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# REACTIONS OF SOME COTTON VARIETIES (*GOSSYPIUM HIRSUTUM* L.) AGAINST SEEDLING DISEASE IN TURKEY

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## ABSTRACT

The aim of study was to determine the reactions of some cotton varieties (*Gossypium hirsutum* L.) registered in Turkey against seedling root rot pathogens *in-vivo*. Twenty varieties were tested to determine reactions against *Rhizoctonia solani*, *Fusarium* spp. and *R. solani*+*Fusarium* spp. in the growth chamber. A pot trial was carried out in a randomized plot design with four replications. The emergence (E), pre-emergence damping-off (PrE), post-emergence damping-off (PsE) and hypocotyl disease index (HDI) values of the fungicide (F) and non-fungicide (NF) treated cotton varieties were determined in the experiment. The highest E against *R. solani* and *Fusarium* spp. was found Stoneville468 and Pg2018 (90%), Sezener76 and İpek607 (90%) in the NF; Gaia (100%), Ba440 (97.50%), Julia and Adn712 (97.50%) in the F respectively. The lowest PrE against *R. solani* was determined Stoneville468 and Pg2018 (%10) in the NF; Gaia (0%) and Ba440 (2.50%) in the F. The lowest PsE against *R. solani* and *R. solani*+*Fusarium* spp. was detected Acala Royale (52.46%;54.17%) and Gaia (52.78%) in the NF; Acala Royale (39.44%;37.78%) in the F respectively. The lowest HDI value against *R. solani* and *R. solani*+*Fusarium* spp. was found Acala Royale (1.67;1.74) in the NF; Acala Royale (1.55;1.54), Gaia and Adn712 (1.65), Stoneville468 and Julia (1.71) in the F respectively. The lowest PrE against *Fusarium* spp. was determined Sezener76, İpek607, Acala Royale (10%); the lowest PsE against *Fusarium* spp. was determined Acala Royale (54.48%) in the NF respectively. The lowest HDI value against *Fusarium* spp. was found Acala Royale (1.78) in the NF. As a conclusion, Gaia and Stoneville468, Sezener76, İpek607 and Acala Royale were the first to precipitate in the PrE and PsE and HDI to *R. solani* and *Fusarium* spp. Acala Royale and Stoneville468 were predominant in the PsE and HDI against *R. solani*+*Fusarium* spp.

**KEYWORDS:**
Cotton, seedling disease, pre-emergence damping-off, post-emergence damping-off, hypocotyl disease index.

## INTRODUCTION

Cotton is an important industry plant with its fiber, seeds, seed coat and linter in textile, oil/biodiesel, animal feeding and paper industry, respectively [1, 2, 3, 4, 5]. In the world, approximately 29.816.000 hectares of cotton is cultivated and a total of 22.767.000 tons of fiber cotton is produced [6]. Cotton is planted mainly Southeastern Anatolia, Aegean and Mediterranean regions in Turkey [7] in 501.853 hectares and produced 882.000 tons of fiber [8]. Turkey is ranked as 7 in the world cotton production with 3.9% sharing [6]. One of the factors that negatively affect the seedling growth in cotton is seedling root rot disease. In the USA, it was reported that the average annual loss in cotton in the 10-year period was 3.1% because of the cotton diseases but the estimated loss in fiber production from seedling diseases was 27% that is more than 109.000 bales reported by National Association of Cotton Diseases in 2004 in the United States [9, 10]. Among the factors that cause root rot disease in the cotton-growing areas in the world, *Rhizoctonia* spp., *Pythium* spp. and *Thielaviopsis* spp. are the most common and destructive disease agents [11]. In Turkey, *Rhizoctonia* spp. was reported as the most common and devastating disease agent while the effect of the others, *Pythium* spp., *Fusarium* spp., and *Alternaria* spp. varied according to location and years [12, 13, 14].

Seedling root rot disease (damping-off) in cotton seedlings are caused by fungal factors originating from soil. The disease is particularly severe in conditions where the soil is cold and humid [15]. The disease is seen in two ways, disease agent firstly attacks in the stage between germination of the seed and its emergence from the soil surface called pre-emergence, and secondly cotton seedling will be attacked and dead after its emergence from the soil surface called the post-emergence. Disease symptoms caused by root rot agents vary according to the age of the plant and development period. The seeds of susceptible plants germinate, soften, shrink after brownishing and eventually rot. Effect of disease is only understood by the stand deficiencies of the seedlings. The damage is mainly seen in the roots that change color and begin to decay and rot.

The roots of the diseased seedlings and upper part of the root, just above the soil, turns to brown color then thinner stem can not stand anymore, fall down and dry [16].

Cultural measures and fungicide dressing are applied for the control against the agent of damping-off disease. However, despite the fact that the disease causes economic loss over the years and fungicides are promising in the control against disease but they cause problems due to phytotoxicity, environmental pollution and harmful effects on human health [17]. Although farmers in Turkey use treated seed, cotton is replanted in some years and stand deficiencies occur when disease incidence is not severe. In order to compensate all these risks, farmers use more seeds in addition to seed dressing and in this case the costs of seed, spraying, soil cultivation and seed bed preparation are increased and economic losses occur due to loss of productivity due to late planting [18].

Resistance is the most economical method used in the control of seedling diseases in cotton. Because the effect of fungicide treatments on seeds may decrease or disappear completely in time. Many studies were performed for determining the reaction of cotton varieties against damping-off disease in the world while very few studies have been conducted to determine the effect of seed fungicide treatments against this disease in Turkey, but testing the reactions of cotton varieties against this disease has not been observed in any study in Turkey. In a study testing the reactions of 7 cotton varieties to seedling diseases, it was reported that some varieties were relatively tolerant to *Phytium ultimum*, and none of the varieties showed sufficient growth without seed fungicide treatment [19]. Some improvement in resistance to cotton seedling disease pathogens in the Multi-Adversity Resistance (MAR) germplasm pools has been reported [20]. In California, Acala Maxxa cotton seed treated with myclobutanil against *R. solani* and treated with metalaxyl against *Pythium* spp. and combinations of these two fungicides were applied in 25 fields, 15 fields of myclobutanil and two fungicide combination achieved high success while metalaxyl was not successful in any field. As a result, these two fungicide combinations provided the best results compared to the control and the other two applications [21]. In a USA study, G49, G50 and G53 lines were reported to be resistant to *R. solani* and *P. ultimum* [22]. Nemli and Sayar [12] in their study on the effects of many fungicides and fungicide combinations on the disease in field trials conducted in Söke, found that fludioxinil + metalxyl-M was effective in seedling emergence. Pima varieties have been planted in many fields in California against *Fusarium oxysporium* f.sp. *vasinfectum* (FOV) 4 and it has been reported that, fungus infects Acala and upland cottons and causes disease [23, 24, 25]. In Iran, the effect of 9 cotton genotypes and carboxy + thiram effective fungicide against damping-off disease was investigated. The disease was lower rate 10 days after the cotton planting in Crema genotype x carboxin + thiram application but it was higher rate 20 days after planting in Oultan genotype x carboxin+thiram application and Oultan genotype x control application had 53% disease rate after emergence [26]. It has been reported that Phytogen 800 and Pima cotton varieties are planted as resistant to FOV 4 race in FOV infected cotton fields in California [27].

The aim of study was to determine the reactions of some cotton varieties (*G. hirsutum* L.) registered in Turkey in recent years against seedling root rot pathogens *in-vivo*.

## MATERIALS AND METHODS

**Origin of plant materials and pathogen used.** Non-treated chemical seeds of 20 upland cotton varieties (*G. hirsutum* L.) Np Özbek100-early growing variety, Gaia, Stoneville468, Naz07, Sezener76, İpek607, Julia, Ba811, Lydia, Adn712, Özaltın112, Özaltın404-Mid-Early growing, Claudia, Candia, Gloria, Ba440, Pg2018-Mid-Late growing [28], Acala Maxxa-susceptible to *R. solani* [22], Acala Royale-resistant to *R. solani* [29] and Lachata-susceptible to *Fusarium* spp. [30] with high germination rates [31, 32] were used as plant material after delinted with the sulfuric acid. Two pathogenic isolates of *R. solani* AG4 and *Fusarium* spp. used in the experiment were originally isolated from the roots of cotton infected with damping-off disease. Isolation, purification and identification of these fungi were carried out at Adnan Menderes University and Mustafa Kemal University, Faculty of Agriculture, Department of Plant Protection [33]. In fungicide application on seeds, fludioxonil 25 g+mefenoxam 10 g (300 ml 100 $kg^{-1}$ delinted seed) registered in Turkey was used against seedling root rot disease [18].

**Preparation of pathogen inoculums.** The inoculum of seedling root rot disease agents (*R. solani* AG4, *Fusarium* spp.) was prepared using the oat bran formulation proposed by Martin [34]. For this purpose, 30 g of oat bran, 30 g of vermiculite and 60 ml of sterile water were placed in autoclavable bags and autoclaved for 1 hour at 121°C for 2 consecutive days. Then Yeast Dextrose Agar (YDA; 15 g of agar, 10 g of dextrose, 20 g of yeast extract, 1000 ml of pure water) and Potato Sucrose Agar (PSA: 200 g of potato, 20 g of agar, 20 g of sucrose, 1000 ml of pure water) media were prepared in which *R. solani* and *Fusarium* spp. cultures were developed for 1 week at 24 ± 1ºC then 1 cm agar disc was cut from the edge of the cultures and mixed into each bag with 4-5 pieces. The bags were tightly closed and incubated in the incubator (24 ± 1°C) for 3 weeks and the sachets were mixed at the end of the first week to prevent agglomeration.

***In-vivo* experiment.** Seeds of 20 cotton varieties after delinted with sulfuric acid were used in the pot experiments as treated and non-treated with fungicides. For this purpose, treated and non-treated cotton seeds were planted separately in plastic containers (1 L; 1/3 peat + 1/3 soil + 1/3 sand) containing the inoculum of the pathogen mixture of 100 mg *R. solani* AG4, *Fusarium* spp. and *R. solani* AG4 + *Fusarium* spp. After 7 days of seed sowing, emerged plants were counted and recorded as not germinated, germinated but then overthrowed and healthy seedlings. The trial consisted of 40 seeds in each pot, with 4 replications in randomized plot design in a growth chamber (216-270 µE / m$^2$ / s; 14:10 h light: dark; temperature and relative humidity, respectively were 24 ± 1°C and 50-70%). In the study, the emergence (%), pre-emergence damping-off (%), post-emergence damping-off (%) were calculated by using the following formula [35]. The hypocotyl disease index (HDI) value was determined using 1-3 scales (1: no symptom on hypocotyl, 2: non-girdling lesion on the hypocotyl; 3: girdling lesion on the hypocotyl) by Colyer and Vernon [36]. Disease values were calculated and obtained data were subjected to Arcsin for transformation [37].

Emergence (%) =
100 × (Number of emerged seedling/Total number of sown seeds)

Pre-emergence damping-off (%) = 100- Emergence (%)
Post- emergence damping-off (%) = 100 × [(A-B)/A]

Where A= the number of healthy seedlings; B= the number of diseased seedlings.

**Statistical analysis.** The significantly of the differences between the characters in the experiments was determined by analysis of variance (ANOVA) and the averages were compared using the DUNCAN test. Statistical analyzes were evaluated at 95% confidence level using the JMP IN package statistics program (SAS Institute, Cary, NC, 5.0 PC version) [38].

## RESULTS

Variance analysis results of the characters examined in the study were given in Table 1. Varieties against *R. solani* AG4 were found to be statistically significant at 5% level for percentage of the emergence, pre-emergence damping-off, post-emergence damping-off and hypocotyl disease index in both fungicide treated and non-treated seeds. In terms of *Fusarium* spp. varieties were significantly different for percentage of the emergence in both seed treatments while they were only significant in the subject of non-treated seeds in relation to pre-emergence damping-off, post-emergence damping-off and hypocotyl disease index. On the other hand, varieties were significantly ($p<0.05$) different against *R. solani* AG4 +

**TABLE 1**
**Variance analysis for the investigated characters and mean of sum of squares**

| Source | Df | Rs E | | Rs PrE (%) | | Rs PsE (%) | | Rs HDI | |
|---|---|---|---|---|---|---|---|---|---|
| | | Non-Fungicide | Fungicide | Non- Fungicide | Fungicide | Non-Fungicide | Fungicide | Non- Fungicide | Fungicide |
| Replicate | 3 | 310.00 | 70.00 | 310.00 | 70.00 | 136.4 | 429.86 | 0.002 | 0.182 |
| Variety | 19 | 880.00* | 1770.00* | 880.00* | 1770.00* | 5115.99* | 1012.95* | 0.94* | 0.27* |
| Error | 57 | 2990.00 | 2380.00 | 2990.00 | 2380.00 | 3031.25 | 1526.59 | 0.41 | 0.32 |
| Total | 79 | 4180.00 | 4220.00 | 4180.00 | 4220.00 | 8283.65 | 2969.41 | 1.36 | 0.78 |

*Significant at the 0.05 probability level; Df: degrees of freedom; Rs: *R solani* AG4; E: emergence (%); PrE: pre-emergence damping-off (%); PsE: post-emergence damping-off (%); HDI: hypocotyl disease index.

| Source | Df | Fs E | | Fs PrE (%) | | Fs PsE (%) | | Fs HDI | |
|---|---|---|---|---|---|---|---|---|---|
| | | Non- Fungicide | Fungicide | Non- Fungicide | Fungicide | Non- Fungicide | Fungicide | Non- Fungicide | Fungicide |
| Replicate | 3 | 180.00 | 270.00 | 190.00 | 563.75 | 28.08 | 46.22 | 0.01 | 0.02 |
| Variety | 19 | 2470.00* | 2520.00* | 2520.00* | 5043.75ns | 3478.35* | 1055.23ns | 1.25* | 0.31ns |
| Error | 57 | 3670.00 | 3830.00 | 3610.00 | 11711.25 | 2098.61 | 2587.09 | 1.23 | 0.64 |
| Total | 79 | 6320.00 | 6620.00 | 6320.00 | 17318.75 | 5605.05 | 3688.56 | 2.51 | 0.98 |

*Significant at the 0.05 probability level; Df: degrees of freedom; ns: not significant; Fs: *Fusarium* spp.; E: emergence (%); PrE: pre-emergence damping-off (%); PsE: post-emergence damping-off (%); HDI: hypocotyl disease index.

| Source | Df | Rs+Fs E | | Rs+Fs PrE (%) | | Rs+Fs PsE (%) | | Rs+Fs HDI | |
|---|---|---|---|---|---|---|---|---|---|
| | | Non- Fungicide | Fungicide | Non- Fungicide | Fungicide | Non- Fungicide | Fungicide | Non- Fungicide | Fungicide |
| Replicate | 3 | 13.75 | 65.00 | 13.75 | 73.75 | 154.91 | 92.74 | 0.017 | 0.014 |
| Variety | 19 | 893.75ns | 1775.00ns | 893.75ns | 1823.75ns | 3264.58* | 3370.45* | 1.23* | 0.50* |
| Error | 57 | 4111.25 | 3035.00 | 4111.25 | 3201.25 | 2042.52 | 3909.11 | 0.66 | 0.31 |
| Total | 79 | 5018.75 | 4875.00 | 5018.75 | 5098.75 | 5462.02 | 7372.31 | 1.91 | 0.83 |

*Significant at the 0.05 probability level; Df: degrees of freedom; ns: not significant; Rs+Fs: *R solani* AG4+*Fusarium* spp.; E: emergence (%); PrE: pre-emergence damping-off (%); PsE: post-emergence damping-off (%); HDI: hypocotyl disease index

**TABLE 2**
**The average values of emergence, pre-emergence damping-off, post-emergence damping-off, hypocotyl disease index for cotton varieties against *R. solani* AG4**

| Variety | E* | | PrE (%)* | | PsE (%)* | | HDI* | |
|---|---|---|---|---|---|---|---|---|
| | Non-Fungicide | Fungicide | Non-Fungicide | Fungicide | Non-Fungicide | Fungicide | Non-Fungicide | Fungicide |
| Gaia | 85.00 ab | 100.00 a | 15.00 ab | 0.00 e | 52.78 e | 55.00 ab | 1.81 cd | 1.65 cd |
| Stoneville468 | 90.00 a | 95.00 abc | 10.00 b | 5.00 cde | 63.96 bcd | 55.00 ab | 1.94 b | 1.74 bc |
| NP Özbek100 | 87.50 ab | 95.00 abc | 12.50 ab | 5.00 cde | 60.07 bcde | 55.00 ab | 1.89 bc | 1.76 ab |
| Naz07 | 87.50 ab | 90.00 bcde | 12.50 ab | 10.00 abcd | 59.72 bcde | 52.78 ab | 1.85 bc | 1.67 bc |
| Sezener76 | 87.50 ab | 95.00 abc | 12.50 ab | 5.00 cde | 56.94 cde | 52.50 ab | 1.85 bc | 1.74 bc |
| İpek607 | 87.50 ab | 95.00 abc | 12.50 ab | 5.00 cde | 65.63 bc | 52.50 ab | 1.92 bc | 1.74 bc |
| Julia | 87.50 ab | 95.00 abc | 12.50 ab | 5.00 cde | 60.07 bcde | 50.00 ab | 1.89 bc | 1.68 bc |
| Claudia | 87.50 ab | 95.00 abc | 12.50 ab | 5.00 cde | 54.17 de | 52.22 ab | 1.82 bcd | 1.73 bc |
| Candia | 85.00 ab | 85.00 de | 15.00 ab | 15.00 ab | 62.15 bcde | 52.78 ab | 1.88 bc | 1.70 bc |
| Gloria | 80.00 ab | 82.50 e | 20.00 ab | 17.50 a | 68.25 b | 49.01 b | 1.87 bc | 1.74 bc |
| Ba440 | 85.00 ab | 97.50 ab | 15.00 ab | 2.50 de | 64.93 bc | 51.39 ab | 1.86 bc | 1.72 bc |
| Ba811 | 80.00 ab | 90.00 bcde | 20.00 ab | 10.00 abcd | 63.49 bcd | 52.78 ab | 1.88 bc | 1.67 bc |
| Lydia | 87.50 ab | 90.00 bcde | 12.50 ab | 10.00 abcd | 63.19 bcd | 52.50 ab | 1.86 bc | 1.66 bc |
| Pg2018 | 90.00 a | 92.50 abcd | 10.00 b | 7.50 bcde | 58.33 bcde | 51.67 ab | 1.83 bc | 1.73 bc |
| Adn712 | 82.50 ab | 85.00 de | 17.50 ab | 15.00 ab | 64.04 bcd | 50.00 ab | 1.85 bc | 1.65 cd |
| Özaltın112 | 87.50 ab | 87.50 cde | 12.50 ab | 12.50 abc | 65.63 bc | 54.51 ab | 1.89 bc | 1.72 bc |
| Özaltın404 | 85.00 ab | 92.50 abcd | 15.00 ab | 7.50 bcde | 67.71 b | 48.61 b | 1.89 bc | 1.68 bc |
| Acala Maxxa/Rs susceptible-Control | 77.50 b | 87.50 cde | 22.50 a | 12.50 abc | 90.53 a | 57.29 a | 2.26 a | 1.86 a |
| Acala Royale/Rs resistance-Control | 82.50 ab | 95.00 abc | 17.50 ab | 5.00 cde | 52.46 e | 39.44 c | 1.67 e | 1.55 d |
| Lachata/Fs susceptible-Control | 87.50 ab | 85.00 de | 12.50 ab | 15.00 ab | 54.17 de | 50.00 ab | 1.76 de | 1.73 bc |
| Cv (%) | 8.50 | 7.10 | 9.90 | 7.60 | 11.70 | 10.00 | 4.60 | 4.40 |

*Different letters between genotypes denote significant differences (LSD test, $p < 0.05$); Rs: *R solani* AG4; Fs: *Fusarium* spp.; E: emergence (%); PrE: pre-emergence damping-off (%); PsE: post-emergence damping-off (%); HDI: hypocotyl disease index

*Fusarium* spp. in terms of post-emergence damping-off and hypocotyl disease index in both fungicide treated and non-fungicide treated seeds (Table 1).

The percentages of the emergence, pre-emergence damping-off, post-emergence damping-off and hypocotyl disease index values of the varieties against *R. solani* AG4 were given in Table 2. The highest percentage of the emergence values were obtained in Stoneville468 and Pg2018 (90.00%) varieties, while the lowest was obtained in susceptible control Acala Maxxa (77.50%) in non-fungicide treated seeds. In the subject that the seeds treated with fungicide, the highest percentage of the emergence value was in Gaia (100.00%) while the lowest was belong to Gloria (82.50%). On the other hand, the lowest pre-emergence damping-off values were attained from Stoneville468 and Pg2018 (10.00%) while the highest one was attained in Acala Maxxa (22.50%) in non-fungicide treated seeds. In fungicide applied seeds, the lowest pre-emergence damping-off value was determined in the Gaia (0.00%) variety while the highest value was determined in Gloria (17.50%). In the meantime, the lowest post-emergence damping-off values of the non-fungicide treated seeds were obtained from the resistant control variety Acala Royale (52.46%) and Gaia (52.17%) while the highest value was obtained from Acala Maxxa (90.53%). The lowest post-emergence damping-off values of the fungicide treated subject was found only in Acala Royale (39.44%), while the highest value was found in Acala Maxxa (57.29%). Besides the varieties that were not treated with fungicide, the lowest hypocotyl disease index values were belong to Acala Royale (1.67), Lachata (1.76) that is susceptible control against *Fusarium* spp., and Gaia (1.81), the highest hypocotyl disease index value was belong to Acala Maxxa (2.26). In fungicide treated varieties, the lowest hypocotyl disease index values were came by Acala Royale (1.55), Gaia (1.65) and Adn712 (1.65) while the highest was came by Acala Maxxa (1.86) (Table 2).

The percentage of the emergence, pre-emergence damping-off, post-emergence damping-off and hypocotyl disease index values of the varieties against *Fusarium* spp. were given in Table 3. The highest percentages of the emergence were taken in Sezener76 and İpek607 (90.00%) varieties, while the lowest percentage was taken in Lydia (65.00%) in non-fungicide treated seeds. The highest percentages of the emergence in fungicide treated seeds were obtained in Julia and Adn712 (97.50%) varieties, while the lowest percentage was obtained in Lydia (70.00%). In despite of the lowest pre-emergence damping-off values of non-fungicide treated seeds were determined with Sezener76, İpek607 and Acala Royale (10.00%) varieties, the highest was determined from Lydia (35.00%). The lowest post-emergence damping-off values for non-fungicide treated seeds were belong to the control variety Acala Royale (54.48%), İpek607 (72.15%) and Sezener76 (72.20%), while the highest values were belong to Lachata (88.20%) and Acala Maxxa (88.15%). Come to that the lowest hypocotyl disease index value of non-fungicide

**TABLE 3**
**The average values of emergence, pre-emergence damping-off, post-emergence damping-off, hypocotyl disease index for cotton varieties against *Fusarium* spp.**

| Variety | E* | | PrE (%)* | PsE (%)* | HDI* |
|---|---|---|---|---|---|
| | Non-Fungicide | Fungicide | Non-Fungicide | Non-Fungicide | Non-Fungicide |
| Gaia | 87.50 ab | 85.00 b | 12.50 bc | 79.80 abc | 2.33 ab |
| Stoneville468 | 85.00 ab | 82.50 b | 15.00 bc | 76.05 bc | 2.16 bc |
| NP Özbek100 | 85.00 ab | 90.00 ab | 15.00 bc | 76.73 bc | 2.21 abc |
| Naz07 | 82.50 ab | 90.00 ab | 17.50 bc | 78.58 bc | 2.27 ab |
| Sezener76 | 90.00 a | 87.50 ab | 10.00 c | 72.20 c | 2.06 c |
| İpek607 | 90.00 a | 87.50 ab | 10.00 c | 72.15 c | 2.14 bc |
| Julia | 85.00 ab | 97.50 a | 15.00 bc | 76.13 bc | 2.20 bc |
| Claudia | 77.50 b | 92.50 ab | 22.50 b | 77.53 bc | 2.32 ab |
| Candia | 82.50 ab | 87.50 ab | 17.50 bc | 78.80 bc | 2.24 abc |
| Gloria | 77.50 b | 85.00 b | 22.50 b | 77.53 bc | 2.26 ab |
| Ba440 | 87.50 ab | 92.50 ab | 12.50 bc | 74.28 bc | 2.25 abc |
| Ba811 | 80.00 ab | 87.50 ab | 20.00 bc | 81.20 ab | 2.41 a |
| Lydia | 65.00 c | 70.00 c | 35.00 a | 73.55 bc | 2.19 bc |
| Pg2018 | 87.50 ab | 87.50 ab | 12.50 bc | 74.28 bc | 2.17 bc |
| Adn712 | 85.00 ab | 97.50 a | 15.00 bc | 73.23 bc | 2.19 bc |
| Özaltın112 | 87.50 ab | 87.50 ab | 12.50 bc | 77.03 bc | 2.23 abc |
| Özaltın404 | 87.50 ab | 92.50 ab | 12.50 bc | 77.03 bc | 2.22 abc |
| Acala Maxxa/Rs susceptible-Control | 85.00 ab | 90.00 ab | 12.50 bc | 88.15 a | 2.24 abc |
| Acala Royale/Rs resistance- Control | 87.50 ab | 90.00 ab | 10.00 c | 54.48 d | 1.78 d |
| Lachata/Fs susceptible- Control | 85.00 ab | 90.00 ab | 17.50 bc | 88.20 a | 2.32 ab |
| Cv (%) | 2.40 | 9.30 | 9.70 | 7.90 | 6.70 |

*Different letters between genotypes denote significant differences (LSD test, $p < 0.05$); Rs: *R solani* AG4; Fs: *Fusarium* spp.; E: emergence (%); PrE: pre-emergence damping-off (%); PsE: post-emergence damping-off (%); HDI: hypocotyl disease index.

**TABLE 4**
**The average values of emergence, pre-emergence damping-off, post-emergence damping-off, hypocotyl disease index for cotton varieties against *R. solani* AG4+*Fusarium* spp.**

| Variety | PsE (%)* | | HDI* | |
|---|---|---|---|---|
| | Non-Fungicide | Fungicide | Non-Fungicide | Fungicide |
| Gaia | 79.76 abc | 51.39 de | 2.24 bcd | 1.74 def |
| Stoneville468 | 79.76 abc | 45.71 f | 2.21 bcd | 1.71 ef |
| NP Özbek100 | 76.39 bc | 55.90 cde | 2.20 bcd | 1.80 bcdef |
| Naz07 | 76.39 bc | 50.40 de | 2.15 d | 1.76 def |
| Sezener76 | 78.82 abc | 49.60 e | 2.25 bcd | 1.76 def |
| İpek607 | 77.43 bc | 55.90 cde | 2.17 cd | 1.84 abcd |
| Julia | 81.85 abc | 51.79 de | 2.27 abcd | 1.80 bcdef |
| Claudia | 84.52 ab | 51.39 de | 2.32 abc | 1.71 ef |
| Candia | 81.25 abc | 59.03 abc | 2.22 bcd | 1.91 a |
| Gloria | 80.46 abc | 57.64 bcd | 2.20 bcd | 1.85 abcd |
| Ba440 | 78.82 abc | 59.72 abc | 2.27 abcd | 1.80 bcdef |
| Ba811 | 84.72 ab | 62.90 ab | 2.33 ab | 1.87 abc |
| Lydia | 80.42 abc | 56.94 cde | 2.19 bcd | 1.85 abcd |
| Pg2018 | 75.69 c | 59.72 abc | 2.18 bcd | 1.83 abcde |
| Adn712 | 77.48 bc | 59.72 abc | 2.19 bcd | 1.81 bcde |
| Özaltın112 | 81.25 abc | 52.50 de | 2.19 bcd | 1.80 bcdef |
| Özaltın404 | 81.60 abc | 52.78 de | 2.24 bcd | 1.78 cdef |
| Acala Maxxa/Rs susceptible-Control | 85.25 a | 67.22 a | 2.36 a | 1.89 ab |
| Acala Royale/Rs resistance-Control | 54.17 d | 37.78 g | 1.74 e | 1.54 f |
| Lachata/Fs susceptible-Control | 87.05 a | 66.88 a | 2.42 a | 1.91 a |
| Cv (%) | 7.60 | 15.30 | 4.90 | 4.10 |

*Different letters between genotypes denote significant differences (LSD test, $p < 0.05$); Rs: *R solani* AG4; Fs: *Fusarium* spp.; PsE: post-emergence damping-off (%); HDI: hypocotyl disease index.

treated seeds was found in Acala Royale (1.78), the highest values were found in Ba811 (2.41), Gaia (2.33) and Lachata (2.32) varieties (Table 3).

Post-emergence damping-off and hypocotyl disease index values of the varieties against *R. solani* AG4 + *Fusarium* spp. were given in Table 4. The lowest post-emergence damping-off values in non-fungicide treated seeds were attained in Acala Royale (54.17%) and Pg2018 (75.69%) while the highest values were attained in Lachata (87.05%) and Acala Maxxa (90.53%) varieties. The lowest post-emergence damping-off values in fungicide treated seeds were belong to Acala Royale (37.78%) and Stoneville468 (45.71%) while the highest values were found in Acala Maxxa (67.22%) and Lachata (66.88%). On the other hand, the lowest hypocotyl disease index value of the varieties in non-fungicide treated seeds was determined in Acala Royale (1.74) variety while the highest values were determined in Lachata (2.42) and Acala Maxxa (2.36) varieties. The lowest hypocotyl disease index values of the fungicide treated seeds were obtained in Acala Royale (1.54), Stoneville468 and Claudia (1.71) varieties while the highest values were obtained in Candia (1.91) and susceptible control Lachata varieties (Table 4).

## DISCUSSION

The percentage of the emergence values were relatively higher in fungicide treated seeds against *R. solani* AG4 and *Fusarium* spp. than non-fungicide treated seeds while post-emergence damping-off and hypocotyl disease index values of the varieties in fungicide treated seeds against *R. solani* AG4 and *R. solani* AG4 + *Fusarium* spp. were relatively lower than non-fungicide treated seeds. Although the resistance to disease is increased with the application of seedling fungicide in upland cotton varieties, it has been found that only a few of the upland cotton varieties are generally hopeful for seedling root rot. Similar to the findings obtained, Hillocks [39] reported that all Egyptian cottons (*Gossypium barbadense* L.) were more resistant than upland cottons (*G. hirsutum* L.) against *Fusarium* spp. additionally, DP6166, Prema, DP6100 and Acala Maxxa varieties were resistant to *P. ultimum* while ChemBred 7, DP6100 and Acala Royale varieties were less susceptible to pre-emergence damping-off caused by *R. solani* and all varieties were reported as susceptible to *T. basicola* in terms of symptom development and healthy emergence in greenhouse conditions in USA. Wang and Davis [29] found that metalaxyl seed applications had no effect on resistant varieties to *P. ultimum*, and seed treatment with that carboxin and pentachloronitrobenzene increased emergence against damping-off disease caused by *R. solani*. It has been reported that triadimenol+pencycuron+tolifluanid fungicide combination had the highest effect while captan+benomyl and difenocanozole had least effect against damping-off (*R. solani*) in cotton and soybean fields in Brazil [40]. It was reported that 4 cotton varieties (Giza80, Giza86, Giza89 and Giza90), which are commonly cultivated in Egypt, are not resistant to *F. solani* isolates during seedling stage [41]. Akpınar [13] reported that the best results for pre-emergence damping-off in pot experiments were taken by 6.25% with pyflufen, 12.5% with trilex, 13.3% with vitavax, 19.4% F5 seed applications. In the field tests, the lowest pre-emergence damping-off rates were found fungicide applications for vitavax (15.8%) and pyflufen (18.5%) in Söke while for vitavax (28.5%) and trilex (41.1%) in Nazilli where the same fungicide applications lead to the emergence of healthy cotton seedlings as 56.2% and 45.8%, respectively. The best result against seedling root rot was obtained in the parcels treated with maxim XL FS 035 (84.37%) in the field trials carried out in Hatay while it was vitavax 200 FF 600 (61.02%) in Söke. Yet, the healthiest emerged plants were noticed again in these parcels where these fungicides were used but the least number of living plants were in the control parcels in that no fungicide used [14]. In the study conducted in Uzbekistan between 2007 and 2011, many upland cotton varieties were reported to be very susceptible to *Fusarium* spp. [42]. In a study conducted in a climate chamber with 8 upland cotton varieties, Phytogen800 was the most resistant variety against FOV followed by MD25-26 and MD25-27 while Phytogen elite breeding lines named PHYx1, PHYx2 and PHYx3 were reported to be moderately resistant genotypes [43]. Şahbaz and Akgül [44] reported that BA525 (6.9%) was the most tolerant to Fusarium isolate while Flash (44.8%) was the most susceptible one in a study with 10 upland cotton varieties registered in Turkey in addition to PG2018 and BA525 varieties were statistically found in the same group and reported as tolerant to Fusarium isolate. Ten different genotypes and 5 common varieties were tested in greenhouse conditions against *Fusarium* spp. and especially the genotypes G5 and G8 showed high degree resistance and statistically located in a different group than other genotypes [45].

While the upland cotton varieties that do not have fungicide applied showed different levels of reactions against seedling root rot agents, it has been determined that the varieties have some resistance. However, it should not be forgotten that susceptible genotypes can not escape infection in suitable conditions for pathogen growth. In parallel with our findings, it was found that the resistance of Acala and non-upland cotton varieties that are not Acala against *Fusarium* spp. was very complex and many major and minor genes played a role in the inheritance of the disease. Moreover, the resistance against *R. solani* and *P. ultimum* in upland cotton varieties is a complex structure under the responsibility of polygenic and minor genes and it has been reported that dominant one or two major genes with resistance to FOV and minor genes are responsible as a result of phenotypic analysis in cotton varieties [46, 47, 48, 49, 50].

## CONCLUSIONS

In the study, pre-emergence damping-off, post-emergence damping-off and hypocotyl disease index values of the varieties with fungicide treated seeds were relatively lower compared to the varieties with non-fungicide treated seeds except the percentage of the emergence which was relatively higher in fungicide treated seeds. Gaia and Stoneville468 varieties against *R. solani* AG4 while Sezener76 and İpek607 varieties against *Fusarium* spp. gave the same results as resistant control Acala Royale in terms of pre-emergence damping-off, post-emergence damping-off and hypocotyl disease index values of the varieties. While Acala Royale variety was predominant, this was followed by Stoneville468 in terms of post-emergence damping-off and hypocotyl disease index values against *R. solani* AG4 + *Fusarium* spp. However, only a few of the upland cotton varieties were found to be promising against seedling root rot (*R. solani* AG4, *Fusarium* spp.). The reasons for this can be attributed to the complexity of the resistance to damping-off agents under the responsibility of major and minor genes, the type and origin of the cotton species, as well as the inoculum density of the pathogens. However, we believe that the findings of the study will shed light on breeding studies to be conducted against seedling root rot disease in cotton. In addition, field trial should be carried out to determine yield and fiber quality characteristics of the same cotton varieties in a field infected with the same disease.

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