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Original article

Vermicomposting effect on the biological and agricultural productivity of cabbage crop (*Brassica oleracea* L.)

Efecto del vermicompost sobre la productividad biológica y agrícola del cultivo de la col (*Brassica oleracea* L.)

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ABSTRACT: Vermicomposting use and products obtained from it in agriculture has led to new scientific research in recent years, resulting in knowledge about the contribution of nutrients to plants, as well as crop production with quality and tolerant to abiotic stress. The cabbage KK-Cross variety is one of the most used in Cuba, the use of mineral fertilizers and chemical pesticides has been progressively increasing in this crop, and therefore, the reduction of chemical products is a necessity for the cabbage production with the least amount of toxic residues. The aim of the present work was to evaluate vermicomposting extract dilution effect on the biological and agricultural productivity of cabbage crop. For this purpose, three dilutions of the product-1/20, 1/40 and 1/60 v/v-were studied under laboratory (seed imbibition) and field (foliar spraying) conditions, compared with a control treatment, under a completely randomized design. The effect on seed germination was evaluated, as well as on crop growth, development and yield. With the 1/40 v/v dilution, a greater stimulus in the seed germination process and plant growth was obtained, the polar and equatorial diameter of cabbage sprouts was higher and the agricultural yield was increased by 88 %.

Key words: biostimulant, growth, development, yield, vegetable.

RESUMEN: La utilización de vermicompost y productos obtenidos del mismo en la agricultura ha derivado en nuevas investigaciones científicas en los últimos años, dando como resultado el conocimiento acerca del aporte de nutrientes a las plantas, así como la producción de cultivos con calidad y tolerantes al estrés abiótico. La variedad de col KK-Cross es una de las más empleadas en Cuba, el uso de fertilizantes minerales y plaguicidas químicos ha ido en aumento progresivamente en este cultivo por lo que, la disminución de productos químicos es una necesidad para la producción de col con la menor cantidad de residuos tóxicos. El objetivo del presente trabajo fue evaluar el efecto de diluciones de extracto de vermicompost en la productividad biológica y agrícola del cultivo de la col. Para ello, se estudiaron en condiciones de laboratorio (imbibición de semillas) y campo (aspersión foliar), tres diluciones del producto-1/20, 1/40 y 1/60 *v/v*, comparados con un tratamiento control, bajo un diseño completamente aleatorizado. Se evaluó el efecto en la germinación de las semillas, así como en el crecimiento, desarrollo y rendimiento del cultivo. Se obtuvo con la dilución 1/40 *v/v*, un mayor estímulo en el proceso de la germinación de las semillas y crecimiento de las plantas, el diámetro polar y ecuatorial de los repollos de col fue superior e igualmente se incrementó el rendimiento agrícola en un 88 %.

Palabras clave: bioestimulante, crecimiento, desarrollo, rendimiento, hortaliza.

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INTRODUCTION

In Cuba, cabbage (*Brassica oleracea* L.) is a horticultural crop of high demand due to the diversity of uses, both fresh and canned, rich in carbohydrates and vitamins. There are several cultivars spread for its production and commercialization by agricultural producers, among them is the KK-Cross cultivar (1); however, for its production, high doses of chemical products are used both for nutrition and protection of the crop, which leads to environmental contamination and affects the product quality by leaving toxic residues in the agricultural fruit (2).

For this reason, the constant search for ecological alternatives to minimize the harmful effects of chemical products in agriculture has become a fundamental task for agricultural sciences, which has allowed the development of research lines aimed at obtaining biostimulants or also called bioactive products that can substitute totally or partially the use of chemical products in crops.

In this sense, the use of vermicomposting and product obtained from it in agriculture has led to new scientific research in recent years, resulting in knowledge about the supply of nutrients to plants as well as the production of crops with quality and tolerant to abiotic stress (3). They are recognized in different countries as worm compost, vermicomposting, liquid humus, vermicomposting tea, leachates, vermicomposting extracts, among other denominations. All these products have become a transformation in modern agriculture since it is currently undeniable that their application in different moments of plant development cycle, brings an increase in yields, besides helping the recycling of residues that are used by the earthworm in the vermicomposting process (4).

Some recent research is directed to the study of the influence that vermicompost exerts in stimulating adaptation to abiotic stresses such as salinity. The presence of heavy metals at toxic levels and water deficiencies), always using them simultaneously or after the stress implementation, as well as in the stimulation of growth and development in different crops, for which different application alternatives have been used (5).

In vegetables specifically, the application of products derived from vermicompost in Cuba, have allowed obtaining satisfactory results, as it is demonstrated by works carried out in the cultivation of bell pepper -*Capsicum annuum* L. (4); tomato seedlings -*Solanum lycopersicum* L. (6); garlic -*Allium sativum* L.(7) and onion -*Allium cepa* L.- (8). The agricultural yield of crops has been increased; however, few studies have been carried out in the cultivation of cabbage.

According to this background, the present research aims to evaluate the effect of a bioproduct based on vermicompost extract on biological and agricultural productivity in the cabbage crop.

MATERIALS AND METHODS

The experimental work was carried out from December 2019 to March 2020, in the areas of the National Institute of Agricultural Sciences (INCA), located in San José de las Lajas, Mayabeque province. The experimental farm is located according to the Cartographic information between the coordinates 351. 400-north latitude and 383.250-east longitude, at an altitude of 130 m a.s.l at kilometer 3½ of Tapaste road.

The experiment was developed on an agrogenic Ferrallitic Red leached soil, according to the New Version of Soil Classification of Cuba (9), which correlates with the Soil Taxonomy: Agric Rhodudalf, and the WRB: Nitisolferralic, lixic, influenced by formation processes such as ferralitization, leaching and anthropogenesis.

Experiments were developed under two conditions: laboratory and field. The cabbage cultivar used was "KK-Cross", starting from certified seeds with 95 % germination, which were previously disinfected with 2 % sodium hypochlorite for 10 minutes and then washed with sufficient distilled water.

The obtaining of the bioproduct with the commercial name "Liplant" was carried out in the laboratory of the Chemistry Department, Faculty of Agronomy, Agrarian University of Havana (UNAH), obtaining the extract from vermicompost of cow manure produced by African red worms (*Eudrilus eugeniae* spp.). The extraction methodology (5) allowed obtaining the physicochemical and spectroscopic characteristics of the vermicompost extract and they were as follows:

pH: 8.5 slightly alkaline.

Total soluble solids: 335.0 mg L^{-1} normal value for cattle manure vermicompost extracts.

Electrical constant: 587.67 S cm^{-1}, which is in the range of values reported in the literature for cattle manure vermicompost extracts.

Percent salinity: 0.03 % low; Percentage of organic carbon: 40.1 % acceptable.

Degree of aromaticity of the vermicompost extract determined by spectroscopy: normal as reported by the literature for cow dung vermicompost extracts where there is predominance of humic substances.

For the experiment under laboratory conditions, it was started from previous work on tomato cultivation (6), evaluating three dilutions of vermicompost extract (1/20, 1/40 and 1/60 volume/volume) at a dose of 25 mL per plate and a control in water. These dilutions were shaken and were poured into glass containers and 60 seeds were subsequently soaked in each for one hour.

A completely randomized design was used and sowing was carried out in Petri dishes at a rate of 10 seeds per dish using filter paper as a moistened substrate. Four plates were used per treatment, each one constituting a replicate. These plates were kept in the dark and the total number of germinated seeds (%) was evaluated after seven days, taking as germination criterion the emission of the radicle, the data for the statistical analysis were transformed using the formula arcos√ (%). Likewise, radicle and hypocotyl lengths were measured in five seedlings per plate, for 20 seedlings per treatment. A simple rank analysis of variance and Duncan's Multiple Range Test at probability $p<0.05$ were applied.

For the field experiment, we started from the best treatment under laboratory conditions, so seeds soaked in 1/40 dilution for one hour were used. Sowing was done by hand in the bed, applying frequent irrigation and control of undesirable plants to achieve plants of good vigor until they reached heights of 18-20 cm after germination, at which time they were ready for transplanting.

Transplanting was carried out in beds 11 m long and 1.20 m wide, to which 1 kg m-2 of organic fertilizer (cow manure) was applied as a base. The plants were transplanted in two rows at 20 cm between plants. A completely randomized design was used, with four treatments and three replications, each treatment had an area of three meters. The treatments studied were as follows:

T1. Dilution 1/20 *v/v* of vermicompost extract (Liplant).

T2. Dilution 1/40 *v/v* of vermicompost extract (Liplant).

T3. Dilution 1/60 *v/v* of vermicompost extract (Liplant).

T4. Control (without vermicompost extract).

Foliar spraying at three times, at 10, 15 and 20 days after transplanting (DAT) did the application of the vermicompost extract dilutions. For the first application, a volume of 10 ml per plant was used and for the second and third application a volume of 40 ml per plant was used, and the same amount of water for those that would function as control. These sprays were made in early morning hours (8:00-9:00 am), to take advantage of the stomatal opening of the leaves, and were made manually using a 16 L capacity backpack, with cone nozzle at constant pressure.

Evaluations performed:

At 15 DAT, 20 plants per treatment were evaluated for total leaf number. At the harvest stage (50 DAT), 20 fruits per plant were evaluated for:

- equatorial diameter (cm)
- polar diameter (cm)
- fresh mass (kg)

Agricultural yield per area (kg m^{-2}) was evaluated

Photosynthetic pigments of chlorophyll a and b content and carotenes were determined and measured with a portable SPAD equipment (Konica Minolta) in SPAD units (10).

The data obtained were analyzed by means of a Simple Rank ANOVA. The resulting means were compared with Duncan's Multiple Range Test for $p\leq0.05$ when there were significant differences between treatments, processed with the Statgraphics Centurion (2013) program under the Windows 7 operating system.

RESULTS AND DISCUSSION

Effects of vermicompost extract dilutions on cabbage seed germination

The evaluation carried out seven days after germination (DAG) (Table 1), showed the positive effect of the vermicompost extract dilutions in this process stimulation in seeds. As can be seen, both the 1/40 and 1/60 v/v dilutions had 97 and 95 % of germinated seeds, contrary to the 1/20 v/v dilution and the control, which reached 90 % germination. The statistical analysis showed highly significant differences ($p<0.05$) with a higher germination percentage for the seeds that were soaked in the 1/40 dilution.

In general, the action of the vermicompost extract dilutions in accelerating the germination process of seeds was evident in the experiment, which was observed in only seven days after seeds were in contact with the bioproduct; however, the higher concentration of the product (1/20) did not accelerate this process in seeds.

As for the positive effect found in the germination process, it could be influenced by the composition of the bioproduct itself, where it is known that vermicompost contains essential nutrients for plants. In this sense, the existence of factors beyond the physical alteration of the seed layers is suggested, and it is recognized that water-soluble bioactive substances such as humic acids, phytohormones or other microbial metabolites present in the vermicompost extract may be responsible for the increase in the percentage of seed germination and seedling growth (11).

On the other hand, the effect on seed germination may also be attributable to a higher enzymatic activity that allows a higher concentration of macro and micronutrients as well as plant growth stimulating substances such as auxins and gibberellins (12).

A similar result to the one obtained in this study was obtained in the tomato crop, where the treatment to the seeds with dilutions of Liplant 1/40 v/v, was more promising, when obtaining similar results to more concentrated

Table 1. Effects of vermicompost extract dilutions on seed germination (transformed data).

Treatments	Germination (%)	Germination (Transformated data)
T1. 1/20	90	1.05 c
T2. 1/40	97	1.59 a
T3. 1/60	95	1.14 b
T4. Control	90	1.02 c
S Ex		0.09 *

Means with equal letters do not differ significantly according to Duncan's test for $p<0.05$

dilutions of the product, highlighting the reduction of the time required to reach 100% germination. Between five and seven days after sowing (DAS), seeds treated with Liplant had a doubling of the germination percentage values, with final stimulations between 25-36 % and in the germination index between 16-22 % with respect to the control.

Table 2 shows the effect of the different dilutions studied on seedling growth in terms of hypocotyl and radicle length. In both variables, the treatment where the seeds were soaked in vermicompost was superior in both variables; for hypocotyl length, the dilution of 1/40 v/v exceeded the remaining treatments by 17-25 %; however, for radicle length, the three dilutions were superior to the control, which was exceeded by 50 %.

The positive effect of vermicompost extracts on root elongation in corn (*Zea mays* L.) seedlings has been demonstrated, and it is hypothesized that the fractions (insoluble and organic) extracted from liquid humus from cow manure vermicompost can be used as biostimulants of plant growth and development in the initial growth phase (13).

Effect of vermicompost extract dilutions on cabbage crop growth and yield

Table 3 shows the effect of dilutions on the number of leaves per plant, where 23 days after transplanting and after the first application of the vermicompost extract dilutions, significant differences were obtained between treatments for p<0.05.

The highest number of leaves was reached in plants that received foliar sprays of 1/40 and 1/60 v/v dilutions, which surpassed the control in 28%, which agrees with an experiment carried out on lettuce (*Lactuca sativa* L.), where similar dilutions of Liplant also increase this indicator (14). Similar studies of foliar applications of vermicompost on recently transplanted cabbage plants caused an increase in the parameters corresponding to biological and agricultural productivity and a greater development of the leaf area of the crop (2).

For agricultural yield and its components, there were also statistical differences among the treatments evaluated. Table 4 shows the results for the polar and equatorial diameter components, as well as fruit mass.

The polar and equatorial diameters are one of the most appreciated indicators by consumers. The current Cuban norm does not establish size specifications for cabbage, but they must be well-formed cabbages, with protective basal leaves and 15 % of tolerance of total defects, besides it is reported that for the KK-Cross cultivar, the polar diameter is approximately 14 cm and the equatorial diameter oscillates between 16 and 17 cm (1). The results of this work, with applications of the vermicompost extract with the dilution 1/40, make that these values are exceeded in 18 % of the polar diameter and 10 % of the equatorial diameter.

Table 2. Effects of vermicompost dilutions on the growth of germinated cabbage seedlings in Petri dishes

Treatments	Hypocotyl length (cm	Radicle length (cm)
T1. 1/20	3.32 b	5.82 b
T2. 1/40	4.08 a	7.65 a
T3. 1/60	3.46 b	6.43 ab
T4. Control	3.24 b	3.86 c
SE x	0.28 *	0.46 *

Means with equal letters do not differ significantly according to Duncan's test for p <0.05

Table 3. Effects of vermicompost extract dilutions on the number of leaves per plant of cabbage variety KK-Cross

Treatments	Number of leaves /plant
T1. 1/20	6.8 b
T2. 1/40	7.8 a
T3. 1/60	7.7 a
T4. Control	6.0 c
SE x	0.34*

Means with equal letters do not differ significantly according to Duncan's test for p <0.05

Table 4. Effect of vermicompost extract dilutions on agricultural yield components of cabbage crop (var KK-Cros)

Treatments	Polar diameter (cm)	Equatorial diameter (cm)	Fress mass (kg fruit^{-1})
T1. 1/20	15.26 ab	19.76 b	1.24 ab
T2. 1/40	16.73 a	20.70 a	1.96 a
T3. 1/60	16.93 a	20.06 ab	1.30 ab
T4. Control	14.06 b	18.3 c	1.02 b
SE x	0.28 *	0.29 *	0.33 *

Means with equal letters do not differ significantly according to Duncan's test for p<0.05.

In the case of the fresh mass of the agricultural fruit, a similar behavior was maintained, resulting in the highest mass in those plants that received the 1/40 v/v dilution spray after transplanting, which exceeded the control by 11 %. A similar experiment carried out with two varieties of kale, obtained that with the application of an organic foliar fertilizer (vermicompost), greater height, greater number of leaves, greater leaf length and width were achieved, and the agricultural yield of the two varieties was increased (2).

Regarding agricultural yield, Figure 1 shows that there were statistical differences between the three dilutions studied (p<0.05), obtaining the highest yield per surface area with the 1/40 v/v dilution, which exceeded the control treatment by 88 %.

This effect on crop yield is related to the very essence of vermicompost, which is undoubtedly an organic fertilizer rich in humus, NPK, micronutrients, beneficial microorganisms (bacteria, fungi, actinomycetes) and growth hormones (auxins, gibberellins, cytokinins) (15,16), all of which work harmoniously to have an effective effect on the plants.

In the experiments carried out on broccoli (*Brassica oleracea* var. italica) with the application of vermicompost, it had a significant impact on the size of the plant, weight and diameter, but not on the number of leaves, surpassing the control treatment and increasing the growth and yield of the crop (17).

The content of photosynthetic pigments is shown in Table 5, where it can be seen that for chlorophyll and carotene content for the KK-Cross cultivar, the dilutions of vermicompost extract were effective in increasing these indicators, all differing significantly with respect to the control, with the 1/40 v/v dilution standing out.

The content of chlorophylls in leaves is a reliable indicator of the photosynthetic activity, the degree of stress and the nutritional level of plants and, on the other hand, carotenes have an important role in the health of human beings, being the antioxidant activity the one that confers greater importance (18,19).

In an experiment carried out with the cabbage cultivar Golden Acre (20), it was proved that plants to which the vermicompost derivative was applied increased the chlorophyll content, corresponding to a higher agricultural productivity. Also, in solanaceae, the chlorophyll index in the bell pepper crop increased significantly with the application of vermicompost leachates (21), and in cabbage, radish (*Raphanus sativus* L) and tomato crops it was shown that vermicompost produced significant increases in photochemical efficiency and chlorophyll-a content in plants (22,23).

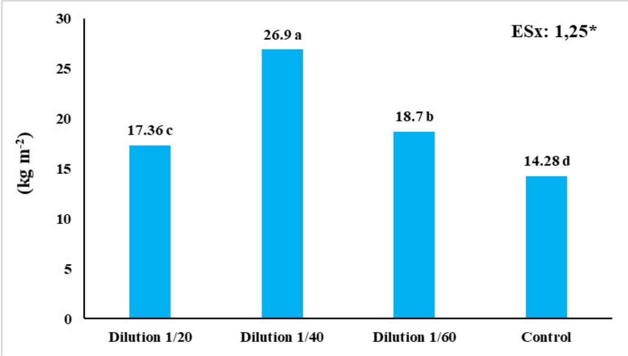

Figure 1. Effect of vermicompost extract dilutions on agricultural yield of cabbage crop (KK-cross)

CONCLUSIONS

- The positive effect of the bioproduct based on vermicompost extract (Liplant) on the cultivation of cabbage (KK-Cross) is demonstrated.
- The imbibition of the seeds in the dilution of 1/40 v/v stimulated the germination process of the seeds and the growth of the seedlings.
- This dilution increased plant development and agricultural yield, which was 88 % higher than the control treatment.

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Table 5. Effect of vermicompost extract dilutions on the content of photosynthetic pigments in cabbage crop (KK-Cross)

Treatments	Chlorophyll a SPAD	Chlorophyll b SPAD	Carotene (mg g^{-1} fresh mass)
T1. 1/20	0,49 c	0,25 c	0,49 c
T2. 1/40	1,75 a	0,82 a	1,52 a
T3. 1/60	0,78 b	0,40 b	0,69 b
T4. Control	0,20 d	0,08 d	0,13 d
SE x	0,04*	0,025 *	0,04 *

Means with equal letters do not differ significantly according to Duncan's test for p <0.05

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