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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Effects of Combination of Copper Fungicide and Plant Activator on Late Blight and Quality Criteria of Potato

Bakırlı Fungusit ve Bitki Aktivatörü Kombinasyonunun Patates Mildiyösü Hastalığı ve Patates Kalite Kriterleri Üzerine Etkisi

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Abstract

Late blight caused by *Phytophthora infestans* is one of the most important fungal diseases that cause damage to both the green parts and tuber of the potato plant and limits potato cultivation. Systemic fungicides are mostly preferred by farmers in the control of potato late blight. The fact that systemic fungicides cause health problems in terms of human and environmental health has revealed the need for research on control methods that do not threaten environmental health. In recent years, successful results have been obtained in the control of many diseases with plant activators known as Induced Systemic Resistance (ISR) promoters. This study was carried out in the spring season of 2016-2017 to observe the effect of copper fungicide and plant activator (*Lactobacillus acidophilus* fermentation product) combination on the control of potato late blight disease and some quality criteria of potato tubers in the experimental plots of Ege University Ödemiş Vocational School in Ödemiş district of İzmir province. The experiment was planned as two separate experiments with Marabel and Melody potato cultivars. The experiment was established according to a split-plot experimental design with four replications. In this study, the effect of the treatments on potato quality and yield criteria such as tuber number, tuber width, tuber length, single tuber weight, yield per decare, and the effects of the pesticides on potato late blight disease and disease severity parameters were evaluated. When the data obtained as a result of the study were evaluated, it was determined that the combination application had a positive effect on the control of potato late blight disease in both potato cultivars compared to the control plots. When the quality criteria of potato tubers were evaluated, the highest number of tubers was obtained from the plots where copper fungicide and plant activator (Isr-2000) combination was applied. Significant increase was obtained in potato quality and yield criteria such as tuber width, tuber length, average tuber weight and yield per decare when the combination plots were compared with the control plots. In conclusion, the use of contact fungicides and plant activator combinations in the control of late blight in the spring period within the scope of sustainable agriculture is promising as an application alternative in the control of plant diseases in organic agriculture.

Keywords: Potato, *Phytophthora infestans*, Organic agriculture, Plant activator, Copper fungicide

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Öz

Phytophthora infestans'ın neden olduğu mildiyö hastalığı patates bitkisinde hem yeşil aksamda hem de yumruda zarara sebep olan, patates yetiştiriciliğini sınırlandıran en önemli fungal hastalıklardan birisidir. Patates mildiyösü ile mücadelede çiftçiler tarafından en çok sistemik fungusitler tercih edilmektedir. Sistemik fungusitlerin insan ve çevre sağlığı açısından sağlık sorunlarına sebep olması, çevre sağlığını tehdit etmeyen mücadele yöntemleri araştırma ihtiyacını ortaya çıkarmıştır. Son yıllarda yapılan araştırmalarda uyarılmış sistemik dayanıklılık (Induced Systemic Resistance) (ISR) teşvik edici olarak bilinen bitki aktivatörleri ile birçok hastalığın kontrolünde başarılı sonuçlar elde edilmiştir. Çalışma İzmir iline bağlı Ödemiş ilçesinde yer alan Ege Üniversitesi Ödemiş Meslek Yüksekokulu deneme parsellerinde bakırlı fungusit ile bitki aktivatörü (*Lactobacillus acidophilus* fermentasyon ürünü) kombinasyonunun, patates mildiyösü hastalığının kontrolündeki ve patates yumrularının bazı kalite kriterleri üzerindeki etkisini gözlemlemek amacıyla 2016-2017 yıllarında ilkbahar sezonunda yürütülmüştür. Deneme Marabel ve Melody patates çeşitleri ile iki ayrı deneme şeklinde planlanmıştır. Deneme, dört tekerrürlü bölünen bölünmüş parseller deneme desenine göre kurulmuştur. Bu çalışmada, uygulamaların yumru adedi, yumru eni, yumru boyu, tek yumru ağırlığı, dekara verim gibi patateste kalite ve verim kriterleri ve patates mildiyösü hastalığına ilaçların etkisi ve hastalık şiddeti parametreleri değerlendirmeye alınmıştır. Çalışma sonucunda elde edilen veriler değerlendirildiğinde, kombinasyon uygulamasının kontrol parsellerine kıyasla her iki patates çeşidinde de patates geç yanıklık hastalığının kontrolü üzerinde olumlu bir etkiye sahip olduğu tespit edilmiştir. Patates yumrularının kalite kriterleri değerlendirildiğinde, bakırlı fungusit ve bitki aktivatörü (Isr-2000) kombinasyonu uyguladığımız parsellerden en yüksek yumru adedi elde edilmiştir. Yumru eni, yumru boyu, ortalama yumru ağırlığı ve dekara verim gibi patatesin kalite ve verim kriterlerinde kombinasyon uygulanan parseller kontrol parselleri ile kıyaslandığında önemli artış elde edilmiştir. Sonuç olarak, sürdürülebilir tarım kapsamında ilkbahar döneminde patates mildiyösü hastalığının kontrolünde kontakt etkili fungusitler ve bitki aktivatörü kombinasyonlarının kullanımı organik tarımda bitki hastalıkları ile mücadelede bir uygulama alternatifi olarak umut vadetmektedir.

Anahtar Kelimeler: Patates, *Phytophthora infestans*, Organik tarım, Bitki aktivatörü, Bakırlı fungusit

1. Introduction

Potato (*Solanum tuberosum* L.), which is a member of the Solanaceae family and has spread throughout the world from the Andes of South America, is one of the most important plants that can respond to the growing hunger problem in the world (Yıldırım et al., 2005). Today, it can be grown in almost every part of Turkey. It is one of the best plants that can be involved in crop rotation, especially in light, sandy-loam soils. Considering the increasing world population and limited agricultural areas, potato is a product that the world cares about both in terms of the product amount obtained per unit area and the quality of the product to meet the needs of more people. In the countries where it is grown, potato is a plant that contributes quite a lot to the national economy due to the high amount of product taken from the unit area (Bostan, 1996).

According to 2021 data from Turkey, the cultivation area of potatoes is 1.389.175 decares, the production amount is 5.100.000 tons, and the yield per unit area is 3671 kg da^{-1} (Anonymous, 2022a). The Ödemiş province has a significant share in terms of potato production in Turkey. According to 2021 data in Ödemiş, potato production takes place in three periods on approximately 92.000 decares of land Ödemiş plain in spring, Gölcük plateau and Bozdağ in summer, and Ödemiş plain again in autumn (Anonymous, 2022b).

Potato late blight (*Phytophthora infestans*) is one of the diseases seen in potato cultivation areas in the Ödemiş district and causes the most yield loss. The pathogen of the disease subsists in crop residues, infected tubers and other plants in the *Solanaceae* family. The spores of the disease's pathogen are airborne and can be carried to healthy plants by air flows. As a result of the increase in humidity in the spring, the pathogen causes sporulation on infected plants and these spores hold on to the plant from the lower leaves of cultivated plants close to the soil with the wind or raindrops. They enter the plant through natural surface openings or injured tissues in cultivated plants and penetrate the plant. They can cause secondary infections during the year (Stevenson, et al., 2001). Fungal spores must first germinate for the development of late blight disease. Appropriate temperature and high proportional humidity, such as water film, dew, and rain on the plant surface are required for this. The presence of free water on the leaf increases the activity of *P. infestans,* the pathogen of the late blight disease as well as many other leaf pathogens (Harrison, 1995; Agrios, 2005; Fry, 2008, Tian et al., 2016).

The most effective method in the fight against the disease is chemical control. Pesticides should be applied with appropriate systemic fungicides when the disease is seen in the field or when the climate conditions are suitable for the disease for chemical control to be successful. Due to the negative effects of systemic pesticides on the environment and human health, the fact that they create resistance on the target organism over time, and the high risk of residues, new solutions should be found in the fight against the disease. As a result of these problems, it has become obligatory to develop more effective, environmentally friendly fungicides against *P. infestans* and to use them with the best application techniques (Cook and Deahl, 1998). Plant activators are substances that activate the natural defence system of plants, allow them to make better use of nutrients, help protect them from stress conditions and similar external agents and factors, affect yield and product quality positively, and have natural strengthening, resistance increasing, soil structure regulating features. Plant activators have recently been preferred as an alternative to traditional plant disease control methods. Very successful results have been obtained from the combination of plant activator and copper hydroxide in blight diseases (Aysan et al., 2019; Tosun and Ergün, 2002).

In this study, copper fungicide with a contact-effective mechanism and a plant activator (ISR-2000), which is thought to increase the resistance by affecting the natural resistance mechanisms of the plant against diseases, were selected. ISR-2000 is a preparation consisting of biological, organic, and natural extracts formulation developed for use in herbal production and presented to agriculture. It contains *Lactobacillus acidophilus,* yeast extract, plant extract, and benzoic acid. It is a natural compound that exists in the plant but does not always appear under normal conditions, activates the natural defence mechanism, and is obtained biologically. The use of ISR-2000 is an environmentally friendly organic product that provides a high defence system and resistance against diseases and stress, an increase in crop yield and quality, an excellent economic return, and an increase in earnings (Yaman, 2006).

The aim of this study was to determine the effects of copper fungicide alone or in combination with a plant activator on plant growth characteristics, tuber quality and yield in the control of late blight disease, which causes significant yield loss in potato plants intensively produced in the spring season in Ödemiş region. It is thought that the results obtained at the end of the study will be useful for potato producers.

2. Materials and Methods

In order to determine the effects of copper fungicide and plant activator (ISR-2000) combination on disease control and plant growth characteristics of two potato cultivars against late blight (Phytophthora infestans) disease in Ödemiş, a study was carried out in the field and laboratories of Ege University Ödemiş Vocational School in the spring potato growing season of 2016-2017. Two different potato cultivars, Melody and Marabel, were used in the study (*Table 1*). Copper fungicide alone, combination of copper fungicide and plant activator (ISR-2000) and Aviso fungicide, which is a licensed commercial preparation with 57% metiram + 4% cymoxanil active ingredient, were used against potato late blight disease (*Table 2*). The study was conducted as two separate experiments on potato cultivars. The soil of the experiment area was determined as loamy sandy texture and poor in organic matter. Climatic data for the spring potato production season in the experimental area are given in *Table 3*.

2.1. Determining the Efficiency of Applications in Field Conditions

This experiment was conducted to determine the efficacy of a combination of copper fungicide and plant activator (ISR-2000) against potato late blight disease by spraying green parts under natural inoculation conditions in an area where the disease was observed in previous years. The experiment was planned according to a split-plot design with 4 treatments (3 fungicides + control) and 4 replications for two different potato cultivars. The experiment was established with 20 plants in each plot after edge effects. In order to prevent the chemical treatments from affecting each other, isolation rows of at least one metre were left between each treatment. All maintenance operations were carried out in the same way in all plots so that there was no difference between the plots. Potato seeds were sown between 15 February and 20 February. Potato harvesting was carried out between 20 June and 1 July. Spraying was started when the first potato late blight disease symptoms were seen in the environment and at least three sprayings were made at 10-12 days intervals at the doses recommended by the companies. The trial was planned in accordance with the Plant Disease Standard Pesticide Trial Methods of the General Directorate of Agricultural Research and Policies of the Ministry of Agriculture and Forestry of the Republic of Turkey. The counts were evaluated according to the 0-5 scale of TAGEM Plant Diseases Standard Pesticide Trial Methods, taking into account the duration of the drug effect and the disease severity in the control (*Table 4*). The values obtained as a result of the treatments were converted into disease severity using the Towsend-Heuberger formula (Towsend and Heuberger,1943). The effects of treatments on late blight of potato disease were calculated by comparing with control plots according to Abbott formula (Anonymous, 2015). The results obtained in the experiment were analysed using the statistical package SPSS v. 28.0 (SPSS, 2021). Significant differences between the averages obtained were determined using Tukey test. Treatments in the same statistical group were grouped with the same letter and the results were interpreted.

2.2. Characteristics Related to Plant Yield and Quality

In the experiment, yield and quality characteristics of tubers obtained at the end of harvest were examined to see the effect of copper fungicide alone and in combination with plant activator (ISR-2000) on plant yield and quality characteristics.

Table 1. Characteristics of potato cultivars

CHARACTERISTICS	MARABEL	MELODY
Plant height	Middle	Middle
Flower Color	White	White
Maturity	Early	Mid Early
Tuber Shape	Oval	Oval-Flat
Tuber Color	Dark yellow	Light yellow
Average Yield	2228 kg da^{-1}	3475 kg da^{-1}
Late Blight Disease Resistance	Resistant	Middle

Table 2. Characterization of experimental units of fungicides applied against potato late blight in feld trials.

Commercial Name	Active Substance	Provider	Formulation	Application dose
Champion	%77 Copper hydroxide	Hektaş	WG	250 g da^{-1}
Aviso	Cymoxanil+Metiram (%4,8+57)	Basf	WG	200 g da^{-1}
ISR 2000	855,81 g/l Lactobacillus acidophilus	Alltech Crop Science	Liquid	100 g da^{-1}

Table 3. Some climate data during the potato growing seasons of Ödemiş, İzmir between 2016-2017 *

Months	Rainfall (mm)		Average temperature (°C)		Relative Humidity (%)	
	2016	**2017**	**2016**	**2017**	**2016**	**2017**
JANUARY	252.5	51.0	9.4	11.7	70.9	74.3
FEBRUARY	187.0	18.5	11.2	11.7	70.2	68.2
MARCH	56.8	50.2	14.0	13.2	58.5	60.7
APRIL	30.2	73.8	17.3	17.0	54.0	78.5
MAY	43.7	18.4	22.7	20.8	54.7	15.3
JUNE	27.1	45.2	25.7	25.0	50.7	53.0

* based on the Ödemiş-İzmir Meteorological Station records

Table 4. The disease rating scale for late blight.

Rating	Reaction Description
0	No infection
1	At least one leaf is infected on one of the 10 branches in the plant.
2	Usually, at least one leaf on each branch is infected, but the plant appears green.
3	50% of the leaf area in the plant is destroyed and necrosis.
4	75% of the leaf area in the plant is destroyed and necrosis.
5	All the leaves are dead, the stems are drying up,

2.3. Sampling and Isolation Studies

Since *Phytophthora infestans* is an obligate parasite, its isolation and development in culture medium is quite difficult. During the experiment, diseased plant samples were collected during the spring potato growing period and isolation studies were carried out using Rye A Agar medium, one of the selective media. The experimental field was carried out under natural inoculation conditions where the disease was observed in previous years and no artificial inoculation was applied to the plants (Caten and Jinks, 1968; Tosun et al., 2003).

3. Results and Discussion

In order to investigate the effect of copper fungicide alone and in combination with plant activator (ISR-2000) in the control of potato late blight disease (*Phytophthora infestans*), which is one of the biggest problems of potato cultivation, trials were carried out on Melody and Marabel potato cultivars during spring potato planting periods for two years in 2016 and 2017. As a result of the statistical analyses performed according to the data obtained, the statistical significance of the effects of variance sources on potato late blight disease and potato yield and quality characteristics are given in *Tables 5* and *6*. The effects of copper fungicide alone (Champion) and copper fungicide and plant activator (Champion + ISR-2000) combination on late blight disease and potato yield and quality traits in two potato cultivars are given in *Tables 7* and *8*. According to F values (*Tables 5* and *6*), the effects of year, variety and fungicide treatments on tuber number were found to be statistically significant at $p \leq 0.01$ level. The effect of the interactions of the factors on the number of tubers was found to be statistically insignificant. The highest number of tubers was obtained with the combination of copper fungicide (Champion) and plant activator (ISR-2000) in both potato cultivars under Ödemiş conditions (11.16 number/plant; 9.99 number/plant). According to the results obtained in this study, the combination of copper fungicide (Champion) and plant activator (ISR-2000) increased the number of tubers, which is similar to the statements of many researchers that plant activators have a positive effect on fruit number. In 2013, some researchers investigated the effect of plant activators alone

on potato tuber size and yield. They found that both activators used in the study increased the number of tubers compared to the control (Öztürk and Yıldırım, 2013). In another study conducted in 2003, researchers reported an increase in the number of tubers in potato plants treated with Crop-set and ISR-2000 compared to the control (Koca and Yıldırım, 2003). The development of the tuber depends on a good vegetative development and the transport of photosynthesis products synthesized in the leaves from the leaves to the tubers. It has been stated by various researchers that late blight disease not only prevents the tuber from reaching the desired size but also causes a decrease in the number of tubers of sufficient size (Glass et al., 2001; Güler et al., 2011).

The effects of cultivar, fungicide treatments and cultivar x fungicide interactions on tuber width were found statistically significant at p≤0.01 level. In both potato cultivars used in the experiment, the highest tuber width values were obtained in plots treated with Aviso fungicide followed by copper fungicide (Champion) and plant activator combination (ISR-2000). Some researchers have reported that tuber width values differ according to potato variety (Çalışkan et al., 1997; Yıldırım et al., 2005). The difference in tuber width measurements between cultivars is similar to the literature. According to the findings obtained in this study, copper fungicide and plant activator (ISR-2000) combination treatment resulted in an increase in tuber width compared to the control. The results obtained are similar to the findings of some researchers who have worked with the plant activator in potato (Öztürk and Yıldırım, 2013; Çalışkan et al., 2021).

Table 5. The F values of tuber number, tuber width(mm) and tuber length(mm)

Source of Variation	df	Tuber Number	Tuber Width (mm)	Tuber Length(mm)
Year	1	25.97^{**}	10.99^{*}	9.64^{*}
Cultivar	1	14.84^{**}	390.75^{**}	199.43^{**}
Treatment	3	55.72^{**}	976.83^{**}	1252.10^{**}
Year x Cultivar	2	0.08^{ns}	15.02^{**}	1.23^{ns}
Year x Treatment	3	1.50^{ns}	5.68^{*}	0.76^{ns}
Cultivar x Treatment	3	1.22^{ns}	25.57^{**}	2.92^{*}
Year x Cultivar x Treatment	3	0.10^{ns}	3.51^{*}	1.10^{ns}

*Significant at the p≤0.05 level
** Significant at the p≤0.01 level
ns non significant

Table 6. The F values of the single tuber weight (g), yield(kg/da) and disease severity (%)

Source of Variation	df	Single Tuber Weight (g)	Yield (kg da^{-1})	Disease Severity (%)
Year	1	11.44^{**}	1.90^{ns}	10.74^{*}
Cultivar	1	312.12^{**}	0.19^{ns}	12.95^{**}
Treatment	3	4223.86^{**}	1967.93^{**}	3881.28^{**}
Year x Cultivar	2	7.56^{*}	28.27^{**}	0.23^{ns}
Year x Treatment	3	4.55^{*}	8.26^{**}	2.41^{ns}
Cultivar x Treatment	3	16.5^{**}	6.67^{**}	0.99^{ns}
Year x Cultivar x Treatment	3	35.78^{**}	6.02^{*}	0.37^{ns}

* Significant at the p≤0.05 level
** Significant at the p≤0.01 level
ns non significant

The effect of cultivar and fungicide treatments on tuber length was found statistically significant at p≤0.01 level, while the effect of cultivar x fungicide interaction was found significant at p≤0.05 level. Among the fungicide treatments, the combination of copper fungicide (Champion) and plant activator (ISR-2000) was observed as the plots with the highest tuber length after the fungicide plots used as comparison in both potato cultivars. It was also reported by different researchers that tuber length values differed according to the cultivars used (Çalışkan et al., 1997; Yıldırım et al., 2005). In this study, the difference in tuber length among the cultivars is in parallel with the literature. In the experiment, an increase in tuber length was observed in the plots where copper fungicide (Champion) and plant activator (ISR -2000) combination was applied compared to the control.

In 2013, researchers reported that plant activators provided an increase in tuber length compared to control plots (Öztürk and Yıldırım, 2013). The results we obtained in terms of tuber length are in parallel with the literature.

Table 7. Means of treatments on late blight, tuber number, tuber width(mm) and tuber length(mm) in the field trial

Treatment	Tuber Number	Tuber Width (mm)	Tuber Length(mm)
Cultivar (Marabel)			
Champion	10.03±0.96a	60.73± 1.81b	83.13±2.14c
Champion+ISR2000	11.16±1.23a	68.15±1.39a	106.86±4.02b
Aviso	10.24± 0.72a	69.43±1.59a	113.11± 2.79a
Control	7.62±0.76b c	46.43±1.28c	57.46±2.32d
$LSD_{(0.05)}$	0.67	1.75	8.95
Cultivar (Melody)			
Champion	9.74±1.05a	65.23±1.60b	96.08±3.11b
Champion+ISR2000	9.99±0.99a	72.85±2.61a	118.84±2.65a
Aviso	9.28±0.48a	74.13±2.51a	121.65± 4.61a
Control	7.16±0.59b	52.42±1.70c	65.22±2.58c
$LSD_{(0.05)}$	0.43	2.30	8.19

* Means with the same letter in the same column are in the same group.

Table 8. Means of treatments on late blight, single tuber weight(g.), yield(kg/da), disease severity(%) and effect (%) in the field trial

Treatment	Single Tuber Weight (g)	Yield (kg da^{-1})	Disease Severity (%)	Effect (%)
Cultivar (Marabel)				
Champion	101.97±2.68c	3200.64±120.47c	40.38±3.20b	56.87
Champion+ISR2000	163.65±5.51b	4734.35±297.02b	25.38±3.50c	72.87
Aviso	180.62±3.64a	5103.13±257.59a	10.50±0.92d	88.67
Control	73.95±4.05d	1810.54±123.04d	93.75±1.48a	0.00
$LSD_{(0.05)}$	15.24	15511.78	6.22	
Cultivar (Melody)				
Champion	114.70±4.62c	3532.88±227.73b	37.63±3.02b	59.26
Champion+ISR2000	188.04±7.29b	4810.10±190.29a	22.13±2.29c	75.87
Aviso	198.70±6.02a	5064.34±306.95a	9.88±1.64d	87.29
Control	83.80±3.09d	1786.45±154.69c	92.00±2.92a	0.00
$LSD_{(0.05)}$	23.98	36840.82	4.36	

* Means with the same letter in the same column are in the same group.

Considering the potato single tuber weight, cultivar and fungicide treatments were found to be statistically significant at the p≤0.01 level. When the effect of the combination of copper fungicide and plant activator (ISR-2000) on potato single tuber weight was examined, it was observed that the highest tuber weight was obtained after the comparative fungicide treatment in both potato cultivars. It was reported by many researchers that the tuber weight values obtained in the studies differed according to the cultivars used. (Arslan and Kevseroğlu, 1991; Yıldırım et al., 2005). The difference in tuber weight parameters of potato cultivars is similar to the literature. In this study, cultivar x fungicide interaction was found to be statistically significant at the level of 1% in terms of average tuber weight. When examined in terms of the effect of the treatment, an increase in tuber weight was detected in both potato cultivars in the parcels where the combination of copper fungicide and plant activator (ISR-2000) was applied. In a study conducted by researchers working with plant activators in potato plant in 2013, it was reported that plant activator application increased single tuber weight compared to control (Öztürk and Yıldırım, 2013). The findings related to single tuber weight are like the literature.

When the effect of copper fungicide and plant activator (ISR-2000) combination on potato yield was analysed, it was 4734.35 kg/da. in Marabel potato variety and 4810.10 kg/da. in Melody potato variety. It was the plot with the highest yield value after the comparative fungicide treated plots. In this study, when the effect of variance

sources on yield per decare of potato was examined, the effect of fungicide treatments and cultivar x fungicide interaction was found to be statistically significant at the $p \leq 0.01$ level. This study, when the effect of the application on yield per decare was examined, in parcels where copper fungicide and plant activator (ISR-2000) combination is applied, a significant increase in tuber yield per decare was observed in both potato cultivars compared to the control. It is also stated by many researchers that potato late blight disease is a devastating disease and adversely affects yield and product quality. The findings obtained in this study on the effect of the treatments on the yield values per decare in potato are in parallel with the literature. (Doke, 1983; Grenville- Briggs et al., 2005; Whisson et al.,2007; Morgan and Kamoun, 2007; Haverkort et al., 2008).

The effect of fungicide applications on disease severity against potato late blight, which was the main objective of this study, was found to be statistically significant at $p \leq 0.01$ level. The lowest disease severity in both potato cultivars was observed in the plots where Aviso comparison fungicide was applied (10.50%; 9.88%). This was followed by the combination of copper fungicide and plant activator (ISR 2000) (25.38%; 22.13%). On the other hand, in the plots where copper fungicide was applied alone, 40.38% disease severity was observed in Marabel potato variety and 37.63% disease severity was observed in Melody potato variety. In the plots where the combination of copper fungicide and plant activator (ISR-2000) was applied, it was found to be an effective application in the control of potato late blight disease with 72.87% efficiency in Marabel potato variety and 75.87% efficiency in Melody potato variety. In the plots where copper fungicide was applied alone, 56.87% effect was observed in Marabel potato variety and 59.26% effect was observed in Melody variety against potato late blight disease compared to the control plot. Supporting the findings of this study, it was reported that the combination of plant activator and copper preparations against tomato bacterial spot disease increased the success in suppressing the disease and prolonged the effect of spraying in a trial conducted in 2003 (Karabay et.al., 2003). Similarly, in a study conducted in tomato in 2005, it was found that the combination of copper hydroxide and plant activator was more effective against bacterial plant diseases when applied together than when applied alone (Türküsay and Tosun, 2005). Some researchers have also stated that the use of plant activators together with fungicides is more effective in the control of plant diseases. It was emphasised that plant activators are more preferable than classical chemical control methods due to the low risk of developing resistance against pathogens and providing long-term protection. In addition, in a study conducted in tomato, some researchers reported that the combination of copper hydroxide and plant activator was effective on tomato late blight disease (Tosun and Ergün, 2002). In a study published in 1997, it was reported that the application of a combination of plant activator and fungicide against grain powdery mildew (Erysiphe graminis) provided 82% protection, while the combination of plant activator with metalaxyl-M fungicide against tobacco downy mildew largely prevented the disease (Novartis, 1997). The results of this study are in parallel with the results of many researchers that plant activators increase plant resistance against plant diseases (Werner et al., 2002; Karavaş, 2002; Karabay et al., 2003; Çetinkaya and Aysan, 2005; Üstün et al., 2005; Boyraz et al., 2006; Delisoy and Altınok, 2019; Karabüyük and Aysan, 2019; Aktepe, 2021).

4. Conclusions

As a result, the combination of copper fungicide and plant activator (ISR-2000), one of the contact-acting fungicides, was found to be significantly effective against potato late blight disease compared to control plots. In the study, it was determined that late blight disease had a significant effect on plant growth characteristics and yield of potato. When potato late blight disease was controlled, it was observed that more and high quality products could be obtained from unit area. There was no difference between the cultivars in terms of resistance to potato late blight disease in the spring potato growing period. The data obtained in this study support the inclusion of copper fungicide and plant activator (ISR-2000) combination in integrated control programmes against fungal diseases in potato production areas. When the results obtained in this study are evaluated in general, it is concluded that the use of plant activators and contact fungicides together in the treatment of fungal diseases in potato production areas will be guiding for potato producers due to its benefits such as increased effectiveness of contact fungicides against the disease, no residue risk, increase in yield and quality.

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