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Effect of organic and chemical fertilization on the onion crop (*Allium cepa* L.)

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ABSTRACT

The bulb onion (*Allium cepa* L.) is a vegetable widely cultivated and in high demand in national and international markets. Due to the risks that the indiscriminate use of agrochemicals represents for human health and the environment, the present study aimed to make a comparative analysis of the effects of organic vs chemical fertilization currently used in the cropping of red hybrid bulb onion (Eureka). Three organic fertilizers (Zumsil®, ComCat® and EcoFungi®) were compared to three chemical fertilizers (15-15-15®, Muriate of Potash® and Nitrofoska®). The response variables were: plant height at 30 and 60 days after transplanting (DAT), length, diameter and average weight of bulbs, yield in tons per hectare and the relationship between height at 30 and 60 DAT. The experiment was carried out under a completely randomized design with four replicates, seven treatments and 28 experimental units. The statistics used include an analysis of variance and a Canonical Biplot that allowed to obtain groups of variables and to determine their correlation with each one of the treatments. Additionally, a marginal analysis of dominant treatments was performed. Positive response of variables was strongly associated with organic fertilizers. From the economic point of view, the ComCat® organic fertilizer represented an ecological alternative with excellent benefits for the producer. This research is in line with the trends for agrochemical-free foods.

Keywords: sustainable agriculture, plant nutrition, yield, production

INTRODUCTION

Bulb onion (*Allium cepa* L.) is the most common and widely grown vegetable of the Alliaceae family (Mekonnen et al., 2017). Originating from Central Asia, it is in great demand in local and international markets due to its multiple uses in the industrial field as well as in fresh produce (Teshika et al., 2019). According to data from the Ministry of Agriculture and Livestock (MAG, 2017), in 2017 the area harvested of bulb onion worldwide was 4,955,432 ha, with a production of 93,168,548 t. The world's largest producer is China, followed by India, Egypt and the United States. In South America, the largest producers are Brazil, Argentina, Peru and Colombia. On the Ecuadorian coast approximately 4,797 ha of bulb onion are grown with average yields of 13.60 t/ha. The provinces with the largest area planted with bulb onion and / or pearl during 2017 were: Manabí with 50% of national production and 18.21 t/ha yields average, followed by Carchi with 17% and 15.16 t/ha, Pichincha and Azuay with 4% each, and yields of 3.87 and 5.25 t/ha, respectively (MAG, 2017).

Bulb onion is a highly appreciated vegetable used as condiment for its therapeutic properties. The bulb onion is used to flavor foods, due to the properties conferred by volatile and non-volatile compounds containing sulfur and to a lesser extent by the content of sugars (Sagar et al., 2020). Pungency develops when sulphur compounds, known as flavor precursors react with the enzyme allinase after the bulb is cut and when the tissue breaks down, flavor precursors are very unstable sulphur compounds responsible for the flavor and the tearing effect of the bulb onion (Brodnitz, 1971).

Bulb onion is an important vegetable in the human diet, and one of the main daily food crops. It is grown mainly for its bulb, as a daily component of meals. The green leaves and the bulbs can be eaten raw, cooked in soups and salads, both as a fresh, dehydrated, industrialized condiment for pickles (in vinegar) and even medicinal (Cheraghipour et al., 2020; Petropoulos et al., 2020). Bulb onion also has useful properties control insects in production fields (Habeeb et al., 2009; Rodrigues et al., 2010).

Due to the risks that the indiscriminate use of agrochemicals represents for human health (Cabral-Pinto et al., 2019) and the environment (Olanipekun et al., 2019; Xiang et al., 2020), some modern agricultural techniques have been questioned and there is an increasing interest in reducing its negative effects. To achieve this objective, it is necessary to resort to agricultural production methods focusing on the efficient use of resources which are conducive to sustainable agriculture. In this sense, there are environmentally friendly products for agricultural use that integrate in their composition plant extracts and/or elements that help the development of the plant, obtaining better yields (Mkindi et al., 2020). Additionally, national and international markets have increased demand for organic products, free of chemical residues which generally deserve prices.

Considering the above, this research proposes a comparative analysis of the effects of organic fertilization versus chemical fertilization in the cultivation of bulb onions (*A. cepa*) in important production areas of Ecuador.

MATERIALS AND METHODS

Location

The present study was developed in the Hacienda "La Teodomira", of the Faculty of Agronomical Engineering of the Technical University of Manabí, located geographically at 01° 09' South latitude and 80° 21' West longitude at an altitude of 47 masl. The experiment was set up in a clay loam soil (Table 1) with an average annual precipitation of 528 mm relative humidity of 79% and an annual temperature of 26.7 °C which ranges between 21 and 31 °C (INEC, 2020).

Genetic material and test management

The red commercial hybrid of bulb onion (Eureka) was used. The group of organic fertilizers was represented by three products: an agricultural amendment (Zumsil®) based on an ionized solution of active silica (22% $Si\ O_4H_4$); an agricultural biostimulant (ComCat®) obtained from the extract of the *Lychnis viscaria* plant and a balanced mixture of selected strains of the arbuscular vesicular mycorrhizae (EcoFungi®); while the chemical fertilizers used were 15-15-15 (N - P_2O_5 - K_2O), Muriate of Potash® (60% of K_2O) and Nitrofoska® (22 N – 8 P_2O_5 -10 K_2O). The control plants were not fertilized in any way (Table 2). Muriate of potash®, Nitrofoska® and 15-15-15® fertilizers were used because is the current chemical fertilization used by local farmers.

The seedbed was made in stretchers above ground level by placing the seeds in a continuous jet, which were covered with a layer of peat and disinfected with Captan® 50 g/L. Four beds (dimensions: 60 m long x 1.20 m wide) were made above ground level for sowing the material. For each bed, three rows of hoses with built-in drippers were used with a field capacity of two liters of water per hour and at a distance of 20 cm between drippers. The beds were irrigated to facilitate transplanting, and fertilizers were applied to the corresponding treatments (Table 2). The transplant was made 50 days after the sowing, removing the plants to 20 cm of height from the base of the neck of stem. To protect the root system from insect pests and fungal diseases, the root was immersed

Table 1. Soil chemical characteristics

pH	Organic matter	NH^{4+}	P	K^+	Ca^{2+}	Mg^{2+}	CIC
	(%)	(mg/kg)		(meq/100 g)			
6,4	1,6	11	34	0,21	17	1,7	25,3
mildly acidic	under	Under	high	medium	high	medium	high

Source: Laboratory for chemical and physical analysis of soil, plant and water samples of the National Institute of Agricultural Research (2017)

Table 2. Factors under study to determine the effects of organic and chemical fertilization on the bulb onion (*Allium cepa*)

	Dose	Aplication
Organic fertilization		
F0 -Control		
F1 - Zumsil®	500 mL/ha	Applied to foliage in four fractions (15, 35, 55 and 75 days after transplanting, DAT).
F2 - ComCat®	250 g/ha	Applied to foliage in four fractions (15, 35, 55 and 75 days after transplanting, DAT).
F3 - EcoFungi®	250 g/ha	Incorporated into the soil in a single application at the time of transplanting.
Chemical fertilization		
N1 - 15-15-15®	150 kg/ha	Incorporated into the soil in a single application at the time of transplanting.
N2 - Muriate of Potash®	100 kg/ha	Incorporated into the soil in two fractions (30% at 15 DAT and 70% at 60 DAT).
N3 - Nitrofoska®	100 kg/ha	Incorporated into the soil in two fractions (30% at 15 DAT and 70% at 60 DAT).

in a dilution of Carbistin® at a dose of 1 ml/L of water, then one plant per hole was deposited at a distance of 0.10 m between plants and 0.15 m between rows. After 125 days of sowing harvest was made, when the bulb reached their physiological maturity state, this harvest was made manually.

The response variables were: plant height at 30 and 60 days after transplanting (DAT), average length of bulbs, average diameter of bulbs, average weight of bulbs, yield in tons per hectare and the ratio between height at 30 and 60 DAT was used to obtain the variable increase in height. The experiment was conducted under a completely randomized design with four replicates, seven treatments and 28 experimental units. The statistics included an analysis of variance and a canonical biplot analysis to obtain groups of variables and determine their correlation with each of the treatments. Additionally, the Partial Budget Calculation was made according to the method used by CIMMYT (1998), considering the variable costs attributed to each treatment and the Net Benefits originated by its application.

RESULTS AND DISCUSSION

Crop development

Through the canonical analysis it was possible to establish differences between the treatments under study ($P<0.05$). In accordance with this result, chemical and organic fertilization do not differ statistically between them, being both different from the control treatments. Control treatments obtained the lowest values for all response variables in the study, except for the length of the bulb whose behavior was similar in all treatments. In this regard, Rosen and Allan (2007) comment that, the yields obtained with organic fertilization are usually similar to those obtained with conventional fertilizer although the benefit for the soils has been proven. It's somewhat complicated to explain those obtained by the crops, since assimilation depends on many other factors such as rain or temperature, among others.

Figure 1 shows the Biplot resulting from the canonical analysis for the groups of fertilizers; which explains 100% of the total variability of the observations and traces multivariate confidence circles achieving confidence intervals for each of the variable means. These circles describe, on the one hand, the association of variables to the treatments and on the other hand, the similarity between the groups and their difference with the control treatment. Additionally, inferences can be made about the existence of variables that are closely correlated, for example: the length and diameter of the bulb with the yield, as well as the increase in height with the length, diameter of the bulb and yield. Similarly, there are some negative correlations, among the increase in height with the weight of bulb, height at 30 DAT and length of bulbs.

The statistical analysis showed that there are no differences between the treatments of the organic group, nor between the treatments of the chemical group. Although the values obtained for the variables related to plant height do not suggest significant statistical differences, it was possible to observe that numerically the organic fertilizers were imposed on the chemicals (Table 3). For example, with the use of Comcat® the plants achieved an average of 25.04 cm at 30 DAT and 45.77 cm at 60 DAT when EcoFungi® was used.

The height achieved with the EcoFungi® probably responds to the fact that the organic fertilizer improved the plants' root system and the structure of the soil, which allowed the plants to obtain better nutritional values. According to the technical sheet of the product, the exploration area is increased by 1000 times. In this regard, Blay et al. (2002) on *A. cepa*, reported that organic treatments increased plant height more than those obtained with chemical fertilization.

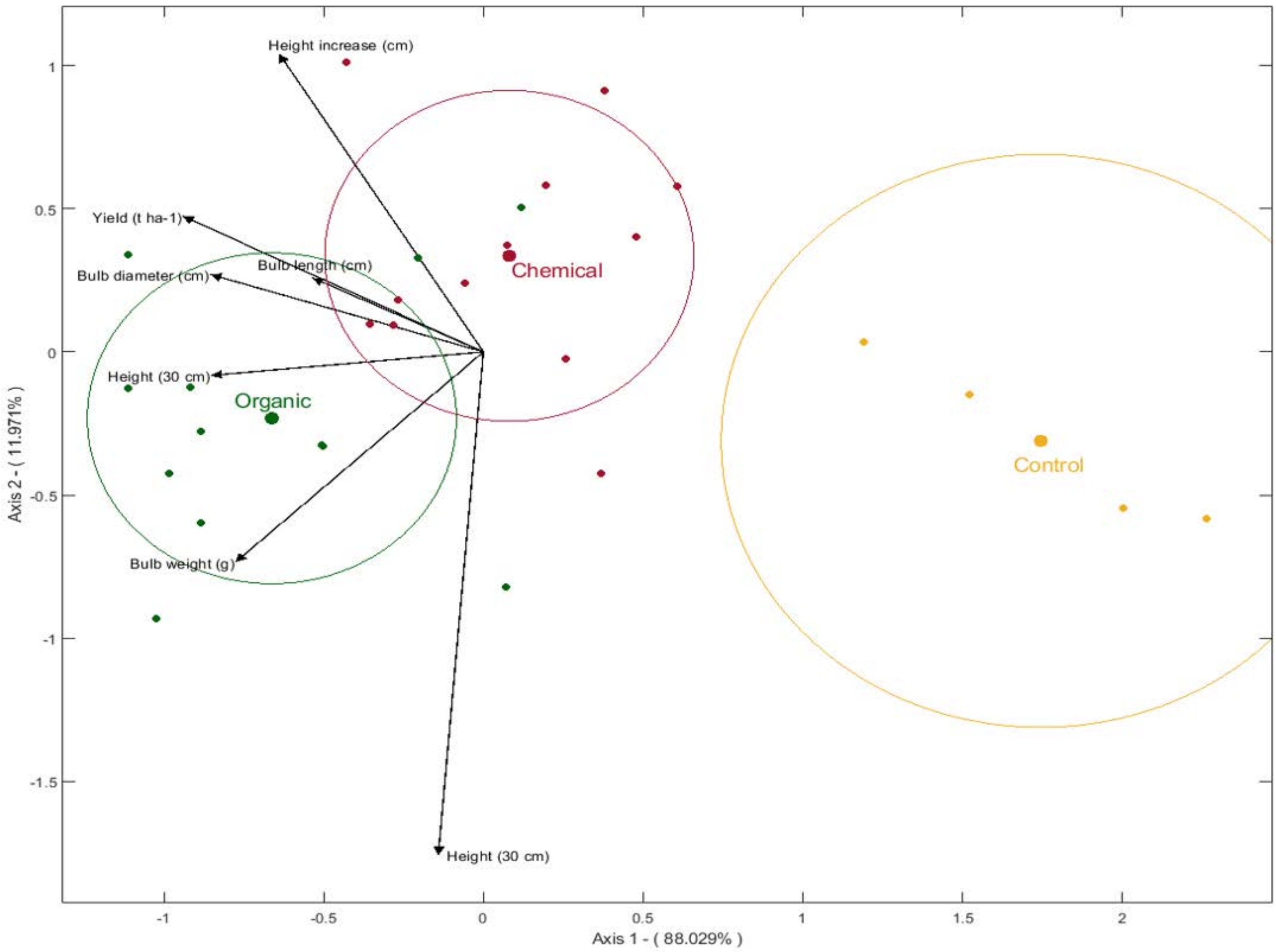

Figure 1. Canonical biplot based on fertilizer groups used to determine effects of organic and chemical fertilization on the bulb onion (*Allium cepa*)

Table 3. Analysis of variance and comparison of means of variables related to the height of bulb onion plants (*Allium cepa*) to determine the effects of organic vs chemical fertilization

Variable	Treatment	Mean		SD	CV	Min	Max
Height 30 DAT (cm)	Control	23,42	ab	1,49	6,38	22,13	25,06
	Zumsil®	22,43	ab	2,09	9,3	20,11	24,93
	Comcat®	25,04	a	0,82	3,26	24,14	26,09
	EcoFungi®	24,2	ab	0,83	3,42	23,15	25,17
	15-15-15	22,22	ab	2,45	11,03	19,7	25,18
	Muriate of potash®	20,05	b	2,28	11,39	17,42	22,49
	Nitrofoska	21,6	ab	2,91	13,47	17,53	24,17
Height 60 DAT (cm)	Control	38,48	b	1,53	3,97	37,36	40,73
	Zumsil®	45,61	a	3,47	7,62	40,6	48,63
	Comcat®	43,62	ab	2,05	4,71	41,8	46,53
	EcoFungi®	45,77	a	1,43	3,13	44,53	47,26
	15-15-15®	42,74	ab	0,69	1,62	42	43,36
	Muriate of potash®	42,14	ab	2,46	5,84	38,8	44,23
	Nitrofoska®	43,61	ab	3,89	8,93	38,56	47,96
Height increase (cm)	Control	15,06	b	2,54	16,86	13	18,6
	Zumsil®	23,18	a	3,01	12,97	19,1	26,35
	Comcat®	18,58	ab	2,38	12,81	15,71	21,37
	EcoFungi®	21,57	ab	2,17	10,05	19,36	24,11
	15-15-15®	20,52	ab	2,55	12,41	18,12	23,66
	Muriate of potash®	22,09	a	1,98	8,96	19,83	24,38
	Nitrofoska®	22,01	a	5,21	23,68	14,39	25,8

Standard deviation (SD); Coefficient of variation (CV) Minimum (Min); Maximum (Max).
Means followed by the same letter are not significantly different at P = 0.05

In this same sense, it is important to point out that the greatest increase in height was obtained with the use of Zumsil® (23.18 cm), followed by Muriate of Potash® (22.18 cm), Nitrofoska® (22.01 cm), EcoFungi® (21.57), 15-15-15 (20.52), Comcat® (18.58) and the control treatment (15.06); this sequence corroborates what was stated by the Canonical Biplot in relation to the similarity of organic and chemical fertilization.

Variables related to yield

They were mostly influenced by the use of organic fertilizers, except for bulb length, where the highest values were obtained when Muriate of Potash® was used, although there is no statistically significant difference (Table 4). This fact is corroborated by Ghoname et al. (2007) who concluded that foliar application of Muriate of Potash® improved the quality of the bulb, in this sense Tränkner et al. (2018) suggest that potassium is a nutrient that allows greater efficiency of photosynthesis, which translates increase yield and quality of the bulbs.

Table 4. Analysis of variance and comparison of means of variables related to the yield of bulb onion plants (*Allium cepa*) to determine the effects of organic and chemical fertilization

Variable	Treatment	Mean		SD	CV	Min	Max
Bulb length (cm)	Control	4,82		0,37	7,69	4,27	5,07
	Zumsil®	5,36		0,3	5,63	4,96	5,62
	Comcat®	5,31		0,54	10,16	4,54	5,73
	EcoFungi®	5,24		0,18	3,4	5,12	5,5
	15-15-15	4,98		0,25	4,94	4,7	5,3
	Muriate of potash®	5,36		0,49	9,21	4,73	5,93
	Nitrofoska	5,28		0,18	3,38	5,1	5,51
Bulb diameter (cm)	Control	5,2	b	0,8	1,5	5,09	5,27
	Zumsil®	5,7	ab	0,15	2,7	5,54	5,86
	Comcat®	5,91	a	0,42	7,16	5,43	4,46
	EcoFungi®	5,85	a	0,1	1,68	5,78	5,99
	15-15-15®	5,63	ab	0,16	2,82	5,41	5,76
	Muriate of potash®	5,69	ab	0,2	3,54	5,4	5,85
	Nitrofoska®	5,71	ab	0,29	5,16	5,27	5,89e
Bulb weight (g)	Control	74,84	c	2,65	3,55	71,85	77,73
	Zumsil®	84,06	bc	5,39	6,41	77,38	90,16
	Comcat®	92,5	ab	4,53	4,9	87,35	97,3
	EcoFungi®	101,21	a	14,07	13,9	85,71	119,8
	15-15-15®	81,47	bc	2,15	2,64	79,81	84,63
	Muriate of potash®	83,42	bc	2,22	2,66	81,25	85,97
	Nitrofoska®	83,66	bc	4,49	5,37	78,37	89,35
Yield (t/ha)	Control	10,52	b	0,89	9,38	9,8	11,77
	Zumsil®	12,65	a	0,75	6,59	11,69	13,27
	Comcat®	12,33	a	0,17	1,54	12,14	12,51
	EcoFungi®	12,32	a	0,19	1,7	12,11	12,57
	15-15-15®	12,08	a	0,49	4,55	11,66	12,69
	Muriate of potash®	11,86	a	0,32	2,95	11,46	12,22
	Nitrofoska®	12,29	a	0,72	6,47	11,4	12,9

Standard deviation (SD); Coefficient of variation (CV) Minimum (Min); Maximum (Max).

Means followed by the same letter are not significantly different at P = 0.05

For this same variable, the lowest value obtained was the control (4.82 cm), since this treatment did not have nutrient applications, and the soil did not provide the necessary amount of nitrogen and potassium that the plant required (Table 1).

As for the diameter of the bulb, the highest values were obtained when using ComCat® and EcoFungi® (5.91 and 5.85 cm respectively), both organic fertilizers; and the lowest value was reported by the control (5.20 cm). The results obtained in this research are similar to those obtained by Yoldas and others (2011), who found a better bulb height when organic fertilization was used in comparison to mineral fertilization. This effect can be attributed to the fact that organic fertilizers are able to promote physiological activities that stimulate the early formation of flowers by increasing production (Suquilanda, 2003), in addition to favoring organic matter content and populations of microorganisms in the soil, which can provide long-term fertility benefits.

The highest weight of the bulb was recorded for EcoFungi® (101.21 g), which represents 35% more, in relation to the control (74.84 g). This result was possibly achieved because EcoFungi® contains mycorrhizal spores, which, by developing structures at the root level, favor the extraction of nutrients from the soil and resistance to adverse factors (Osorio et al., 2020). Similar effect was reported by Akoun (2004), who mentions that the bulb yield was influenced positively by the application of organic fertilizer.

The results obtained for the variable yield establish that the 3 organic fertilizers analyzed in this study favor bulb onion production, being the best value the one reached by Zumsil® (11.38 kg/plot). In this aspect Langmeier et al. (2002) suggested that organic systems tend to be more efficient than conventional systems, presumably as a result of greater microbial activity or due to the accumulation of organic nutrient reserves.

Figure 2 shows the biplot resulting from the canonical analysis for the fertilizers included in study. Increases in bulb diameter and lenght, yield, plant height at 60 DAT and the increase in plant height are strongly related to the use of the organic fertilizer Zumsil®, while increases in bulb weight were associated with the organic fertilizers ComCat® and EcoFungi®.

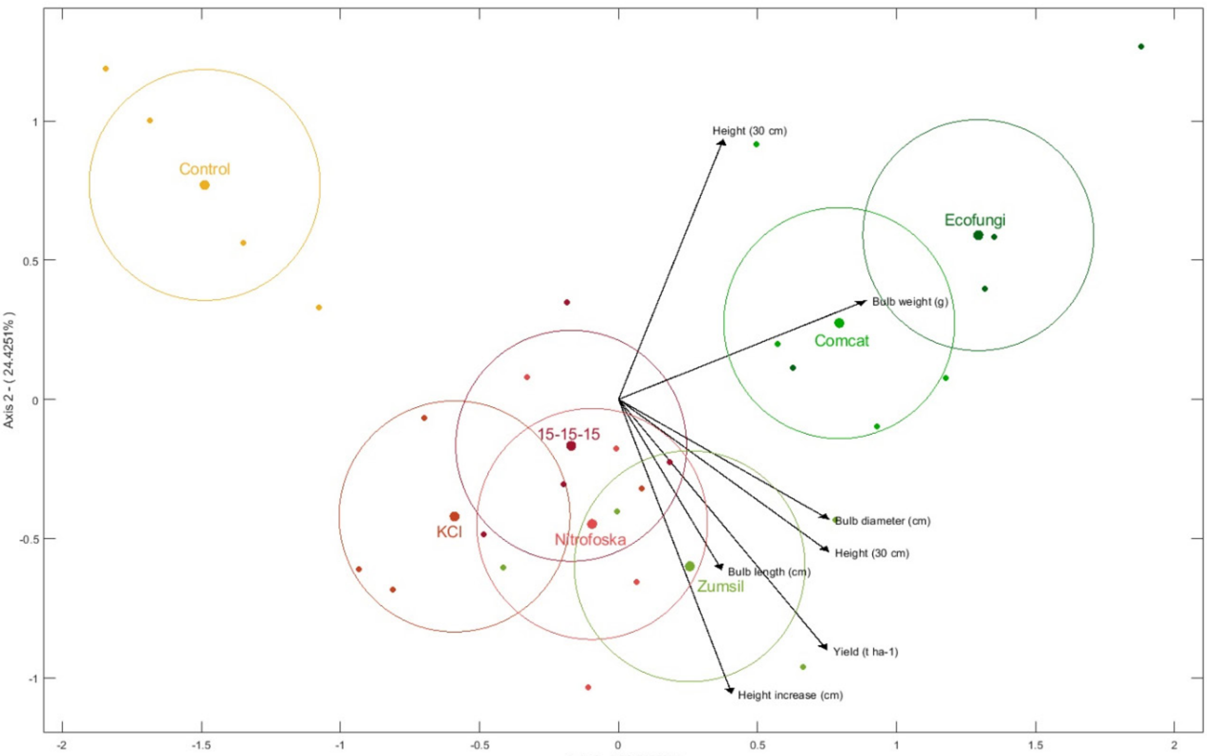

Figure 2. Canonical biplot based on the treatments used to determine the effects of organic and chemical fertilization on the bulb onion (*Allium cepa*)

Economic analysis

To carry out the economic analysis, adjusted yields were used, considering 10% of loss in transport and/or storage. The marginal analysis of dominant treatments was made (Table 5). In this way it was possible to determine that the best treatment, considering the economic point of view, was the organic fertilizer ComCat® with which presents a net benefit of USD 5,964.56 and a marginal return rate of 11,851.00 %.

Table 5. Marginal analysis of dominant organic and chemical fertilization on the bulb onion (*Allium cepa*)

Treatments	NP (USD)	VC (USD)	MINP (USD)	MIVC (USD)	MRR (%)
Zumsil®	6.113,09	70,00	148,53	9,00	16,50
ComCat®	5.964,56	61,00	118,51	1,00	118,51
15-15-15®	5.846,05	60,00	731,21	32,00	53,65
Control	5.114,84	28,00	-	-	22,85

NP = Net Profit; VC = Variable costs; MINP = Marginal increase in net profit; MIVC = Marginal increase in variable costs; MRR = Marginal rate of return. Note: Treatments with superior VC and lower NP than the control were excluded from the table

CONCLUSIONS

Production related plant variables analyzed in this study showed higher values and relation to organic than chemical fertilizer, stating that organic fertilization could enhance bulb onion production in Ecuador.

From the economic point of view, to correlate plant variables with fertilizers and determined that ComCat® organic fertilizer, presents an ecological alternative with excellent benefits for the producer.

In general, it can be concluded that it is more profitable to use organic than chemical fertilizers. Besides, it must be considered intangible environmental benefits coming out of the use of organic alternatives.

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