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Direct and Residual Effect of Various Vermicompost on Yield and Quality of Broccoli

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ABSTRACT

Direct and residual effect of three kinds of vermicompost at various application rates on yield and quality of broccoli were investigated in field experiment organically. The experiment used a factorial randomized block design which consisted of two factors. The first factor is the kind of vermicompost consisted of three levels : v1= the mixture of spent mushrooms waste (SMW), cow dung (CD) and vegetable wastes (VW), v2=SMW, CD and leaf litter (LL), v3= SMW, CD, VW and LL. The second factor is the application rates of vermicompost consisted of four levels : 5, 10, 15, and 20 t ha^{-1} and one control (inorganic treatment). The results of this study showed that direct effect of vermicompost application had non-significantly different yield with the control. While residual effect of vermicompost application significantly (P<0,5) had higher yield of broccoli than the control. Yield of broccoli at the residual effect decrease by 36-44%. Application of v3 vermicompost 15 t ha^{-1} had relatively stable yield either at direct or residual effect. The inorganic treatment had lower quality of broccoli than the treatment using vermicompost. Application of v2 vermicompost 5-10 t ha^{-1} relatively had stable quality of broccoli either at the direct or residual effect. It suggests that application of vermicompost is important to maintain productivity and quality of organic vegetables.

KEYWORDS: Direct, residual effect, vermicompost, yield, quality, broccoli

INTRODUCTION

Broccoli is a popular vegetable and useful for health. Broccoli is an excellent source of antioxidants, vitamin C, fiber and folate. It is also a good source of potassium and vitamin A. Broccoli is low in calories. It is also fat and cholesterol free [1;2]. The vegetables that contain high antioxidants and minerals that includes green leafy vegetables were most strongly associated with a reduction in risk of cancer and cardiovascular disease [3;4]. The composition and quality of horticultural crops such as broccoli is influenced by many pre-harvest, harvesting and post-harvest factors. The pre-harvest factors are genotypic variation, cultural practices, and climatic conditions [5]

Cultural practices greatly affected the yield and quality of vegetables was nutrient and water management such as fertilization [6]. Some studies have shown slightly enhanced levels of certain micronutrients, e.g. vitamin C content, in organic foods compared with foods grown conventionally [7]. Nurhidayati *et al.* [8] reported that the cabbage grown organically had the higher quality compared with grown using inorganic fertilizer. Chishaki and Horiguchi [9] showed some compounds related to secondary metabolism such as phenolic compound indicated a positive response when limited N, P and K content in the soil.

One organic fertilizer that has a good quality is vermicompost. Vermicompost is compost produced from organic materials through earthworm activity (vermicomposting). Vermicompost has been shown to have higher levels of macronutrients and micronutrients than traditional compost produced from the same raw material [10;11;12;13]. As a organic fertilizer, vermicompost also has a slow release process which could match the nutrient requirement of a crop and thus limits the loss of nutrient for plant. Therefore, it also has residual effect on the succesive plant. Jat and Ahlawat [14] reported that vermicompost application increased soil nutrient status (N and P) in subsequent crops compared to no vermicompost application. However, the residual value was determined the vermicompost quality and the application rate. The effects of vermicompost on the growth of other plants have been evaluated by other researchers through various greenhouse and field studies, including cereals and legumes [15], vegetables [16;17;18], ornamental and flowering plants [19] and field crops [20]. Application of vermicompost can increase is the growth and yield of vegetables such as tomatoes [21], peppers [22] and Chinese cabbage [23], garlic [24] and strawberry [25] However, the effect of vermicompost on the growth and yield highly variable [26]. The variability may depend on the cultivation system into which it is incorporated, as well as on the physical, chemical and biological characteristics of vermicompost, which widely depending on the original feedstock, the earthworm species used, the production process, and the age of vermicompost [27;28;29]. Nurhidayati *et al*. [8] reported that the cabbage treated with the various vermicompost materials had higher yield than the inorganic treatment.

Despite the potential of vermicompost as organic fertilizer has been demonstrated. However, direct and residual effects of application of vermicompost on different types of material on the yield and the quality of vegetables have not been studied so far. In addition few data are so far available on the agronomic performance of broccoli in response to vermicompost under local conditions.

2. Objectives:

This study was conducted to describe the direct and residual effects of different vermicompost materials on the yield and quality of broccoli, and to assess the potential of vermicompost compared to inorganic treatment for two growing seasons of broccoli.

MATERIALS and Methods

3.1. Preparation of vermicompost and experiment design:

The study was undertaken to determine the potential of three types of vermicompost as organic fertilizer for organically broccoli cultivation. Three types of vermicompost was derived from three kinds of material composition which consisted of a mixture of spent mushrooms waste, cow dung, and vegetables wastes (v1), spent mushrooms waste, cow dung, and leaves litter (v2) and spent mushrooms waste, cow dung, vegetables wastes and leaves litter (v3). The materials were collected from traditional market, around the campus of the University of Islam Malang, farmland, cattle farm and agroindustry of oyster mushrooms. The spent mushrooms waste made from sawdust. Spent mushrooms waste serves as bedding of earthworm to provide a favorable environmental condition for the earthworm. The bedding material was placed at the bottom and top of the plastic pot. A mixture of cow dung, vegetables residue and leaves litter was placed at the middle. The materials were feed of earthworm. The amount of bedding material needed for each of is equal 6 kg, while the organic material as much as 6 kg of feed worm. After that, 285 grams of healthy earthworms *Lumbricus rubellus* were introduced into the plastic pots. The moisture content of 80% was maintained during vermicomposting. The plastic pots were covered with black cloth to avoid the sunlight. The duration of vermicomposting was four weeks and two weeks for composting. In addition we used flour of eggs shells and fish meal as additives materials derived from the waste of broiler breeding industry and fishing industry. Three samples were collected from each vermicompost type at maturity to be subjected to laboratory analysis. Total N was determined by the Kjeldahl method and total C by Walkley-Black method using dichromate oxidation. pH of vermicompost was determined by digital-pH meter using H_2O extractant. Total P was determined by Olsen method using colorimetric [30]. K-exchangeable were determined by extraction in 1 M NH4OAc at pH 7.0. Potassium in this solution was determined with a flame photometer [31]. Lignin and cellulose content were determined by acid detergent solution method using Cetyltrimethyl-ammonium bromide reagent [32]. The results of analysis were presented in Table 1.

3.2. Experiment 1:

This study is a field experiment conducted at Tawangargo village, Karangploso district, Malang regency, East Java, Indonesia with latitude 07^{o}56 S, longitude 112^{o}36 E, altitude 1060 m above sea level which contain Inceptisol soil type and the average temperature of 17^o-22^{o}C. This experiment was established in 2015. Soil analyses of the plough layers of the site showed C-organic 1.03%; N-Total 0.47%; P-Bray II 112.17 mg kg^{-1}

and K 2.26 cmol kg^{-1} soil, cation exchange capacity 42.48 cmol kg^{-1} soil, and 28 % sand, 56 % silt and 16 % clay. Land preparation was done as appropriate. The first experiment was carried out to determine the direct effects of three types vermicompost applied in the first broccoli plant. Broccoli transplants were planted 16 November 2015 on a bed with size 1 m x 3 m with a planting distance of 50 cm X 40 cm (in double row per 0.5 m raised bed configuration, at a population of 50,000 plants ha^{-1}). The experimental plots were arranged in a factorial randomized block design.The first factor was three types of vermicompost (v1, v2, and v3). The second factor was four application rates (d1=5; d2=10; d3=15, and d4=20 t ha^{-1}). There were 12 treatment combinations and one control treatment using a recommended rate of conventional NPK (15:15:15) fertilizer with dose 500 kg ha^{-1}. This gives a total of thirteen treatments with three plot replications of each treatment. Cow dung was applied to the entire plot with a dose of 5 ton ha^{-1} except control. Vermicompost treatments were applied by incorporating them into the soil a week before transplanting while the NPK fertilizer application was done one week after transplanting (WAT). Crop irrigation was carried out if there was no rain for two days. Weed was carried out manually. Insect pest and disease control were carried out appropriately using bio-pesticide. Harvesting was carried out at the age of 56 days after transplanting by pulling out entire plants per plot and then collected and weighted the fresh weight of total biomass and the weight of marketable yield and diameter of florets. Furthermore, the plants were determined their quality which consisted of vitamin C content, sugar content, total soluble solid, phenolic compound content, and kalium content. The plants was also dried in the oven at 70 ° C for 2 x 24 hours to determine the dry weight of total biomass. Yield and quality parameters considered were subjected to analysis of variance and means were compared by Tukey test at 5%. Dunnet test at 5% was used to compare with control.

Table 1: The chemical composition of three types of vermicompost on dry weight basis

No.	Chemical properties	Vermicompost 1	Vermicompost 2	Vermicompost 3
1	C-organic (%)	17.07	15.44	16.48
2	Polyphenol (%)	0.49	0.47	0.45
3	Celulose (%)	37.21	35.34	34.00
4	Lignin (%)	17.74	17.55	18.16
5	Total N (%)	1.33	1.19	1.31
6	C:N ratio	12.69	12.97	12.62
7	P (%)	0.77	0.89	0.92
8	K (%)	0.59	0.46	0.42
9	pH	6.63	6.97	6.93
10.	Ash (%)	2.72	0.46	0.42

3.3. Experiment 2:

This was carried out to determine the residual effects of three types vermicompost applied in the first broccoli plant. The experimental treatments, design, plot layout and spacing used in 2015 were maintained. There was no application of new compost for all treatments. The plots were prepared with zero tillage to afford minimum disturbance to the soil. Seedlings were transplanted on 10 February 2016. Maintenance and harvesting of plants were carried out as done in 2015. The observed variables have been explained in the previously sub-chapter. The collected data were subjected to statistical analysis as in Experiment 1.

RESULTS AND DISCUSSIONS

4.1. Direct and Residual Effect of three types vermicompost on yield of broccoli:

Based on statistical analysis showed that application of vermicompost at various application rates significantly affected total fresh and dry weight of biomass at both the direct and residual effect. For direct effect, vermicompost v1 gave the highest yield at the application rate 15 t ha^{-1}, while vermicompost v2 and v3 at the application rate 20 t ha^{-1}. For residual effect almost all vermicompost gave the highest yield at the application rate 10-25 t ha^{-1}. The lowest decrease of total weight of biomass for vermicompost v1 was found at doses of 20 t ha^{-1}, v2 at doses of 5 t ha^{-1}, and v3 at a dose of 10 t ha^{-1}. The total fresh and dry weight of biomass at the direct effect were not significantly different with control, while the residual effect of vermicompost application gave higher total fresh and dry weight of biomass than the inorganic treatment (control) (Fig.1).

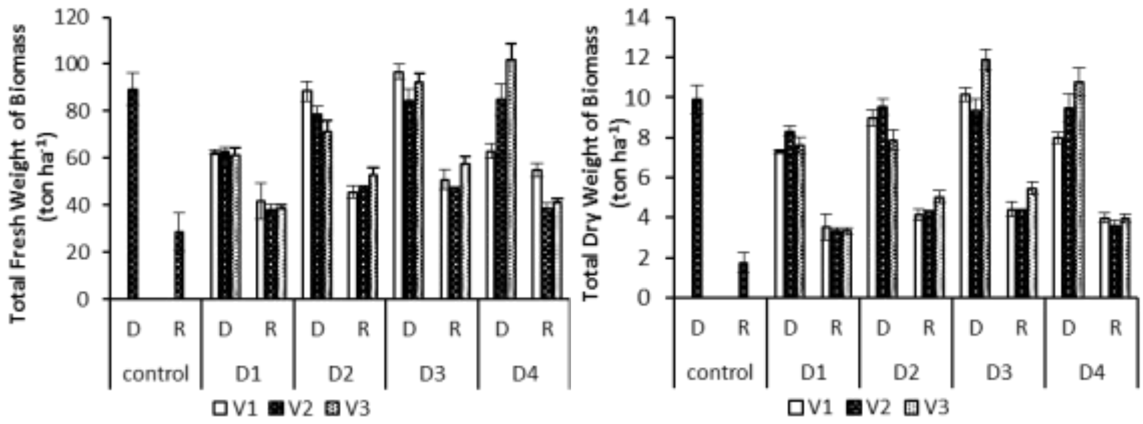

Fig. 1: Direct (D) and residual (R) effect of three types vermicompost at various doses on the total fresh and dry weight of biomass of broccoli.

Overall the direct effect had higher yield than residual effect (Fig.1). It means the yield of broccoli has decreased in second planting. The average decrease of total fresh weight of biomass in the residual effect for vermicompost v1, v2 and v3 were 36%, 44%, and 40%, while total dry weight of biomass was 53, 58 and 52%, respectively. The lowest decrease of the total weight of biomass at the residual effect was found on the application of vermicompost v1 and v3 with application rate of 10 t ha^{-1}.

Overall the direct effect had higher yield than residual effect (Fig.1). It means the yield of broccoli has decreased in second planting. The average decrease of total fresh weight of biomass in the residual effect for vermicompost v1, v2 and v3 were 36%, 44%, and 40%, while total dry weight of biomass was 53, 58 and 52%, respectively. The lowest decrease of the total weight of biomass at the residual effect was found on the application of vermicompost v1 and v3 with application rate of 10 t ha^{-1}.

Table 2: Marketable Yield, Floret Diameter and Harvest Index of Broccoli in Response to Different Vermicompost Types and Rate for Direct and Residual Effect.

Treatment		Marketable weight (t ha-1)		Floret diameter (cm)		Harvest Index (%)	
Type of vermi-compost	Rate (t ha^{-1})	Direct Effect	Residual Effect	Direct Effect	Residual Effect	Direct Effect	Residual Effect
v1	5	^{ns}15.66 ab	*7.50 ab	^{ns}12.26 ab	^{ns}8.08 a	^{ns}25.07 cde	^{ns}18.40 abcd
	10	^{ns}17.36 bc	*8.10 abc	^{ns}13.06 bcd	^{ns}8.90 abc	^{ns}19.64 a	^{ns}17.79 ab
	15	^{ns}18.77 cde	*8.85 cd	^{ns}13.56 cde	*9.27 bc	^{ns}19.39 a	^{ns}17.62 ab
	20	^{ns}17.74 bc	*9.40 d	^{ns}12.54 abc	*9.68 bc	*28.17 e	^{ns}17.20 a
v2	5	^{ns}12.70 a	*7.34 a	^{ns}11.49 a	^{ns}8.54 ab	^{ns}20.28 ab	^{ns}19.31 abcd
	10	^{ns}16.64 bc	*8.24 abc	^{ns}12.46 abc	*9.33 bc	^{ns}21.23 abcd	^{ns}17.35 a
	15	^{ns}17.84 bcd	*9.30 d	^{ns}13.50 cde	*10.01 c	^{ns}21.21 abc	^{ns}19.66 abcd
	20	^{ns}20.99 ef	*7.72 ab	*14.58 e	*9.30 bc	*24.83 cde	^{ns}20.18 bcd
v3	5	^{ns}13.08 a	*7.58 ab	^{ns}10.37 a	^{ns}8.73 ab	^{ns}21.49 abcd	^{ns}19.58 abcd
	10	^{ns}16.98 bc	*10.97 e	^{ns}12.10 ab	*9.59 bc	*23.88 bcd	^{ns}20.81 d
	15	^{ns}20.42 de	*12.06 f	^{ns}12.99 bcd	*11.25 d	^{ns}22.13 abcd	^{ns}21.06 d
	20	*25.72 f	*8.43 bcd	^{ns}13.87 de	^{ns}8.93 abc	*25.28 de	^{ns}20.64 cd
Control		18.96	5.98	13.02	7.73	21,21	22.34
HSD 5%		2.66	1.04	1.20	1.21	4,06	2.76
Dunnet 5%		1.58	0.57	0.71	0.67	2.41	3.74

Means followed by different letters in the same column are statistically significant different at Tukey- test, P=0.05 ; * = significant ; ns = non-significant at Dunnet test , P=0,05

The interaction effect between vermicompost types and rates were significant on marketable yield, floret diameter and harvest index (Table 2). The highest marketable yield and floret diameter was found at vermicompost v1 at the dose 15 t ha^{-1}, while v2 and v3 at the dose 20 t ha^{-1} for direct effect. For residual effect, the highest marketable yield and floret diameter was found at vermicompost v1 at the dose 20 t ha^{-1}, while vermicompost v2 and v3 at the dose 15 t ha^{-1}. The highest harvest index was found at the highest dose for direct effect, while for residual effect was found at the lowest dose (Table 2). The lowest decrease of the yield of broccoli at the residual effect was found on the application of vermicompost v3 with application rate of 15 t ha^{-1}. For some treatments using vermicompost, the marketable yield, floret diameter and harvest index at the direct effect were not significantly different with inorganic treatment, while at the residual effect application of vermicompost gave higher marketable yield, floret diameter and harvest index than the inorganic treatment (control). Differences in the yield of broccoli at the direct and residual effect was due to differences in the chemical composition of three types vermicompost used. The chemical composition of vermicompost will affect the mineralization rate of vermicompost [33]. Mafongoya *et al*.[34] reported that the nitrogen, polyphenol, and lignin) content of organic matter regulate decomposition and nutrient release.

Table 3: Residual total N, P-available, and K-exchangable of the soil which measured after harvesting the first broccoli

Treatments: Type of vermicompost	Rate (t ha^{-1})	Total N (%)	P-Bray 1 (mg kg^{-1})	K-exchangable (me 100 g^{-1})
v1	5	0.26 ab	29.11 a	2.26 a
	10	0.26 ab	55.32 d	3.03 bc
	15	0.27 abc	72.13 e	3.12 cd
	20	0.28 bc	73.45 e	3.32 de
v2	5	0.25 a	49.06 bcd	2.98 bc
	10	0.26 ab	54.35 cd	3.42 ef
	15	0.28 bc	68.45 e	3.58 f
	20	0.29 c	72.34 e	2.86 b
v3	5	0.26 ab	44.14 b	2.89 b
	10	0.27 abc	50.54 bcd	3.34 def
	15	0.28 bc	74.40 e	3.48 ef
	20	0.29 c	48.34 bc	2.86 b
Control		0.24	25.18	2.04
HSD 5%		0.02	6.80	0.25
Dunnet 5%		0.01	4.03	0.15

Means followed by different letters in the same column are statistically significant different at Tukey- test, P=0.05 ; * = significant ; ns = non-significant at Dunnet test , P=0,05

Vermicompost type, rate and their interaction significantly influenced the residual N, P and K nutrient contents of the soil after harvesting the first crop. This results showed a higher level of nutrient depression in the lowest rate than the higher rate treatments (Table 3). It was observed that v1 had the least residual N followed by v2 and v3. Application of vermicomposts v2 and v3 had significantly higher residual P and K than vermicompost v1. The plot treated with NPK fertilizer had the lowest residual nutrient. This results are in line with reported by Jat and Ahlawat [14] that application of vermicompost improved the total N, P, and K status of the soil after the harvest of both the crops in the sequence. It showed that the improvement of soil chemical properties was better in vermicompost application treatments than what was obtained with inorganic treatment (NPK fertilizer inclusive). Based on correlation analysis showed that there was a positive correlation between residual NPK nutrient content of the soil and yield variables of the second broccoli (Table 4).

Table 4: Correlation matrix (Pearson) between variables residual nutrient of the soil and yield variables

Variables	TFWB	TDWB	MY
N	0,5428*	0,6451*	0,6031*
P	0,6966*	0,6661*	0,6193*
K	0,8045**	0,8297**	0,7564*

* significant at the 0.05 level ;** significant at the 0.01 level
TFWB = Total fresh weight of biomass; TDWB =Total dry weight of biomass; Marketable yield

It means the higher the residual nutrient content, the higher the yield of the second broccoli. Nutrient content of N, P, and K soils treated with vermicompost are higher than those treated with inorganic fertilizers. The results are in line with those reported by Arancon *et al.* [35] that the total N content in soil without application of vermicompost decreased significantly. This shows that vermicompost contain large amounts of C and N that could have provided a larger source of N for mineralization. Use of vermicompost not only reduces the requirement of chemical fertilizers but also supplements important all essential nutrients to increase crop yield besides improving the soil properties and processes [36]. However, this study showed a decrease in the yield of second broccoli. It was due to low C/N ratio of the vermicompost. In general, high quality organic matter characterized by a C/N ratio < 20, low lignin and polyphenols content will release higher N-minerals than low quality. A high C/N ratio of vermicompost is suggested to be the reason for their better residual properties. This improves soil physical, chemical and biological properties, thus enhancing plant performance in the subsequent growing season. The results of this study indicated that the residual effect of vermicompost was not able to meet the nutrient needs of the second broccoli.

4.2. Direct and Residual Effect of three types vermicompost on quality of broccoli:

Based on statistical analysis showed that application of vermicompost at various application rates significantly affected the quality of broccoli at both the direct and residual effect. Vitamin C and phenolic compound content of broccoli were higher in residual effect than direct effect. While sugar, total soluble solid content, and K-mineral of broccoli were higher in direct effect than residual effect (Fig.2). Vitamin C and phenolic compound content of broccoli were higher in vermicompost application than NPK fertilizer application for direct effect. However, for residual effect, vitamin C and phenolic compound content were higher in NPK fertilizer than vermicompost application. It means secondary metabolite compounds such as vitamin C and phenolic compounds will increase under limited nutrient availability conditions. Chishaki and Horiguchi [9] reported that some compounds related to secondary metabolism such as phenolic compound showed a positive response when limited N, P, and K content in the soil. While the sugar content, total soluble solid and content of K-mineral increase with increasing soil nutrient content. The average increase of vitamin C content in the residual effect for vermicompost v1, v2 and v3 were 32%, 25%, and 19%, and phenolic compound was 12%, 19%, and 25%, respectively. While the K-mineral content decreased by 13%, 12%, and 18%, sugar content was 53, 58, and 52%, and total soluble solid was 64%, 50%, and 55%, respectively.

Based on the quality parameters of broccoli, there is a tendency that the lowest dose of application provides the best broccoli quality except for K-mineral content where the highest K content is found in the application rate range of 10-15 t ha^{-1}. Stability of broccoli quality in direct and residual effect was found in application of vermicompost v2 with dose application of 5-10 t ha^{-1}. Oliveira *et al.* [37] reported organically grown tomatoes had better quality and had higher soluble solids and higher vitamin C content and a significantly higher amount of flavonoids compared to conventionally produced tomatoes [38]. Doring *et al.* [39] reported that total soluble solids [% Brix] did not differ significantly among treatments using organic and inorganic fertilizer, but total sugar content was higher at the organic treatment. Theunissen *et al.* [40] stated that the improved quality of the crop was due to the improved soil quality from application of vermicompost into the soil.

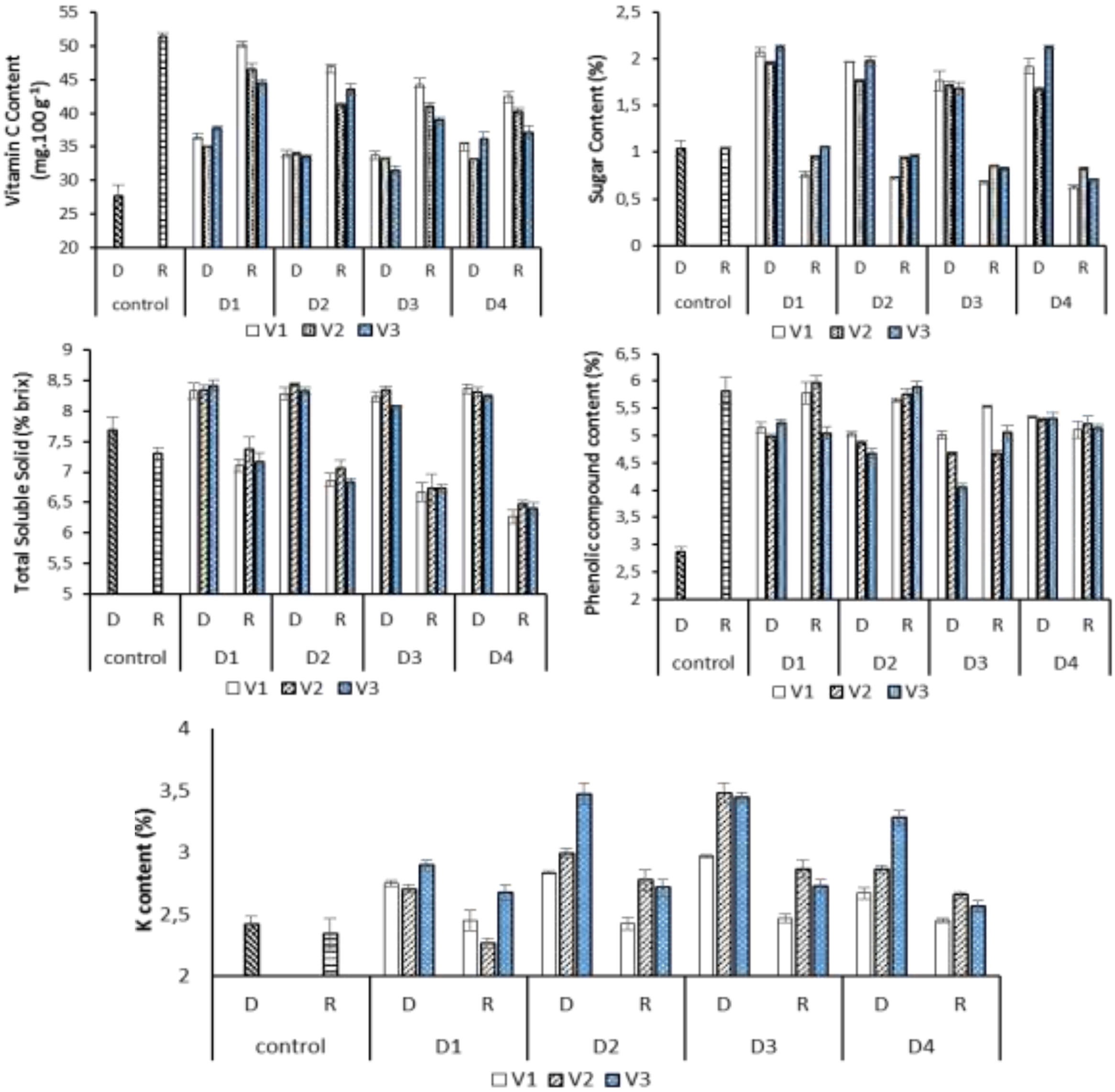

Fig. 2: Direct (D) and residual (R) effect of three types vermicompost at various doses on the quality of broccoli.

Conclusions:

Direct effect of vermicompost application gave yields of broccoli that were non-significantly different with inorganic treatment, while the residual effect of vermicompost application significantly had higher yields of broccoli than inorganic treatment. Application of vermicompost had higher residual nutrient content than inorganic treatment. However, the yields of broccoli tend decrease at the residual effect of vermicompost application. Vermicompost made from the mixture of spent mushrooms waste, cow dung, vegetables wastes and leaves litter with application rate 15 t ha^{-1} gave the best yield of broccoli for two growing season with the lowest decrease of its residual effect. While vermicompost made from the mixture of spent mushrooms waste, cow dung, and leaves litter with application rate 5-10 t ha^{-1} relatively had stable quality of broccoli both at the direct and residual effect.

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