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ORIGINAL PAPER

Effects of seaweed fertilizer and wood vinegar on nutrient uptake, plant growth and yield of cucumber (*Cucumis sativus* L) grown in a greenhouse

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Abstract

This study was carried out at Mersin University, Silifke Vocational School Research and Application. It was conducted in a greenhouse in 2022. The Flora F1 cucumber variety was used to study the effect of the application of seaweed fertilizer and wood vinegar on nutrient uptake, plant growth and yield of cucumber. Wood vinegar (WDV) was prepared in 0.5% solution, and seaweed (SW) fertilizer was applied in a dose of 5 ml dm^{-3}. They were used alone and combined [SW+WDV(S+F)], into soil and over cucumber leaves. The SW+WDV(S+F) application produced the highest early yield (1.87 kg $plant^{-1}$) and 5.38 kg $plant^{-1}$ in total yield. These values were 1.47 kg $plant^{-1}$ and 3.83 kg $plant^{-1}$ in control, respectively. Also, it was determined that the SW+WDV(S+F) application provided an increase of 50.1% in total fresh biomass and 37.5% in total dry biomass compared to the control. It was found that while the amounts of N, P, K, Fe, Mn, Cu and Zn were the lowest in the control, the SW+WDV(S+F) application resulted in the highest values. The SW+WDV(S+F) application corresponded to an increase of 28.85% in nitrogen (N), 81.08% in phosphorus (P), and 59.88% in potassium (K) compared to the control. According to the results of study, it was determined that the use of wood vinegar and seaweed ferlilizer, into the soil and over leaves, had a positive effect on plant growth, yield and nutrient aptake. This positive effect may have been due to the beneficial chemical compounds contained in the seaweed fertilizer, and the suppression of disease and harmful organisms by wood vinegar in both soil and leaves.

Keywords: *Cucumis sativus* L, organic fertilizer, plant nutrients, biomass, yield

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INTRODUCTION

Cucumber (*Cucumis sativus* L.) is an annual vegetable from the Cucurbitacea family. In 2022, total vegetable production in Turkey was about 31.8 million tons, and cucumber production under greenhouse reached 1.17 million tons (TUIK 2022). In some studies, the use of wood vinegar has a positive effect on plant growth and yield by preventing nematode growth in the soil (Koç et al. 2020); it is also beneficial for the germination of seeds (Mu et al. 2004, Namli et al. 2014, Luo et al. 2019), and it enhances soil quality by providing organic matter to the soil (Birol, Gunal 2022). It is also reported that wood vinegar can be used as a plant growth regulator and as an agent against plant diseases and weeds (Apai, Thongdeethae 2001, Pangnakorn 2008, Pangnakorn et al. 2011).

Wood vinegar is preferred in organic agriculture. Especially using it together with other organic fertilizers can increase its effectiveness. It has been reported that the use of wood vinegar together with fermented liquid organic manure increases yield and quality in soybean (Pangnakorn 2010). In a study on tomato cultivation, the effect on yield and quality was investigated by testing wood vinegar and bioextracts. It has been reported that wood vinegar and the bioextracts applied have a similar effect on yield and quality, but this positive effect increases when they are used together (Mungkunkamchao et al. 2013). Wood vinegar accelerates plant and root growth (Tsuzuki et al. 1989, Kadota et al. 2002, Mu et al. 2003, Kadota, Nimii, 2004), improves seed germination (Lei et al. 2017, Agoncillo 2018), and also prevents the development of some soil pathogens and fungal diseases (Quan 1994, Yagi, Tsukomato 2002, Chuaboon et al. 2016), hence wood vinegar has been reported to create beneficial growth conditions.

In a study with the application of wood vinegar in celery cultivation, it was reported that this substance increased yield and quality (Wei et al. 2009). Likewise, coconut shell vinegar was tested in the cultivation of soybeans (Travero, Mihara 2016), while another pyrolygenous acid from palm kernel shell applied in 2% concentration to pineapple increased the biomass of the plant, while 4% concentration increased fruit weight (Mahmud et al. 2016). In some studies, it has been reported that the use of seaweed extract alone or with other organic materials has a positive contribution to plant growth, yield, fruit quality and nutrient intake (Crouch 1990, Crouch et al. 1990, Crouch, Van Staden 1992, Stirk, van Staden 2003, Turan, Kose 2004, Rathore et al. 2009, Gencsoylu 2016). In a study on cucumbers, it was reported that the use of seaweed increased plant growth and root development (Nelson, van Staden, 1984).

In this study, the effects of the use of seaweed and wood vinegar in the cucumber greenhouse cultivation on nutrient uptake, plant growth, early and total yield have been investigated, and one of the aims was to help cucumber producers, especially those engaged in organic farming, to apply alternative fertilizers.

MATERIAL AND METHODS

The Flora F1 cucumber variety was used as plant material. Seedlings were planted in the experimental plots. The experiment was set up in a randomized plot design with 4 replications and 10 plants in each replication. In addition, 5 plants were planted in pots (3 liter) filled with soil for biomass observations. The plants which had been planted in pots were harvested on the 30th day, and biomass measurements and observations were taken. The plants grown in the plots remained there until the end of the harvest period. In the experiment, 5 different applications were applied: (1) no treatment, i.e. control (C); (2) seaweed fertilizer applied to soil (SW); (3) wood vinegar applied to soil (WDV); (4) seaweed fertilizer and wood vinegar applied together to soil (SW+WDV(S)); (5) seaweed fertilizer and wood vinegar applied together to soil and over leaves [SW+WDV(S+F)]. The concentration of wood vinegar solution was 0.5%, while the seaweed fertilizer was prepared in a dose of 5 ml dm^{-3}. Starting from the day of planting, these substances were applied three times at ten-day intervals to the plants in the pot experiment, 6 times at ten-day intervals in the plot experiment. Meanwhile, only water was given to control plants, both over leaves and to soil.

Parameters

Number of leaves, internodes and flowers: the leaves, nodes and flowers of the plants removed at the end of the 30th day were counted and given as pieces.

Diameter of the main stem: the diameter of the main stem of the harvested plants was measured with a digital caliper and given in mm.

Main stem and root length: the main stem and roots of the harvested plants were measured with a ruler and given in cm.

Fresh root and dry weight: the roots of the harvested plants were washed and cleaned. The fresh weights were found in grams by weighing on precision scales. Roots whose fresh weights were taken were dried in an oven at 65°C until constant weight, then weighed on a precision balance and given in grams (Yarsi et al. 2017).

Fresh biomass weight: the harvested plants were washed and cleaned, and the fresh weight of the plant was weighed on a precision scale and given in grams.

Dry biomass weight: the fresh weight of the plant parts was dried in an oven at 65°C until constant weight and weighed on a precision scale and given in grams.

Early and total yield: the first 20 days of harvest were evaluated as early yield. Each batch was harvested separately, and the total weight was divided by the number of plants and the early yield per plant was expressed in kg. The yield obtained until the end of the harvest was again divided by the number of plants in the plots, and the total yield per plant was expressed in kg.

Nutrient content

P was determined by the vanado-molybdate yellow method (Jackson 1973); N was analyzed by the Kjeldahl digestion method (Westerman, 1990); K^+ was determined as explained by Nouck et al. (2021), and the levels of Fe, Mn, Zn and Cu were determined according to Bremner (1996), Mertens (2005*a*, *b*) and AOAC (2005).

Statistical analyses

Analysis of variance was made using JMP Software (version Pro 13), in line with a randomized plot design. When differences were found in ANOVA, means were compared using the Fisher's protected least significant difference (LSD) test at $P<0.05$.

RESULT AND DISCUSSION

Plant growth parameters

In this study, as Figure 1*a* shows, the SW+WDV(S+F) application has the highest value of the number of leaves, 19.00 leaves per plant. This application was followed by SW+WDV(S) with 18.28 leaves. On the other hand, the control had the lowest value of 13.78 leaves. A similar result was found as regarded the number of internodes (Figure 2*b*).

The number of flowers was 21.70 in the SW+WDV(S+F) application, a higher value than in the other applications, and it was approximately 150.5% more than in the control (Figure 1*c*). Considering the main stem diameter, it was 6.48 mm after the SW+WDV(S+F) application, 6.32 mm after SW+WDV(S) and 6.24 mm after WDV, in the same group statistically. This value was determined as 5.64 mm for the SW application, and the lowest one of 4.91 mm was detected in the control (Figure 1*d*).

While the SW+WDV(S+F) application resulted in the highest value of the main stem length (58.31 cm), this parameter was the lowest (41.22 cm) in the control (Figure 2*a*). Whereas the control had the shortest root length (26.8 cm), it was longer (35.1 cm) in the SW+WDV(S+F) treatment, as well as in SW+WDV (S) (33.7 cm) and in DWV (28.2 cm) (Figure 2*b*).

When Figure 2*c* is examined, it is seen that the effect of the applications on the fresh root weight is statistically significant. SW+WDV(S+F) was the application with the highest fresh root weight (5.08 g), while the control had

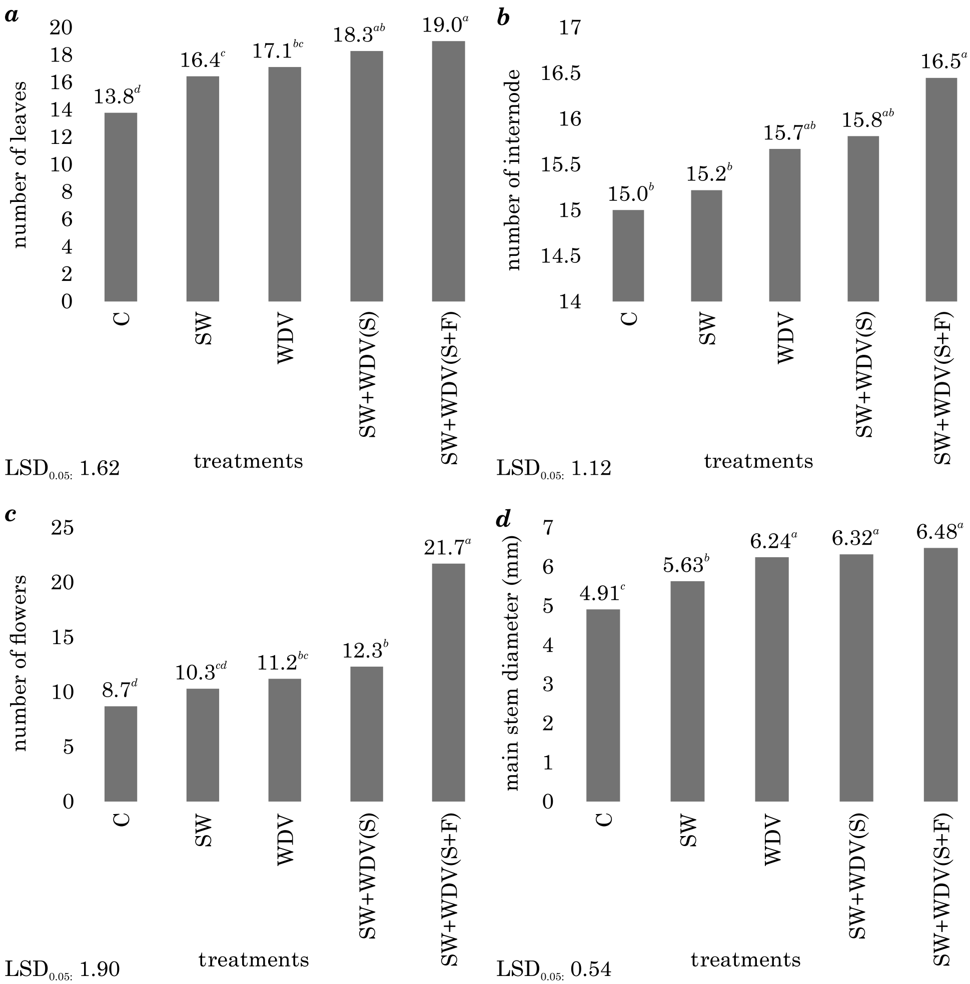

Fig. 1. The effect of using seaweed and wood vinegar on number of leaves (*a*), number of internodes (*b*), number of flowers (*c*) and main stem diameter (*d*). In all the figures, means followed by the same letters do not differ significantly ($P<0.05$)

the lowest value (2.29 g). Considering the dry root weight, SW+WDV(S+F) and SW+WDV (S) applications were in the same group, having the highest values of 0.79 g and 0.76 g, respectively, while the control had the lowest root dry weight of 0.45 g (Figure 2*d*).

Figures 3*a* and 3*b* show that the fresh and dry biomass weight differ statistically significantly. While the fresh biomass weight was the highest (77.82 g) in the SW+WDV(S+F) treatment, this parameter was the lowest (51.83 g) in the control. The results concerning dry biomass were similar.

Significant differences are seen between the applications in terms of early yield. While SW+WDV(S+F) ensured a 27.2% increase in early yield com-

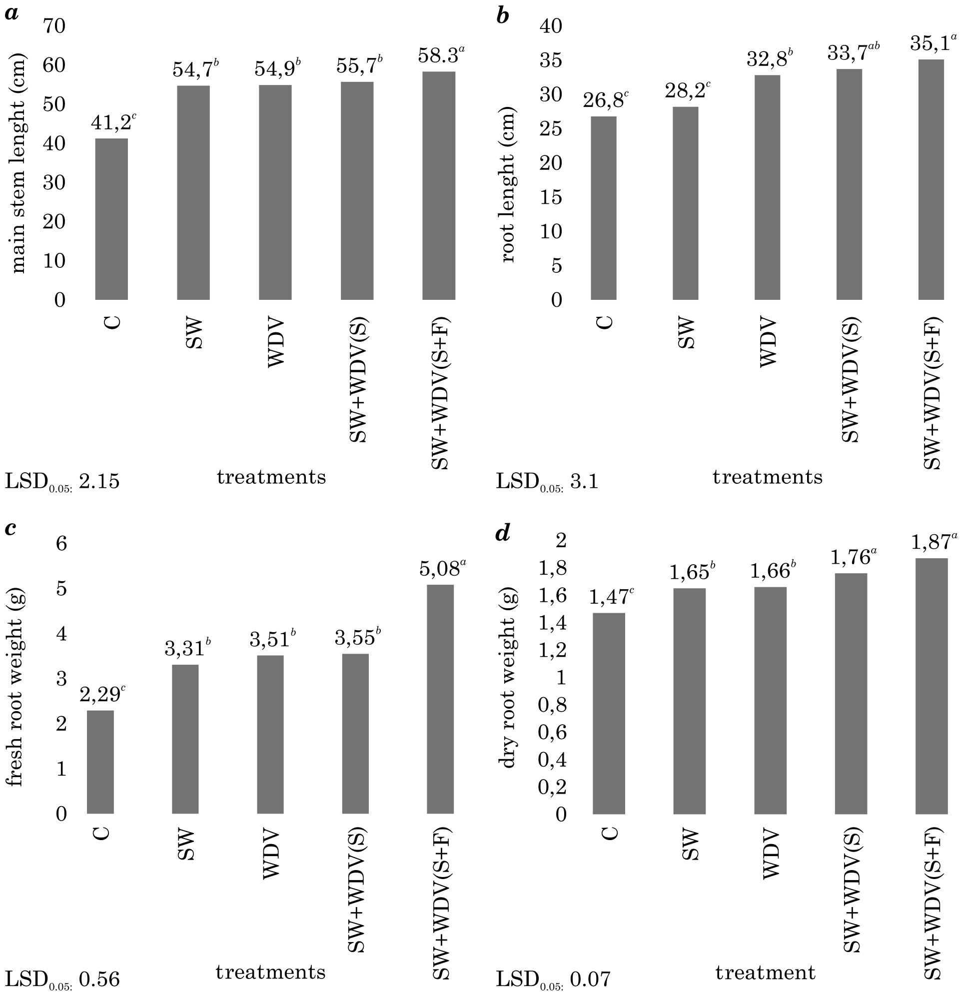

Fig. 2. The effect of using seaweed and wood vinegar on main stem lenght (*a*), root lenght (*b*), fresh root weight (*c*) and dry root weight (*d*). All means in the figures followed by the same letters do not differ statistically significantly ($P<0.05$)

pared to the control, this increase was 19.7% in the WDV application and 12.2% in the SW+WDV(S) and SW applications (Figure 3*c*). Significant differences were determined between the applications in total yield efficiency. While the total yield per plant was determined as 5.38 kg plant^{-1} in the SW+WDV(S+F) application, the value of this parameter fell to 3.83 kg plant^{-1} in the control. In the SW+WDV(S+F) application, a yield increase of approximately 50.0% was achieved compared to the control. Relative to the control, this increase was 36.8% in the SW+WDV(S) application, 25.8% in the WDV application, and 19.1% in the SW application (Figure 3*d*).

In recent years, use of biofertilizer has become more widespread,

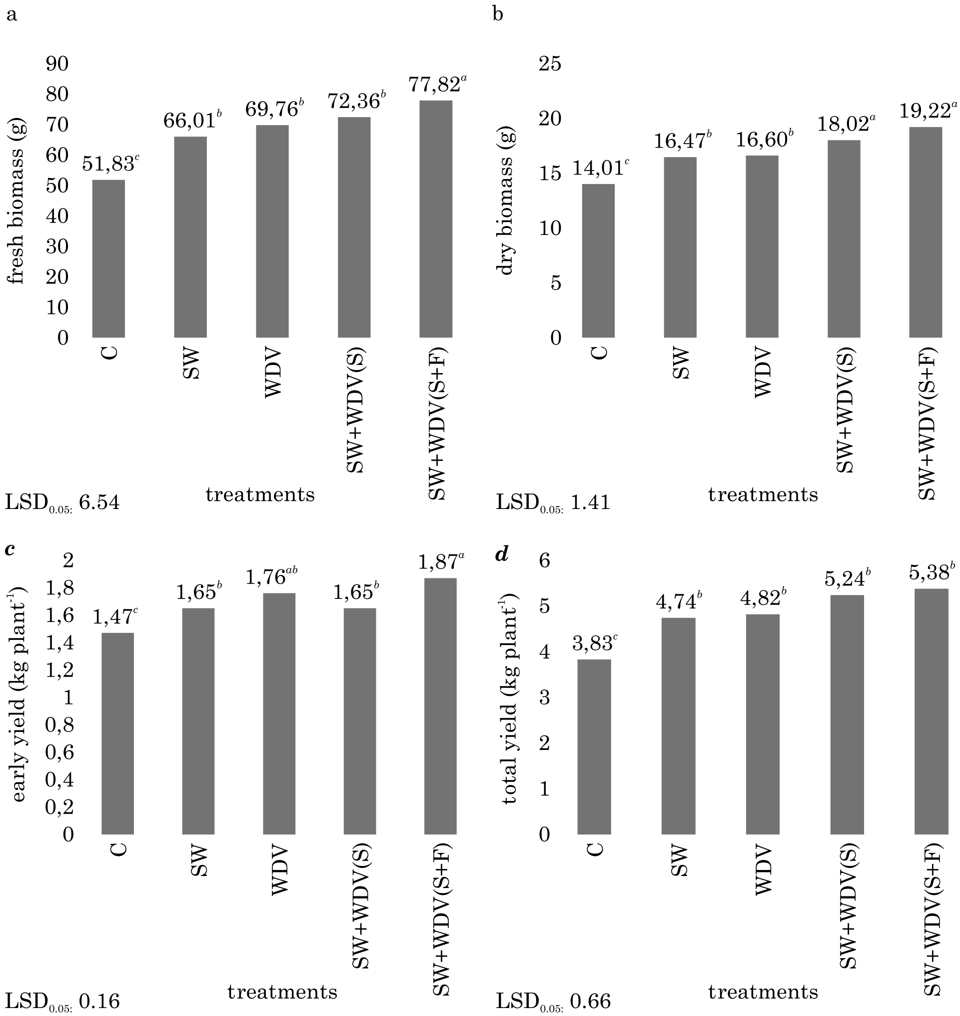

Fig. 3. The effect of using seaweed and wood vinegar on fresh biomass (*a*), dry biomass (*b*), early yield (*c*) and total yield (*d*). All means in the figures followed by the same letters do not differ statistically significantly ($P<0.05$)

especially in organic farming or sustainable farming. In this study, the effects of wood vinegar and seaweed fertilizer on the plant growth and yield of the cucumber plant grown in a greenhouse were investigated. It was observed that the use of seaweed and wood vinegar provided significant increases in plant biomass and yield. Especially the SW+WDV(S+F) application was determined to have created significant differences in plant growth and yield compared to the control. The WDV, SW and SW+WDV(S) applications also produced a positive effect compared to the control. The results revealed that the SW+WDV(S+F) application significiantly increased fresh biomass weight (by 50.1%) and total yield (by 40.5%) compared to the control. These increases were 39.6% and 36.8%, respectively, in the SW+WDV(S) application. The WDV application resulted in the respective increase of 34.5% and 25.8%, and the SW application raised these two parameters by 27.3% and 23.7%, respectvely. The results of this study are similar to those reported by some other researchers (Apai, Thongdeethae 2001, Pangnakorn 2008, Pangnakorn 2010, Pangnakorn et al. 2011, Siriwardena et al. 2020, Zhu et al. 2021).

Considering the results of this study, an increase in the tested parameters was higher when WDV and SW were used than in the control treatment. This can be explained by the fact that wood vinegar prevents the development of pathogens in the soil and thus helps plants to grow more easily. The increase in plant growth and yield owing to the use of seaweed can be attributed to seaweed providing nutrients to the plant and having a positive effect on the development of beneficial microorganisms in the soil. Thus, a synergistic effect was created by using wood vinegar and seaweed both into the soil and over the leaves, hence a significant increase in plant growth and yield was achieved. In addition, there are many studies that prove reduction in leaf diseases when such substances are applied to leaves. This effect can explain why the SW+WDV(S+F) application led to high values of biomass measurements as well as early and total yield. Similar interpretation is given by other researchers (Yoshimura, Hayakawa 1991, Koç et al. 2020).

Nutrient uptake

When Table 1 is examined, it appears that the amounts of N, P, K, Fe, Mn, Cu and Zn are the lowest in the control. It was determined that the SW+WDV(S+F) application resulted in the highest values of these nutrients, whereas the control correlated with the lowest values. Regarding the uptake of macro- and microelements, the most positive effects were obtained through the SW+WDV(S+F) application, followed by SW+WDV(S), WDV and SW. In the control, the amounts of macro- and micronutrients were determined

Table 1

Effect of seaweed and wood vinegar on nutrient in cucumber cultivar at leaves (dry weight)

Treatments	N (%)	P (%)	K (%)	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})
Control	3.57^{d}	0.37^{c}	1,67^{d}	217.6^{e}	343.0^{d}	15.30^{c}	272.6^{e}
SW	4.00^{c}	0.43^{bc}	2.26^{c}	324.7^{d}	471.7^{c}	16.33^{b}	333.3^{d}
WDV	4.30^{b}	0.53^{b}	2.50^{b}	342.0^{c}	470.6^{c}	16.62^{b}	374.4^{c}
SW+WDV(S)	4.40^{ab}	0.53^{b}	2.66^{a}	410.8^{b}	504.8^{b}	17.40^{b}	417.7^{b}
SW+WDV(S+F)	4.60^{a}	0.67^{a}	2.67^{a}	436.3^{a}	534.6^{a}	18.60^{a}	454.3^{a}
$LSD_{0,05}$	0.199	0.100	0.14	15.1	19.5	0.84	15.5

Means followed by the same letters do not differ statistiocally significantly (P<0.05).

to be the lowest. It was found out that especially the use of SW and WDV together created a synergistic effect and therefore affected the nutrient intake positively.

In terms of the nutrient content, the SW+WDV(S+F) application led to the highest value of nutrients in dry weight of leaves. Compared to the control, it ensured an increase of 28.85% in nitrogen (N), 81.08% in phosphorus (P), 59.88% in potassium (K), 55.86% in manganese (Mn), 21.57% in copper (Cu), 66.65% in zinc(Zn) and approximately 100% in iron (Fe). The improved development of the root system owing to the application of the fertilizers positively affected the uptake of macro- and micro-elements from the soil. In a study conducted by Yang et al. (2023), the use of seaweed increased the mineral content of Fuji apples. The reasons for particularly high levels of microelements may be the fact that both wood vinegar and seaweed fertilizer are rich in nutrients. In addition, wood vinegar may facilitate the transition of microelements, such as Fe, Mn, Zn and Cu, which in the soil are unuavailable to plants, into the soil solution, in addition to which it affects the soil pH, making the soil nutrients more easily absorbed by plants. Many researchers have expressed their support of this conclusion (Villegas-Pangga et al. 2000, Mohan et al. 2006, Jung, 2007, Wei et al. 2010, Ojha et al. 2018, Theapparat et al. 2018, Ilavarasi et al. 2019, Koc et al. 2019)

CONCLUSION

According to the results of this study, the application of wood vinegar together with seaweed into the soil and over the leaves in cucumber cultivation encourages plant growth and provides significant increases in yield and nutrient content in leaves. This positive effect might be attributed to the beneficial chemical compounds contained in the seaweed fertilizer, and the suppression of disease and harmful organisms from both soil and leaves by wood vinegar. Especially in organic farming, producers can be advised to use wood vinegar and seaweed fertilizer. They will gain economically high profits by increasing early and total yield. In addition, it can be predicted from this study that the use of wood vinegar and seaweed fertilizers – compared to control plants – will increase the quality of fruits because they positively affect the nutrient intake.

The rapid increase in organic agriculture in recent years and the tendency of consumers to turn to organic products will encourage the use of such practices by farmers. For this reason, recommending this study to producers and implementing its results in practice will be important for environmentally friendly agriculture.

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