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EVALUATION OF HARVEST WASTE IN SOILLESS AGRICULTURE TOMATO CULTIVATION

ABSTRACT

In this study, it was carried out in order to determine the amount of plant nutrients that can be obtained from the wastes of tomato plants grown with soilless agriculture technique in the greenhouse and to make suggestions for evaluation possibilities. For this purpose, cocopeat and plant samples were taken from the soilless greenhouse where tomatoes were grown at the end of production. The stem, leaf, fruit and root of the collected cocopeat and plant samples were separated and N, P, K, analyzes were made in these separated samples. According to the results obtained, the amount of N that can be added to the soil with the cocopeat wastes is determined as 10.58 kg, the amount of P 0.09 kg and the amount of K 0.52 kg for one decare area. The total N amount that can be gained from the roots, stems, leaves and fruits of the waste tomato plant per decare area was determined as 6.65-11.97 kg, P content 1.22-2.52 kg and K amount between 5.10-18.21 kg. Considering the distribution of the amount of NPK that can be added to the soil according to the plant parts. On average, 4.18 kg in root, 2.50 kg in stem, 7.58 kg in leaf and 7.46 kg in fruit were found to be wasted due to not evaluating plant wastes. The organ with the highest N content among plant parts is the leaf, and 42.73% of the total N is found in the leaf. P and K are mostly found in fruits. In addition, 41.73% of P and 36.62% of K are excreted with fruit. It will be possible to improve the soils with insufficient organic matter content throughout Turkey by composting the wastes from greenhouses. In addition, it has been determined that these wastes are very important in terms of reducing the visual pollution caused by these wastes, harmful emissions that will arise as a result of burning and bringing them into the economy.

Keywords: *Plant wastes, recycle, tomato, plant nutrients*

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INTRODUCTION

Greenhouse cultivation has become widespread in many countries in recent years, as it allows plant production all year round and is a farming method with high economic returns (Pardossi et al., 2004). However, one of the problems associated with this production system is the generation of large amounts of solid waste as a result of production (Anton et al., 2005). Researching the evaluation methods of such wastes is of great importance in terms of both reducing environmental pollution and bringing waste into the economy. The purpose of sustainable greenhouse systems. It should be a system that protects resources, is socially supported, commercial, competitive, environmentally friendly, has reliable production technology, reduces the need for energy, water and chemical drugs, and does not produce waste as much as possible (Giuliano et al., 2010). Among the plants grown in the greenhouse, tomato is the dominant product (Alkoaik and Ghaly, 2006). Although tomato cultivation in greenhouses is agriculturally profitable, intensive cultivation of this species results in a large amount of post-harvest vegetable waste. While an average of 28.5 t ha^{-1} $year^{-1}$ vegetative waste is generated after production from other plants grown in greenhouses, an average of 49 t ha^{-1} plant waste is generated annually after production in greenhouse tomato cultivation (Manzano-Agugliaro, 2007). Kurklu et al. (2004) reported that 11148099 tons of biomass waste from tomato greenhouses and 1587039 tons of biomass waste from eggplant greenhouses are produced every year in Antalya, where greenhouse cultivation is the most intense in our country. Cheuk et al. (2003) stated that the materials formed as a result of plant production consist of fruit, plant pruning wastes and all plant organs; They determined that as a result of greenhouse tomato and pepper production, 175 tons ha^{-1} organic waste was obtained annually.

On the disposal of greenhouse waste; Atılgan et al. (2014) in Antalya province, Güzey and Atılgan (2015) in Denizli province, Boyaci (2018) in Kırşehir and Boyacı and Kartal (2019) in Antalya province Kumluca district. It has been determined that it is disposed of in a way that harms nature and the atmosphere by leaving it in the field, throwing it into a river or stream, waiting for it to self-destruct, and throwing it into the garbage cans. Researchers have stated that if these wastes are evaluated as biomass energy or fertilizer without harming the environment, they will contribute to the country's economy as a source of energy and fertilizer, as well as reducing environmental pollution. Nowadays, it has become widespread to use the wastes generated as a result of plant production as input in agricultural production, both by preventing environmental pollution and by evaluating wastes. It has been determined by many studies that plant wastes or agro-industrial wastes can be used effectively in agriculture. It has been determined that these wastes can be used as a source of organic matter and plant nutrients by applying them directly to the soil, and can also be used as a growing medium with mixtures at certain rates (Özenç, 2004; Benito, 2005, 2006; Çerçioğlu, 2019). Çıtak et al. (2006), by composting greenhouse plant wastes, a significant amount of plant nutrients can be added to the soil. They stated that this situation will contribute to the reduction of the amount of chemical fertilizers used, as well as the prevention of environmental pollution resulting from the burning of wastes.

Ferna´ndez-Go´mez et al. (2013), the huge amount of plant waste left in greenhouse tomato cultivation can be converted into valuable organic products by using low-cost techniques such as vermicomposting in order not to cause environmental problems. Parra et al. (2008) reported that greenhouse plant wastes should be evaluated as an opportunity to generate energy or produce valuable organic products. Since greenhouses are closed areas where intensive plant production is carried out, the organic matter level of greenhouse soils decreases in a shorter time compared to open plant production areas. Therefore, converting greenhouse plant waste into valuable organic matter using low-cost techniques such as composting or vermicomposting should be the preferred recycling method. It has been determined that the use of these wastes by making compost provides the recycling of a significant amount of nutrients and the use of these composts, especially in soils with low organic matter content, can provide significant advantages. It has been concluded that the establishment of waste collection and compost facilities that enable the recycling of these materials, called waste, can provide significant advantages in terms of both the environment and economy (Sönmez et al., 2002; Sönmez et al., 2008). The disposal of greenhouse waste poses a serious problem for producers. These wastes either cause environmental pollution by being destroyed by incineration or are tried to be disposed of randomly by throwing them around the garden. In addition, many disease agents, pathogens and pests use these wastes as intermediate hosts and continue their life cycle, causing the spread of diseases and pests in production areas. Since burning waste is harmful to the environment and its potential benefits are not utilized, its use in agriculture with composting, which is an alternative disposal method, has gained importance in recent years and has been the subject of many scientific studies (Çerçioğlu, 2019).

Substrate culture is used more widely than hydroponic culture among soilless agriculture methods. Although organic and inorganic substrates can be used as growing media in substrate culture, the most widely used organic-based substrate, especially in tomato cultivation, is the cocopeat obtained from coconut fibers. An average of 600 cocopeat slabs (100x20x16 cm) are used in tomato cultivation in a one-decare greenhouse area (Gül, 2019). Assuming that the cocopeat is used as substrate in 10000 da of existing hydroponic farms, approximately 6000000 cocopeat slabs annually are output as waste by hydroponic farms. These waste growing media, which are discarded after 2-3 years of use in greenhouses, have also begun to enter the category of wastes that need to be evaluated (Sönmez et al., 2016). Although waste cocopeats are evaluated by adding seedling mortar, especially by enterprises that grow potted ornamental plants, it is not possible to evaluate all waste cocopeats in this way. Therefore, it is of great importance to determine alternative evaluation methods of cocopeats.

The high nutritional content of vegetable wastes used in composting directly affects the quality of the compost to be obtained. In the study. It is aimed to determine the amount of plant nutrients that can be obtained from the cocopeat, plant roots, stems, leaves and fruits, which are the growing medium. In this way, suggestions were presented for the evaluation possibilities of wastes whose nutrient content was determined.

MATERIAL AND METHOD

In the study, vegetable wastes obtained from tomato plants grown with substrate culturetechnique were used as material. The number of plants in the soilless agricultural greenhouse, whose side walls and roof are covered with polycarbonate cover material, is calculated as 2400 per decare. Plant samples were taken at the end of the vegetation period together with the whole plant root to represent the greenhouse. At the end of the growing period, the plant samples taken from the greenhouse were divided into cocopeat, root, stem, leaf and fruit samples from the growing medium and made ready for analysis in the laboratory (Kacar, 1972). Fresh and dry weights of plant parts washed with distilled water were dried in an oven at 65ºC until constant weight was determined.

The analyzes of the samples were made in Kırşehir Ahi Evran University Central Research and Application Laboratory with 3 replications. In the analysis methods of cocopeat samples; cocopeat pH and electrical conductivity values in saturated samples with glass electrode pH and EC meters (Thomas, 1996), organic matter. The total nitrogen (N) content was determined according to the modified Walkley-Black method (Nelson and Sommers, 1996) and the Kjeldahl method (Bremner et al., 1982). Potassium (K) available to the plant - it was determined according to the 1N ammonium acetate (NH_4OAC, pH=7) method (Helmke and Sparks, 1996) and the K concentration was calculated with a Flame Photometer. Plant-available phosphorus (P) - it was determined by the 0.5 M $NaHCO_3$ method (Kuo, 1996) and the P concentration was calculated by UV-VIS spectrophotometer. In plant analysis methods - plant samples were incinerated according to the block-chip method using HNO_3 and $HClO_4$ (Jones and Case, 1990) and homogeneous filtrates were obtained.

Potassium (K) - Helmke and Sparks, (1996) made according to the method and in Flame photometer, Phosphorus (P) - element reading was performed in the UV-VIS spectrophotometer according to the method reported by Kuo (1996). Total nitrogen (N) in plants - determined according to the Kjeldahl method reported by Bremner et al., (1982).

RESULT AND DISCUSSION

Plant nutrient element that can be obtained from the growing medium in soilless agriculture

The chemical analysis results of the waste cocopeat used in the greenhouse in the study are given in Table 1. Accordingly, the N, P and K contents of the waste cocopeat were determined as 0.88%, 0.01% and 0.04%, respectively. In our findings, it is noteworthy that the waste cocopeat contains higher levels of N compared to P and K.

Table 1. Chemical analysis results of the waste cocopeat

Growing medium	pH	EC	OM	N	P	K
	-	dS m^{-1}	g kg^{-1}	%	%	%
Cocopeat	7.86	1.25	433.2	0.88	0.01	0.04

The amounts of plant nutrients that can be added to the soil for one decare with the residual cocopeat are given in (Table 2). Accordingly, the amount of N that can be added to the soil for one decare with the cocopeat waste was determined as 10.58 kg, the amount of P 0.09 kg and the amount of K 0.52 kg.

Table 2. The amount of plant nutrients that can be added to the soil for one decare with the waste cocopeat

Growing medium	N, kg	P, kg	K, kg
Cocopeat	10.58	0.09	0.52

Depending on the climate characteristics and product diversity in our country, large amounts of organic waste are generated in agricultural areas. These wastes are generally not subject to any systematic evaluation. The use of cocopeats in hydroponic culture vegetable production has increased in recent years, and in parallel, the amount of waste cocopeats released after production has increased significantly. It is estimated that an average of 10-14.5 tons of cocopeat waste is produced every 2-3 years. Cocopeat wastes have a serious potential and these wastes should be evaluated by mixing with other materials (Sönmez et al., 2017). Sonmez et al. (2016) in the study aiming to recycle agricultural wastes to agricultural fields; They determined that the application of greenhouse plant wastes (80%), used cocopeat (10%) and waste mushroom compost (10%) by mixing in different ratios provided significant increases in the macro and micronutrient contents of the soils compared to the control. It has been shown that when the cocopeat is mixed with the soil directly or as compost, it increases the water holding capacity of the soil as well as increases the nutrient content of the soil. In our findings, it has been determined that mixing the waste cocopeat with the soil will be beneficial due to the nutrients it contains. Çınar and Akdemir (1999) found the economic optimum nitrogen dose as 12.5 kg da^{-1} in their study where they carried out the economic analysis of nitrogen fertilization in Çukurova conditions. Öztürk and Engindeniz (2018), in their study where they analyzed the efficiency of input use in greenhouse tomato production, determined that the use of nitrogen in plastic and glass greenhouses in fall, spring and single crop tomato cultivation ranged from 11.85 kg da^{-1} to 13.42 kg da^{-1}. Therefore, 10.58 kg da^{-1} N obtained from the waste cocopeat, which we determined in our findings, will be able to meet a significant part of the N amount needed in tomato cultivation. In addition, since the cocopeat has the ability to hold water up to 750-1100% of its dry weight, the addition of the cocopeat can make a positive contribution to soils with low water and nutrient retention (Ilahi and Ahmad, 2017; Arachchi and Somasiri, 1997). Organic matter content of 69% of Turkey's soils is less than 2% (Ülgen and Yurtsever, 1988). Therefore, the organic matter that the vegetable wastes from the greenhouses and the waste cocopeat can provide to the soil will make a significant contribution. Mixing the waste cocopeats with the soil provides important contributions to the increase of the organic matter content and water holding capacity of the soil, as well as providing the nutrients in the cocopeat to the soil (Kadıoğlu and Canbolat, 2019; Yangyuoru et al., 2006). The cocopeat, which is used as a plant growing medium, is a material with a highly fibrous structure and high water holding capacity (Abad et al., 2002). In their study, Alaboz and Çakmakçı (2020) reported that cocopeat material can be used to increase the water holding capacity in medium and coarse textured soils, to reduce irrigation times and to use water effectively in sandy loam textured soils. Kotuby-Amacher et al. (1997) reported that the threshold EC value of the soil was 2.5 dS m^{-1} for tomato and 1.3 dS m^{-1} for pepper. In our findings, the EC value of the waste cocopeat was determined as 1.25 dS m^{-1}. Therefore, it is foreseen that the waste cocopeat to be added to the soil will not increase the EC value at a level that will increase the salinity in the soil.

Plant nutrient that can be obtained from plant parts

In the waste plant samples taken from the greenhouse, the average fresh weight per plant was found to be 1.267 kg. Accordingly, the amount of wet waste that can be obtained from the post-harvest waste in a one-decare greenhouse was determined as 3040 kg. The amount of dry weight corresponding to this weight is 0.185 kg on average per plant, which corresponds to a total of 443.47 kg of dry matter. As a result of the calculations, the ratio of dry weights obtained from the plant to wet weights was determined as 14.59% on average. Bilgin et al. (2012) calculated the annual amount of biomass waste generated in plastic covered greenhouses in Turkey, Mediterranean, Aegean and Antalya provinces, and the ratio of the amount of tomato plant waste on dry basis to wet basis was calculated as 14.85%. Accordingly, it was determined that the result obtained in the study was similar. The tomato plant wastes used in the study were taken from plants grown up to the 7^{th} fruit cluster in the cocopeat growing medium with soilless farming technique. Since the average yield of 18-20 clusters is obtained in soilless agricultural enterprises where tomato cultivation is carried out commercially, the amount of plant waste obtained from such enterprises will also be higher.

In the study, as a result of the analysis obtained from the post-harvest wastes in the greenhouses the N content in dry matter was 0.86-1.63% in the root, 1.08%-1.36% in the stem, 3.14-3.55% in the leaf and 1.85-2.20% in the fruit. P content was determined as 0.11-0.20% in the root, 0.38-0.49% in the stem, 0.38-0.55% in the leaf and 0.46-0.59% in the fruit. It was determined that the K content varied between 1.02%-1.77% in the root, 2.10-3.89% in the stem, 1.43%-4.57% in the leaf and 1.45%-4.55% in the fruit. As can be seen in Table 3, greenhouse plant wastes that are removed at the end of the growing season contain a significant amount of plant nutrients.

Table 3. N, P and K values of different parts of tomato plant

Plant parts	Values	Plant nutrients		
		N (%)	P (%)	K (%)
Root	Min.	0.86	0.11	1.02
	Avg.	1.21	0.15	1.37
	Max.	1.63	0.20	1.77
Stem	Min.	1.08	0.38	2.10
	Avg.	1.26	0.45	3.13
	Max.	1.36	0.49	3.89
Leaf	Min.	3.14	0.38	1.43
	Avg.	3.37	0.48	2.71
	Max.	3.55	0.55	4.57
Fruit	Min.	1.85	0.46	1.45
	Avg.	1.98	0.52	2.74
	Max.	2.20	0.59	4.55
Total	**Min.**	**6.93**	**1.33**	**6.00**
	Avg.	**7.82**	**1.60**	**9.95**
	Max.	**8.74**	**1.83**	**14.78**

The minimum, maximum and average values of the amount of plant nutrients that can be gained on a decare area with different organs of the tomato plant and wasted by the disposal of these plant wastes are given in Table 4. The total amount of N that can be gained to one decare area with the wastes of the tomato plant varies between 6.65-11.97 kg, the amount of P varies between 1.22-2.52 kg and the amount of K varies between 5.10-18.21 kg.

Table 4. Amounts of N, P and K that different parts of tomato plant can bring to one decare of soil

Plant parts	Values	Plant nutrients			
		N (kg)	P (kg)	K (kg)	Total
Root	Min.	0.84	0.10	0.97	1.91
	Avg.	1.82	0.23	2.13	4.18
	Max.	2.74	0.41	3.83	6.98
Stem	Min.	0.48	0.18	1.01	1.67
	Avg.	0.65	0.23	1.62	2.5
	Max.	0.8	0.28	2.31	3.39
Leaf	Min.	2.86	0.33	1.38	4.57
	Avg.	3.89	0.57	3.12	7.58
	Max.	5.28	0.86	5.49	11.62
Fruit	Min.	2.46	0.62	1.74	4.82
	Avg.	2.75	0.74	3.97	7.46
	Max.	3.15	0.98	6.59	10.72
Total	**Min.**	**6.65**	**1.22**	**5.10**	**12.97**
	Avg.	**9.11**	**1.77**	**10.84**	**21.72**
	Max.	**11.97**	**2.52**	**18.21**	**32.71**

The amounts of wasted plant nutrients show significant differences according to different organs of the plant, and the average values of plant nutrients are given in Figure 1 to indicate these differences.

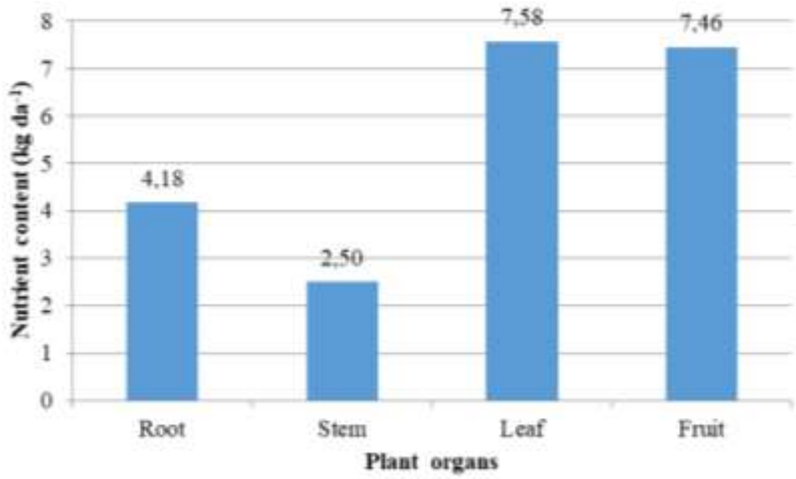

Figure 1. Average plant nutritional values of different organs of tomato plant wastes obtained from one decare area

As seen in Figure 1, 4.18 kg of plant nutrients in the root, 2.50 kg in the stem, 7.58 kg in the leaf and 7.46 kg in the fruit are wasted due to the inability to evaluate the wastes. When the plant nutrients excreted by different organs of the tomato plant at the end of the harvest were examined, it was determined that the nutrients discarded by different plant parts differed significantly (Table 5).

As seen in Table 5, the organ with the highest N content is the leaf, and 42.73% of the total N is found in the leaf. P and K are found in the most discarded fruits. 41.73% of P and 36.62% of K are excreted with fruit.

Table 5. Percentage distribution of the average amount of plant nutrients discarded by the different organs of the tomato plant according to the plant organs

Plant parts	Values	Plant nutrients		
		N (kg)	P (kg)	K (kg)
Root	Avg.	1.82	0.23	2.13
	%	19.99	13.14	19.63
Stem	Avg.	0.65	0.23	1.62
	%	7.11	12.99	14.99
Leaf	Avg.	3.89	0.57	3.12
	%	42.73	32.15	28.76
Fruit	Avg.	2.75	0.74	3.97
	%	30.17	41.73	36.62
Total	Avg.	9.11	1.77	10.84
	%	100	100	100

It has been determined by many studies that vegetable wastes or agricultural industry wastes can be successfully used in agricultural production. Plant-based wastes, beyond being a serious source of organic matter, also have an important potential in terms of plant nutrients they contain. With the recovery of these materials, both the organic matter content of our soils with low organic matter content will be increased and less chemical fertilizers will be used as they will be enriched in terms of plant nutrients (Çıtak et al., 2006). Approximately 70% of Turkey's soils are insufficient in terms of organic matter, and accelerating organic fertilizer applications over time may be a factor in minimizing the negative effects of chemical fertilizers. In addition, the amount of use of organic fertilizers and chemical fertilizers will decrease and the negative effects caused by the use of intensive chemical fertilizers will be prevented (Sönmez et al., 2008). In studies on the amount of plant nutrients that can be obtained from post-harvest plant wastes; Cheuk et al. (2003) that the materials formed as a result of plant production are fruit, plant pruning wastes and all plant organs; determined that 175 ton ha^{-1} organic waste is generated annually as a result of greenhouse tomato and pepper production. Kaygısız (1996) reported that vegetable wastes can be a significant source of NPK by composting, and determined the amount of N, P and K that tomato wastes can bring to the soil as 9.5 kg, 2.7 kg and 13 kg per decare. Sonmez et al. (2002) As a result of not evaluating the tomato wastes in the greenhouses (82142 da) in Antalya province, an annual average of 762.28 tons N, 48.22 tons P, 572.53 tons K, 467.39 tons Ca, 174.96 tons Mg, 1.84 tons Fe, 1.98 tons Mn, 0.71 tons Zn, 0.81 tons They reported that Cu could not be added to the soil and disappeared. Researchers determined that these plant wastes contain N, P_2O_5 and K_2O equivalent to 3910 tons of chemical fertilizers. (Sönmez et al., 2008) Fresh weights of tomato, pepper, cucumber and eggplant plant wastes from greenhouses in Antalya region at the end of the growing season were determined as 584745, 48014, 89757 and 54605 ton ha^{-1}, respectively. In total, it has been determined that 777112 tons of plant waste is generated per hectare. Researchers report that 7043 ton ha^{-1} with tomato waste, 832 ton ha^{-1} with pepper waste, 1435 ton ha^{-1} with cucumber waste and 904 ton ha^{-1} with eggplant plant wastes could not be evaluated and wasted. In addition, with these plant wastes, N, P_2O_5 and K_2O fertilizers, which are equal to 7159 ton ha^{-1} only for Antalya, could not be evaluated by not adding them to the soil. It has been determined that the use of these wastes by making compost provides the recycling of a significant amount of nutrients and the use of these composts, especially in soils with low organic matter content, can provide significant advantages. However, it has been concluded that the establishment of waste collection and composting facilities that enable the recycling of so-called waste materials can both reduce environmental pollution and provide significant economic advantages. In the study, a significant amount of N, P and K can be obtained from tomato wastes, as in the studies of the researchers. According to the calculations, 36.44 kg of calcium ammonium nitrate (26%), 4.07 kg of triple super phosphate (42%) and 21.68 kg of potassium sulfate (50%) can be obtained from decare with these nutrients. However, as these wastes could not be evaluated, it was determined that a significant amount of N, P_2O_5 and K_2O equivalent to those in chemical fertilizers were wasted.

CONCLUSION

It has been determined that the vegetable wastes released as a result of agricultural production can provide plant nutrients to the soil, and the use of these wastes especially for the improvement of soils with low organic matter levels is extremely important in terms of agricultural production. Therefore, in order to reduce environmental pollution caused by vegetable waste and to bring these wastes to the economy, it is of great importance to investigate methods of evaluating more effectively.

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