INTERNATİONAL JOURNAL OF AGRİCULTURE & BİOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
22–0211/2023/29–1–83–90
DOI: 10.17957/IJAB/15.2006
http://www.fspublishers.org

Full Length Article

Performance of Some Biological Agents and Fungicides against Fusarium Wilt of Chickpea

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Received 17 May 2022; Accepted 08 June 2022; Published 30 December 2022

Abstract

Fusarium wilt caused by *Fusarium oxysporum* f. spp. *ciceris* is a disease that causes significant yield loss in chickpea (*Cicer arietinum* L.) worldwide. This study was aimed at investigating the effects of some fungicides (triticonazole + pyraclostrobin, fluxapyroxad, prothioconazole + tebuconazole) and three bioagents (*Bacillus subtilis, Mesorhizobium ciceri* and *Serretia odorifera*) against fusarium wilt of chickpea. Azkan and ILC482 cultivars were used in the experiment. Azkan is a most common cultivar in Turkey. ILC482 is susceptible to fusarium wilt disease.The experiment was conducted in a growth chamber. The seeds were treated with fungicides and the bioagents, and planted in pots containing pathogen-contaminated soil. The data about emergence rates, disease severity, plant height, root length, root-stem fresh and dry weight and total biomass of the plants were recorded. All of the investigated characters except for disease severity were higher for fungicide applications. Disease severity was higher pozitife control plots. But bioagents were quite effectively in controlling the disease. Considering the harm caused by chemicals to the environment, biological agents can be suggested fo fusarium wilt control in the chickpea cultivation. © 2023 Friends Science Publishers

Keywords: Bacteria; Chemicals; *Cicer arietinum*; Fusarium; Wilt

Introduction

Chickpea (*Cicer arietinum* L.) is the most produced edible legumes after dry beans in the world and India is the most important producing country. Other important chickpea growing countries are Australia, Turkey, Mexico, Argentina and Myanmar. India alone meets 74% of the world's chickpea production (Rawal and Navarro 2019). It's order is the first among edible legumes in Turkey. It has a cultivation area of 511,560 ha and a production of 630,000 t (TUIK 2020).

The concept of global climate change has been on the agenda in recent years. With this fact, increasing population, decreasing water resources and irregular precipitation regimes (floods, drought) have forced us to use resources the most efficient and to get maximum and sustainable yield (Ceyhan *et al*. 2012; Kahraman *et al.* 2016). The chickpea is the most suitable crops among grain legumes for these expected conditions (Aldemir and Ceyhan 2015; Gökmen and Ceyhan 2015; Kafadar *et al.* 2019).

The most important biotic stress agents affecting chickpea production are chickpea anthracnose (*Ascochyta rabiei*) (Jabeen *et al.* 2011; Javaid *et al.* 2020a), chickpea wilt (*Fusarium oxysporum* f. spp. *ciceris*) (Mohamed *et al.* 2015*)* and chickpea leaf gallery fly *Liriomyza cicerina* (Cikman and Civelek 2007). Chickpea wilt and root rot (*Pythium ultimum*) are considered to be the most important diseases after chickpea anthracnose. Bayraktar and Dolar (2009) reported *F. oxysporum, F. solani, F. equiseti, F. semitectum, F. acuminatum, Macrophomina phaseolina* and *Rhizoctonia solani* are the pathogens that causing root rot and wilt in chickpea were. The pathogens can cause disease alone or together. Among these pathogens, the most common and harmfull is *F. oxysporum* f. spp. *ciceris.* The pathogen can survive on different hosts as well as in the soil for many years. The infections of the disease in the plant is directly related to environmental factors such as the genetic resistance of the host, the inoculum density, the age of the plant, the race of the pathogen, temperature, humidity, and the availability of nutrients (Haware *et al*. 1990). Wilting and root rot caused by fusarium become more important especially in dry years. The pathogen damages the root structure of the plant and clogs the vascular bundles of the plant. For this reason, the plant lives water extraction problem from the soil and consequently plant lives water deficiency problem and finally the plant can be die.

It is very difficult to control soil-borne diseases such as fusarium wilt. As cultural control methods, it is

To cite this paper: Kılınç AT, N Kayan (2023). Performance of some biological agents and fungicides against fusarium wilt of chickpea. *Intl J Agric Biol* 29:83–90

recommended to use healthy seeds, avoid frequent planting and excessive water, burning diseased plant residues and a 4–5 year rotation (Ozan and Maden 2004) There is no effective chemical control method for fusarium wilt. Although it is recommended to control the disease by using resistant varieties, there is not yet a registered chickpea variety in Turkey as resistant to root rot and wilt (Yıldırım and Güldür 2019).

It is known that many biological agents such as species of *Trichoderma* (Ali *et al.* 2020; Khan and Javid 2020; Khan *et al.* 2021), *Penicillium* (Javaid *et al.* 2020b; Khan and Javaid 2022) and *Aspergillus* (Khan and Javaid 2021), and plant growth promoting rhizobacteria (Sharf *et al.* 2021) are used to fight against plant diseases in the worldwide. Antagonist microorganisms act on pathogens with different biocontrol mechanisms such as antibiosis, competition, induced resistance, and hyperparasitism (Ozaktan *et al.* 2010). The possibility of using such organisms as part of root rot and wilt control should be evaluated. This study aimed to investigate the effects of different fungicides and biocontrol bacterial species on fusarium wilt disease in chickpea cultivars under Eskisehir climatic condition where typical continantal climate prevails.

Materials and Methods

Plant material

Azkan and ILC482 chickpea cultivars were used as material. Azkan has been registered by the Transitional Zone Agricultural Research Institute and ILC482 has been registered by the GAP International Agricultural Research and Training Center. Azkan was included in the study because it is the most common cultivar, suitable for machinery harvest, in our country. ILC482 was used in the study because it was evaluated as sensitive to fusarium wilt in different studies.

Pathogen

The pathogen was obtained from the Transitional Zone Agricultural Research Institute. *F. oxysporum* f. spp. *ciceris* isolated from diseased plant samples collected from Kütahya-Aslanapa. The virulence of the pathogen was found to be high in conducted at the Transitional Zone Agricultural Research Institute. Diagnosis of the pathogen was made by classical and molecular methods.

Fungicides

Insure perform (F1): FS (flowable concentrate for seed treatment) contains 80 grams of Triticonazole and 40 g of Pyraclostrobin active substances per liter in the formulation Systiva (F2): FS contains 333 g of Fluxapyroxad active substance per liter in the formulation. Lamardor (F3): FS contains 150 g/L Prothioconazole + 20 g/L Tebuconazole active ingredients per liter in the formulation.

Biological agents

Serretia odorifera (So): It is a bacterial strain isolated at the Transitional Zone Agricultural Research Institute and determined to have high phosphorus dissolving efficiency. *Bacillus subtilis* (Bs): Biological fungicide containing 1.34% *B. subtilis* QST 713 strain (min. 1 x 109 cfu/mL) in suspension concentrate formulation. *Mesorhizobium ciceri* (Ms): Obtained from the Central Research Institute of Soil, Fertilizer and Water Resources.

Development of Fusarium isolates, preparation of soil inoculum

F. oxysporum f. spp. *ciceris* isolate was cultivated in sterile petri dishes containing PDA (Patato Dexrose Agar) and grown in a sterile cabinet for 10 days at 25 ± 2°C in 12 h of light and 12 h of darkness. The experiment was conducted with the soil inoculation method of Nene and Haware (1980) (Bayraktar and Dolar 2009). For the inoculum, 810 g of sieved sand and 90 g of chickpea flour were mixed into each of the heat-resistant oven bags. The bags were moistened by adding 65 mL of distilled water, and sterilized in an autoclave at 1.5 atm pressure, 121°C for 15 min. The sterilization process was repeated one day later in the same way. The sterilized sand-chickpea flour mixture was inoculated with 90 discs with a diameter of 0.7 cm taken from fusarium isolates developed in a PDA medium for 10 days in a sterile cabinet. The inoculated mixture was developed for 14 days in 12 h of light and 12 h of darkness, and in a climate room with a temperature of 26 ± 2°C.

A mixture of soil, sand, and burnt manure (1:1:1)(v:v:v) was prepared and moistened with water. The mixture was put into oven bags weighing 4.25 kg. The prepared bags were sterilized in an autoclave at 121°C and 1.5 atm pressure for 15 min, and the same procedures were repeated one day later.

Pot experiment

Plastic pots with a diameter of 15 cm were used in the study. For the sterilization of the pots, the pots were kept in containers filled with water containing 1% NaOCl for 1 day. Sterile soil mixture and inoculum (10:1) (h:h) were mixed homogeneously into the sterilized pots, and then 550 g soil mixture were put into each pot. It was waited for 6 days for the fungus to cover the mixture. Negative control plots were prepared with 500 g soil mixture, 45 g sand and 5 g chickpea flour.

The seeds to be used in the experiment were kept in 1% NaOCl solution for 3 min for sterilization. Afterthen, it was passed through sterile distilled water 6 times and dried on a blotting paper. Since the fungicides used in seed

spraying are not licensed for chickpea, wheat was taken as a reference. It was used by diluting at the recommended rates (0.5 mL kg^{-1} for Insure perform and Lamardor fungicides, 1.5 mL kg^{-1} for Systiva fungicides) in wheat seed spraying. The fungicides to be used in applications where two or three different fungicides will be used were first diluted and then mixed in equal proportions. The seeds were dried after being treated with fungicides. *B. subtilis* (3 mL kg^{-1}) and *M. ciceri* (10 g kg^{-1}) used in the experiment were treated at the recommended rates. For *S. odorifera*, a solution containing 1×10^6 bacteria per mL was prepared and the seeds were wetted with a spray. In the double and triple mix, the seeds were first treated with *S. odorifera*, *B. subtilis* and finally with *M. ciceri*. In bacterial applications, the second application was made after the first application. The third application was made after the first two applications drying. The applications were made in a cool and shaded environment so that the bacteria would not lose their vitality. It was sown immediately afterward.

Fungicide applications: F1 (Triticonozole + Pyraclostrobin) ; F2 (Fluxapyroxad); F3 (Prothiconazole + Tebuconazole); F1 F2; F1 F3; F2 F3; F1 F2 F3. Bacteria applications were: Bs (*B. subtilis*); Mc (*M. ciceri*); So (*S. odorifera*); Bs Mc; Bs So; Rc So; Bs Mc So. Control applications: (+) Control: There was dissease contamination in the soil, there is no fungicide and bacteria in the seed. (-) Control: No dissease contemination in the soil, no fungicide and bacteria in the seed.

The experiments were laid out as a randomized plots designed in a factorial arrangement with 3 replication. Seeds contaminated with fungicide and bacteria were sown as 5 seeds per pot. While sowing different applications, different gloves were used for each application. The pots were randomLy placed in the growth chamber. It was grown at 26 ± 2°C in 12 h of light and 12 h of darkness. Plants were irrigated when needed.

Observations were started 10 days after sowing the seeds and evaluated 6 weeks later. To take measurements on the plant, the chickpea plants were taken out of the pot with the soil, their roots were washed with tap water, and then the measurements were taken.

The emergence rate was taken 10 days after the sown. After determining the root length and plant height of each plant, root fresh weight and stem fresh weight were determined 6 weeks later after sowing. Root dry weight and stem dry weight were measured after two days of drying at 48°C. Total biomass was determined by adding root and stem dry weights of all plants in each pot. Disease severity was evaluated according to Trapero-Casas and Jimenez-Diaz (1985) 0–4 scale, and Townsend and Heuberger (1943) formula was applied to scale values in calculating disease severity rates (%) (Table 1).

Data analysis

Logarithmic transformation was applied to the emergence rate and disease severity data (Petersen 1994). Square root transformation was applied to the data of plant height, root length, root fresh weight, root dry weight, stem fresh weight, stem dry weight and total biomass (Petersen 1994). The data were evaluated with the analysis of variance in the randomized plots arranged factorial experimental design using the Jump 7 statistical software. When the differences between the applications were determined using Tukey's multiple comparison test.

Results

Emergence rate

The differences between cultivars and applications for emergence rate is statistically significant at the level of 1%. The difference between cultivar × application interaction is not statistically significant (Table 2). While the emergence rate of cv. Azkan was 63.8%, it was 77.1% for ILC482. The highest emergence rate was found at 93.3% in F1 F2 application among the treatments. F1 and F1 F2 F3 treatments followed this application with 90%. The lowest emergence rate was found in (+) control treatment with 30% (Table 2).

Root length

The differences among the treatments for root length was found to be statistically significant ($P < 0.01$). The difference between cultivars and cultivar × application interaction is not statistically significant (Table 2). The mean root length of cv. Azkan and cv. ILC482 were 10.6 and 11.3 cm, respectively. The maximum root length was measured in Bs Mc application with 12.9 cm among the treatments. This was followed by the (-) control application with 12.7 cm. The lowest root length was determined as 2.83 cm in the (+) control treatment (Table 2).

Plant height

The differences among the treatments for plant height was found to be statistically significant ($P < 0.01$). The difference between cultivars and cultivar × application interaction was not statistically significant (Table 2). The mean plant height of cv. Azkan was 20.83 cm, and it was 20.20 cm for cv. ILC482. The highest plant height was recorded as 23.97 cm in the F1 F2 application. This result was followed by the F2 application with 23.67 cm. The lowest plant height of 8.61 cm was measured in the (+) control treatment.

Root fresh weight

The differences among the treatments for root fresh weight was found to be statistically significant at the 1% level. The difference between cultivars and cultivar × application

Table 1: Evaluation of disease symptoms

Disease Score	Observed Symptoms
0	No visible symptoms of disease
1	Onset of wilting, discoloration of fine veins on lower leaves
2	Wilting, chlorosis and necrosis of half of the plant
3	General wilting, drying of leaves, shedding and dieback from tips
4	Drying and death of half or most of the plant

$$Disease\ severity\ (\%) = \frac{\sum(n.v)}{N.V} \times 100$$

n: Scale Value v: Number of plants included in the scale, N: Highest scale value, V: Total number of plants)

Table 2: Effects of different fungucides and bacterias on some traits of chickpea cultivar

	Emergence rate (%)	Root lenght (cm)	Plant height (cm)	Root fresh weight (g/plant)	Stem fresh weight (g/plant)
Azkan	63.8 b	10.6	20.8	2.4	3.04
ILC482	77.1 a	11.3	20.2	2.6	3.02
Mean	70.45	11.00	20.50	2.50	3.03
Control (+)	30.0 e	2.8 b	8.6 b	0.39 c	0.54 f
Control (-)	83.3 a-c	12.7 a	19.4 a	2.45 ab	2.44 c-e
F1	90.0 ab	12.0 a	23.0 a	3.14 ab	3.92 ab
F2	46.7 e	11.3 a	23.7 a	2.61 ab	3.14 b-d
F3	63.3 a-d	12.4 a	23.4 a	3.77 a	4.59 a
F1 F2	93.3 a	12.2 a	24.0 a	3.44 ab	3.89 ab
F1 F3	80.0 a-c	11.1 a	20.1 a	2.92 ab	3.66 a-c
F2 F3	73.3 a-d	11.7 a	20.6 a	3.25 ab	3.62 a-c
F1 F2 F3	90.0 ab	12.5 a	20.3 a	3.80 a	3.59 a-c
Bs	63.3 a-d	10.5 a	20.3 a	2.17 ab	2.78 b-e
Mc	56.7 cd	9.01 a	20.1 a	1.30 bc	2.19 de
So	80.0 a-c	9.82 a	19.4 a	1.50 bc	1.76ef
Bs Mc	73.3 a-d	12.9 a	22.5 a	2.10 ab	2.76 b-e
Bs So	80.0 a-c	12.1 a	22.1 a	2.60 ab	2.88 b-e
Mc So	63.3 a-d	11.0 a	20.7 a	2.63 ab	3.38 a-d
Bs Mc So	60.0 b-d	11.9 a	23.0 a	2.28 b	3.36 a-d
Mean	70.45	11.00	20.50	2.50	3.03
General mean	70.45	11.00	20.50	2.50	3.03
Cultivar	**	ns	ns	ns	ns
Application	**	**	**	**	**
Culti. x appl.	ns	ns	ns	ns	**

ns: non-significant, *: $P \leq 0.05$, **: $P \leq 0.01$

interaction was not statistically significant (Table 2). The mean root fresh weight of cv. Azkan and cv. ILC482 were 2.42 and 2.62 g, respectively. The highest root fresh weight was recorded in the F1 F2 F3 application with 3.80 g and single application of F3 followed the this result with 3.77 g (Table 2).

Stem fresh weight

The differences among the applications and the cultivar × application interaction is statistically significant at the 1% level for stem fresh weight. The difference between cultivars is not statistically significant (Table 2). While the stem fresh weight of cv. Azkan was found as 3.04 g, it was found as 3.02 g for cv. ILC482. The highest stem fresh weight was found in the F3 application with 4.59 g, while the lowest stem fresh weight was found in the (+) control application with 0.54 g (Table 2). The cultivars showed different response to treatments with repect tos tem fresh weight, the highest stem fresh weight was recorded in cv. Azkan (5.31 g) treated with F3 application (Fig. 1A). In both cultivars, the lowest stem fresh weight were recorded in the (+) control application.

Root dry weight

The differences among cultivar × application interaction and applications was found to be statistically significant at the 1% level for root dry weight. The difference between the cultivars was not found to be statistically significant (Table 3). The mean root dry weight of cv. Azkan and cv. ILC482 were recorded as 0.27 and 0.28 g, respectively. While the highest root dry weight was found as 0.42 g in F3 treatment, the lowest root dry weight was found in the (+) control application with 0.04 g (Table 3). The genotypes showed different response to treatments with respect to root dry weight, the highest root dry weight with 0.45 g was observed in cv. Azkan under F3 treatment (Fig. 1B). The lowest root dry weight was recorded in (+) control application for the both cultivars.

Stem dry weight

The differences between cultivars was statistically significant at the level of 5% while the difference among applications and cultivar × application interaction was statistically significant at the level of 1% for stem dry

Table 3: Effects of different fungucides and bacterias on some traits of chickpea cultivar

	Root dry weight (g/plant)	Stem dry weight (g/plant)	Total biomas (g/plant)	Disease severity (%)
Azkan	0.27	0.91 a	3.67	62.0
ILC482	0.28	0.77 b	3.57	61.8
Mean	0.28	0.84	3.62	61.90
Control (+)	0.04 d	0.24 f	0.50 j	96.2 a
Control (-)	0.26 a-c	0.61 b-e	3.02 e-h	39.6 g
F1	0.34 a-c	1.00 a-d	5.58 a-c	46.2 e-g
F2	0.27 a-c	1.11 ab	3.92 c-f	63.7 b-e
F3	0.42 a	1.21 a	5.17 a-d	56.8 b-f
F1 F2	0.34 a-c	1.04 a-c	6.54 a	37.6 h
F1 F3	0.32 a-c	1.07 a-c	4.37 b-e	54.8 d-f
F2 F3	0.31 a-c	0.93 a-e	3.32 d-h	73.6 a-d
F1 F2 F3	0.38 ab	1.00 a-d	5.94 ab	44.0 fg
Bs	0.28 a-c	0.63 de	2.49 hı	72.7 a-d
Mc	0.21 bc	0.58 c-e	1.55 ı	71.2 a-d
So	0.19 c	0.50 e	2.13 g-ı	80.0 ab
Bs Mc	0.26 a-c	0.88 a-e	3.04 e-h	62.2 b-e
Bs So	0.28 a-c	0.86 a-e	4.35 b-e	62.0 b-e
Mc So	0.27 a-c	0.91 a-e	2.60 f-ı	76.2 a-c
Bs Mc So	0.27 a-c	0.87 a-e	3.45 d-g	54.3 c-f
Mean	0.28	0.84	3.62	61.90
General mean	0.28	0.84	3.62	61.90
Cultivar	ns	*	ns	ns
Application	**	**	**	**
Culti. x applic.	**	**	**	**

ns: non-significant, *: $P \leq 0.05$, **: $P \leq 0.01$

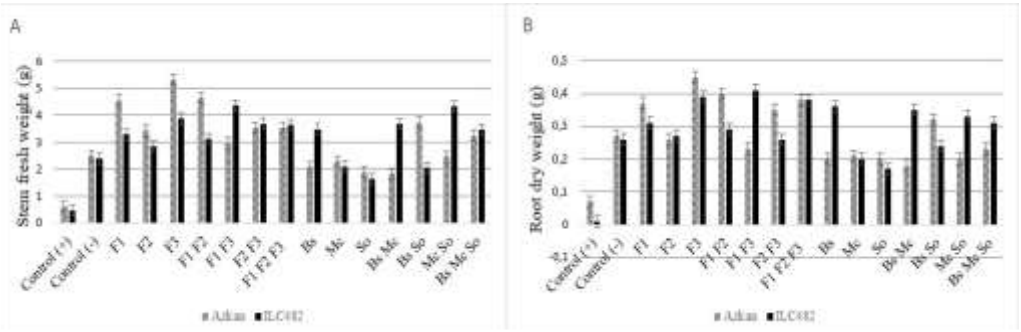

Fig. 1: The interaction between cultivar and application on stem fresh weight (**A**) and root dry weight (**B**) of chickpea

weight. The stem dry weight of cv. Azkan was 0.91 g and it was 0.77 g for cv. ILC482. The highest mean stem dry weight was observed in the F3 application with 1.21 g while the lowest stem dry weight was observed in the (+) control application with 0.24 g (Table 3). The cultivars showed different response to treatments with respect tos tem dry weight. While the highest stem dry weight was observed in cv. Azkan in F3 applications, it was obserwed in cv. ILC482 in F1 F3 application (Fig. 2A). In both cultivars, the lowest stem dry weight was recorded in the (+) control application.

Total biomass

The differences among cultivar × application interaction and applications was found to be statistically significant at the 1% level for total biomass. The difference between cultivars was not found to be statistically significant (Table 3). Total biomass of cv. Azkan and cv. ILC482 were 3.67 and 357 g, respectively. The highest total biomass was found in the F1 F2 application with 6.54 g, while the lowest total biomass was found in the (+) control application with 0.50 g for the applications (Table 3). The highest total biomass for the cultivar x application interaction was seen in cv. Azkan in F1 F2 treatment with 8.01 g. This application was followed by cv. Azkan in F1 F2 F3 application with 6.09 g. The lowest total biomass of 0.35 g was observed in cv ILC482 in (+) control application (Fig. 2B).

Disease severity

The differences among applications and cultivar × application interaction for disease severity is statistically significant at the 1% level. The difference between the cultivars is not statistically significant (Table 3). While the mean disease severity was found to be 62% in cv Azkan and 61.8% in cv. ILC482. The highest disease severity was found in (+) control application with 96.2% while the lowest disease severity was observed in the F1 F2 application with

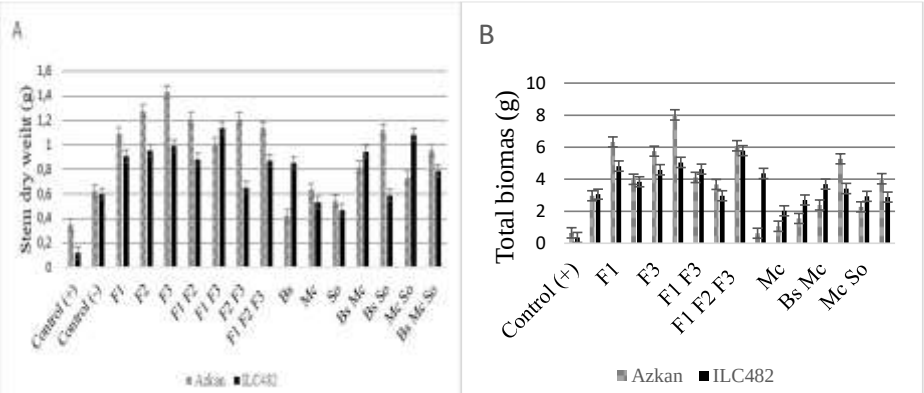

Fig. 2: The interaction between cultivar and application on stem dry weight (**A**) and total biomas (**B**) of chickpea

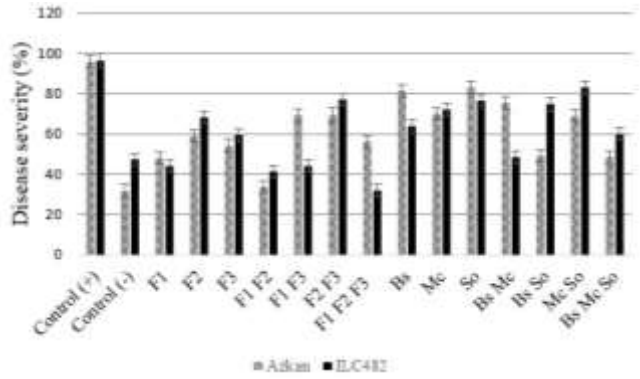

Fig. 3: The interaction between cultivar and application on disease severity of chickpea

37.6% (Table 3). Althogh the highest disease severity recorden in (+) control treatment in both cultivars, the cultivars showed different response to the other treatments. Therefore, cultivar x application interactions was significant with respet to disseae severity (Fig. 3).

Discussion

It was observed that the emergence rates decreased with the effect of the pathogen. The cv. ILC482 has a better emergence rate than that of the cv. Azkan. This can be explained by the high germination rate of the cv. ILC482. The emergence rate of the cv. Azkan has decreased due to the seed remaining in the soil for a longer time without emergence and its contact with the pathogen increases.

F. oxysporum f. spp. *ciceris* is a soil-borne pathogen. Roots are contacted the pathogen infected immediately and causes the first damage. Therefore, it is an expected result to have a greater effect on the roots (Coninck *et al*. 2015). The lowest root length was determined in (+) control applications. All fungicide and bacteria applications increased the root length compared to the (+) control. According to the mechanism of action of bacteria and fungicides, it can be said that they are effective aganist the pathogen infection and development. Akhtar *et al.* (2010) reported that different bacterias cause great increases in plant growth, pod number and nodulation. They also pointed out that co-inoculation of bacteria reduced wilting in diseased plants. It has been determined that some phosphate solvent microfungi collected and isolated from Mazıdağı, Turkey, positively affect the root length (Ozdemir 2014).

Bacterial and fungicide applications affected plant height positively. Plant height was higher in fungicide applications compared to bacterial applications. In a study conducted with lentil plant in India, it was reported that some bacteria applications increased plant growth, a number of pods and nodulation in lentils (Akhtar *et al*. 2010). Karimi *et al*. (2012) isolated three different bacterial species from the chickpea rhizosphere in Iran. They reported that the bacteria significantly increased the plant height and fresh and dry weight of the plant compared to the control application. It has been determined that some phosphorus dissolving microfungi isolated from the Mardin Mazıdağı, Turkey, location increase plant height (Ozdemir 2014). Ben Abdallah *et al*. (2019) stated that *B. subtilis* and *B. amyloliquefaciens plantarum* increased plant height by 10.6%. As with the results obtained in the experiment, the bioagents used in these studies increased the plant height. Therefore, it is possible to say that different bacterial applications

increase plant height and have the potential to be used in chickpea cultivation.

Root fresh weight is directly related to the health of the plant root. A healthy plant is expected to have a strong root. *F. oxysporum* primarily affects the root of the plant and then damages the plant. Since the pathogen contamined in the root of the plant without any obstacles, the most damage was seen, as a result of thisthe lowest roow fresh weight was estimated in (+) control applications.. It can be said that fungicides and bacteria are effective in protecting the root in our study. In a study conducted on tomatoes, it was determined that two endophytic bacteria (*B. subtilis* and *B. amyloliquefaciens plantarum*) increased the root fresh weight by 16.3% under field conditions (Abdallah *et al.* 2019). Ozdemir (2014) conducted his study with phosphorus-dissolving microfungi, and Karimi *et al.* (2012) carried out their studies with bacteria obtained from chickpea rhizosphere. Both researchers stated that the bioagents increased the root fresh weight of the plant. Microorganisms with PGPR properties regulated plant growth and competed with the pathogen to keep the root healthier (Noumavu *et al.* 2016).

If the stem of the plant is healthy, the root of the plant is expected to be healthy. Since *F. oxysporum* causes wilting by affecting the vascular systems of the plants, it is expected that the stem fresh weights of the unhealthy plants will below. Karimi *et al.* (2012) conducted their studies with bacteria obtained from the rhizosphere. They reported that some bacterial strains increased the stem fresh weight as well as other growth parameters.

The high root dry weight indicates that the plant has a healthy root structure. The means of fungicide applications in both cultivars were higher than the means of bacteria applications. Khan *et al.* (2014) conducted their studies with Carbendazim and some Trichoderma species. They stated that chemical and bioagents reduced the severity of wilt disease in chickpeas and that bacteria applications were performed as well as fungicides. Ozdemir (2014) worked with microfungi with the potential to dissolve phosphorus. He reported that, in addition to other growth parameters, the dry weight of corn and chickpea plants increased significantly.

In the study examining the effect of bacteria on wilt disease in lentils, it was determined that bacteria increased plant growth, a number of pods and nodulation (Akhtar *et al.* 2010). In the study conducted with bacteria obtained from chickpea rhizosphere, it was stated that some bacteria increased the dry weight of the plant as well as other parameters (Karimi *et al.* 2012). Ozdemir (2014) reported that microfungi have positive effects on the dry weight, fresh weight and plant height of the plant.

In the study conducted with phosphorus-dissolving microfungi, it was determined that phosphorus-dissolving fungi significantly increased some growth parameters such as stem and root length, fresh and dry weight (Ozdemir 2014). In this study, it was determined that phosphorus solvent bacteria increased plant height, root length, root and stem weight and root and stem dry weight compared to positive control application. However, *S. odorifera, B. subtilis, M. ciceri and B. subtilis+R. ciceri* applications did not increase the total biomass in cv. Azkan.

Both bacteria and fungicides prevented the disease significantly compared to the (+) control. It has been determined that the effectiveness of bacteria in the present study are limited than fungicides. Bacterial applications decreased the disease severity by 29% in cv. Azkan compared to (+) control, whereas chemical fungicide applications decreased it by 43%. Bacterial applications decreased by 26% in cv. ILC482 compared to (+) control application, whereas chemical fungicide applications decreased by 46%. Subhani *et al.* (2011) reported that some fungicides tried against *F. oxysporum* f. spp. *ciceris* were successful. While these fungicides caused a decrease in wilted plants in greenhouse conditions, they reduced mycelial formation in laboratory conditions. In another study, they found that *B. subtilis* and *T. harzianum* isolates and their mixtures reduced fusarium wilt disease by up to 40%. They stated that these bioagents can be used in the fight against wilt disease (Moradi *et al*. 2012).

Conclusion

In the results of all parameters examined in this study, generally better results were obtained from fungicide applications than bacterial applications. The emergence rate, plant height and total biomass were found to be higher in Insure perform + Systiva applications. However, stem fresh weight, root dry weight and stem dry weight were found to be higher in Lamardor application. However, since some fungicides can be harmful in the long run, it is not right to plan for high yields only for the short term. Bacteria used as bioagents do not have such problems. One of the environmental problems is the uncontrolled and excessive use of pesticides. This problem causes soil pollution with chemicals. If bacteria are used continuously, it can be assumed that the population of beneficial bacteria will increase and the number of pathogens will decrease in the coming years. For these reasons, biological agents can be recommended for fusarium wilt control in chickpea cultivation.

Acknowledgements

We would like to thank the directorate of the Transitional Zone Agricultural Research Institute

Author Contributions

N.K. planned to experimental; A.T.K conducted the experiment and made the analysis; N.K. and A.T.K. wrote the article. The article was summarized from the M. Sc thesis of A.T. Kılınç.

Conflicts of Interest

All authors declare no conflict of interest

Data Availability

Data presented in this study will be available on a fair request to the corresponding author.

Ethics Approval

Not applicable in this paper

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