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Effect of Bio-Organic Alternatives in the Agronomic Response of Onion on Los Angeles Farm

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Abstract

Context: Onion (*Allium cepa* L.) is an edible bulb that ranks, as a green vegetable, third in terms of harvested area. In general terms, world production of this crop is made intensively, with a broad application of agrochemicals, which threatens agricultural sustainability, health, and protection of the environment.
Aim: To evaluate the effect of bio-organic alternatives in the agronomic response of onion.
Methods: A randomized block experimental design with seven treatments was used (absolute control and samples with natural liquid humus, improved liquid humus, fortified liquid humus, fortified liquid humus, plus Phosphoric inducer BayFolan Forte, FitoMas E), and four repetitions. The treatments were made every seven days, starting seven days after the plantation of bulbs. Plant height, pseudostem thickness, leaf number, bulb diameter, and crop yield were the indicators evaluated. The main economic indicators of each treatment were determined. Costs, income, profit, and economic effect were calculated.
Results: The results show the positive effect of the morphophysiological and yield indicators related to the application of different bio-organic alternatives. The study produced greater profits than the control.
Conclusions: The application of bio-organic alternatives showed a positive effect on the morphophysiological and yield indicators evaluated. The fortified liquid humus plus the phosphoric inducer showed the best results, producing the highest profits in the financial assessment.

Key words: *Bio-organic alternatives, agroecological alternatives, fortified liquid humus plus phosphoric inducer.*

Introduction

Green vegetables are an extremely important topic, since yearly increases in world *per capita* production are taking place. Onion (*Allium cepa*. L) is an edible bulb that ranks third within green vegetables, in terms of harvested area, only after potato and tomato. According to the Food and Agriculture Organization of the United Nations (FAO) (2015), five million hectares were harvested, with production reaching 88 tons, 16.8 t. ha^{-1}, on average.

Currently, one of the greatest concerns is the supply of foods as a result of a fast growing rate of the population. The estimates show that by mid-2013, the world population consisted of 7.2 billion inhabitants, according to studies conducted by the United Nations Organization for Food and Agriculture (FAO), which will rise in up to a billion more by 2025. The cropland area used was increased by eight percent, and the *per capita* arable land was drastically reduced (0.45 to 0.25 ha) (FAO, 2015).

Generally, world crop production is based on intensive systems, with widespread application of agrochemicals, which harms farmer health and that of his family, since growers usually live within the production unit, and collaborates with field labor, and participates as end consumers. Society is much more interested in the reduction of harm caused to the environment by farming, especially in relation to health risks derived from excessive agrochemical use.

Worldwide, agriculture is undergoing a crisis motivated by negative impacts; therefore, agroecology is an alternative to future agriculture as a true scientific base that embraces sustainable agriculture. Many are the examples of places where the experience shows the feasibility of achieving agricultural productions through sustainable systems (Vázquez & Funes, 2014).

According to Castillo (2014), the use of biofertilizers is an alternative to achieve sustainable agriculture, since it ensures mineral fertilizer substitution, proper crop yields, and crop quality enhancement. An example of this kind of product is fortified, improved, and natural liquid humus from cattle wastes and sugar cane residues after milling. Other crop growth and development stimulating products are also being increasingly used, such as Bayfolan Forte and FitoMas-E, which are highly important under Cuban conditions for a prospering and sustainable agriculture.

This research seeks for alternatives in the production of onions using novel systems, under the premise of establishing an ecological, sustainable, and multipurpose type of agriculture, to achieve acceptable economic yields, in relation to food nutrition, the application of humus variants, Bayfolan Forte, and FitoMas-E instead of chemicals, under the Cuban edaphoclimatic conditions.

Materials and Methods

This study was conducted on Los Angeles Farm, belonging to the Hugo Camejo Cooperative of Credits and Services (CCS), on typical brown-grayish soil (Soil Institute, 1975; Hernández et al., 1999), located 8 km south of the capital city of the province, on 21º 19´ 40¨ north latitude, and 77º 56´ 25¨ west longitude, at 85 meters above sea level (Cuban Institute of Geodesics and Cartography, 1984)

A randomized block experimental design with seven treatments, and four repetitions, was used. The doses employed in the study are shown in Table 1.

The treatment composition is described below:

Natural liquid humus: It contains cytokines, auxins, humic acids, and glucose.

Improved liquid humus: It contains a combination of NLH, plus phosphorine, azotobacter, and glucose.

Fortified liquid humus It contains phosphorine, azotobacter, glucose, cytokines, auxins, and minerals.

Fortified liquid humus + phosphoric Inducer: It contains cytokines, auxins, humic acids, minerals, phosphorine, azotobacter, phosphoric acid, and glucose.

Bayfolan Forte: It contains vitamins and phytohormones, plus other 17 chemical elements, such as Boron (B), Calcium (Ca), Iron (Fe), Copper (Cu), and others.

FitoMas-E: It contains 12 free amino acids, nitrogenized bases, saccharides, polysaccharides, and biologically active oligosaccharides.

Table 1. Doses of the treatments used in the study

Treatment	Dose (L/ha)
T-1 Relative control	
T-2 Natural liquid humus	2.0
T-3 Improved liquid humus	2.0
T-4 Fortified liquid humus	2.0
T-5 Fortified liquid humus + Phosphoric inducer	2.0
T-6 Bayfolan Forte	2.0
T-7 FitoMas- E	2.0

The biostimulants were applied as recommended by the Basic Technological and Scientific Unit (UCTB), from Soils Camagüey. Regarding the four variants of liquid humus, 20 mL of each stimulant were used in a 2 L total volume for application in the four repetitions of the treatment.

The repetitions were made in onion, F1 Hybrid Yellow Granex. The products tried were applied to the foliage in the early hours, following soil moisturizing by irrigation, at a frequency of seven days, after 7 days of bulb plantation. A 16 liter backpack was used for application; the doses were adjusted per treatment.

Plantation took place on September 10th, 2018, and harvest was made on January 14th, 2019. The soil was prepared 45 days before sowing, through reduced tilling, using multi-plowing before light harrow application, and then furrowing. The seeds used were certified, with a 92% germination capacity. The sowing method was plantation of the bulbs manually, using 2.0 cm diameter bulbs of 0.80 m x 0.05 m, in one row per furrow, manually.

Weed control of dicotyledonous species was achieved using a multi-plow. After crop establishment, the undesirable plants were controlled manually.

The type of soil, and the results of soil analysis were taken into account to set the dose of mineral fertilizers. An N-based mineral fertilizer was used: 100-120 kg/ha, P_2O_5: 0-100 kg/ha, K_2O: 0- 200 kg/ha. Irrigation was made by sprinkling. It was applied every 3-4 days, with a net partial rate of 250 $m^3.ha\text{-}^1$.

The technical quality standards recommended by (Marrero et al., 2009) were considered in the evaluated parameters.

At 30 and 60 days, phenological indicators plant height, pseudostem thickness, and number of leaves, were evaluated. At 60 days, bulb diameter and crop yield were evaluated. In each treatment, 10 plants were evaluated per repetition. Plant height was determined by measuring the base of the pseudostem to the tip of the leaf, after establishment, using a cm measure tape. Pseudostem thickness was determined using a gauge caliper (mm). The number of leaves was determined by counting the sample plants. Bulb diameter was determined individually, using a gauge caliper (mm). Crop yield was evaluated in treatment samples from plants covering 1 m^2, then the plants were weighed (kg), and the results were converted into $t.ha^{-1}$.

Statistical processing of the results was done using Statistical Package for Social Science (SPSS) version 11.5.1 for Window (2003). It was used to check the normal distribution of data in each variable; analysis of variance was performed to observe the existence or not, of differences among the means of the variables analyzed. A Duncan multiple range test (0.05% error) was conducted according to the phenological indicators of the crop.

The main economic indicators of each treatment were determined. It was based on calculation of costs, income, profit, and the economic effect, according to the branch standards of the Ministry of Agriculture (Methodology for Economic Evaluation of Agricultural Companies, 1990).

Results and discussion

Table 2 shows the effect of biostimulant application on plant height.

At 30 days, plant dynamic growth shows no statistical differences among the plants when the bio-organic variants were applied, except for the control. The highest numeric value was achieved with the fortified liquid humus plus the phosphoric inducer (T-5).

At 60 days, the fortified liquid humus plus the phosphoric inducer (T-5) showed the greatest height values, averaging 56.95 cm, which differed from all the other treatments.

The results achieved with the fortified liquid humus plus the phosphoric inducer is very favorable, increasing plant height in 38.3 and 59.95 cm respectively, compared to the control, which averaged 31.35 and 44.75 cm at 30 and 60 days.

This evidences the positive results of these bio-organic alternatives of fertilization, since this product contains humic acids, growth hormones, phosphorine, azotobacter, and essential chemical elements that influence metabolic processes of the plant, such as phosphorous, a chemical element that intervenes in photosynthesis, root growth, and cell breathing, the activation of amino acids that take part in the synthesis of the protein part of this compound, and in plant transpiration, thus providing energy in the form of adenosine triphosphate (ATP), so it can develop properly. Likewise, another aspect associated to the positive response of plants to the application of these products is the moment of application, which is early in the morning, the time when stomas are open, for better nutrient uptake, and translocation into different parts of the plant.

Factors such as high or very low temperatures, light hours, and soil moisture, can intervene in the normal growth and development of onion; according to Guenkov, (1969), the ideal temperature for the crop is 19 °C. During the experiment, higher values were reported at an average temperature of 24.8 °C, which could have made the plant reach lower height values, like the ones mentioned by Huerres & Caraballo (1996), between 80 and 85 cm high, under optimum temperature values.

Similar results were reported by Cárdenas, (2017), using these biopreparations on the leaves of New Kuroda carrots, using natural liquid humus, and different combinations. The best results were observed with fortified liquid humus (29.4-53.1 cm), at 30 and 60 days. Similar effects were reported by Zamora, (2014), using FitoMas-E, plus humus lixiviate from soil worm, and the humus lixiviate plus efficient microorganisms, in onions, whose results (43.56, 42.91, 47.51 cm, respectively) were evaluated at 50 days of establishment.

Table 2. Effect of application of the bio-organic product on plant height (cm)

Treatments	30 days	60 days
T-1 Control	31.35 ^{c}	44.75 ^{f}
T-2 NLH	35.45 ^{b}	50.3 ^{e}
T-3 ILH	36.5 ^{ab}	51.2 ^{d}
T-4 FLH	37.25 ^{ab}	55.62 ^{b}
T-5 FLH Phosphoric inducer	38.3 ^{a}	56.95 ^{a}
T-6 Bayfolan Forte	38 ^{a}	55.5 ^{bc}
T-7 FitoMas-E	37.8 ^{a}	55 ^{c}
SEx	0.88	0.17

Note: superscript values with unequal letters indicate significant differences for p≤ 0.05 (Duncan 2011)

Table 3 shows the effect of bio-stimulant application on pseudostem thickness; there are differences between the treatments at the time of evaluation.

The results observed at 30 days show average values of each treatment, being the highest the ones using Bayfolan Forte (T-6), with 8.85 mm, fortified liquid humus, plus phosphoric inducer (T-5), with 8.55 mm, and FitoMas-E (T-7), and 8.52 mm, which do not differ statistically among themselves, but they differ from the control and the natural liquid humus (T-2). At 60 days, it was different, the fortified liquid humus plus the phosphoric inducer showed the highest average value (15.03 mm), statistically differing from the other treatments.

This is given by proper establishment of nutrients required by the plants in adequate proportions during their vegetative cycles, responding favorably. It evidenced the importance of bio-organic enhancers in growth. Additionally, the fortified liquid humus plus the phosphoric inducer, and Bayfolan Forte, have a greater nutritional composition, conferring the plants necessary elements for their growth and development, along with more efficient metabolic processes.

The results clearly show that also FitoMas-E concentrations are determining factors in average pseudostem thickness.

In genetics, phosphorous also plays a key role. This element is among the substances that form genes and chromosomes. Therefore, this is an important element of genetic information transference from one generation to the next one, being necessary for the development of new cells (Coello, 2017).

These results are similar to Armas (2017), who reported indexes between 4.5 and 4.8 mm, and 6.9 and 7.1 mm, at 45 and 60 days, respectively, when studying treatments using fortified liquid humus and Bayolan Forte in black beans CC 25-9, which was corroborated by Morales (2017) in tomato, with satisfactory results using fortified liquid humus, FitoMas-E, and Bayolan Forte, at 30 and 60 days, averaging 4.3-4.9 mm, 4.3-5.0 mm, and 4.3-4.9 mm, respectively.

Table 3. Effects of bio-organic product application on pseudostem thickness (mm)

Treatments	30 days	60 days
T-1 Control	6.55^{d}	10.15^{f}
T-2 NLH	7.7^{c}	11^{e}
T-3 NLH	8.2^{b}	12^{d}
T-4 FLH	8.3^{b}	12.1^{d}
T-5 FLH Phosphoric inducer	8.55^{ab}	15.03^{a}
T-6 Bayfolan Forte	8.85^{a}	13.65^{b}
T-7 FitoMas-E	8.52^{ab}	12.78^{c}
SEx	0.09	0.16

Note: superscript values with unequal letters indicate significant differences for p≤ 0.05 (Duncan 2011)

Table 4 shows the leaf average per plant in each treatment, during the two stages evaluated.

Following the statistical analysis, no differences were observed among treatments Bayfolan Forte (T-6), with 5.3 leaves per plant, Fortified Liquid Humus plus Phosphoric inducer (T-5), with 5.2 leaves, FitoMas-E (T-7), with 4.95 leaves, and Improved Liquid Humus (T-3), with 4.95 leaves. These treatments reached the highest values at 30 days, compared to the control. However, at 60 days of evaluation, the Fortified Liquid Humus treatment plus the Phosphoric inducer (T-5), averaged 7.8 leaves per plant (the highest), differing statistically from the other treatments.

The effect of Fortified Liquid Humus plus Phosphoric inducer may be given by the nutritional composition, which has such an influence that the formation and development of leaves takes place favorably, with a positive intervention of phosphorus, whose role is critical at the cell level, by storing and transferring assimilable chemical energy in the form of ATP, to reactions and processes that require it for application. In this case, the control (T-1) only reached 4.65 and 6.7 leaves per plant, at 30 and 60, respectively, the lowest index in the study.

Phosphorus is an essential macroelement of plant growth. Heavy concentrations of phosphorus are found in the merismatic tissues of plants regions, which take part in the synthesis of nucleoproteins. Phosphorus participates in metabolic processes, such as photosynthesis, energy transference, and synthesis and degradation of the carbohydrates cited by Coello (2017).

Table 4. Effect of the application of bio-organic products on the number of leaves

Treatments	30 days	60 days
T-1 Control	4.65^{b}	6.7^{c}
T-2 NLH	4.75^{b}	6.9^{bc}
T-3 ILH	4.95^{ab}	6.75^{bc}
T-4 FLH	4.9^{b}	6.4^{c}
T-5 FLH Phosphoric inducer	5.2^{ab}	7.8^{a}
T-6 Bayfolan Forte	5.3^{a}	7.0^{b}
T-7 FitoMas-E	4.95^{ab}	6.5^{c}
SEx	0.12	0.09

Note: superscript values with unequal letters indicate significant differences for p≤ 0.05 (Duncan 2011)

Guenkov (1969) said that plants should form a well-developed leaf system to produce bigger and more fruits, which can be achieved with sufficient nutritional substances throughout the process. These results coincide with the reports on vegetative growth and plant development, where in the starting phase of bulb formation, the plant reaches the highest number and development of leaves, and begins thickening of the diameter of the bulb. Guenkov (1983) established ranges for onion, between 7 and 12 leaves, depending on the varieties.

A similar result was reported by Zamora, (2014) in onion, using another cultivar, with FitoMas-E, worm humus lixiviate, and worm humus lixiviate plus efficient microorganisms, with results averaging 5.49, 5.46, 5.81 leaves per plant, at 25 days, respectively, and at 50 days, the values were 7.91, 8.41, 8.27 leaves per plant, respectively. Estrabao, (2017), in beet variety Detroit Dark Red reported similar values; the best response in the treatment based on fortified liquid humus, averaging 3.6 and 7.2 leaves per plant at 30 and 60 days, respectively. Table 5 shows bulb diameter, a quality indicator that, after crop establishment, at 60 days, underwent statistically significant differences in the treatment with Bayfolan Forte (T-6), averaging 46.03 mm, compared to the other treatments, followed by fortified liquid humus plus phosphoric inducer (T-5), with 45.03 mm. The control (T-1) showed the lowest value (24.08 mm).

The bio-organic enhancers influence vegetative development, since these products are made of essential chemical elements that participate in metabolic processes of plants, providing efficient development, and influencing on the quality of harvest. This behavior occurs possibly by the fact that the concentration of different organic and chemical compounds favor the photosynthetic capacity, tissue development, and cell multiplication, thus significantly increasing bulb thickness in the period evaluated (Fontes, 2018).

Jaramillo et al., (1997), on analyzing the different factors that intervene in the formation of onion bulbs, highlighted these as the most important: light intensity and duration, temperature, and their interaction.

Table 5. Effect of the application of bio-organic products on bulb diameter (mm)

Treatments	30 days
T-1 Control	24.08^{f}
T-2 NLH	37.75^{e}
T-3 ILH	39.85^{d}
T-4 FLH	40.65^{d}
T-5 FLH Phosphoric inducer	45.03^{b}
T-6 Bayfolan Forte	46.03 ^{a}
T-7 FitoMas-E	43.18 ^{c}
SEx	0.27

Note: superscript values with unequal letters indicate significant differences for p≤ 0.05 (Duncan 2011)

Studies done by Yumar et al. (2010) in onion variety Granex2000 F1 showed the results of three applications of FitoMas-E, in which the highest bulb diameter was achieved with the 2 L/ha dose (94 cm), at 80 days, higher than the ones observed in the current study. Zamora (2014) found similar results in the same crop, but in different varieties and sowing dates. The greatest bulb diameter was observed with the use of worm humus lixiviate plus efficient microorganisms, at 50 days (39.57 mm). Table 6 shows the effect of the application of bio-organic products on crop yields. As shown, there are statistically significant differences between the treatments. The highest average values were observed with the application of fortified liquid humus plus the phosphoric inducer (T-5), which produced 12.89 t. ha^{-1}, higher than the other treatments studied during the research. The control (T-1) showed the lowest value (7.2 t. ha^{-1}), in relation to the parameters evaluated.

The result achieved using fortified liquid humus plus the phosphoric inducer, the treatment producing the highest yields, is linked to the values obtained when evaluating the number of leaves per plant, and the thickness of the pseudostem. It is physiologically associated with this crop, since the leaves work as a reception organ of the chemical elements needed by the onion to be further translocated through the conduction tissues into the organs that need to perform their functions, thus favoring normal crop growth and development.

This treatment is made up of plant hormones, biostimulants, and essential mineral nutrients, such as phosphorus, a macro element that intervenes in the metabolic processes of onion, as part of the cell protoplasm, stimulates the reproduction of merismatic tissues, and cell multiplication, thus taking part in bulb development, enabling greater formation of tunics and more compact bulbs.

The function of phosphorus in this crop is fully developed, since it stimulates growth to diseases, strengthens young plants, speeds crop maturity, and improves harvest yields. Flowering and fruiting depend exclusively on this nutrient cited by (Coello, 2017).

These results are way below the genetic potential of the studied variety, but the effects observed with the application of fortified liquid humus treatments plus the phosphoric inducer (T-5), and Bayfolan Forte (T-6) are above the findings reported in the province of Camagüey, with 7.1 t. ha^{-1}. However, they correspond to the national values (12.98 t. ha^{-1}, reported by the National Statistics Office and Information (Cuba, 2016).

Yielding takes place throughout growth and development, since the plant emerges, until the formation of the last organ, under the influence of edaphoclimatic factors cited by (Estrabao, 2017). Likewise, Palacio & Montenegro, (2006) said that yields increase or decrease in relation to various morphological and anatomical characteristics. The interaction of these three aspects determines crop yield, and, therefore, yields have a high variability in time and space.

Similar results were achieved by Cárdenas, (2017) in carrots, demonstrating the effect of the fortified liquid humus treatment, producing yields of 9.2 Kg/m^{2}, and responses to the applications of these bio-organic alternatives during growth and development. The results achieved by Zamora, (2014) are different, in the Red Creole variety, using another sowing time with different climate behavior, and different soil. The benefits were achieved with the applications of worm humus lixiviate plus efficient microorganisms, reaching 16.99 t. ha^{-1}.

Table 6. Effect of the application of bio-organic products on crop yields

Treatments	Yields t/ha^{-1}
T-1 Control	7.2 ^{g}
T-2 NLH	8.70 ^{f}
T-3 ILH	9.9 ^{e}
T-4 FLH	11.77 ^{c}
T-5 FLH Phosphoric inducer	12.89 ^{a}
T-6 Bayfolan Forte	12.24 ^{b}
T-7 FitoMas-E	10.98 ^{d}

SEx	0.1231

Note: superscript values with unequal letters indicate significant differences for p≤ 0.05 (Duncan 2011)

Table 7 shows the economic indicators of selection, being the fortified liquid humus plus phosphoric inducer treatment (T-5) the one with the highest gains (23 821.24 $ ha^{-1}, and an economic effect of 9 446.15 $.$ha^{-1}$, higher than the other treatments. The lowest value was observed in the control (T-1), with 14 375.09 $.$ha^{-1}$. This result shows that the utilization of these bio-organic products in onion production can substitute imports in the country. Though the historical yields can be kept, income is shown to be higher.

Table 7. Analysis of economic indicators of selection of bio-organic products used in onion

Tmts	Total cost $/t	Yield t.ha^{-1}	Income ($)	Profit $ ha^{-1}	Ec. effect $.ha^{-1}
T-1	5 612.46	7.20	54 784.80	14 375.09	
T-2	5 661.02	8.70	66 198.30	16 947.43	2 572.34
T-3	5 692.46	9.90	75 329.10	18 973.75	4 598.66
T-4	5 712.46	11.77	89 557.93	22 322.28	7 947.19
T-5	5 760.96	12.89	98 080.01	23 821.24	9 446.15
T-6	5 724.46	12.24	93 134.16	23 066.77	8 691.68
T-7	5 740.46	10.98	83 546.82	20 516.57	6 141.48

Conclusions

The different bio-organic alternatives showed positive effects on the morpho-physiological and yield parameters in onion.

The fortified liquid humus plus the phosphoric inducer showed the best results compared to the other treatments, with 12.89 t.ha^{-1}.

The treatment of fortified liquid humus plus phosphoric inducer produced greater profit compared to the control (23 821.24 $.ha^{-1}).

Author contribution

Pedro López Labarta: research planning, analysis of results, manuscript redaction, final review.

Yaima de las M. Daniel Ortega: research planning, assembling, analysis of results, manuscript redaction, final review.

Yohandri Viamontes Pacheco: Experimental assembling, analysis and interpretation of results.

José Luis Montejo Viamontes: research planning, analysis of results, manuscript redaction, final review.

Dania González Gort: analysis of results, redaction of the manuscript, and final review.

Conflicts of interest

There are no conflicts of interest.

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