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THE EFFECT OF DIFFERENT DOSES OF LIQUID VERMICOMPOST APPLICATION ON YIELD AND YIELD COMPONENTS OF SOME POTATO (*SOLANUM TUBEROSUM* L.) VARIETIES

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Abstract

This is one of the early studies to produce healthy, yielding, and high-quality tubers from the potatoes grown in Bayburt, an organic agriculture basin, using liquid vermicompost that can supplement organic fertilizers. The purpose of this study was to examine the effect of liquid vermicompost applications (0, 3, 6, 9, and 12 L ha^{-1}), which can supplement the stable manure used as bottom fertilizer, on yield and yield components of potato (*Solanum tuberosum* L.) varieties (Agria and Lady Olympia). The research was designed in random blocks with three replications. As a result of the study, it was found that the tuber yield was within the range of 20.24-30.40 tons' ha^{-1}, the protein ratio was within the range of 1.53-2.51%, and the starch ratio was within the range of 11.98%-15.99%. The liquid vermicompost doses applied to the potato varieties created significant differences in all three parameters. Due to the positive effect of the Agria (3.40 tons/da) variety on the yield and vegetative development of potatoes, It was concluded that 9 L liquid vermicompost application per decare would be beneficial.

Key words: *Solanum tuberosum* L., Organic agriculture, Yield, Liquid vermicompost, Population.

Introduction

Potato (*Solanum tuberosum* L.) is one of the most important plants in meeting the nutritional need of humans, which has become an important issue due to the increasing world population. A healthy and balanced diet is important for meeting not only the daily nutritional needs but also the need for carbohydrates, protein, and vitamins.

Fertilization is used in plants to obtain the best yield and quality product. For correct fertilization, the relationship between fertilizer and product should be identified correctly. Fertilization applied at the right time, in sufficient quantity, and in the required form contributes to high-quality and yield products (Ozturk *et al.,* 2007). It is known that fertilization affects both plant yield and nutrient content (Jankowski *et al.*, 2014). In Turkey, the use of chemical fertilizers is on the rise due to agricultural lands with low organic matter content. Despite this, the rate of fertilizer utilization by plants is short of expectations. Artificial fertilizers have some negative effects, such as disrupting the soil structure oil structure and polluting groundwater, which increases the use of organic fertilizers. Organic fertilizers generally consist of animal or vegetable products and some microorganisms. Using organic fertilizers ensures that plants are produced a high quality and yield, soil structure is preserved, and agricultural activities continue using sustainable methods without damaging the groundwater (Kacar & Katkat, 2007).

Mineral fertilizers were preferred in potato production in the past. But recently, organic fertilizers have been used more frequently. Moreover, it is common to see that organic fertilizers and mineral fertilizers are used together. Bahadirli & Dogan (2021) reported that the yield and quality results obtained in mineral fertilizer applications were similar to those obtained from the combined use of organic and mineral fertilizers. On the other hand, reported that more yielding products were produced in the applications "vermicompost + nitrogen" and "vermicompost + phosphorus" than in the application of triple superphosphate and ammonium sulfate. In addition, many previous studies reported that the best yield values were obtained in the applications of fermented fertilizer, compost fertilizer, and vermicompost (Yourtchi *et al.,* 2013; Boke, 2014; Eleroglu & Korkmaz, 2016).

This study was carried out to determine the liquid vermicompost dose appropriate for obtaining the best yield and quality values in potato varieties (Agria and Lady Olympia) grown under the ecological conditions of Bayburt.

Material and Methods

Field experiment: The province of Bayburt is located between the latitudes of 40˚ 37' North and 39˚ 52' South and the longitudes 40˚ 45' East and 39˚ 37' West and connects the Eastern Black Sea Region to Eastern Anatolia Region. It is the "roof" of the Eastern Black Sea Region with an altitude of 1550 m and a surface area of 3739 km^2. Bayburt has a transitional climate as it lies between the North and East. However, a continental climate predominates in Bayburt. Therefore, summers are generally short, dry, and hot, and winters are long, cold, and rainy, although not as much as in the Eastern Anatolia Region. The average annual precipitation is 433.4 mm in the region, and generally, it falls outside the growing season. The annual average temperature is 7.0ºC. Table 1 shows the average precipitation, temperature, and relative humidity in Bayburt for 2020 when the cultivation was carried out, and other years (1980-2020).

Soil samples were collected from the trial field at a depth of 0-30 cm and analyzed in the Soil, Water, and Plant Analysis Laboratory of the Black Sea Agricultural Research Institute, Samsun. As a result of the analysis, the soil of the trial field was found to be loamy, slightly alkaline (pH 7.90), very calcareous (17.31%), and salt-free (0.01%), and have an organic matter content of 0.99% (very low), an available phosphorus content of 1.33 kg da^{-1}(very low), and potassium content of 43.8 kg da^{-1}(high).

Experimental treatments: This study was carried out under the ecological conditions of the province of Bayburt in 2020. The potato varieties "Agria" (mid-late) and "Lady Olympia" (mid-early) were procured from the Agricultural Credit Cooperative of Bayburt. The research was designed in random blocks with three replications. Each plot was 2.8 m wide and 5.95 m long. The seeds were planted in 4 rows at a planting density of 70x35 cm. Stable manure (30 tons per hectare) was applied as bottom fertilizer to the land by deep ploughing in the autumn. Potatoes were planted on April 18, 2020, using a planting machine (a tuber per hole). Then, 3, 6, 9, and 12 L ha^{-1} of liquid vermicompost were applied three times: when the plants had 4-5 leaves and once every 21 days. Table 2 shows the chemical properties of the liquid vermicompost suppliedby Ekosol Farming and Livestock Company and analyzed by the General Directorate of Plant Production, Ministry of Agriculture and Forestry, Republic of Turkey.

Table 1. Climate average of Bayburt province between 1980-2020 and some climate data for 2020.

Months	Monthly average rainfall (mm)	Monthly average temperature (°C)	Monthly average relative humidity (%)
	Long years average (1980-2020)		
April	63.47	7.17	58.18
May	77.50	11.67	57.80
June	47.02	15.54	54.83
July	22.70	19.04	50.46
August	14.71	15.22	49.69
September	43.40	16.61	50.24
	Monthly average precipitation, temperature and relative humidity for 2020		
April	88.0	7.0	57.1
May	113.8	12.1	55.0
June	51.9	17.2	49.4
July	61.0	20.5	48.9
August	14.4	18.7	44.5
September	8.5	18.4	39.6

Table 2. Chemical properties of liquid vermicompost.

Content	Amount
Organic matter	7%
Total nitrogen	7%
Organic nitrogen	0.2%
Maximum EC (dS/m)	10
pH	8.5-10.5

Examined parameters: Plant care was carried out under organic conditions during the growing season. The plants were harvested at the end of September. The following parameters were examined in the study: plant height, number of branches, tuber yield per hectare, number of tubers per plant, large tuber ratio, medium tuber ratio, small tuber ratio, marketable tuber ratio, tuber yield per plant, single tuber weight, protein ratio, starch ratio, dry matter ratio, and specific gravity.

Statistical analyses: The data obtained were analyzed using the SPSS software package. The differences between the means and their significance were determined using the Duncan Multiple comparison test (Payne *et al.*, 2011).

Results and Discussion

Plant height and the number of branches: As a result of the study, it was found that the difference between the varieties in terms of plant height was significant at $p<0.01$, while the difference between the liquid vermicompost doses was significant at $p<0.05$. The interaction "variety x fertilizer dose" was found to have no statistically significant effect in this regard (Table 3). The plant height was 50.99 cm for Agria and 38.75 cm for Lady Olympia. The mean plant height for different doses of liquid vermicompost was found to be within the range of 42.75-47.19 cm. The control and the fertilizer dose of 3 L ha^{-1} were found to have the highest plant height (47.19 and 46.72 cm, respectively), whereas the lowest plant height (42.75 cm) was observed to be in the fertilizer dose of 12 L ha^{-1} (Table 3). Plant height, one of the important parameters, is affected by many environmental factors, such as the genetic structure of plant variety, cultivation techniques, climate, and environmental factors (Bradshaw, 2009; Eaton *et al.*, 2017; Raja *et al.*, 2018). When the potatoes were examined in terms of the number of branches, it was found that the variety, fertilizer dose, and the interaction "variety x fertilizer dose" had no significant effect on the number of branches. The mean number of branches of the varieties was within the range of 5.86-6.57, while that of the fertilizer doses was within the range of 5.8-6.6 (Table 3).

Tuber yield per hectare: On the other hand, it was found that there was a significant difference between the potato varieties in terms of tuber yield per hectare ($p<0.01$). Moreover, the interaction "variety x fertilizer dose" also created significant differences in this regard ($p<0.01$). The highest tuber yield per hectare was observed in Agria, with 30.30 tons, whereas the lowest was in Lady Olympia, with 20.28 tons. Agria (mid-late) had a higher yield than Lady Olympia (mid-early) because it had a longer growing period than Lady Olympia. As a matter of fact, with the formation of tubers, most of the dry matter generated by the plant is transferred to tubers, and tuber yield increases depending on the length of the growing period (Ekin, 2009). In the literature, it has been reported that plant height, number of tubers, and tuber weight positively affect tuber yield (Özkaynak & Samancı, 2005). In the present study, we found that liquid vermicompost had no positive effect on plant height. However, Yourtchi *et al*., (2013) reported that the vermicompost application positively affected plant height in potatoes.

It was found that there were significant differences between the fertilizer doses in terms of tuber yield per hectare ($p<0.05$). The tuber yield per hectare was found to be 20.81 tons in the control group and 20.76 and 20.75 tons in the liquid vermicompost doses of 3 and 6 L, respectively. The highest tuber yield per hectare was observed in the liquid vermicompost dose of 9 L with 30.39 tons, whereas the lowest was in 12 L with 20.24 tons (Table 3). In the present study, it was observed that the tuber yield of the potato varieties increased with the liquid vermicompost application at certain doses. This result was similar to those reported by Sikder *et al*., (2017), Fahrurrozi *et al*., (2019), and Hindersah *et al*., (2019). The increase in tuber yield is directly proportional to

the increase in tuber diameter, tuber weight per plant, and thus the increase in marketable tuber ratio (Yourtchi *et al.*, 2013). Liquid vermicompost application increases photosynthesis by stimulating the metabolism in leaves and has a positive effect on plant growth by accelerating the development of the plant root system (Morales-Corts *et al.*, 2018). Humic acids, micronutrients, and plant growth regulator components in liquid vermicompost stimulate plant growth by increasing the number and development of roots (Alvarez & Grigera, 2005).

Tuber number per plant and ratios of large, medium, small, and marketable tuber: The difference between the varieties in terms of the number of tubers per plant was found to be significant ($p<0.05$), whereas the difference between the fertilizer doses was not significant in this regard. Moreover, the interaction "variety x fertilizer dose" had a significant effect in terms of the number of tubers per plant ($p<0.01$), (Table 3). The number of tubers per plant of the varieties was found to vary between 8.47 and 9.65. Although the different fertilizer doses had no significant effect, the number of tubers per plant varied between 8.71 and 9.84 (Table 3). Ratios of large, medium and small tubers are of great importance both in terms of yield and in determining the marketable tuber ratio, which is an important criterion in introducing potatoes into the market. The variety, fertilizer dose, and the interaction "variety x fertilizer dose" were found to have significant effects on all these parameters ($p<0.01$) (Tables 3 and 4).

The highest ratio of large tubers and marketable tuber ratio were observed in Agria at 35.85% and 55.48%, respectively, and the highest ratios of medium and small tubers were observed in Lady Olympia at 63.83% and 27.54%, respectively. On the other hand, the lowest ratios of medium and small tubers were observed in Agria with 57.37% and 5.90%, respectively; and the lowest ratio of large tubers and marketable tuber ratio were observed in Lady Olympia with 8.68% and 18.45%, respectively. In potato varieties, yield parameters can vary depending on genetic, environmental, and climatic factors (Wass, 2016; Eaton *et al.*, 2017). In the present study, the highest ratio of large tubers and marketable tuber ratio were observed in the fertilizer dose of 9 L per hectare at 38.97% and 47.8%, respectively; In comparison, the highest ratios of medium and small tubers were observed in the fertilizer doses of 12 and 6 L per hectare with 72.77% and 20.52%, respectively. On the other hand, the lowest ratio of large tubers and marketable tuber ratio were observed in the fertilizer dose of 12 L per hectare at 9.35% and 27.39%, respectively; In comparison, the lowest ratios of medium and small tubers were observed in the fertilizer doses of 9 and 3 L per hectare with 46.86% and 12.88%, respectively (Tables 2 and 4).

Tuber yield per plant, single tuber weight, and protein ratio: The variety, fertilizer dose, and the interaction "variety x fertilizer dose" were found to have significant effects in terms of yield of tubers per plant and single tuber weight ($p<0.01$) (Table 4). Agria was found to have better results than Lady Olympia in terms of tuber yield per plant and single tuber weight (810.06 g plant^{-1}, 98.59 g, respectively, for Agria; 548.71 g plant^{-1} and 53.11 g, respectively, for Lady Olympia). In the liquid vermicompost application at different doses, the tuber yield per plant and the single tuber weight were found to be 623.56 g plant^{-1} and 80.28 g, respectively, in the control group. They increased to 659.01, 722.84, and 843.24 g plant^{-1} and 80.63, 70.52, and 88.26 g at the fertilizer doses of 3, 6, and 9 L, respectively, and then decreased to 548.26 g plant^{-1} and 59.58 g, respectively, at the fertilizer dose of 12 L ha^{-1} (Table 4). There is a linear relationship between tuber yield per plant and single tuber weight. These two parameters are affected by soil structure, physiological characteristics of varieties, and plant stress factors during the tuber formation period. On the other hand, a good tuber formation is an important parameter for the marketing of potatoes. Several previous studies reported that, compared to other fertilizers, liquid vermicompost application increased the tuber growth by increasing the plant nutrient requirement and soil quality (increased water holding capacity, increased soil stability, and increased soil aeration by preventing soil compaction), and thus, increased quality and marketable tuber ratio. Our results were similar to those reported by Parman (2007), Marpaung *et al*., (2014), Piya *et al*., (2018), and Fahrurrozi *et al*., (2019). According to the variance analysis results, the fertilizer dose was found to have a significant effect in terms of protein ratio ($p<0.05$), but not the variety and the interaction "variety x fertilizer dose" (Table 4). The control group was found to have the highest protein ratio (2.51%). The protein ratio decreased to 1.53% in the liquid vermicompost dose of 3 L ha^{-1} then increased to an average of 2.20% in 6, 9, and 12 L ha^{-1} (Table 4).

Starch ratio, dry matter ratio, and specific gravity: The variety, fertilizer dose, and the interaction "variety x fertilizer dose" were found to have significant effects in terms of starch ratio, dry matter ratio, and specific gravity ($p<0.01$) (Table 4). The highest ratio of starch and dry matter was observed in Agria (15.75% and 26.29%, respectively), while the lowest (14.06% and 25.45%, respectively) in Lady Olympia. The specific gravity ratio of the varieties was found to be close to each other (Agria, 1.08%; Lady Olympia, 1.07%). When the liquid vermicompost doses were evaluated in terms of starch ratio and dry matter ratio, it was found that the highest starch ratio and dry matter ratio were observed in control (15.99% and 26.84%, respectively) and in the fertilizer dose of 9 L ha^{-1} (15.74% and 26.65%, respectively); while the lowest in the fertilizer doses of 6 and 3 L ha^{-1} (11.98% and 25.03%, respectively) (Table 4). The specific gravity ratios were similar. The control and the fertilizer dose of 3 L ha^{-1} had the highest specific gravity (1.09). The difference between the protein, starch, and dry matter ratios and the specific gravity of the tubers of the potato varieties is due to genetic, climatic, and environmental factors. In the literature, it was reported that the specific gravity of tubers decreased depending on the length of the storage period, and the starch ratio of tubers increased depending on the maturation period of the plant (Abbas *et al.*, 2011; Tesfaye *et al.*, 2012; Chemeda *et al.*, 2014). Some previous studies reported that potatoes produced using organic fertilizers were healthier than those produced using chemical inputs. Similarly, it was reported that organic potatoes produced using organic fertilizers had more dry matter, starch, and total protein than those produced using chemical fertilizers (Moschella *et al.*, 2005; Camin *et al.*, 2007; Maggio *et al.*, 2008; Bartova *et al.*, 2013).

Table 3. Average values and variance analysis values of plant height, number of branches, tuber yield per hectare, tuber number per plant, large tuber ratio, medium tuber ratio and small tuber ratio in potato cultivars applied with different liquid vermicompost doses.

Applications		P.H (cm)	N.B (number)	T.Y.H (t ha^{-1})	T.N.P. (number)	L.T.R (%)	M.T.R (%)	S.T.R (%)
Variety	Agria	50.99	5.86	30.30	8.47	35.85	57.37	5.90
	Lady Olympia	38.75	6.57	20.28	9.65	8.68	63.83	27.54
	Mean	**44.87**	**6.22**	**20.79**	**9.06**	**22.27**	**60.6**	**16.72**
Liquid Vermikompost (L ha^{-1})	0	47.19a	6.6	20.81ab	8.97	22.93b	58.06c	18.77a
	3	46.72ab	5.8	20.76ab	9.03	22.33b	64.38b	12.88b
	6	43.25bc	6.3	20.75ab	9.84	17.75c	60.92bc	20.52a
	9	44.43abc	6.4	30.40a	8.71	38.97a	46.86d	13.27b
	12	42.75c	6.1	20.24b	8.77	9.35d	72.77a	18.14a
	Mean	**44.87**	**6.2**	**20.79**	**9.06**	**22.26**	**60.60**	**16.72**
	D.F.	**Variance analysis**						
V	1	144.19**	4.81	22,83**	5.44*	407.52**	16.36**	540.74**
L	4	3.10*	0.81	2.96*	0.65	51.54**	28.09**	10.91**
VxL	4	2.34	1.61	11.79**	28.90**	45.38**	24.76**	54.87**

* 5%, ** 1% Significant at level. In addition, the difference between the averages shown with the same letter is not significant (p<0.05), **PH:** Plant height, **NB:** Number of branches, **TYH:** Tuber yield per hectare, **TNP:** Tuber number per plant, **LTR:** Large tuber ratio, **MTR:** Medium tuber ratio, **STR:** Small tuber ratio

Table 4. Average values and analysis values of variance related to marketable tuber ratio, tuber yield per plant, grain tuber weight, protein ratio, starch ratio, dry matter ratio and specific gravity in potato varieties applied fertilizer dose.

Applications		M.T.R (%)	T.Y.P (g plant^{-1})	G.T.W (g)	P.R (%)	S.R (%)	D.M.R (%)	S.G
Variety	Agria	55.48	810.06	98.59	2.21	15.75	26.29	1.07
	Lady Olympia	18.45	548.71	53.11	2.04	14.06	25.45	1.08
	Mean	**36.97**	**679.39**	**75.85**	**2.13**	**14.91**	**25.87**	**1.08**
Liquid Vermikompost (L ha^{-1})	0	37.02b	623.56c	80.28b	2.51a	15.99a	26.84a	1.09a
	3	34.80b	659.01bc	80.63b	1.53b	15.52c	25.03c	1.09a
	6	38.44b	722.84b	70.52c	2.21a	11.98e	25.62b	1.07b
	9	47.18a	843.24a	88.26a	2.10a	15.74b	26.65a	1.07c
	12	27.39c	548.26d	59.58d	2.29a	15.29d	25.24c	1.07c
	Mean	**36.97**	**679.38**	**75.85**	**2.13**	**14.90**	**25.88**	**1.08**
	D.F.	**Variance analysis**						
V	1	771.72**	162.75**	391.64**	1.02	854.24**	90.34**	33.26**
L	4	22.82**	23.57**	18.53**	3.61*	661.56**	68.17**	49.72**
VxL	4	21.29**	39.62**	11.29**	1.71	659.33**	23.99**	15.13**

* 5%, ** 1% Significant at level. In addition, the difference between the averages shown with the same letter is not significant (P<0.05), **MTR:** Marketable tuber ratio, **TYP:** Tuber yield per plant, **GTW:** single tuber weight, **PR:** Protein ratio, **SR:** Starch ratio, **DMR:** Dry matter ratio, **SG:** Specific gravity

Table 5. Eigenvalues and percentage of variance for investigated parameters of PCA analysis.

	PC1	PC2	PC3	PC4	PC5
Eigenvalue	8.213	2.445	1.458	1.272	1.051
Variability (%)	48.311	14.381	8.576	7.481	6.181
Cumulative (%)	48.311	62.692	71.268	78.749	84.930

The principal component analysis (PCA): Five principal components (Table 5, Fig. 1) were identified in the principal component analysis (PCA) carried out using the following parameters: potato varieties, fertilizer doses, plant height, number of branches, tuber yield per hectare, number of tubers per plant, large tuber ratio, medium tuber ratio, small tuber ratio, marketable tuber ratio, tuber yield per plant, single tuber weight, protein ratio starch ratio, dry matter ratio, and specific gravity.

The first and second principal components explained 62.692% (48.311% and 14.381%, respectively) of the total variation. Therefore, the PCA result was considered significant since the first two principal components explained around 70% of the total variation (Larrigaudiere *et al.,* 2004) According to Kaiser (1960), for the components, values between 0 and 0.5 are interpreted as "unacceptable", 0.5 as "the lowest", 0.5-0.7 as "moderate", 0.7-0.8 as "good", 0.8-0.9 as "very good", and 0.9 and above as "excellent". As can be seen in Table 6, the first principal component consisted of 11 different components, three of which were excellent.

The second principal component consisted of 3 different components. The third component consisted of the "fertilizer dose" variable alone, the fourth component consisted of the "starch ratio" variable alone, and the fifth

component consisted of the "specific gravity" variable alone. It is very important that the variables "fertilizer dose", "starch ratio," and "specific gravity" alone make up a component. In addition, this result was supported by the fact that, as a result of the variance analysis, significant differences were observed between the fertilizer doses in terms of starch ratio and specific gravity.

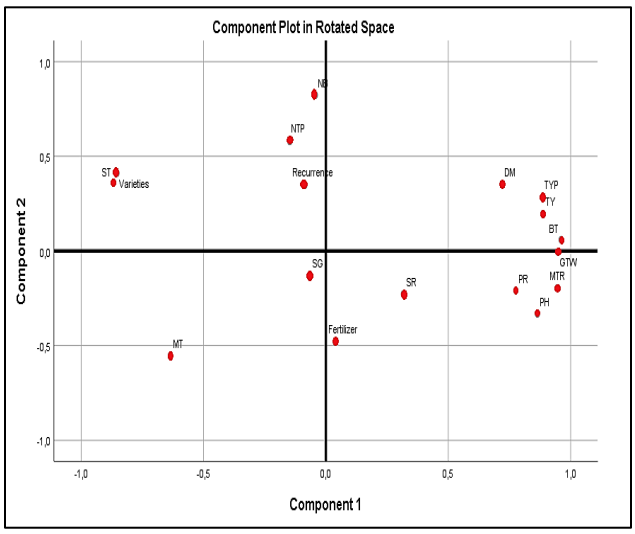

Fig. 1. Potato yield characteristics in the weight plane explained by the first two principal components.

Tablo 6. Component matrix of PCA.

Component	1	2	3	4	5
Fertilizer	0.076	-0.477	0.731	-0.343	0.033
Varieties	-0.884	0.343	0.018	0.032	-0.062
Recurrence	-0.113	0.340	0.477	-0.014	0.206
PH	0.887	-0.263	-0.316	0.052	0.101
NB	-0.108	0.818	0.070	0.286	0.082
TYH	0.868	0.264	0.033	-0.058	0.138
TNP	-0.192	0.566	-0.415	-0.429	0.173
LTR	0.954	0.134	0.184	-0.081	-0.016
MTR	-0.590	-0.600	-0.376	-0.021	0.069
STR	-0.893	0.293	0.000	0.139	-0.025
MTR	0.957	-0.122	0.038	-0.185	0.010
TYP	0.862	0.352	0.081	-0.162	0.140
GTW	0.945	0.069	-0.093	-0.095	0.091
PR	0.790	-0.148	-0.390	0.263	-0.072
SR	0.334	-0.202	0.270	0.722	-0.156
DMR	0.690	0.409	-0.005	0.249	-0.328
SG	-0.055	-0.136	0.012	0.365	0.876

PH: Plant height, **NB:** Number of branches, **TYH:** Tuber yield per hectare, **TNP:** Tuber number per plant, **LTR:** Large tuber ratio, **MTR:** Medium tuber ratio, **STR:** Small tuber ratio, **MTR:** Marketable tuber ratio, **TYP:** Tuber yield per plant, **GTW:** Grain tuber weight, **PR:** Protein ratio, **SR:** Starch ratio, **DMR:** Dry matter ratio, **SG:** Specific gravity

Conclusion

As a result of the study, it was found that in organic potato cultivation, the application of liquid vermicompost as a foliar fertilizer in certain periods, in addition to the stable manure used as bottom fertilizer, is effective in increasing some important parameters such as tuber yield per hectare, marketable tuber ratio, protein ratio, and starch ratio. This study was carried out under the conditions of Bayburt. It was found that the liquid vermicompost dose of 9 L per hectare had the optimum tuber yield (30.40 tons), marketable tuber ratio (47.18%), protein ratio (2.21%), and starch ratio (15.99%) in the variety "Agria", which has superior quality characteristics.

As a result, it was determined that the application of 9 L^{-1} liquid vermicompost fertilizer dose positively affected the yield and vegetative growth of potato Agria. However, it was concluded that it would be beneficial to conduct more comprehensive studies examining the effects of different dosage applications on many potato cultivars.

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