 | 2.97 | 2.87 | 1.188 | 1.148 |
|         | 8 | 3.14 | 3.03 | 1.256 | 1.212 |
| Ascorbic | 2 | 3.25 | 3.38 | 1.300 | 1.352 |
|         | 4 | 3.49 | 3.55 | 1.396 | 1.420 |
|         | 8 | 3.76 | 3.61 | 1.504 | 1.444 |
| Bion | 2 | 3.81 | 3.72 | 1.524 | 1.488 |
|         | 4 | 3.88 | 3.83 | 1.552 | 1.532 |
|         | 8 | 4.05 | 3.91 | 1.620 | 1.564 |
| Control | - | 2.63 | 2.38 | 1.052 | 0.952 |

LSD 0.05% for:
- Chemical inducers (A)
- Concentrations (B)
- Interactions (A) × (B)
Results presented in Fig. 1 indicate that phenol contents including the free, conjugated and total phenols were obviously higher in plants treated with any of IRCS than the untreated control during the two growing seasons. Peanut plants treated with bion and salicylic acid recorded the highest phenol contents. Meanwhile, butyric acid gave lower values compared to the other treatments. Increasing the concentration of IRCS led to an increase of phenol contents in peanut leaves during the two growing seasons.

All tested IRCS increased the activity of oxidative-reductive enzymes, i.e. peroxidase (PO) and polyphenol oxidase (PPO) in peanut leaves compared to untreated control during the two growing seasons (Fig. 2). The highest activity of PO was shown when salicylic acid was applied followed by bion. The same trend was recorded for PPO activity. Results also showed that increasing the concentration of any of the IRCS was accompanied by an increase in enzyme activities during the two successive seasons.

Salicylic acid treatment might led to a reduction of Cercospora leaf spot by increasing activities of many classes of PR-proteins (Ata et al., 2008; Nighat et al., 2011). Effect of salicylic acid (SA) in induced resistance of peanut leaf spot might be also due to the increase of oxidative-reductive enzymes activity and phenol compounds content. This is also in agreement with Mahmoud et al. (2006), who stated that, there is a significant increase in the total peroxidase activity after treatment with salicylic acid. They added that salicylic acid in generation of the oxidative burst in incompatible interactions by inducing a rapid transient generation of O$_2^-$ which is responsible for regulation of peroxidase activity. Effect of nicotinic acid and butyric acid as inducers might be also due to the increase of oxidative-reductive enzymes activity and content of phenol compounds that were clear in increasing of enzymes activity and phenol content and this was in agreement with Meena et al. (2001), Khalifa et al. (2007), Khalifa et al. (2011), Abdel Aal et al. (2012) and Ibrahim et al. (2013).

Mahmoud et al. (2006) found that, the IRCS showed changes in the activity of oxidative-reductive enzymes and phenolic contents in primordial pods of peanut. This biochemical changes became a marker to induce resistance (Cadena-Gomez and Nicholson, 1987; Edreva, 1989; Reuveni et al., 1992). Another possible role for peroxidase is the oxidative cross-linking of pre-existing hydroxyproline-rich structural proteins in the cell wall, making the cell wall more resistant to degradation by microbial enzymes (Bradley et al., 1992) as well as generation of hydrogen peroxide consider an antimicrobial agent (Peng and Kuc, 1992). While, phenol compounds play an important role in plant defense such phenols are essential for the biosynthesis of lignin, which consider an important structural component of plant cell walls (Hahlbrock and Scheel, 1989).

**Induction as affected by plant growth regulators**

Four plant growth regulators were applied and evaluated at three concentrations for each, i.e. 50, 100 and 200 ppm. Results in Tables 4 and 5 prove that all tested plant growth regulators decreased disease parameters and consequently increased peanut pod yield during both seasons (2016 and 2017) comparing with the control. Both naphthalene acetic acid (NAA) and indole butyric acid (IBA) at 200 ppm were the most effective regulators for promising disease control and consequently increased peanut pod yield during both investigated seasons. However, baclobrazole at 50 ppm revealed the lowest reduction for each of incidence and severity of the disease in both seasons.

Naphthalene acetic acid (NAA) is widely used in agriculture for various purposes. Tomlin (2006) has been shown that NAA greatly increased cellulose fiber formation in plants when paired with another phytohormone called gibberellnic acid. Because it is in the auxin family it has also been understood to prevent premature dropping and thinning of fruits from stems. In order to obtain its desired effects it must be applied in concentrations ranging from 20–100 µg/ml (Navalon et al., 1997).

Phenol contents were obviously higher in plants treated with any of growth regulators as resistance inducers than the untreated control during the two growing seasons (Fig. 3). In this respect peanut plants treated with naphthalene acetic acid (NAA) and indole butyric acid (IBA)
Fig. 1. Effect of certain IRCS on phenolic contents (mg/g fresh weight) in peanut leaves

Fig. 2. Effect of foliar spraying with some IRCS on peroxidase (PO) and polyphenoloxidase (PPO) activity in peanut leaves
Table 4. Effect of the foliar spraying with some growth regulators on incidence and severity of the disease during two successive seasons (2016 and 2017)

| Growth regulator                  | Conc. (ppm) | Disease incidence and severity (%) |       |       |       |       |       |       |
|-----------------------------------|-------------|-----------------------------------|-------|-------|-------|-------|-------|-------|
|                                   |             | 2016                              | 2017  | 2016  | 2017  |       |       |       |
|                                   |             | DI                  | DS     | DI     | DS     |       |       |       |
| Indole butaric acid (IBA)         |             | 50                   | 24.76  | 12.15  | 27.49  | 14.78 |       |       |
|                                   |             | 100                  | 18.29  | 9.32   | 22.34  | 11.20 |       |       |
|                                   |             | 200                  | 12.85  | 7.16   | 17.55  | 9.15  |       |       |
| Naphthalene acetic acid (NAA)     |             | 50                   | 20.63  | 10.24  | 23.67  | 11.53 |       |       |
|                                   |             | 100                  | 16.72  | 8.11   | 18.24  | 9.41  |       |       |
|                                   |             | 200                  | 10.38  | 6.23   | 12.73  | 7.94  |       |       |
| Gibberellic acid (GA3)            |             | 50                   | 22.66  | 11.82  | 26.44  | 13.07 |       |       |
|                                   |             | 100                  | 19.47  | 9.33   | 21.19  | 11.72 |       |       |
|                                   |             | 200                  | 13.54  | 6.98   | 15.08  | 8.33  |       |       |
| Baclobtrazole                     |             | 50                   | 29.15  | 17.52  | 31.73  | 19.20 |       |       |
|                                   |             | 100                  | 24.36  | 13.26  | 26.11  | 16.83 |       |       |
|                                   |             | 200                  | 19.03  | 9.80   | 21.70  | 13.71 |       |       |
| Control                           |             | -                   | 56.17  | 38.46  | 62.42  | 41.94 |       |       |
| LSD 0.05% for                     |             |                      |        |        |        |       |       |       |
| Growth regulators (A)             |             |                      | 0.44   | 0.40   | 0.35   | 0.41  |       |       |
| Concentration (B)                 |             |                      | 0.34   | 0.31   | 0.27   | 0.30  |       |       |
| Interactions (A) × (B)            |             |                      | 0.76   | 0.69   | 0.60   | 0.70  |       |       |

DI= Disease incidence            DS= Disease severity

Table 5. Effect of foliar spraying with some growth regulators on peanut pod yield during two successive seasons (2016 and 2017)

| Growth regulator                  | Conc. (ppm) | Peanut pod yield |       |       |
|-----------------------------------|-------------|------------------|-------|-------|
|                                   |             | Kg/plot (10.5 m²) | Expected pod (Ton/fad.) |       |       |
|                                   |             | 2016              | 2017  | 2016  | 2017  |       |       |
| Indole butaric acid (IBA)         |             | 50                | 2.79  | 2.65  | 1.116 | 1.060 |       |       |
|                                   |             | 100               | 2.93  | 2.80  | 1.172 | 1.120 |       |       |
|                                   |             | 200               | 3.16  | 3.08  | 1.264 | 1.232 |       |       |
| Naphthalene acetic acid (NAA)     |             | 50                | 2.84  | 2.77  | 1.136 | 1.108 |       |       |
|                                   |             | 100               | 2.99  | 2.84  | 1.196 | 1.136 |       |       |
|                                   |             | 200               | 3.46  | 3.35  | 1.384 | 1.340 |       |       |
| Gibberellic acid (GA3)            |             | 50                | 2.63  | 2.54  | 1.052 | 1.016 |       |       |
|                                   |             | 100               | 2.94  | 2.69  | 1.176 | 1.076 |       |       |
|                                   |             | 200               | 3.29  | 2.94  | 1.316 | 1.176 |       |       |
| Baclobtrazole                     |             | 50                | 2.55  | 2.42  | 1.020 | 0.968 |       |       |
|                                   |             | 100               | 2.71  | 2.64  | 1.084 | 1.056 |       |       |
|                                   |             | 200               | 3.06  | 2.84  | 1.224 | 1.136 |       |       |
| Control                           |             | -                 | 2.41  | 2.10  | 0.964 | 0.840 |       |       |
| LSD 0.05% for                     |             |                   |        |        |        |       |       |       |
| Chemical inducers (A)             |             |                   | 0.18   | 0.26   | 0.23  | 0.03  |       |       |
| Concentrations (B)                |             |                   | 0.14   | 0.20   | 0.18  | 0.02  |       |       |
| Interactions (A) × (B)            |             |                   | 0.31   | 0.45   | 0.40  | 0.05  |       |       |
recorded the highest phenol contents in both seasons. However, baclobtrazole and gibberellic acid (GA3) revealed the lowest phenol contents. Results also indicated that, increasing the concentration of plant growth regulators led to an increase in phenols of peanut leaves during the two growing seasons.

Results illustrated in Fig. 4 show that all tested growth regulators increased the activity of oxidative-reductive enzymes in peanut leaves compared to untreated control in both growing seasons. The highest PO and POP activity was shown when naphthalene acetic acid was evaluated followed by indole butyric acid (both at 200 ppm), while gibberellic acid and baclobtrazole at 50 ppm recorded the lowest PO and POP activity compared to other treatments in the two successive seasons.

Naphthalene acetic acid present in the environment undergoes oxidation reactions with hydroxyl radicals and sulphate radicals. In micropropagation of various plants, NAA is typically added to media containing nutrients essential to the plants survival. It is added to help induce root formation in various plant types. It can also be applied by spraying it onto plants and is typical in agricultural use (Navalon et al., 1997).

Several reports have been published on the use of growth regulators releasing the compound ethiphon for inductions of resistance in plants (Abd-El-Kareem et al., 2001; Hussein, 2011). The effect of growth regulators in reducing the disease might be due to its effect on synthesis of pathogenesis-related proteins (PR-proteins), lignification, papilla formation and activity of oxidative enzymes (PO, PPO and CAT) which realized in this study by increasing the activity of oxidative-reductive enzymes (Matsumoto and Asada, 1990; Abd-El-Kareem et al., 2001).

**Induction disease resistance by sulfate mineral salts**

All sulphate minerals at the different concentrations showed significant reduction of incidence and severity of the disease compared to control (Table 6). Copper sulphate (CuSO₄) revealed the lowest percentage of disease parameters, while manganese (MnSO₄) and Zinc sulphates (ZnSO₄) recorded the lowest ones in this respect. Results also showed that, there is a positive relationship between sulphate mineral concentrations and their effect on the infection by Cercospora leaf spot in the two successive season.

Regarding peanut pod yield, results in Table 7 indicate that, pod yield significantly varied among the tested sulphate minerals and their concentrations, in both successive seasons. Generally, copper sulphate (CuSO₄) at all concentrations tested gave the highest peanut pod yield in both seasons followed by zinc sulphate (ZnSO₄). General positive correlations were obtained between sulphate mineral concentrations and their effect on peanut pod yield in the two successive seasons.
Fig. 4. Effect of the foliar spraying with some growth regulators on peroxidase and polyphenoloxidase activity in peanut leaves

Table 6. Effect of the foliar spraying with some sulfate mineral salts on incidence and severity of the disease during two successive seasons (2016 and 2017)

| Sulfate mineral salt | Conc. (mM) | Disease incidence and severity (%) | 2016 | 2017 |
|----------------------|------------|-----------------------------------|------|------|
|                      |            | DI      | DS    | DI    | DS    |
| CuSO₄                | 1          | 44.75   | 11.18 | 47.50 | 13.43 |
|                      | 2          | 32.25   | 9.07  | 33.50 | 11.57 |
|                      | 4          | 26.50   | 8.90  | 28.25 | 9.50  |
| ZnSO₄                | 1          | 42.25   | 12.37 | 43.50 | 14.87 |
|                      | 2          | 34.75   | 10.47 | 37.50 | 12.47 |
|                      | 4          | 31.50   | 9.59  | 32.75 | 10.59 |
| MgSO₄                | 1          | 45.25   | 12.08 | 47.00 | 13.08 |
|                      | 2          | 43.75   | 10.07 | 45.00 | 11.32 |
|                      | 4          | 37.75   | 9.13  | 40.00 | 10.43 |
| MnSO₄                | 1          | 50.50   | 13.12 | 51.75 | 15.01 |
|                      | 2          | 46.50   | 11.21 | 47.50 | 12.46 |
|                      | 4          | 41.25   | 10.62 | 43.75 | 11.37 |
| Control              | -          | 68.75   | 44.30 | 71.75 | 46.52 |

LSD 0.05% for

| Sulfate minerals (A) | 1.66 | 0.70 | 2.07 | 0.66 |
| Concentration (B)    | 1.29 | 0.54 | 1.61 | 0.51 |
| Interactions (A) × (B)| 2.88 | 1.21 | 3.59 | 1.14 |

DI= Disease incidence    DS= Disease severity
Table 7. Effect of foliar spraying with some sulfate mineral salts on peanut pod yield during two successive seasons (2016 and 2017)

| Sulfate mineral salt | Conc. (mM) | Peanut pod yield |  |  |  |  |
|----------------------|------------|------------------|---|---|---|---|
|                      |            | Kg/plot (10.5m²) | 2016 | 2017 | 2016 | 2017 |
| CuSO₄                | 1          | 3.39             | 3.30 | 1.355 | 1.320 |
|                      | 2          | 4.40             | 4.26 | 1.760 | 1.704 |
|                      | 4          | 4.33             | 4.25 | 1.730 | 1.699 |
| ZnSO₄                | 1          | 3.38             | 3.17 | 1.352 | 1.269 |
|                      | 2          | 3.58             | 3.43 | 1.430 | 1.373 |
|                      | 4          | 4.29             | 4.09 | 1.714 | 1.634 |
| MgSO₄                | 1          | 3.16             | 3.09 | 1.262 | 1.235 |
|                      | 2          | 3.32             | 3.17 | 1.327 | 1.267 |
|                      | 4          | 3.75             | 3.65 | 1.499 | 1.460 |
| MnSO₄                | 1          | 3.25             | 3.09 | 1.302 | 1.235 |
|                      | 2          | 3.34             | 3.29 | 1.337 | 1.317 |
|                      | 4          | 3.86             | 3.66 | 1.545 | 1.463 |
| Control              | -          | 2.59             | 2.56 | 1.038 | 1.025 |

LSD 0.05% for

| Sulfate minerals (A) | 0.06 | 0.09 | 0.005 | 0.02 |
|----------------------|------|------|-------|------|
| Concentration (B)    | 0.04 | 0.07 | 0.004 | 0.001 |
| Interactions (A) X (B)| 0.10 | 0.16 | 0.009 | 0.003 |

Results illustrated in Fig. 5 indicate that phenol contents were obviously higher in plants treated with all sulfate mineral salts as inducers than the untreated control during the two growing seasons (2016 and 2017) with visible increase when copper sulfate, was tested.

All tested sulfate mineral salts increased the activity of oxidative-reductive enzymes in peanut leaves compared to untreated control in both growing seasons (Fig. 6). Among all tested treatments, the highest value for each of (PO) and (POP) activity was produced when copper sulfate at 4mM was sprayed followed by magnesium sulfate at 4mM, while zinc and manganese sulfates at 1mM recorded the lowest value for each of (PO) and (POP) activities.

Microelements might play a positive role for stimulating natural defense mechanisms in peanut plants such as increasing the level of phenols and activities of the oxidative enzymes (Meena et al., 2001). Moreover, microelements interacts with N metabolism and is intimately involved in carbohydrate synthesis, photosynthesis, coenzymes to many of plant enzymes and synthesis of other compounds associated with the defense of plant against pathogens like phytoalexins and lignin (Engelhard, 1993).

Magnesium deficiency rarely limits plant growth, however, it is necessary for groundnut stems from its role as a carrier of phosphorus in oil formation, and its effect on seed viability. Magnesium supply may be omitted from the pod zone without adverse effects on pod development of some cultivars provided adequate Mg in the root zone (Zharare et al., 1993).

On the other hand, copper activate four distinct mitogen-activated protein kinases (MAPKs). Copper also present in three different forms in proteins: (a) blue proteins without oxidase activity (e.g., plastocyanin); (b) non-blue proteins, which produce peroxidases and oxidize monophenols to diphenols; and (c) multicopper proteins, which act as oxidases and catalyze (Jonak et al., 2004).
Fig. 5. Effect of some sulfate salts on phenolic contents (mg/g fresh weight) in peanut leaves

Fig. 6. Effect of the foliar spraying with some sulfate salts on peroxidase (PO) and polyphenoloxidase (PPO) activity in peanut leaves
Induction disease resistance by silicate minerals

Results in Table 8 indicate that all silicate minerals at the different concentrations and the fungicide Seal-Matreax resulted in significant reduction the incidence and severity of the disease compared to non-treated control in the two successive seasons. Generally, calcium silicate (CaSiO$_3$) followed by potassium silicate (K$_2$SiO$_3$) gave the lowest percentages without significant differences in between. Aluminum silicate (Al$_2$SiO$_3$) and Seal-Matreax recorded the lowest ones in this respect. Results also showed that, there is a positive relationship among silicate mineral concentrations and their effect on the infection by Cercospora leaf spot. An opposite way of both aluminum silicate and Seal-Matreax and a reduction in pod yield was recorded as their concentrations increased in the two successive season (2016 and 2017).

Regarding peanut pod yield results in Table 9 reveals that, peanut pod yield significantly varied among the tested silicate minerals at their different concentrations in the two successive seasons. Generally, calcium silicate (CaSiO$_3$) at 1600 ppm reslited in the highest peanut pod yield in the two growing seasons followed by potassium silicate (K$_2$SiO$_3$) at the same concentration. Results also showed that, there is a positive relationship between silicate minerals concentrations and their effect on peanut pod yield where, aluminum silicate (Al$_2$SiO$_3$) and Seal-Matreax recorded the lowest pod yield in this respect.

Results presented in Fig. 7 indicate that phenol contents were obviously higher in plants treated with all silicate mineral salts as inducer resistance than the untreated control during both growing seasons. Peanut plants treated with calcium silicate (CaSiO$_3$) recorded the highest phenol contents followed by potassium silicate. Meanwhile, aluminum silicate (Al$_2$SiO$_3$) and Seal-Matreax resulted in the lowest values. Results also indicated that, increasing the concentration of silicate mineral salts led to an increase in phenol contents in peanut leaves during both growing seasons.

Results also, show that all tested silicate mineral salts increased the activity of oxidative-reductive enzymes (Fig. 8). The highest (PO) and (PPO) activity was produced by both calcium silicate and potassium silicate at 1600 ppm. However, aluminum silicate and Seal-Matreax recorded the lowest (PO) and ((PPO) activity compared to the other treatments in the two successive seasons.

A possible effect of foliar application of silicon (Si) sources on disease control might be explained on the basis of the establishment of a physical barriers on the host tissue (Samuels et al., 1991; Bowen et al., 1992). In case of bean anthracnose (Colletotrichum lindemuthianum), Si applied on foliage was effective even without establishing a physical barrier. Thus, increased plant resistance to diseases through Si treatment is associated with active and/or passive mechanisms (Datnoff et al., 2007). Several modifications may occur in the plant surface after Ca or Si application, including pH, increase and changes in the osmotic potential and on the populations of microorganisms.

Calcium plays an important role in reducing many plant diseases (Biggs, 2004; Sugimoto et al., 2008) as it might has a critical metabolic role in carbohydrates removal, cell wall deposition and formation of pectates in the middle lamella (El-Neshawy et al., 2004). Also, it forms strengthening bridges, especially in the pectate materials that form the middle lamella of plant cells. Calcium is, also, important in maintaining selectivity of cell plasmalemma, and in binding the plasmalemma to the cell wall. Calcium also binds strongly to oxalic acid, an important toxin produced by many pathogens, thus reduced host penetration by the pathogen and thus might as major limiting factor to groundnut production. The developing pods require adequate Ca in the surrounding soil for proper pod development and production of high quality seed (Cox et al., 1982; Gascho and Davis, 1994).
Table 8. Effect of the foliar spraying with some silicate mineral salts on disease incidence and severity during two successive seasons 2016 and 2017

| Silicate mineral salt | Conc. (ppm) | Disease incidence and severity (%) |       |       |
|----------------------|------------|------------------------------------|-------|-------|
|                      |            |                                    | DI 2016 | DS 2016 | DI 2017 | DS 2017 |
| **Al_2SiO_3**        | 200        | 46.50                              | 14.84 | 50.75 | 15.92 |
|                      | 400        | 50.50                              | 16.65 | 51.50 | 17.57 |
|                      | 800        | 60.25                              | 17.70 | 57.50 | 18.57 |
|                      | 1600       | 62.50                              | 18.85 | 62.50 | 19.63 |
| **MgSiO_3**          | 200        | 40.50                              | 13.90 | 42.50 | 14.68 |
|                      | 400        | 39.50                              | 12.74 | 41.00 | 13.62 |
|                      | 800        | 36.50                              | 11.91 | 38.25 | 12.96 |
|                      | 1600       | 33.25                              | 11.31 | 36.50 | 12.53 |
| **K_2SiO_3**         | 200        | 26.50                              | 11.09 | 29.00 | 12.08 |
|                      | 400        | 21.75                              | 10.19 | 22.50 | 11.17 |
|                      | 800        | 18.25                              | 9.64  | 20.00 | 10.75 |
|                      | 1600       | 17.50                              | 8.89  | 17.50 | 9.39  |
| **CaSiO_3**          | 200        | 14.75                              | 10.32 | 18.25 | 11.21 |
|                      | 400        | 15.75                              | 9.54  | 17.50 | 10.30 |
|                      | 800        | 10.50                              | 7.39  | 13.25 | 8.17  |
|                      | 1600       | 10.25                              | 7.65  | 11.75 | 8.08  |
| **Seal-Matreax**     | 200        | 47.50                              | 17.52 | 48.75 | 18.36 |
|                      | 400        | 48.25                              | 18.31 | 50.75 | 19.32 |
|                      | 800        | 52.50                              | 19.12 | 52.75 | 20.45 |
|                      | 1600       | 53.75                              | 20.21 | 54.25 | 21.38 |
| **Control**          | -          | 71.75                              | 42.72 | 74.25 | 44.25 |

**LSD 0.05% for**

|                | (A)        | (B)        |
|----------------|------------|------------|
| **Silicate minerals** | 1.20 | 0.42 | 1.22 | 0.44 |
| **Concentration**     | 1.21 | 0.40 | 1.20 | 0.41 |
| **Interactions (A) × (B)** | 2.39 | 0.84 | 2.44 | 0.87 |

DI=Disease incidence  DS=Disease severity
Table 9. Effect of the foliar spraying with some silicate mineral salts on peanut pod yield during two successive seasons 2016 and 2017

| Silicate mineral salt | Conc. (ppm) | Peanut pod yield |          |          |
|----------------------|-------------|------------------|----------|----------|
|                      |             | 2016            | 2017     | 2016     | 2017     |
|                      |             | Kg/ plot (10.5m²) | Expected pod (Ton/fad.) |          |          |
| Al₂SiO₃              | 200         | 3.96            | 3.93     | 1.585    | 1.573    |
|                      | 400         | 3.25            | 3.20     | 1.300    | 1.279    |
|                      | 800         | 3.22            | 3.16     | 1.288    | 1.265    |
|                      | 1600        | 2.91            | 2.88     | 1.164    | 1.152    |
| MgSiO₃               | 200         | 3.99            | 3.90     | 1.595    | 1.558    |
|                      | 400         | 4.09            | 4.07     | 1.635    | 1.627    |
|                      | 800         | 4.31            | 4.18     | 1.723    | 1.673    |
|                      | 1600        | 4.91            | 4.73     | 1.965    | 1.890    |
| CaSiO₃               | 200         | 4.30            | 4.11     | 1.720    | 1.558    |
|                      | 400         | 4.49            | 4.42     | 1.795    | 1.627    |
|                      | 800         | 4.84            | 4.81     | 1.935    | 1.673    |
|                      | 1600        | 5.42            | 5.13     | 2.169    | 1.890    |
| K₂SiO₃               | 200         | 3.56            | 3.17     | 1.423    | 1.268    |
|                      | 400         | 3.97            | 3.90     | 1.589    | 1.559    |
|                      | 800         | 4.46            | 4.25     | 1.786    | 1.698    |
|                      | 1600        | 4.95            | 4.86     | 1.982    | 1.945    |
| Seal-Matreax         | 200         | 3.97            | 3.96     | 1.589    | 1.585    |
|                      | 400         | 3.41            | 3.26     | 1.365    | 1.305    |
|                      | 800         | 3.97            | 3.24     | 1.589    | 1.295    |
|                      | 1600        | 2.95            | 2.89     | 1.180    | 1.155    |
| Control              | -           | 2.66            | 2.56     | 1.065    | 1.025    |

LSD 0.05% for
Silicate minerals      (A)  0.08  0.04  0.04  0.05
Concentration          (B)  0.07  0.03  0.03  0.04
Interactions (A) × (B)  0.16  0.07  0.07  0.10
Fig. 7. Effect of some silicate mineral salts on phenolic contents (mg/g fresh weight) in peanut leaves

Fig. 8. Effect of foliar spraying with some silicate mineral salts on peroxidase (PO) and polyphenoloxidase (PPO) activity in peanut leaves
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مكافحة مرض تباع الأوراق السكرئسبوري باستخدام الأصناف المقاومة والكيمياويات المبردة للمقاومة

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7- قسم أمراض النبات
8- معمل الخدمات الجامعية

تم اختيار رو بفعل ستة أصناف من القول السوداني للإصابة بمرض تباع الأوراق السكرئسبوري وهي إسماعيلية، جيزة، الفيوم، الفيوم، النوبية، وروف الدويا الطبيعية بمحاكاة بحوث الإسامة الإسماعيلية موسمي 2015 و2016 والصنف الإسماعيلية أظهرنا مقاومة حيث سجل أقل نسبة وسادة إصابة تبلغ 39٪ كانت الأصناف جيزة 6 وجيزة 5 متوسطة قابلية للإصابة، وكانت الأصناف جيزة 9، جيزة 9، أظهرنا أقل قابلية للإصابة حيث أُعطى على نسبة وسادة إصابة أُعطى الصنف 49٪، بينما أُعطى الصنف جيزة 4 أقل مقصود، تم اختبار أربعة أنواع من مستحاثات المقاومة الكيمياوية رداً على المجموعة الخضرية وهي الأحماض العضوية، منظمات الامور، أملاح الكثيريات، ولأمال السلوكات تحت ظروف الدويا الطبيعية بالحقل في مقاومة مرض تباع الأوراق السكرئسبوري في القول السوداني، أظهرت كل المستحاثات المختبرة نقص معنوي في المرض مقاومة بالبيئات غير المعاملة في الموسيس الزراعيين 2015 و2016، حيث تم اختبار فعالية خمس مستحاثات كهربائية وهي: حمض السالسيليك، حمض البوريتريك، حمض النتيلودي، حمض الأوكسالك بالإضافة إلى البيون باستخدام ثلاث تركيزات 10 مليمول لكل منهم وأوضحت النتائج أن البيوني بتركيز 8 مليمول يلي حمض السالسيليك بنفس التركيز لما أكثر فعالية في هذا الصدد أُعطي أقل نسبة وسادة إصابة وأُعطي محصول بينما أُعطي حمض النتيلودي بتركيز 2 مليمول أعلى نسبة وسادة إصابة وأُعطي محصول، تم اختيار أربعة أنواع نظامين نمو، وهي: حمض الإيندين بوريتريكي، حمض النتيلودي، حمض النتيلودي، والكثيريات الذائبة بذاكرة تركيز 200 مليمول لكل منها (0، 100، 200 و 300 جزء في المليمول) وكان حمض النتيلودي بتركيز 50 جزء في المليمول كان الأقل فاعلاً حيث أُعطي نسبة وسادة إصابة وأُعطي محصول، تم استخدام أملاح الكثيريات مثل كريمات النحاس، كريمات الزئبق، كريمات النتيلودي، وصفيات الناتج، بخاصة الزيت الذي يحتوي على مستحاثات كهربائية rid. أ- 389

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1- محمد عبد الفتاح خليفة
2- محمد علي سعد الدين
3- جمعية الزراعة القاهرة
4- جامعة القاهرة
5- مهندس قرى الزراعة
6- كلية الزراعة
7- قسم أمراض النبات
8- معمل الخدمات الجامعية

المحكمون:

2- أحمد عبد الحليم