



Research Article

Effects of Solid and Liquid Vermicompost Application on Bean Growth and Common Bacterial Blight Disease in Different Growth Medium

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Abstract. In this study, the effect of solid and liquid forms of vermicompost on plant growth and bacterial common blight disease in different growth media were investigated. Vermikompost was applied at the rate of 1/100, 1/150, 1/200 in liquid form and vermicompost in solid form at the rate of 10%, 20%, 40% to peat and soil growing medium. The pathogen, *Xanthomonas axonopodis* pv. *phaseoli* (Xap), was applied to the leaves by spraying at a concentration of 10^7 CFU mL⁻¹. The effects of applications on plant growth parameters, total chlorophyll content, and disease severity were evaluated. It was determined that the effects of the applications varied according to vermicompost form and growth medium. Liquid vermicompost applications displayed more positive effects on root growth in the soil growing medium. However, the application of liquid vermicompost did not affect disease severity. It was observed that the 40% dose of vermicompost in solid form inhibited plant growth and caused chlorosis in both growth media. However, 10 and 20% of doses had no adverse effects on plant growth. Also, the application of 10% solid vermicompost to peat growing medium reduced the disease development by 48%. In soil growth medium, application doses of 10% and 20% prevented disease development by 62% and 54%.

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Katı ve Sıvı Solucan Gübresi Uygulamalarının Farklı Yetiştirme Ortamlarında Fasulye Gelişimine ve Bakteriyel Adi Yaprak Yanıklığı Hastalığına Etkileri

Anahtar kelimeler:

Vermikompost, fasulye, *Xanthomonas axonopodis* pv. *phaseoli*, biyolojik kontrol

Özet. Bu çalışmada, katı ve sıvı formlardaki Vermikompostun farklı yetiştirme ortamlarında bitki büyümesi ve bakteriyel adi yaprak yanıklığı hastalığına etkisi araştırılmıştır. Vermikompostun sıvı formu 1/100, 1/150, 1/200 oranlarında, katı formu ise %10, %20, %40 oranlarında torf ve toprak yetiştirme ortamına uygulanmıştır. Fasulye yaprak patojeni, *Xanthomonas axonopodis* pv. *phaseoli* (Xap), 10^7 CFU mL⁻¹ konsantrasyonda yapraklara püskürtülerek uygulanmıştır. Uygulamaların bitki büyüme parametrelerine, toplam klorofil içeriğine ve hastalık şiddetine etkileri değerlendirilmiştir. Genel olarak uygulamaların bitki gelişimi ve hastalık şiddetine etkileri vermicompost formuna ve yetiştirme ortamına göre değiştiği belirlenmiştir. Sıvı vermicompost, toprak yetiştirme ortamında kök gelişimi üzerinde daha olumlu etkiler göstermiştir. Bununla birlikte, sıvı vermicompost hastalık şiddetini etkilememiştir. Katı vermicompostun %40'lık dozunun bitki büyümesini engellediği ve her iki büyüme ortamında kloroza neden olduğu belirlenmiştir. Bununla birlikte, %10 ve %20'lik dozların bitki büyümesi üzerinde hiçbir olumsuz etkisi gözlenmemiştir. Ayrıca, torf yetiştirme ortamına %10 katı vermicompost uygulanması hastalık gelişimini %48 oranında azaltmıştır. Toprak ortamında ise %10'luk katı formdaki vermicompost %62, %20 dozunda ise %54 oranında hastalık gelişimini önlemiştir.

INTRODUCTION

The concept of vermiculture, which started in the second half of the twentieth century and started industrial production in the 1980s; is defined as the process of ripening organic wastes via earthworm (Saday, 2013). Vermicompost, is obtained by consumption of fermented waste by earth worms such as *Eisenia spp.*, *Perionyx excavates*, *Dendrobaena veneta* and *Lumbricus rubellus* earthworms (Dominguez and Edwards, 2011). Factors such as high content of organic matter and plant nutrients which are almost fully absorbable, increase in beneficial microbial activity and improvement in physical structure of soil give vermicompost a unique place in agricultural production (Bellitürk and Görres, 2012). Vermicompost may contribute to germination, rooting, growth and early ripening of the plant. Also, benefits such as support to sustainable waste management, absence of production waste, potential to reduced utilization of chemical pesticides and fertilizers make it an economic and environmentally friendly production input in agricultural production (Edwards *et al.*, 2010; Vanlı and Bedük, 2013).

The common bean is widely produced all over the world and consumed in different forms as an important economic product. However, beans are subject to many diseases and pest attacks which account for significant crop losses (Graham and Ranalli, 1997; Singh and Schwartz, 2010). One of the most important disease is common bacterial blight disease caused by *Xanthomonas axonopodis* pv. *phaseoli* (Xap). The pathogen can be observed in all bean producing continents and causes significant yield losses (CABI, 2019). Xap effects leaves, shoots, pods, and seeds. The agent is seedborne and can enter the plant through natural openings and wounds. The bacterial agent that settles under the seed coat can remain alive for many years (EPPO, 2006; CABI, 2019). In intensive infections, the disease can cause up to 40% yield loss (Singh and Miklas, 2015). Despite some methods have been proposed to control the disease, the most commonly used approach is chemical control with pesticides. Against the relative success achieved by the pesticide, intensive use of chemicals has led to negative effects on environmental health, it also causes pathogens to develop resistance to these chemicals (Vidaver, 2002; Bruce, 2010; Griffin *et al.*, 2017). On the other hand, organic inputs promoting contribute to plant health and development are gaining increasing interest. In this context; vermicompost and vermicompost extracts have an important potential to contribute to yield and plant health.

Vermicompost and its extracts can contribute to plant growth in many ways. Though this contribution can be at different levels depending on soil structure, plant type and species, vermicompost raw material and formation process and the application dose and type (Franke-Whittle *et al.*, 2019). In general, vermicompost may enhance plant development; i) by providing micro and macro nutrients and facilitating their absorption ii) by increasing the concentration of humic acid in the soil, iii) by supplying plant hormones, iv) by increasing soil porosity and moisture retention capacity, v) by changing soil mass density and pH vi) increasing microbial activity (Sarma *et al.*, 2010; Simsek-Ersahin, 2011; Datta *et al.*, 2016).

The vermicompost in different forms, has the potential to be used against diseases and pests in addition to its contributions to plant growth and yield. Studies conducted with vermicompost products have generally focused on soil-borne diseases or root pathogens. In vitro studies have shown that the effect levels of vermicompost extracts against fungal and bacterial plant pathogens vary according to microorganisms (Tutar, 2013). In addition, in vivo studies with vermicompost show significant inhibition of diseases caused by pathogens such as: *Pythium solani* and *Verticillium sp.* (Chaoui *et al.*, 2002; Edwards and Arancon, 2004), *Rhizoctonia solani*, *Fusarium spp.* (Chaoui *et al.*, 2002), *Sclerotium rolfsii* (Sahni *et al.*, 2008), *Erwinia chrysanthemi* (Kharayat and Singh, 2016) *Ralstonia solanacearum* (Singh *et al.*, 2017).

Edwards and Arancon (2004) and Simsek-Ersahin (2011) stated that the effect of vermicompost applications to inhibit plant diseases is biological, rather than chemical. Disease inhibition mechanisms of vermicomposts are defined in two types as "general and specific" (Edwards and Arancon, 2004; Simsek-Ersahin, 2011). It is reported that General inhibition occurs by activation of one or more mechanisms such as; competition, antibiosis, hyperparasitism and stimulated plant resistance (Sarma *et al.*, 2010; Simsek-Ersahin, 2011; Datta *et al.*, 2016). The second type of disease inhibition mechanism is the "specific suppression", by which a narrow pathogen group or a pathogen is suppressed (Edwards and Arancon, 2004; Simsek-Ersahin, 2011). Increased microbial activity and diversity in soil is an important factor in both mechanisms (Sarma *et al.*, 2010; Simsek-Ersahin, 2011; Datta *et al.*, 2016). Furthermore, the most important factor that distinguishes vermicompost from other composts is solomic fluid. Wang *et al.* (2006) stated that during the formation process of vermicompost, solomic fluid within the digestive systems of the worms mixes with the manure and imbues it with anti-microbial properties.

In this scope, studies on the control of bacterial leaf pathogens the application of different vermicompost forms to the different growing medium and on plant growth are very limited. In this study, the effects of vermicompost of solid and liquid forms on plant growth parameters and against common bacterial blight disease

caused by the leaf pathogen *Xanthomonas axonopodis* pv. *phaseoli* (Xap) on common bean at different growth medium (soil and peat) were investigated.

MATERIAL AND METHOD

Vermicompost Preparation

Vermicompost was used in two different forms as solid vermicompost (VC) and liquid vermicompost (VS). The general characteristics of vermicomposts are given in table 1.

Solid vermicompost (VC): The worm food prepared for the production of solid vermicompost consists of a mix of 85-90% cow dung which passed through manure separator and 10-15% of household and garden waste (tea pulp, fruit and vegetable wastes). *Eisenia fetida* worms, which were left in 80*120 cm size plastic crates with grids at the bottom, were fed periodically with the food. The worms in plastic crates incubated at 18-24°C. The feeding was made once per week, for 8-10 thousand worms per square meter with a height of 5-7 cm. As a result of the weekly feeding, the food that the worms turned into fertilizer reached a height of approximately one meter within 4 months. In order to separate worms from the fertilizer, small crates with fresh food used to lure them. For the purpose of moisture reduction, the fertilizer was taken out of plastic crates and laid on covered concrete floor with air circulation and reversed weekly. After three months of moisture reduction and rest, solid worm fertilizer (vermicompost - VC) moisture level was lowered approximately to 20-30% (It was dried up to level that could be sieved) (Edwards, 2004). Subsequently is was sieved to be made ready for use.

Liquid vermicompost (VS): The other form of worm fertilizer used in the study, is a commercial preparation obtained from the same worm species (*Eisenia fetida*) (Cansuyu Organic Liquid Worm, Turkey) (Table 1)

VC was applied to the growing media by mixing 10%, 20% and 40% (w/w) in three different ratios (Edwards and Arancon, 2004). VS was again prepared in three different doses by diluting 1/100 (recommended dose by producer), 1/150 and 1/200 (v/v) with water. Prepared VS suspensions were applied twice as 20 ml plant⁻¹ by drenching method after seed sowing and 24 hours before pathogen inoculation (Table 2).

Table 1. Solid vermicompost (VC) and liquid vermicompost (VS) properties used in the study.

Çizelge 1. Çalışmada kullanılan Katı vermikompost (VC) ve sıvı vermikompostun (VS) özellikleri.

Content	VS	VC
Total organic matter	%58	%52.3
Total Nitrogen	%0.82	%4.1
Total Humic and Fulvic Acid	%35.67	%46.1
Water soluble Potassium oxide	3.63	2.9
Total Phosphor Pentaoxide (P ₂ O ₅)	-	%2.1
Microbial density (CFU mL ⁻¹)	8.6x10 ⁷	-
pH	9.02	8.1

Pot Experimental Design

Seeds of common bean (*Phaseolus vulgaris* cv. Gina) were planted in 300 ml plastic pots filled with two different growth medium which consists of sterile peat, and soil/perlite/animal manure (1/1/1) mix. The pots were kept in the climate chamber at 24 °C for plant growth (16 hours of light and about 50% humidity): Hoagland nutrient solution was regularly applied for the nutrient needs of bean seedlings grown in peat.

Pathogen Inoculation and Disease Suppression Analysis

The pathogen, *Xanthomonas axonopodis* pv. *phaseoli* (Xap), isolated from common bean in Antalya, Turkey, was provided by Prof Dr Hüseyin Basım (Faculty of Agriculture, Akdeniz University, Antalya, Turkey). When the bean seedlings were at a three-leaf stage, the pathogen was inoculated by spraying. For this purpose, Xap grown on TSA medium (1.7 g L⁻¹ tryptone, 0.3 g L⁻¹ soybean peptone, 0.25 g L⁻¹ glucose, 0.5 g L⁻¹ NaCl, 0.5 g L⁻¹ K₂HPO₄ and 15 g L⁻¹ agar) at 28 °C for 48 h was inoculated. Xap suspension was prepared from this fresh culture at density of 10⁸ CFU mL⁻¹, (0.01% the Tween added). Immediately after pathogen application, seedlings were kept in polyethylene cabins for 48 hours in the climate chamber (kept in the dark for the first 24 hours) in order to generate high humidity for pathogen development

On the 21st day after pathogen application, disease symptoms is scored according to scale 1-5 (1: No symptoms, 2: 1-5% of the leaf necrosis or individual spots, 3: 6-25% of the leaf symptoms and necrosis, 4: 26% of the leaf symptoms and necrosis in -50; 5: symptoms and necrosis in 50% of the leaf or death of the leaf) (Akköprü, 2020). Disease severity was calculated using the formula below based on score values. The efficacy of the treatment was calculated as compared to the pathogen-alone treatment.

$$\text{Disease index} = \frac{\sum (\text{Rating number} \times \text{Number of leaves in the rating})}{\text{Total number of leaves} \times \text{Highest rating}} \times 100 \quad (1)$$

Determination of Plant Growth Parameters

At the end of the experiments, the number of leaves of the plants was determined by counting all leaves except cotyledon and bifoliate leaves. Leaf chlorophyll content was determined by using chlorophyll meter (Konica Minolta SPAD-502 Plus) on the last day of the experiment. The plants were uprooted and cut from the root collar. Roots were washed with tap water to remove residues of the growing medium. The water on the roots and stems were removed with the help of drying papers to determine the fresh root and stem weight. Afterwards, both plant parts were dried in a drying-oven at 65 °C 72h and then weighed.

Data Analysis

Experiments including treatments were set up according to completely randomised with ten replicates. In all experiments, at least, 10 seedlings were used in each group. Data obtained in climate chamber studies were analysed using SPSS v17.0 statistical software. Significant differences between treatments were determined using Duncan's multiple range test with a significance level of $P \leq 0.05$.

Table 2. Vermicompost application doses in soil and peat growing medium and working groups formed with Xap.

Çizelge 2. Toprak ve Torf yetiştirme ortamında vermicompost) uygulama dozları ve Xap ile oluşturulan çalışma gurupları.

NC (- Xap)	PC (+Xap)
VC %10	VS 1/100
VC %20	VS 1/150
VC %40	VS 1/200
VC %10 +Xap	VS 1/100 +Xap
VC %20 +Xap	VS 1/150 +Xap
VC %40 +Xap	VS 1/200 +Xap

* Xap: *Xanthomonas axonopodis* pv. *phaseoli* NC: (negative control), PC: only Xap application, VC: Solid vermicompost, VS; liquid vermicompost.

RESULTS

Disease Suppression

It was determined that the effect of vermicompost applications on disease severity varies based on to growth medium, application form and dosage. The most successful application in terms of suppressing the disease in peat growth medium was VC 10% which was observed to be 48% efficient. This effect was found to be statistically significant. Although other doses of VC administration caused decreases in disease severity by up to 31%, this effect was not found to be statistically significant. VS applications did not have a significant effect on disease formation in peat growth medium. (Fig. 1).

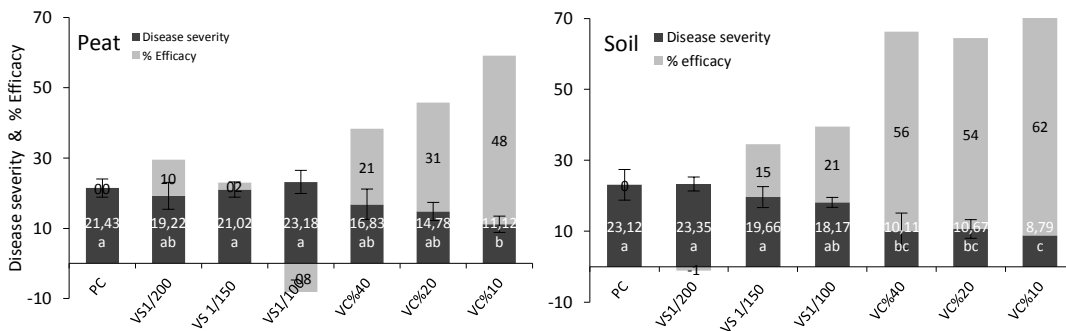


Figure 1. The effect of solid and liquid vermicompost applied to soil and peat growth mediums on Bacterial common blight disease caused by Xap. Disease severity was scored on the basis of scale of 1-5 after 21 days in pathogen inoculation. The gray color indicates the % efficacy and the black part of the column indicates the severity of the disease.

Şekil 1. Toprak ve torf yetiştirme ortamlarına uygulanan katı ve sıvı vermicompostun Xap'nin neden olduğu fasulye adi yaprak yanıklığı hastalığına etkisi. Hastalık şiddeti patojen uygulamasında 21 gün sonra 1-5 skalası ile değerlendirilmiş. Gri renki kolon % etkinliği, siyah kolon ise hastalık şiddetini göstermektedir.

* Mean values followed by the same letter were not significantly different based on the Duncan's Multiple Range Test at $P < 0.05$ significance level. N: > 15.

In soil growth medium, all doses of VC application significantly inhibited the disease. The most successful application was VC10% with 62% efficacy, followed by VC 20% and VC40% with 54 and 56% efficiencies. The obtained effects were also statistically significant. VS applications did not have a significant effect on disease formation in soil growth medium (Fig.1). In general, VC10% was the most successful in suppressing disease, but no significant effect was observed for VS.

Total Chlorophyll Content of the Leaves

The total leaf chlorophyll content of bean seedlings varied according to vermicompost form and growth medium. The highest chlorophyll content was observed in VS 1/200 Xap application in peat and VS 1/150 Xap applicatin in soil. The VC 40% application of had a negative effect on the total chlorophyll content in both growth media in presence/absence of the disease and caused a decrease. (Fig. 2).

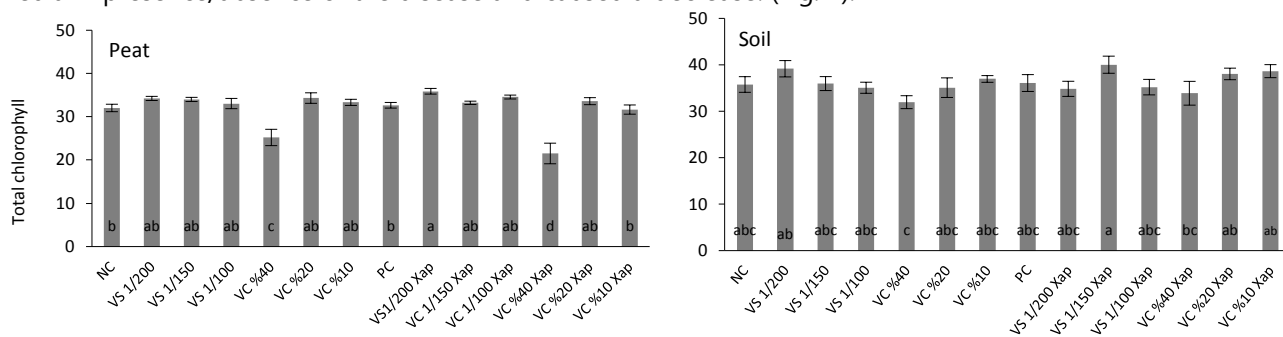


Figure 2. The effect of vermicompost forms (VC, VS) on total chlorophyll content in peat and soil growth media.

Şekil 2. Vermikompost formlarının (VC, VS) torf ve toprak yetiştirme ortamlarında toplam klorofil içeriğine etkisi.

* Mean values followed by the same letter were not significantly different based on the Duncan's Multiple Range Test at P < 0.05 significance level. N: > 12

Plant Growth Parameters

Root Fresh Weight (RFW)

The lowest values were obtained from the control groups (NC, PC) in terms of plant root fresh weight in the peat growth medium and the highest values were obtained from VC 10% and 20% applications. Under the pressure of disease, the most successful VC application compared to the positive control was obtained from 20% Xap group. Although the other applications showed a positive effect, but they were not found to be significant (Fig. 3). In soil growth medium, the lowest value was taken from the VC 40% application and the highest root age weight VS was taken from the 1/100 group. VS 1 /100 Xap group was the most successful application under disease pressure. VC applications had no positive effect on root fresh weight. Furthermore, VS applications yielded better results in soil growing environment both under disease pressure and in disease-free groups compared to VC applications (Fig. 3).

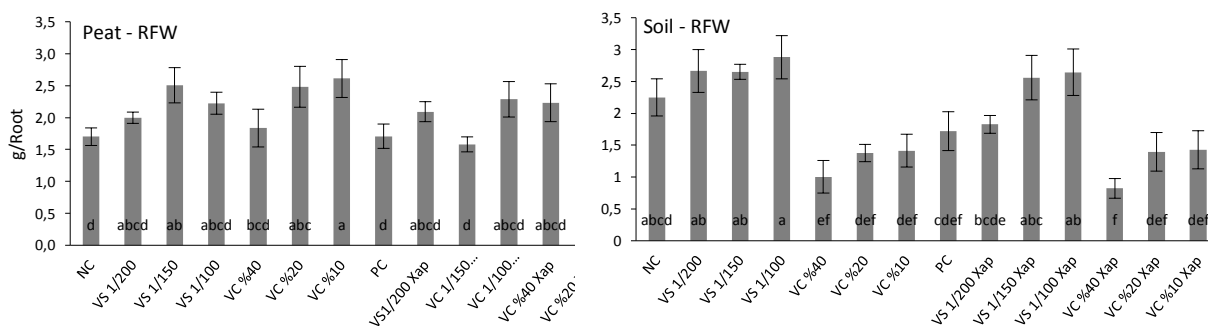


Figure 3. Plant Root fresh weight (RFW) of VC, VS applications in peat and soil growth media effect.

Şekil 3. VC ve VS uygulamalarının torf ve toprak yetiştirme ortamlarında bitki kök yaş ağırlığına (RFW) etkisi.

* Mean values followed by the same letter were not significantly different based on the Duncan's Multiple Range Test at P < 0.05 significance level. N: > 12.

Root Dry Weight (RDW)

Root dry weight values varied according to growth medium. In peat medium, the lowest VC value was obtained from 10% Xap group and the highest VC value was obtained from 10% group. In general, however, there was no statistically significant difference between the groups in the presence/absence of pathogens (Fig. 4). In soil medium, the highest value was obtained from VS 1/100 group and the lowest value was obtained from VC 40%

Xap group in terms of RDW, but the difference between applications was not found to be statistically significant (Fig. 4). Under disease stress, the most successful group that achieved an increase in RDW compared to the positive control was VS 1/100 Xap. Other VS applications did not make a statistically significant difference. In addition, although VC applications under disease stress caused a decrease compared to the positive control, this effect was not found to be statistically significant.

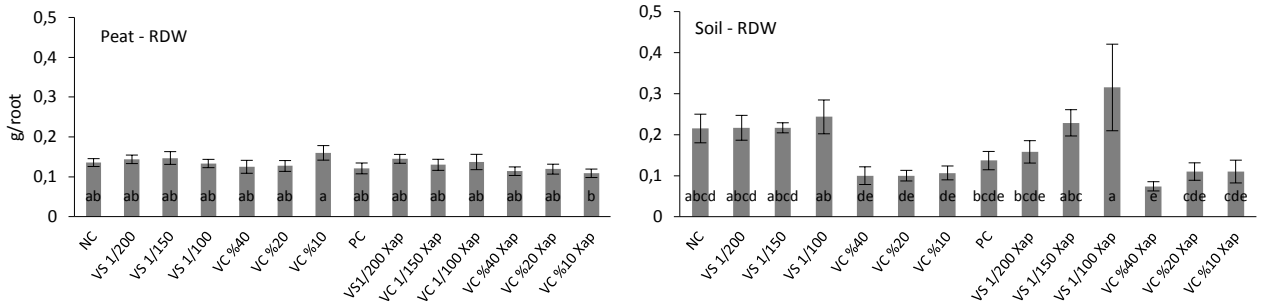


Figure 4. RDW effect of vermicompost formulation (VC, VS) on peat and soil growing medium.

Şekil 4. Vermikompost formülasyonunun (VC, VS) torf ve toprak yetiştirme ortamın da RDW etkisi.

*Mean values followed by the same letter were not significantly different based on the Duncan's Multiple Range Test at P < 0.05 significance level. N: >12.

Shoot Fresh Weight (SFW)

No significant effect of VC and VS applications on shoot fresh weight was observed in soil growth medium. However, in conditions where there is no disease pressure in peat medium, application VC 20% significantly increased shoot fresh weight and this positive effect was observed even under disease stress. Other applications showed no significant effect compared to their respective control groups (NC and PC) (Fig. 5).

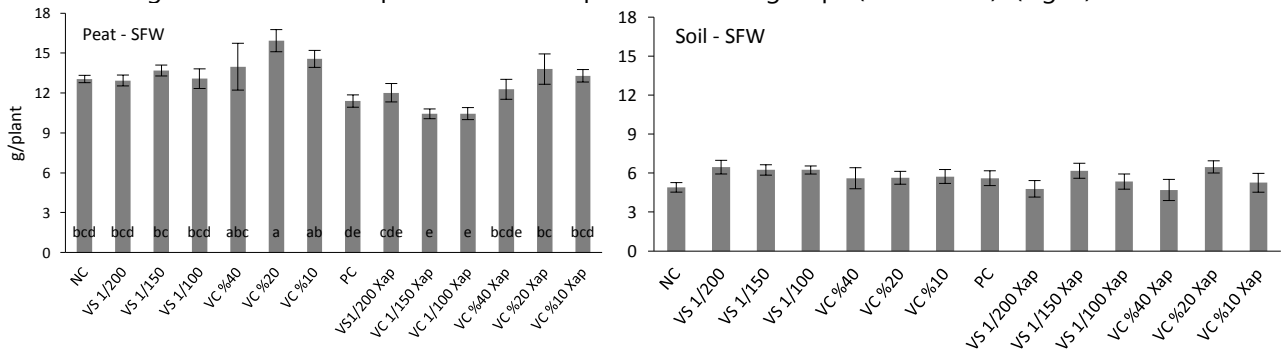


Figure 5. Effect of different vermicompost formulations (VC, VS) on shoot weights of common bean developed in different growth media (mixture of peat and soil).

Şekil 5. Farklı vermicompost formülasyonunun (VC, VS) farklı yetiştirme ortamlarında (torf ve toprak karışımı) geliştirilen fasulye sürgün yaş ağırlıklarına etkisi.

*Mean values followed by the same letter were not significantly different based on the Duncan's Multiple Range Test at P < 0.05 significance level. N: >12.

Shoot Dry Weights (SDW)

In peat growth medium, the highest values of SDW were obtained from NK and VS 1/150 applications while the lowest value was obtained from VC 40% application. Under the pressure of the disease, VC 40% Xap application significantly reduced the dry weight of the shoot compared to the positive control group. No statistically significant difference was observed in other applications, VS 1/200 application yielded the highest value in soil growth medium. While the lowest VC value yielded from the 40% Xap application under the pressure of disease, no statistically significant difference was found between the groups (Fig. 6).

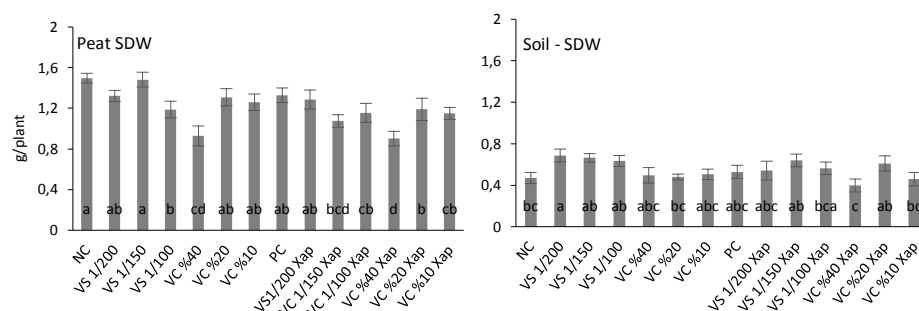


Figure 6. The effect of different vermicompost formulation (VC, VS) on peat and soil growth media in terms of SDW of bean. *Şekil 6. Vermikompost formülasyonunun (VC, VS) torf ve toprak yetiştirme ortamlarına uygulamasının fasulye SDW etkisi.*

*Mean values followed by the same letter were not significantly different based on the Duncan's Multiple Range Test at $P < 0.05$ significance level. N: >12

DISCUSSION

In this study, the effect of solid and liquid vermicompost forms on common blight disease caused by Xap, and plant growth parameters were investigated in two different growing media consisting of soil mixture and peat.

Composting and vermicompost are the two best methods for biological conversion of solid organic wastes (Datta *et al.*, 2016). However, nutritional quality and microbial activity of vermicompost is higher than compost (Tognetti *et al.*, 2005). In addition, the mixing of solomic fluid in the digestive system of worms into the structure of vermicompost, separates vermicomposts from other composts. Enzymes and proteins such as fetidine, agglutidine, chitinase, lumbricidine which are present in the structure of solomic fluid enable the vermicompost to gain antimicrobial properties (Wang *et al.*, 2006). This property makes important contributions to its effectiveness against soil pathogens.

Franke-Whittle *et al.* (2019) showed that the chemical and microbiological properties of vermicomposts may vary according to raw material, production process and region. In this framework, the differences in liquid and solid form of vermicompost can affect its effectiveness (Bademkiran *et al.*, 2018). There is still a lack of information on liquid vermicompost production methodology and optimum application rates according to the target (Simsek-Ersahin, 2011). In contrast, while solid vermicompost can only be applied to soil, liquid vermicompost may be applied to leaves, seeds and soil (Scheuerell and Mahaffee, 2002). On the other hand, although solid form vermicompost applications are limited, slow release provides long-term efficacy.

In our study, it was determined that vermicompost in two different forms had different effects on chlorophyll content, plant development and disease severity. It was observed that in soil medium VS applications increased root development even under disease pressure. However, in peat medium, VC application was more successful. Also, in peat medium VC 20% applications were successful with regard to shoot fresh weight. Bademkiran *et al.* (2018) have revealed that liquid vermicompost gives better results than solid vermicompost in terms of morphological and developmental parameters in field conditions. In contrast, Zaller (2006) could not determine an effect of foliar application of aqueous vermicompost extracts on plant growth and nutrient content of different tomato varieties under field conditions. On the other hand, thorough vermicompost studies were found to show increase in fresh and dry weight of the chard (Aksu *et al.*, 2017), bean (Kadam and Pathade, 2014) and lettuce (Adiloğlu *et al.*, 2018) and to improve of yield and chlorophyll content in lettuce (Kibar, 2018). In general, it is seen that vermicompost forms may exhibit different effects according to plant type, application method and target. The findings of this study support this case.

In contrast, Zaller (2006) could not determine an effect of foliar application of aqueous vermicompost extracts to different tomato varieties under field conditions, in terms of plant growth and nutrient content. On the other hand, thorough vermicompost studies were found to show increase in fresh and dry weight of the Chard (Aksu *et al.*, 2017), Bean (Kadam and Pathade, 2014) and Lettuce (Adiloğlu *et al.*, 2018) and improvement of yield and chlorophyll content in for lettuce (Kibar, 2018). In general, it is seen that Vermicompost forms may exhibit different effects according to plant type, application method and target. The findings of this study support this case.

The doses of vermicompost were observed to be an important factor for the promoting effect. So that, one of the most significant results of our study is that the VC 40% application adversely affects plant growth and chlorophyll content in both growing medium (peat and soil). Atiyeh *et al.* (2000) observed the adverse effects of high application dose, in the form of a decrease in the number of flowers in tomatoes. Lazcano and Dominguez, (2010) observed that the application of 25% vermicompost in primrose and pansy caused death of 20% of plants,

photosynthetic damage, decrease in leaf size and flower formation. In general, it appears that it is necessary to adjust the application doses according to the culture plant.

For maximum benefit, Franke-Whittle *et al.* (2019) stated that growing environment and plant factors should be taken into consideration rather than compost characteristics alone. In our study, it was observed that the effects of liquid and solid vermicompost applications on plant growth and disease varied according to soil and peat growth media. The addition of worms and vermicompost to soil may improve microbial diversity, physical properties of the soil and its nutrient content (Pathma and Sakthivel, 2012; Gupta *et al.*, 2014; Datta *et al.*, 2016). Also, it has been determined that vermicompost application provides more positive contributions to soil pore rate, useful water content, cation exchange rate in clay soil compared to sandy soil and increases bean yield and growth parameters (Manivannan *et al.*, 2009).

It was observed that VC application significantly suppressed the common bean blight caused by Xap in both growth media. However, it was also observed that the dose of VC affects the suppression level. On the other hand, no suppressive effect of VS application was determined in both growing media. In the soil growth medium, all three doses of VC were suppressed the disease significantly. On the other hand, in the peat growth medium, it was observed that only 10% application of VC suppressed the disease significantly. The 10% application dose was the most successful application for both growing media. Although many studies have been conducted on the disease suppression properties of vermicompost applications on culture plants such as chili pepper, strawberry, radish, grape and cucumber; these studies are generally focused on soil based fungal pathogens such as *Phytophthora spp.*, *Fusarium spp.*, *Pythium spp.*, *Rhizoctonia spp.*, *Verticillium spp.* and *Plectosporium spp.* (Chaoui *et al.*, 2002; Scheuerell and Mahaffee, 2002; Sarma *et al.*, 2010; Simsek-Ersahin, 2011; Datta *et al.*, 2016). In these studies, it was stated that the main factor in disease suppression was the change in soil microflora due to vermicompost. The change in soil microflora is argued to be based on the suppression of pathogens in the soil by mechanisms such as competition, antibiosis, hyperparasitism. In addition, it has been reported that, besides facilitating nutrient uptake, useful compost bound humic acid fractions and plant growth regulators (Sarma *et al.*, 2010) which can limit disease development by supporting plant health.

It is possible that the factors mentioned in this study may be effective in decreasing the severity of the disease. However, the fact that Xap is a leaf pathogen, inoculated directly to the leaves in the study and that vermicompost is applied only to the soil shows that other mechanisms might be involved to protect of plant. In this context, the first mechanism which should be considered is the stimulated plant induced systemic resistance mechanisms. A limited number of studies have demonstrated that this mechanism may also be effective with compost applications. It was determined that compost application to *Arabidopsis thaliana* activated the GUS gene, which is an induced resistance marker, and that *Pseudomonas syringae* pv. *maculicola* was significantly suppressed (Zhang *et al.*, 1998). Mishra *et al.* (2018) found that vermicompost extracts were upregulated the CHIT-1, PAL-1 and LOX-1 genes by activating plant induced resistance in the cucumber. The bacterial speck disease and its pathogen *Pseudomonas syringae* pv. *tomato* (Vallad *et al.*, 2003), and tomato leaf spot disease caused by *Septoria lycopersici* (Kavroulakis *et al.*, 2005) were limited with compost application the way of inducing systemic resistance mechanism. The findings obtained in our study show that stimulated plant resistance might in effect. In addition, the observed decrease in level of disease with the VC40% application may be caused by the stress of the plant due to phytotoxicity or damage. As it is known, systemic acquired resistance (SAR) system, which is one of the basic resistance mechanisms of plants, may activate by damage, besides biotic and abiotic factors (Conrath, 2006).

Also, the decrease in disease severity might had be caused by endophytic microorganisms which may be present in the vermicompost microflora. Endophyte bacteria or microorganisms is live in the internal tissues of the plant but do not cause any disease or harm (Hardoim *et al.*, 2008). In the pathosystem we created with vermicompost in the study, endophyte microorganisms may have entered the plant and colonized all tissues of the plant through vascular bundles. Thus, the pathogen might had be suppressed within the plant via biological control mechanisms such as competition, antibiosis and hyperparasitism.

CONCLUSION

The vermicompost applications in liquid and solid forms are observed to affect plant growth parameters at different levels, according to the growth medium was determined that application doses were especially important in solid vermicompost and when it was added to the growth medium at a rate of 40% adversely affected plant growth parameters and caused phytotoxicity. When applied to the growth medium by irrigation, no effect of liquid vermicompost was observed to the leaf disease caused by Xap. In contrast, solid vermicompost was

found to be successful in suppressing the disease in both growth media. This implies that one or more of the above-mentioned mechanisms may have limited the severity of the disease by working together.

The vermicompost application might help to plant growth and control the disease, thereby it can be reduced the chemical fertilizer and pesticide inputs. This shows that vermicompost applications may be ensured the control of the leaf pathogens with environmentally friendly and sustainable approach.

CONFLICT OF INTEREST

Authors have declared no conflict of interest.

DECLARATION OF AUTHOR CONTRIBUTION

Authors declares the contribution of the authors is equal.

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