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Development of Environmentally Friendly Tea Compost from Raw Tea Waste Using Biotechnological Method

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Abstract – Current agricultural production systems tend to focus on yield results at any cost. The resulting increases in yield lead tea producers to use intensive chemical inputs in conventional agricultural production to achieve more yield in a short time. And this increases their dependence on chemical agents. The excessive use of chemical agents leads to soil acidification and serious negative impacts on the environment in tea growing areas. Therefore, it is necessary to develop both production and consumption-based approaches to ensure global food security and reduce dependence on external inputs and environmental damage. Therefore, for the first time in the world, using enzymes (protease, lipase, dehydrogenase, hydrolase, urease, nitrogenase, cellulase), a fast-mineralizing organo tea vermicompost technology was produced from unprocessed tea waste from tea factories. The developed tea vermicompost was used for 2 years in field studies in Ardeşen district, where tea is grown, at a rate of 400 kg da^{-1}. As a result of the two-year field study, the tea yield in the control groups was 659 kg da^{-1}, while the yield when chemical fertilizers were used was 830 kg da^{-1}. The highest yield was obtained when the developed tea-vermicompost was applied: 852 kg da^{-1}. In addition, the compost was found to increase the content of plant minerals in tea plantations and protect the tea plant from stress with its low content of antioxidants, resulting in yield increases.

Keywords – Tea, Compost, Biotechnological Method

I. Introduction

In 2018, the report organized by FAO reported that awareness of the anti-inflammatory, antioxidant and weight-reducing effects of tea consumption has increased. Global tea production and consumption is expected to continue to increase over the next decade due to strong demand in developing countries. Major producing countries include China, India, Kenya, and Sri Lanka. Together with these countries and Turkey, tea is produced in nearly 48 countries on an economic basis [1]. The increasing demand for tea is causing tea producers to intensively use chemical inputs in conventional farming systems to achieve higher production in a short period of time. This is one of the main reasons for the rapid deterioration of ecological balance. The increasing dependence on chemical agents leads to soil acidification and serious environmental damage in tea growing areas [2]. In China, the world's leading producer and exporter of tea, tea plantations reportedly experience more soil acidification than other grain farming systems. In addition, 46% of tea plantations nationwide have soil pH below 4.5 [3]. Decreasing soil pH in tea plantations affects soil properties by altering soil chemical processes. It also leads to soil nutrient losses, nutrient imbalance, and increased formation of Al and Mn toxicity [4], [5]. In addition, soil acidification significantly affects the diversity and functionality of soil organisms [6].

In parallel with the increase in production, solid waste consisting of trash, fiber, and dust generated during the processing of fresh tea leaves into black tea in tea factories is a major environmental problem. Since raw tea waste is generated in large quantities in tea factories, it weighs on average about 4% of the green shoots harvested [7]. Developing countries usually prefer incineration methods for the disposal of the harvest residues generated in large quantities. However, these methods pollute the environment and contribute to global warming [8]. Therefore, it is necessary to develop both production and consumption-based approaches to ensure global food security and reduce the use of external inputs and environmental damage. One approach that has recently attracted attention in the literature as a solution for a sustainable food system is regenerative agriculture (RA) [9], [10]. Generally, the definition of RA is expressed as improving soil health, soil carbon, soil physical quality, and soil biodiversity [11]- [14]. One of these methods is vermicomposting, which is considered an environmentally friendly technology. This is because it contributes to the biodegradation of waste and provides macronutrients to the soil [15]. It can also improve the physical properties of soil [16] and reduce the salinity [17] and alkalinity [18] of soil. It can increase urease activity by affecting the activity of soil enzymes such as acid phosphatase, acid invertase, and catalase [19]. In this study supported by TARGEM, for the first time in the world, raw tea waste from tea plants was mineralized by rapid biotechnological methods using beneficial worms, enzymes (protease, lipase, dehydrogenase, hydrolase, urease, nitrogenase, cellulase) and microorganisms (*Aspergillus flavus, Bifidobacterium spp. Bacillus subtilis, Rhodotorula spp., Lactobacillus, Rhodopseudomas spp.*) Thus, the biocompost technology was developed to produce an exclusive organic tea fertilizer. The biocompost product was developed in a plant-friendly format to enable sustainable use of local resources.

II. Materials and Method

In this study, raw tea waste received from tea factories in Turkey was directed to composting facilities. Composting was planned in accordance with the composting procedure at the transfer pile. Long piles were formed from the compost prepared in this way. These piles were regularly mixed during composting to determine the water content, organic matter, pH, porosity, microorganisms, C/N ratio, etc., homogeneous in terms of parameters. The composting piles were aerated and mixed on days 3, 14, 27, 39, 54, 69, and 76. A total of seven measures (mixing procedures) were performed. The solid compost fertilizer was developed as a standard solid organic fertilizer in accordance with the Regulation on the Principles and Implementation of Organic Agriculture in Turkey [20]. This regulation governs the production, import and marketing of organic, organic and soil amendment fertilizers, as well as microbial, enzymatic and other agricultural products.

A. *Process for the use of enzymes and microorganisms*

Tea waste from the tea factory was sieved through a 4-mm sieve. Then, bed stacks containing %40 tea raw waste + %60 Mushroom cultivation waste + worm (50,000 pieces tonne-1) +PGPR (*Aspergillus flavus, Bifidobacterium spp. Bacillus subtilis, Rhodotorula spp, Lactobacillus, Rhodopseudomas spp.,*) + enzymes with product number (protease (ATCC 1621), lipase (ATCC 87190), dehydrogenase (ATCC 8585), hydrolase (ATCC 24725), urease (ATCC 9029), nitrogenase (ATCC29413), cellulase (ATCC 1513)). Enzymes were mixed in 150 L of water adjusted to an enzyme concentration of 80 EU ml^{-1} by spraying stacks of raw tea waste + mushroom cultivation waste + worm + PGPR (microbial load of $1x10^9$ cfu ml^{-1} with 150 L) in 3 replicates. PGPR with microbial load of $1x10^9$ cfu ml^{-1} were inoculated by spraying stacks of raw tea waste + mushroom cultivation waste + worm with 150 L of water. After three months of incubation with composting, the changes in the initial content of tea waste over time were analysed for the final compost.

B. *Field Experiment*

At the end of the vermicomposting process, control, chemical fertilizer, and 400 kg da^{-1} tea-vermicompost mixture trials were conducted as a field trial in the tea plantations of Ardeşen/Rize. the chemical fertilizer in the ratio of 25:5:10 was applied in spring at 120 kg da^{-1} and included in the trial as a positive control. In this study, it was included in the experiment to determine the extent to which organic fertilization contributes to efficiency compared to chemical fertilizer. Experimental abstract is shown (Figure 1).

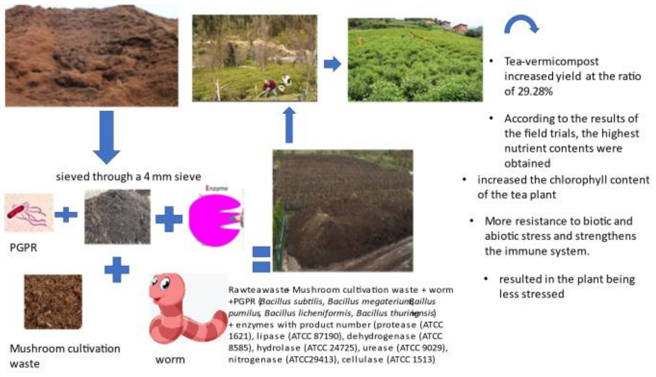

Fig. 1 Experimental abstract

III. RESULTS

The effect of organic and chemical fertilizers applied to tea plots on tea plant yield and nutrient content in all three shoot periods was found to be statistically significant ($p < 0.05$). Based on two-year average values.

Tea yield was obtained in the first and second years (287, 307 kg da^{-1}) in the control groups from the fresh tea leaves collected in the first sprouting period. Tea yield (359, 411 kg da^{-1}) was obtained in the groups fertilized with vermicompost (400 kg da^{-1}) and yield was obtained in the groups fertilized with chemical fertilizers (355, 383 kg da^{-1}).

Tea yield was obtained in the first and second years (221 and 276 kg da^{-1}) in the control groups from the fresh tea leaves collected in the second sprouting period. Yields were obtained in the groups treated with vermicompost (269 and 370 kg da^{-1}) and in the groups treated with chemical fertilizers (295 and 344 kg da^{-1}).

In the third sprouting period, the yield was obtained in the control groups (125 and 102 kg da^{-1}), while the yield was obtained by applying vermicompost (158 and 137 kg da^{-1}) and chemical fertilizers (155 and 128 kg da^{-1}).

The nutrient contents of the tea plant samples taken as a two-year average were in the control groups as N (0.76%), other nutrient concentrations (mg kg^{-1}), K (87488), P (363), Mg (523), Na (153.)), Ca (1884), Fe (238), Zn (10.39), Cu (4.22), Mn (6.70) were determined. When tea-vermicompost was applied, N (1.14), K (103739), P (728), Mg (570), Na (168), Ca (2489), Fe (273), Zn (11.32), Cu (4.60), Mn (7.17) were determined. For chemical fertilizers: N (1.31), K (105724), P (775), Mg (565), Na (195), Ca (2482), Fe (277), Zn (11.48), Cu (4.60), Mn (8.35).

Using the average total yields of the two years, the optimal application rate for fertilization with organic tea-vermicompost for Ardeşen was calculated to be 412.23 kg da^{-1}. It was estimated that this application rate would result in a tea yield of 850.56 kg da^{-1} (Figure 2).

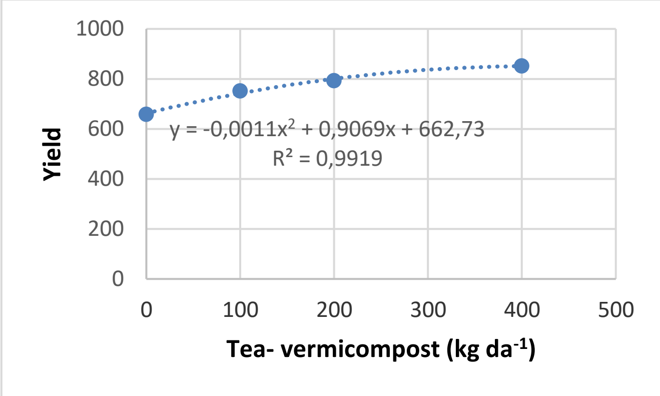

Fig. 2 Yield estimates for the Ardeşen region as a function of organic fertilizer application.

The effects of the first, second, and third shoot periods on antioxidant enzyme (EU gr/leaf) and chlorophyll (SPAD) content, their two-year averages, in the control application CAT (71), POD (1276), SOD (139), chlorophyll content (8), in tea-vermicompost application CAT (41), POD (777), SOD (72), chlorophyll content (152), in chemical fertilizer application CAT (56), POD (1148), SOD (82), chlorophyll content (75) determined.

IV. DISCUSSION

The results of the two-year field study show that tea yields obtained in three growing seasons with the developed organic fertilizer Tea-vermicompost increased compared to the control group. These increases were determined at 400 kg da^{-1} and 25:05:10 chemical fertilizer applications (29.28%, 25.94%). The similarly prepared tea-vermicompost is reported to increase plant growth and increase the taproot length of okra [21], aboveground fresh and dry weights in plant tissues, leaf area and extractable mineral element concentration [22]. According to the results of the field trials, the highest nutrient contents were obtained with a 25:5:10 fertilization with chemical fertilizers and an organic tea-vermicompost application of 400 kg da^{-1}. The application of vermicompost (400 kg da^{-1}) resulted in an increase of (53-75% N), (104-101% P), (13-16% Mg), (14-39% Na), (38-38% Ca), (12-16% Fe), (21-28% Zn), (11-11% Cu), (4.0-26.0% Mn) compared to chemical fertilizers and the control group. In a similar study, tea-vermicompost manure is found to increase the uptake of soluble mineral nutrients and microbial by-products as well as nutrients from the soil [23], [24]. Again, composting tea waste is not only an environmentally friendly disposal method, but also creates a more productive environment for plant growth as it contains nutrients and tannic acid [25]. It also contains a significant amount of humic acid, which stimulates plant growth and yield [26], and during the "mineralization" process, soluble mineral nutrients, beneficial microorganisms, humic and fulvic acids, plant growth hormones, and plant growth regulators known to be present in solid vermicompost are likely to be extracted into the tea. These potential beneficial components are the most important factors that positively influence plant growth [27].

The application of organic tea-vermicompost increased the chlorophyll content of the tea plant compared to chemical fertilizers and control applications. Other studies indicate that chlorophyll content depends on nitrogen supply to the plant [28], [29]. When organic fertilization was evaluated in terms of antioxidant enzyme activity, it was found that the lower activity compared to chemical fertilization and control application resulted in the plant being less stressed and therefore enzyme activity decreased. Therefore, it can be concluded that the tea plant in the region increases the resistance to biotic and abiotic stress and strengthens the immune system. In the study of wheat seed treatment with bio stimulants under cold stress, it was reported that the accumulation of ROS decreased due to the direct or indirect scavenging effect of the product [30]. Compared to control treatments, higher antioxidant activity was observed in control group plants compared to tea-vermicompost treated plant groups in a study using tea-vermicompost fertilization [31], higher antioxidant capacity of leafy vegetables reportedly associated with lower growth in plant tissue, lower N concentration, and accumulation of higher amounts of phenolic compounds [32], [33].

V. CONCLUSION

The fact that there is no statistically significant difference between the use of organic fertilizer and chemical fertilizer in terms of yield, and the close values show that the developed product will make a significant contribution to the production of sustainable and organic tea in the region. Based on these results, it is considered that in the context of soil and groundwater pollution and waste management due to excessive use of fertilizers, there is an important contribution to the economy of the country. In addition, sustainable tea is believed to prioritize agricultural management and provide an important source of income for tea waste disposal.

With the increase of excessive use of chemical fertilizers, tea grown in our country at the rate of 700,000 tons per year produces nearly 17% of waste, resulting in 119,000 tons of waste to be disposed of annually. Since the areas and methods of use of this waste are not yet clear, the pollution and costs incurred in its disposal are a burden on the country's economy, just as the loss of soil fertility and the work to improve it incur additional costs.

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