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Effect of Vermicompost Tea on Faba Bean Growth and Yield

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ABSTRACT

This study investigated the effect of vermicompost tea (VCT) as a natural foliar fertilizer in faba bean. To determine the effect of VCT at different doses on the growth and reproduction of faba bean, VCT was produced and three different concentrations (0, 10, and 20% VCT) were applied as a foliar fertilizer to faba bean plants. Plant height, number of flowers, and pods per plant as well as soluble sugars were measured weekly after treatment for a period of 11 weeks. Treated plants were larger and had more flowers per clump, as well as more clumps and pods per plant than the control. Moreover, treated plants reached the flowering stage at least 3 weeks earlier than the control. This could be explained by the presence of nutrients, humic acid, and probably hormones in VCT, which may positively affect growth, reproduction, and yield. Treatment at 10% VCT presented better values than 20% VCT. The latter contained more humic acid, which probably limited growth and flowering. The soluble sugar and protein contents were higher in treated plants, and the highest values coincided with the flowering and reproductive stages. Similarly, seeds produced by treated plants were richer in protein that control seeds. These results indicate that 10% VCT is a useful fertilizer to improve growth in faba bean. This study highlights the possibility of using VCT as a foliar fertilizer to increase growth in faba bean.

Introduction

The recommendations of the European Union aim to reduce chemical inputs and pesticides in agriculture to preserve human health and the environment. Thus, it is important to develop credible and usable alternatives to overcome the limitation of chemical inputs. Many organic materials have been proposed as a source of nutrients for plant crops. Seaweed, humic substances and compost are the most promising sources of biostimulants (Baldotto and Baldotto 2014; Du Jardin 2015; Mupambwa, Dupe, and Mnkeni 2015; Sharma et al. 2014).

Vermicompost is natural organic substances resulting from the degradation of plant and livestock waste by earthworms. This organic matter is enriched with beneficial microorganisms and recoverable nutrients for plants (Arancon et al. 2012; Canellas et al. 2015; Olivares et al. 2015).

Several studies have reported improved yields under greenhouse conditions in legumes and vegetables (Amiri, Ismaili, and Hosseinzadeh 2017; Arancon et al. 2005, 2006; Doan et al. 2013; Fernández-Luqueño et al. 2010; Khan and Ishaq 2011; Manh and Wang 2014; Yang et al. 2015) using vermicompost in the roots. Olivares et al. (2015) emphasized the interest of the use of vermicompost tea (VCT) as spray on tomatoes. However, there is no information on the effect of VCT as a foliar fertilizer on faba bean growth and yield. Indeed these studies focused on impact of vermicompost on soil and root of plant and its effect on yield of different species. Water extract of vermicompost (called VCT) may contain higher levels of nutrient that would be assimilated by foliar tissues and therefore may induce an effect on plant growth and production.

Therefore, the aim of this study was to examine the effect of different doses of VCT as a foliar fertilizer on the growth and yield of faba bean under greenhouse conditions.

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Material and Methods

Experimental Conditions

Experiments were performed at the experimental station of the Department of Agronomic Sciences of Blida University (45 km south of Algiers, Algeria, 36°31′06″N 2°54′19″E). The experiments were conducted in a growth chamber under the following conditions: light cycle: 16:8 h (light:dark), photosynthetic photon flux: 250 μmol m ^{2} s ^{1}, relative humidity: 60%, and temperature: 28 °C/22 °C (day/night).

Plant Material and VCT Production

Bean seeds were sown in wells containing peat until germination. At the two-leaf stage, seedlings were placed in pots containing 300 cm^3 of a mixture of 1/3 soil and 2/3 peat. Seedlings were then placed on shelves and were well irrigated during the whole experiment period.

The experimental design was completely randomized using one plant per pot with 10 replicates. Three blocks were used corresponding to three foliar treatments [control (water), 10% and 20% of VCT].

The used vermicompost was obtained by converting food and organic wastes by worms [Red Wigglers (*Eisenia foetida*)] in a worm bin. The VCT recovered in the bottom of worm bin arises mainly from the water contained in the waste (about 80% of their mass) and was carried mineral and nutrients when flowing into vermicompost (Ndegwa and Thompson 2001). VCT is a result of degradation of organic wastes by worms. This degradation releases the liquid content of the plant cells and passes through the vermicompost already present in the bin. Therefore, it thus carries different solutes such as humic acids as well as mineral and organic elements. This tea was used in our experiment.

Three treatments were used. Control (water) 10 and 20% VCT were performed by adding VCT to water. The choice of these dilutions was based on a previous study performed in our laboratory (Djazouli et al. 2017). The resulting solutions were left to stand for 24 h before use. Treatments were applied for 4 weeks to the foliage every week 3 days after transplanting. Each seedling received 50 mL of treatment and applied on foliage (Kim et al. 2015). The physical and chemical characteristics of the vermicompost and the VCT are mentioned in Table 1.

Measurements

Plant growth parameters were measured weekly during 11 weeks after the first treatment.

Each week after the first application of treatment, plant height, clump number per plant, flowers number per clump, and pod number per plant were assessed. The total soluble sugar content was measured based on the method of Yemm and Willis (1954) using anthrone reagents. The total protein content on green parts and in seed at maturity was measured according to the Bradford (1976) method using bovine serum albumin as a standard.

At maturity, grain yield was measured by weighing the seed produced by each plant separately.

Statistical Analyses

Data were analyzed statistically by ANOVA in a general linear model using SYSTAT (vers. 12, SPSS2009). Mean comparison was performed using the Duncan test at the 0.05 level, which generated least significant differences (LSD) in order to identify significant variations between treatment means.

Table 1. Chemical proprieties and nutrient concentrations of the VCT, vermicompost and used soil.

			VCT	
Parameter	Soil	Vermicompost	20%	10%
Electrical conductivity (mS cm^{-1})	0.6 ± 0.1	4.2 ± 0.2	3.4 ± 0.1	1.8 ± 0.1
pH	7.1 ± 0.1	8.6 ± 0.1	8.4 ± 0.1	7.9 ± 0.1
Humic acid (mg L^{-1})	98 ± 10.8	1278 ± 12.1	590.0 ± 12.9	357 ± 9.4
Nitrogen (mg L^{-1})	17.6 ± 0.7	90.5 ± 1.3	58.9 ± 1.1	35.1 ± 1.0
Calcium (mg L^{-1})	5.7 ± 2.1	286 ± 4.1	75.1 ± 3.7	38.2 ± 3.0
Magnesium (mg L^{-1})	0.9 ± 0.1	6.5 ± 0.7	5.5 ± 0.7	2.7 ± 0.5
Phosphorus (mg L^{-1})	0.8 ± 0.1	5.7 ± 0.7	3.7 ± 0.8	2.0 ± 0.3
Potassium (mg L^{-1})	1.0 ± 0.2	8.1 ± 0.6	2.9 ± 0.4	1.3 ± 0.3

Results

The mineral composition, humic acid content, electronic conductivity (EC), and pH are presented in Table 1. As expected, treatment with 10% VCT showed lower mineral and humic acid contents as well as EC compared to 20% VCT.

All traits increased weekly, except for soluble sugars in control plants. The increase in values was more marked for plants treated with VCT. VCT application, regardless of the concentration, positively affected all measured traits (Table 2). Interestingly, the lower concentration in VCT provided the highest trait values.

Plants were 6 and 14 cm higher than control with 20 and 10% VCT, respectively. Differences were more pronounced in the reproductive stages. Indeed, plants treated with VCT produced not only clumps, flowers and pods earlier, but also more than control (Table 2). Flowering began at 3 weeks after treatment with 10% VCT, at 5 weeks with 20% VCT and at 8 weeks in control plants (Table 2). Pods were observed 1 week after flowering in each treatment. The number of flowers and pods increased over time until a maximum was reached at 11 weeks after treatment (Table 2). Moreover, treated plants produced three-fold (20%VCT) and four-fold (10% VCT) more clumps than control. Similarly, a higher number of flowers and pods per clump were observed in treated plants compared to control ones, with the highest values noted for treatment at 10% VCT (Table 2). Grain yield was also affected positively by VCT treatments (Figure 1). Compared to control, this trait increased more than 65 and 68% for 10 and 20% VCT, respectively.

The total soluble sugar content was measured and presented large variations depending on the concentration of VCT used (Table 3). A slight weak variation was observed in control plants with a mean value of 1.2 mg g^{-1} DM. In contrast, treated plants presented variable values of the soluble sugar content that ranged from 1.6 (first week after treatment with 20% VCT) to 9.2 μmol g^{-1} DW (third week after treatment with 10% VCT) at the beginning of flowering. Protein content increased along the plant development (Table 3). The raise was always higher in plant that received VCT treatments than for

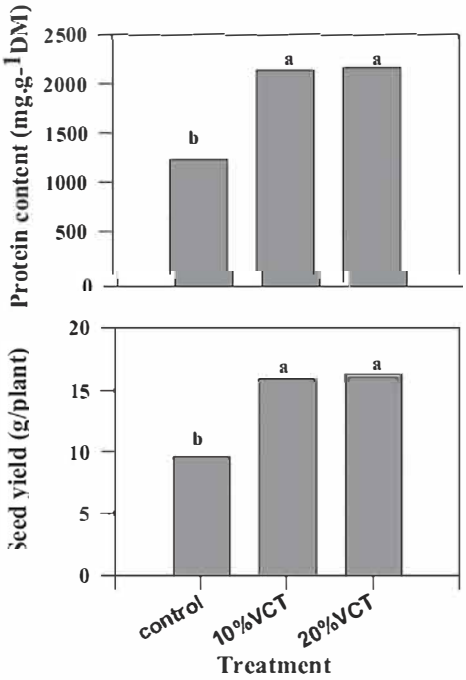

Figure 1. Grain protein content and grain yield by plant measured in faba bean plants treated with different doses of vermicompost.

Table 2. Morphological and reproductive traits measured in faba bean plants treated with different doses of VCT for a period of 11 weeks.

Week after treatment	Plant height (cm)				Clump number/plant				Flowers number/clump				Pods number/plant			
	CT	20%	10%	LSD	CT	20%	10%	LSD	CT	20%	10%	LSD	CT	20%	10%	LSD
W1	5.9^{b}	6.2^{b}	10.3^{a}	1.4	0.0^{c}	0.0^{c}	0.0^{c}	ns	0.0^{c}	0.0^{c}	0.0^{c}	ns	0.0	0.0	0.0	ns
W2	6.7^{b}	6.7^{b}	11.9^{a}	1.0	0.0^{c}	0.0^{c}	0.0^{c}	ns	0.0^{c}	0.0^{c}	0.0^{c}	ns	0.0	0.0	0.0	ns
W3	7.7^{b}	7.6^{b}	14.6^{a}	1.2	0.0^{b}	0.0^{b}	1.0^{a}	0.2	0.0^{b}	0.0^{b}	3.0^{a}	0.7	0.0	0.0	0.0	ns
W4	8.9^{b}	8.9^{b}	17.2^{a}	1.5	0.0^{b}	0.0^{b}	2.0^{a}	0.3	0.0^{b}	0.0^{b}	6.0^{a}	1.2	0.0^{b}	0.0^{b}	4.0^{a}	1.0
W5	10.4^{b}	10.0^{b}	20.1^{a}	2.0	0.0^{c}	0.7^{b}	3.4^{a}	0.4	0.0^{c}	2.0^{b}	8.0^{a}	1.3	0.0^{b}	0.0^{b}	6.0^{a}	1.2
W6	12.0^{b}	10.8^{b}	22.3^{a}	2.1	0.0^{c}	2.0^{b}	4.0^{a}	0.4	0.0^{b}	9.0^{a}	9.0^{a}	2.1	0.0^{c}	3.0^{b}	6.0^{a}	1.1
W7	13.5^{b}	12.3^{c}	24.5^{a}	2.1	0.0^{c}	3.7^{b}	7.0^{a}	0.7	0.0^{b}	13.0^{b}	17.0^{a}	2.1	0.0^{c}	9.0^{a}	11.0^{a}	2.4
W8	16.0^{b}	15.4^{b}	31.6^{a}	2.2	0.7^{c}	6.7^{b}	11.0^{a}	1.5	0.0^{c}	19.0^{b}	28.0^{a}	3.3	0.0^{c}	13.0^{b}	24.0^{a}	3.1
W9	20.4^{b}	21.8^{b}	38.0^{a}	2.2	3.5^{c}	13.3^{b}	16.2^{a}	2.1	3.5^{c}	23.0^{b}	30.0^{a}	4.5	3.0^{c}	13.6^{b}	26.5^{a}	4.1
W10	26.4^{c}	32.4^{b}	45.0^{a}	3.5	5.4^{c}	18.3^{b}	22.7^{a}	2.3	10.5^{c}	24.0^{b}	31.5^{a}	3.7	7.5^{c}	14.5^{b}	27.5^{a}	4.1
W11	34.7^{c}	40.4^{b}	48.7^{a}	4.5	9.0^{c}	32.0^{b}	38.4^{a}	3.1	11.0^{c}	27.0^{b}	36.0^{a}	4.9	10.5^{c}	16.0^{b}	33.0^{a}	3.7

For each trait within each line, means with same letters are not statistically different according Duncan test at the 0.05 probability level. CT, control; LSD, least significant difference.

Table 3. Soluble sugar and protein content measured in faba bean plants treated with different doses of VCT for a period of 11 weeks.

	Total soluble sugars (μmol g^{-1} DM)				Protein content (mg g^{-1} DM)			
Week after treatment	CT	20%	10%	LSD	CT	20%	10%	LSD
W1	1.2^{b}	1.6^{ab}	1.9^{a}	0.4	85.3^{b}	89.4^{a}	87.5^{ab}	1.9
W2	1.0^{c}	3.1^{b}	4.4^{a}	1.1	85.9^{b}	91.2^{a}	92.4^{a}	3.4
W3	1.1^{b}	7.9^{a}	9.2^{a}	1.5	87.6^{c}	94.2^{b}	99.7^{a}	2.9
W4	1.1^{b}	4.8^{a}	5.7^{a}	1.2	88.3^{b}	107.3^{a}	105.3^{a}	2.6
W5	0.9^{c}	3.0^{b}	4.5^{a}	1.1	89.5^{b}	110.7^{a}	112.4^{a}	3.1
W6	1.5^{b}	4.0^{a}	4.3^{a}	1.0	91.2^{b}	112.4^{a}	115.6^{a}	3.7
W7	1.1^{c}	4.4^{b}	5.7^{a}	1.1	95.4^{c}	115.2^{b}	119.2^{a}	2.9
W8	1.2^{c}	3.0^{b}	4.3^{a}	0.9	99.8^{c}	117.6^{b}	120.4^{a}	2.4
W9	1.3^{b}	4.0^{a}	4.8^{a}	0.9	102.2^{c}	119.6^{b}	122.0^{a}	2.1
W10	1.1^{c}	4.1^{b}	5.4^{a}	1.0	105.0^{c}	124.3^{b}	129.9^{a}	2.8
W11	1.0^{c}	4.8^{b}	6.1^{a}	1.2	107.2^{b}	136.5^{a}	134.8^{a}	2.1

For each trait within each line, means with same letters are not statistically different according Duncan test at the 0.05 probability level. CT, control; LSD, least significant difference.

control. As expected grains were richer in protein that green parts (Table 3 and Figure 1). Seeds at maturity were more than 70% richer in proteins than control whatever VCT treatment (Figure 1).

Discussion

Values of mineral, humic acid content, pH and EC were quite similar to those known in vermicompost and compost (Khan and Ishaq 2011; Kim et al. 2015; Manh and Wang 2014; Yang et al. 2015).

The results obtained in this study revealed that foliar VCT application increased growth parameters, reproductive development and therefore yield (Table 2 and Figure 1). Indeed, plant height increased by a rate of 0.4 (20% VCT) and 0.5 cm per day (10% VCT) from treatment to the end of the experiment, while control plants grew 0.3 cm per day. Similar results using vermicompost in the substrate or as a spray drench applied to the roots have been reported in cereals, fruits, and legumes (Amiri, Ismaili, and Hosseinzadeh 2017; Doan et al. 2013; Fernández-Luqueño et al. 2010; Hosseinzadeh, Amiri, and Ismaili 2016; Khan et al. 2015; Manh and Wang 2014; Yang et al. 2015; Zhang et al. 2011), or as a foliar spray (Kim et al. 2015), or both (Olivares et al. 2015).

This stimulation of growth may result from water soluble bioactive molecules like phytohormones, humic, and fulvic acids, minerals, amino acids, or microbial metabolites present in vermicompost (Arancon et al. 2012; Baldotto and Baldotto 2014). Analysis of the VCT used in our study revealed that the humic acid content (Table 1) was quite similar to those already reported (Arancon et al. 2012; Yang et al. 2015). These molecules are known to be involved in many developmental processes in plants and in growth stimulation (Amiri, Ismaili, and Hosseinzadeh 2017; Baldotto and Baldotto 2014; Kim et al. 2015). The greatest effect of humic substances is in improving root nutrition (Du Jardin 2015), which results in greater shoot growth and increased dry weight (Hosseinzadeh, Amiri, and Ismaili 2016; Rose et al. 2014), as observed in this study (Table 1). Plant height increase was already observed on other legume species treated by vermicompost (Amiri, Ismaili, and Hosseinzadeh 2017; Sinha et al. 2010). No information is available on faba bean. Moreover, foliar application increases absorption of the nutrients resulting from plant degradation and therefore can be used faster by the growing faba bean. Olivares et al. (2015) reported that spraying humate and plant growth promoting bacteria increased nitrate uptake in tomatoes. Even though they were not measured in our study, phytohormones are known to play a central role in plant growth. Indeed, it has been reported that food waste vermicompost contains several phytohormones (Zhang et al. 2015) or molecules that present hormone-like effects (Baldotto and Baldotto 2014; Eyheraguibel, Silvestre, and Morard 2008; Mendoza-Hernández, Fornes, and Belda 2014) that may explain the effects of applying VCT in promoting growth and flowering. These substances may promote enzymes linked to C and N assimilation pathways, thereby increasing nutrient uptake and assimilation (Canellas et al. 2015; Hernandez et al. 2015; Khan et al.

2015; Olivares et al. 2015). Similar results were observed by Amiri, Ismaili, and Hosseinzadeh (2017) which reported an increase of number of pods in Chickpea supplied by vermicompost.

Other studies have attributed the effect of VCT application to the availability of minerals, mostly nitrogen, which can be used quickly by plants (Amiri, Ismaili, and Hosseinzadeh 2017; Khan et al. 2015; Sinha et al. 2010; Yang et al. 2015). In fact, humic acid, phytohormones, and minerals stimulate growth; this probably increases light interception, which in turn enhances photosynthesis, leading to increased growth and yield (Datta et al. 2012; Hosseinzadeh, Amiri, and Ismaili 2016; Mondal, Datta, and Mondal 2016). Nevertheless, it is well-known that increased N availability favors vegetative growth. In our study, application of VCT led to earlier flowering (Table 2). This fact may result from hormones or C/N ratio modification, or both. Previous studies have highlighted that the addition of vermicompost promotes flowering and yield, probably due to the presence of hormones such as indole acetic and gibberellic acids or molecules with hormone-like effects (Baldotto and Baldotto 2014; Fernández-Luqueño et al. 2010; Khan et al. 2015; Kim et al. 2015). As results, higher yield was observed in both VCT treatments. In fact, higher nutrients and hormones increased leaf area and plant growth which led to higher reproductive development that in turn raised grain yield (Figure 1). Studies on other legumes reported similar results (Amiri, Ismaili, and Hosseinzadeh 2017; Hosseinzadeh, Amiri, and Ismaili 2016; Fernández-Luqueño et al. 2010; Khan and Ishaq 2011). However, higher plant growth observed in plant treated at 10% VCT did not yielded more than those that received 20% VCT. Nevertheless, increase of VCT treatment did not raised twice the yield (Figure 1). This could be explained by the competitiveness between vegetative and reproductive development (Abid et al. 2017). Moreover, yield values observed in our study were higher than those reported by Wu and Wang (2000) and Abid et al. (2017). This could be due to experiment conditions, genotype used, and fertilizer treatment. Indeed, experimental conditions and genotypes were different between the three studies. Field experiments were conducted for the studies of Wu and Wang (2000) and Abid et al. (2017) and chemical fertilization was done. In contrast, in our conditions plants were cultivated and fertilized by foliar spray. Controlled conditions as well as spray fertigation may have induced fast growth and higher yield.

The soluble sugar content was markedly higher in treated plants than in the control (Table 2). Moreover, the accumulation of sugars started earlier in treated plants, which coincided with reproductive stages. Previous reports have highlighted that the addition of vermicompost results in a higher content in carbohydrates and soluble sugars (Canellas et al. 2015; Kim et al. 2015; Zhang et al. 2011). The increase in the number of flowers and pods in treated plants probably induced sink-source modification, which results in the accumulation of soluble sugars. This increase in sugars is necessary for mitotic activity in developing seeds (Patrick and Stoddard 2010). Protein content in vegetative part of plant raised along the plant development and was higher in VCT treatments (Table 3). Moreover, seed constitutes a strong sink for protein reserves which could explain the higher content in this organ compared to green part of plant (Figure 1 and Table 3). The observed values were in the range of those reported by Abid et al. (2017) in a collection of 11 faba bean genotypes. Spray of VCT may promote enzymes linked to C and N assimilation pathways, which favored increasing nutrient uptake leading probably to higher protein content (Canellas et al. 2015; Hernandez et al. 2015; Khan et al. 2015; Olivares et al. 2015).

Intriguingly, the treatment at 20% VCT led to less growth and flowering than 10% VCT (Table 2). Higher concentrations of humic acid, hormones, and minerals exceeding the demand of plants could be responsible for the lower values of growth and flowering traits (Manh and Wang 2014; Yang et al. 2015). Indeed, a higher humic acid concentration was noted in 20% VCT (Table 1), which probably limited both growth and flowering.

Conclusion

Growth and reproductive traits in faba bean plants treated with VCT were higher than in

control plants. Foliar application of VCT to faba bean plants resulted in earlier flowering and a higher number of pods per plant which probably favored higher yield. It appears that foliar application of VCT had a beneficial effect on growth and production in faba bean plants. Our results indicate the potential use of VCT obtained from food waste as a cheap foliar fertilizer to cultivate faba bean and other corps under organic conditions. These results provide the possibility of increasing biological inputs for vegetable cultivation. The application of these substances can be help to develop sustainable agriculture systems around the world, mostly in regions were the use of fertilizers is an economically limiting factor. However, further research is important to refine the impact of these applications on the production and the impact on diseases and pests in this species and other legumes.

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