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The Search For Nature-Friendly Solution To Late Blight (Phytophtora Infestans) Disease

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Abstract – Potato is the most important food source after cereals in plant nutrition. During potato cultivation , potato late blight disease caused by *Phytophtora infestans* causes significant quality and yield losses. Potato late blight can be controlled with synthetic fungicide applications. On the other hand, the resistance of the agent to fungicides and public concerns about food safety, environment and human health have led to the need to search for alternative disease control strategies. In our study, in inhibitory effects of sodium bicarbonate, horticultural oil, potassium soap combination and apple vinegar againts *Phytophtora infestans* were investigated by experimating in field conditions during the spring potato production season. As a result of the experiment, it was observed that the combination of sodium bicarbonate (SBC), potassium soap (PS) and horticultural oil (HO) was effective treatment compared to the control plot both in potato quality and yield criteria and in the control of potato late blight. Among the treatments, SBC+PS+HO combination ranked first with 61.75% disease severity and 35.25% effect. In apple vinegar treatment and 75.63% disease severity and 19.38% effect has been observed. It was concluded that both treatments can be an alternative to synthetic chemical fungicides in the control of potato late blight disease, especially for organic potato and hobby garden producers.

Keywords – Sodium bicarbonate ($NaHCO_3$), Potassium soap, Horticultural oil, Apple vinegar, Late Blight.

I. Introduction

Potato is the most widely cultivated tuberous vegetable worldwide. Potato, which plays the second largest role in plant-based nutrition after cereals, is a cultivated plant originating from the high Andes Mountains in South America. Solanum tuberosum is the most widely known and cultivated species in the World [1]. Today, potato which is an important source of energy and meets the basic food requirement of the people due to valuable nutrients it contains, is consumed in kitchen by cooking as a meal, as well as by processing in different ways in the industry (chips, frying, mash etc.). Potato tubers that cannot be consumed as food and are not in industry can be used as animal feed. Potato plant makes great contributions to the economy of the producer and the country in the countries where it is grown due to the high amount of product obtained from the unit area. Potato, which is one of the staple foodstuffs of many counries due to its different usage areas and the fact that it can be consumed in various ways, is consumed as a carbonhydrate source in Germany, the Netherlands, Ireland, Fransa and USA in Europe ([2], [3]). According to the data of 2020, the cultivation area of potato in our country is 147.965 hectares, the production amount is 5.200.000 tons and the yield obtained from unit area is 3514 kg/da [4]. Potato contains carbonhydrate, protein and mineral substances as well as vitamins B1, B2 and B6 with a large proportion of vitamin C [5]. The basic condition for a healty, efficient and high quality production is that the seed, which is the basic input of plant production, is qualified. Vegetative propagation of potato by tuber is easily affected by many disease agents, especially fungi, and other physiological negativities due to the fact that the tubers are an organ containing a high proportion of water [6].

Late blight disease, caused by the oomycete pathogen *Phytophthora infestans*, is one of the most serious tomato and potato diseases worldwide. It is a disease that can cause significant yield losses and serious economic problems for potato producers [7]. The disease can occur in a wide range of climatic conditions and, if left uncontrolled, causes the plant to dry out completely.

Severe economic losses of up to 90% occur when the disease occurs early in the growing season [8]. Late blight is characterized by rapidly expanding white lesions on the leaf surface of susceptible potato varieties. A few days after the first lesions are observed, the entire disease can destroy the entire plant. Between 1846 and 1851, P. infestans caused a famine in Ireland which caused 1 million people deaths and 2 million people had to emigrate to many countries, especially America [9]. The cause of potato damage was identified by DeBary in 1876 as a plant pathogen called late blight (*Phytophthora infestans*). The beginning of the science of phytopathology was in those years with the experiments of Antony De Bary on potato mildy mildew ([10], [11]). Although it is very easy to access all kinds of commodities in a globalized world, a problem caused by a plant pathogen can trigger food supply crises on a global scale. In today's world of rapid movement of people and commercial goods, the spread of such disease agents from one area to another is also rapid. The increasing need for food due to population growth has led to an intensification of the world trade in crop production and an increase in the risk of transporting harmful organisms with this trade. Fungicide application is the most commonly used control method to control potato late blight disease in susceptible potato varieties ([12], [13]). Uncontrolled and large-scale application of fungicides causes environmental pollution. It also develops resistance to pathogenic fungicides over time ([14], [15], [16]). Fungicides therefore do not represent a continuous and sustainable control method. However, among the methods of controlling harmful organisms, chemical control is the most preferred method in our country as in the whole world due to its advantages such as being easier to apply and getting effective results in a short time. Unconscious and uncontrolled application of pesticides has become a major health problem for humans and the environment [17]. As a result of scientific studies, pesticides have been found to cause tumors or cancer, infertility, mental retardation and other problems in non-target organisms and their use has been restricted or banned [18]. Despite these restrictions, it is seen that the use of pesticides in some regions of our country is very intensive and at the same time unconscious. ([19], [20]). In particular, famines caused by major epidemics or an increase in the need for food in direct proportion to population growth have increased the importance of the struggle. In recent years, researchers have focused on alternative ways to combat diseases, as the harm of intensive use of pesticides to humans and nature has become better understood. In some studies conducted in this framework, substances of natural origin such as carbonate, phosphate salts, vinegars, vegetable oils and silicates have started to be included in alternative control programs ([21], [22], [23], [24]). Preparations called pesticide soaps, for example potassium soap, contain potassium fatty acids. Pesticide soaps are used as an alternative to insecticides, herbicides, fungicides and algicides. For soap to be particularly effective against insects, it must come into direct contact with the insect in liquid form. After drying, the effect on the insect decreases. Soaps are effective by preventing the insect from breathing. Pesticide soaps are often used to control soft-bodied insects such as aphids, thrips. Hard-shelled insects such as ladybirds and other beetles are less affected by soaps [25]. Sodium bicarbonate has been used as a fungicide against fungal diseases since 1933. It has antacid properties. The use of sodium bicarbonate (NaHCO3) and potassium bicarbonate (KHCO3) in the control of various fungal diseases in plants has increased in recent years ([26], [27]). In 1985, Lindsay found that sodium bicarbonate suppressed various fungal diseases of cucumber plants. Spraying plants with sodium bicarbonate (NaHCO3) solution has been reported by several researchers to provide good control of various plant diseases ([21], [28], [29], [30], [31], [32]). Sodium or potassium bicarbonate combined with oil has been effective in controlling plant diseases ([33], [34]). Oils are actually products that act as adjuvants in pesticide applications, especially in the control of narrow-leaved weeds ([35], [36]). Adjuvants are products that increase the residence time of the products they are used with on the leaves of the plants, thus increasing their duration of action, and that spread and adhere easily on the leaves. There are two types of adjuvant oils: petroleum (mineral) oils refined from petroleum and vegetable oils derived from seed oils. In agricultural areas, mineral oils were first used, and vegetable oils were introduced in the following periods. The use of vegetable oils and their esters for plant protection in agricultural areas is increasing day by day due to their environmental friendly properties such as high biodegradability and renewable raw materials [37]. Vegetable oils (olive oil, soybean oil, etc.) are used as natural alternatives to fungicides ([38]. In trials, apple vinegar has been shown to be a natural product against pathogens that cause disease in humans: The effect of apple vinegar and other natural vinegars on plant diseases is also being investigated. Many researchers have reported that apple vinegar has an inhibitory effect against fungal and bacterial pathogens ([39], [40], [41]). The healing properties of apple vinegar are thought to be due to its organic acids and bioactive substances. It is also antimicrobial thanks to its phenolic acids and flavonoids. Apple vinegar contains maleic acid, which is reported to be used in the treatment of many diseases. Thanks to its maleic acid, apple vinegar has bactericidal and fungicidal properties ([42], [43], [44], [45], [46]).

Our study was carried out to see the effect of sodium bicarbonate, horticulture oil and potassium soap combination and apple vinegar alone as an alternative to synthetic chemical preparations in order to protect the environment and human health in the solution of potato late blight disease, which causes significant yield loss in potato.

II. Materials And Methods

In our experiment, we aimed to demonstrate the applicability of natural origin and environmentally benign substances in the control of *Phytophtora infestans.* The effect of natural preparations on potato plant growth traits was also evaluated. For this purpose, the experiment was carried out in the field of our college located in Ödemiş district of İzmir in a two-year period between February and June, which is the spring potato production season, in 2016-2017. Our aim is to put forward a sustainable method of combating potato late blight disease with natural, nature-friendly, residue-free preparations that we use at home as an alternative to synthetic chemical pesticides. Marabel potato variety, which is an early variety widely used in the region, was used as material in the experiment. It was aimed to determine the effect of sodium bicarbonate (NaHCO3), potassium soap, horticultural oil combination and apple cider vinegar alone on mildew disease and potato plant growth characteristics. A 16 lt. water capacity, manual arm, back-type sprayer was used for spray applications. The doses of the preparations used were applied as indicated in the literature (Table 1) ([47], [48], [49], [50], [51], [52]).

Table 1. Preparations and Doses Used in the Trial (Tezcan, 2012).

Application Preparations	Application Dosage	Formulation
Sodium bicarbonate (SB)	5 gr / 4 lt. water	Solid (in powder form)
Potassium Soap (PS)	5 ml / 4 lt. water	Liquid
Horticultural oil (HO)	5 ml. /4 lt. water	Liquid
Apple Vinegar	15 ml. /4 lt. water	Liquid

In this study, it was aimed to determine the effectiveness of sodium bicarbonate, potassium soap, horticultural oil and apple cider vinegar against potato late blight disease in the spring potato production season under field conditions. The experiment was carried out as a green part spraying. The effectiveness of the preparations in combination depends on their effect on each other. Sodium bicarbonate is highly alkaline when mixed with water. Fungal spores germinate best in acidic conditions. Because of this property, sodium bicarbonate inhibits or slows down the growth of fungal spores. Horticultural oil is important as it makes sodium bicarbonate more effective. It also helps the sodium bicarbonate to stick to the plant. Potassium soap provides better adhesion of water and sodium bicarbonate to the leaf. Its most important feature plays a role in the mixing of water and oil [53].

In the field where late blight disease was observed every year, our trial was carried out under natural inoculation conditions. The experiment was planned as 3 characters (2 treatments + 1 control) and 4 replicates according to the randomized block design. Each plot was established with 20 plants after edge effects. Isolation rows of 1 m in length were left between the plots so that the treatments were not affected from each other. Before spraying, the plots were calibrated to determine the amount of water to be used. Control plots were only sprayed with water. All maintenance operations were carried out in the same way in all plots to avoid any difference. Seeds were sown in the second half of January. Potato harvest was done in the second half of June. Spraying started when the first symptoms of potato mycelia were detected. According to weather conditions, a total of 4 sprays were sprayed at 7-day intervals. The assessment of potato late blight disease was carried out in accordance with the method recommended by the Ministry of Agriculture and Forestry. The 0-5 scale in the same method was used for the evaluation. 0: No disease, 1: At least one leaf in one of the 10 branches of the plant is infected, 2: Usually at least one leaf in each branch is infected but the plant looks green, 3: 50% of the leaf area of the plant is destroyed and necrosed, 4: 75% of the leaf area of the plant is destroyed and necrosed, 5: All leaves are dead and the stems are drying [54]. As a result of the counts, the Towsend-Heuberger formula was used to determine the severity of the disease and the Abbott formula was used to determine the effectiveness of the treatments [55], [56]. SPSS version 25.0 statistical package program was used to compare the parameters obtained as a result of the applications. Duncan's test was used to determine the differences between the averages of the treatments at $p \leq 0.05$ significance level. The treatments in the same statistical group were grouped with the same letter and the results were interpreted [57].

In this study, in order to see the effect of treatments on potato yield and quality traits in the spring potato production season, yield and quality traits such as tuber number, tuber width, tuber length, single tuber weight, yield per decare were examined in the tubers obtained from the plots at the end of harvest. The number of tubers harvested from each plot was counted and divided by the number of plants in the plot to calculate the number of tubers (number/plant). The width (mm/plant) of the tubers in the plot was measured with the help of calipers. The stolon and crown region parts of the potato tubers were determined as the tip part and the tuber length (mm/plant) was determined by measuring with calipers. After determining the total yield in the plots, the single tuber weight (g/plant) of the variety was determined by dividing by the total number of tubers. The tubers obtained from all of the plots within the harvest area were weighed and the tuber yields of the plots were calculated first and then the yields per decare (kg/ha) were calculated [58].

For the isolation of potato late blight agent (*P.infestans*), which is very difficult to grow in culture medium, diseased plant samples were collected during the vegetation period and brought to the laboratory. Then, the plant parts were placed in sterile petri dishes with the fungal growth parts facing upwards. Potato slices disinfected with 0.5% sodium hypochlorite solution were placed on them. Petri dishes were kept in an incubator at 18ºC for 5-7 days. Then, hyphae fragments taken from the mycelial mass developing on potato slices were grown on Rye A agar, one of the selective media [59].

III. Results And Discussion

This study was carried out in the spring season in marabel potato variety, which is the most preferred potato variety as edible against late blight disease, which is one of the destructive diseases of potato. The aim of the experiment was to observe the effect of sodium bicarbonate, potassium soap and horticultural oil combination and apple vinegar on potato late blight disease and potato yield and quality characteristics. In the 2016 and 2017 spring season, the results of the analysis of variance of the examined values such as tuber number, tuber width, tuber length, single tuber weight, yield per decare and disease severity are given in Tables 2 and 3. The averages of the effects of the treatments on potato quality and yield criteria and late blight disease are given in Tables 4, 5 and 6.

As a result of the analysis of variance, the effect of pesticide treatments on tuber number was found to be statistically significant at p≤0.01 level. The effect of the combination of sodium bicarbonate (SBC), potassium soap (PS) and horticultural oil (HO) on the number of tubers was higher than apple vinegar and control plots (9.20 number/plant).

Table 2. Tuber number, tuber width and tuber length f values of potato quality criteria for 2016 and 2017

Source of Variance	df	Tuber number	Tuber Width (mm.)	Tuber length (mm.)
Year	1	24.82*	8.70$^{n.s.}$	1.15$^{n.s.}$
Treatment	2	11.61**	75.61**	80.59**
YearxTreatment	2	3.47$^{n.s.}$	0.48$^{n.s.}$	0.59$^{n.s.}$

*p≤0.05, ** p≤0.01 , n.s. not significant

Table 3. Single tuber weight, yield per decare and potato yield criteria for the years 2016 and 2017

f values of disease severity

Source of Variance	df	Tuber weight (g)	Yield per decare (kg/da.)	Disease severity (%)
Year	1	0.62 $^{n.s.}$	3.52 $^{n.s.}$	0.10 $^{n.s.}$
Treatment	2	39.93**	88.93**	207.44**
YearxTreatment	2	1.46 $^{n.s.}$	0.51 $^{n.s.}$	0.15 $^{n.s.}$

*p≤0.05, ** p≤0.01 , n.s. not significant

According to the analysis of variance of tuber width, tuber length, single tuber weight and yield per decare criteria, pesticide applications were found to be significant with 99% confidence. The highest tuber width (56.00 mm.), tuber length (74.00 mm.), single tuber weight (91.50 g.) and yield (2581.50 kg/ha) values were obtained from the plots where SBC+PS+HO combination was applied. An increase in quality criteria was also observed in apple vinegar treated plots compared to the control plot.

Table 4. Mean effects of treatments on tuber number, tuber width and tuber length criteria in 2016 and 2017

Treatment	Tuber number			Tuber Width (mm.)			Tuber length (mm.)		
	2016	2017	Ort.	2016	2017	Ort.	2016	2017	Ort.
SB+PS+HO	9.41a	9.00a	9.20A	55.25a	56.75a	56.00A	72.75a	75.25a	74.00A
A.V.	8.75ab	7.25b	8.00B	50.00b	50.75b	50.38B	64.33b	64.00b	64.16B
Control	8.16b	7.00b	7.58B	45.75c	47.25c	46.50C	57.00c	58.00c	57.50C
$LSD_{(0.05)}$	0.93		0.66	1.88		1.33	4.10		2.90

SB: Sodium Bicarbonate, PS: Potassium Soap, HO: Horticultural Oil, AV: Apple Vinegar; Treatments with the same letter are in the same group. The averages of the pesticide treatments are expressed in capital letters.

Table 5. Mean effects of the treatments on single tuber weight and yield per decare criteria in 2016 and 2017

Treatment	Tuber weight (g)			Yield per decare (kg/da.)		
	2016	2017	Ort.	2016	2017	Ort.
SB+PS+HO	92.50a	90.50a	91.50A	2560.75a	2602.25a	2581.50A
A.V.	81.50b	82.50b	82.00B	2004.75b	2077.75b	2041.25B
Control	71.50c	76.50c	74.00C	1731.75c	1889.50c	1810.63C
$LSD_{(0.05)}$	5.54		3.91	181.42		128.28

SB: Sodium Bicarbonate, PS: Potassium Soap, HO: Horticultural Oil, A.V.: Apple Vinegar; Treatments with the same letter are in the same group. The averages of the pesticide treatments are expressed in capital letters.

In the analysis of variance of the treatments on the control of potato late blight disease, the effect of the treatments was found to be statistically significant at $p \leq 0.01$ level. It was determined that the combination of SBC+PS+HO had an effective antifungal performance in the treatment of potato late blight disease compared to the control with 61.75% disease severity and 34.25% effect of the application on the disease. In the plots treated with apple cider vinegar, 75.63% disease severity and 19.38% effect against potato late blight disease were observed. Compared to the control plot (93.50%), both treatments were effective in the control of potato late blight disease.

Table 6. Mean effects of treatments on potato late blight disease in 2016 and 2017

Treatment	Disease Severity (%)			Effect (%)		
	2016	2017	Ort.	2016	2017	Ort.
SB+PS+HO	61.50c	62.00c	61.75C	34.75	33.75	34.25
A.V.	76.25b	75.00b	75.63B	18.75	20.00	19.38
Control	94.00a	93.50a	93.75A	0.00	0.00	0.00
$LSD_{(0.05)}$	4.57		3.23			4.48

SB: Sodium Bicarbonate, PS: Potassium Soap, HO: Horticultural Oil, A.V.: Apple Vinegar; Treatments with the same letter are in the same group. The averages of the pesticide treatments are expressed in capital letters

Although there is literature recommending the combination of SBC+PS+HO that we applied in our study, no literature was found in which this application was used. There is a large number of literature indicating that the materials used in the combination have antifungal effects against various fungal diseases when applied alone or in binary combinations. Palou et al. 2001 reported that sodium bicarbonate alone was effective in controlling a wide range of fungal diseases in many plant species. They also noted that sodium bicarbonate is readily available, cheap and has a low risk of phytotoxicity [60]. It has been reported by many researchers that carbonate and bicarbonate salts are fungicidal to *Sclerotium rolfsii* and suppress powdery mildew disease in squash ([61], [62], [63], [64], [65], [66], [67]). Some researchers have tried various oils in mildew diseases to see their fungal effects. In a study conducted with mineral oil in pumpkin, it was reported that mineral oil significantly suppressed mildew disease (Collina, 1996). In another study, it was reported that horticultural oil was effective in reducing the size and pustules of cucumber mildew disease [68]. They reported that the combination of bicarbonate and horticultural oil provided very good protection against a large number of pathogens under greenhouse conditions. Under field conditions, they reported that the combination of bicarbonate and horticultural oil was effective against powdery mildew disease in pumpkin [34]. Helmy, 2016, in a study on chamomile grown for medicinal purposes, reported that the combination of sodium bicarbonate and mineral oil was successful in controlling powdery mildew disease under greenhouse and field conditions and that plant quality criteria were also improved compared to control plots [69]. Although there is no study on the combination we applied in our study, the positive effects obtained against fungal pathogens in studies conducted with the materials in the combination are in parallel with our study. It was reported that apple vinegar reduced the bacterial cancer and wilt disease *Clavibacter michiganensis subsp. michiganensis* (Cmm), a seed-borne pathogen in tomato, in seed applications. There are numerous studies showing that apple vinegar is effective in controlling many fungal and bacterial pathogens ([70], [71], [72], [40], [46]). It has been reported that apple cider vinegar can be used for surface sterilization against different fungal pathogens such as monilia disease (*Monilia fructicola*) in stone fruits, lead mold (*Botrytis cinerea*) in strawberries and blue mold agent (*Penicillium expansum*) in apples [73]. In our study, although a very high effect was not observed in the plots where apple vinegar was used, it was observed to be effective in the control of potato late blight disease compared to the control. These results are in parallel with the literature.

IV. Conclusion

Since synthetic chemical pesticides used in the treatment of potato late blight disease have become a threat to both human and environmental health, it has become obligation to search for alternative environmentally friendly practices. The materials we used in our study are the materials we use in our homes when preparing food, which are accessible, cheap, have no durability problems, and have no harmful effects on humans and nature. High potato quality and yield criteria depend on healthy of potato plants. As revealed in our study, the control against fungal diseases such as potato late blight, which affect potato yield and quality, and the increase in yield quality criteria are interdependent. Our study is the first trial of home-made preparations against potato late blight disease in Turkey. The combination of sodium bicarbonate, potassium soap, horticultural oil and apple vinegar were effective in the control of late blight disease under field conditions compared to the control plot. When using eco-friendly homemade preparations, it is important to remember that they should always be tested on a small part of the plant first to make sure that they will not harm our plants. Also, using bleach-based soap should be avoided, as it can be harmful to plants. To avoid phytotoxicity of the plant with home-made preparations, it is important that the application is not carried out during the hot hours of the day or when the sun is high in the sky. The use of these materials as natural alternatives to synthetic fungicides will be of particular interest to hobby gardeners and producers of organically grown crops. We believe that our study is important for guiding future studies on this subject.

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