Investigation note

Organic sources and potato production in the Andean region

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Abstract

The objective of the study was to evaluate the effect of three organic sources with three levels of application in the production of Yungay potato (*Solanum tuberosum* L.) under family farming conditions in the Andean region of Perú. A randomized complete block design with a 3x3 factorial arrangement plus one (1) additional treatment (control) was used. The number of stems and tubers per plant, yield and the category extra were evaluated. The experiment was conducted at 3 425 masl, in Huari, Ancash, Peru, from October 2019 to March 2020, under rainfed conditions. The superiority of the mean of the factorial over the control and the interaction between organic sources and application levels was observed, with the island guano standing out with 5 t ha^{-1}.

Keywords: *Solanum tuberosum* L., island guano, yield

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In the Andean region of Peru, potato (*Solanum tuberosum* L.) is the main source of food and economic income, and its cultivation is conducted mainly by family farmers located between 3 500 and 4 200 masl, who still preserve ancestral technology, based on reduced soil mechanization and restriction on the use of agrochemicals (Caycho *et al*., 2009). Under these management conditions, they obtain yields of 5 t ha^{-1}, a value lower than the national average of 16.1 t ha^{-1} (FAO, 2020), so it is urgent to develop technologies according to their reality, which promote competitiveness and sustainability in the use of resources.

In this sense, among the different existing alternatives, the incorporation of different organic sources is an interesting option to favor the increase of yield and preserve their ancestral technology, in addition to improving the physical, chemical and biological properties of the soil (Alaluna and Villagarcía, 2000; Bolo *et al*., 2020). Thus, various studies show positive results in potato cultivation, such as those evidenced by Ríos *et al*. (2015) with the incorporation of island guano (1 and 2 t ha^{-1}), by obtaining yields (46.7 and 55.9 t ha^{-1}, respectively) higher than the control (24.9 t ha^{-1}), Peñaloza *et al*. (2019) with chicken manure (2, 3 and 4 t ha^{-1}), by observing increasing yields and finding no significant differences for the number of tubers and stems per plant, Villagaray *et al* (2021) with sheep manure (0; 0.25; 0.5; 1 and 1.50 kg $plant^{-1}$), by reaching the highest yield (20.31 t ha^{-1}) with the highest dose (1.5 kg $plant^{-1}$), significantly surpassing the control (11.89 t ha^{-1}). In this context, the present study aimed to evaluate the effect of three organic sources with three levels of application on the production of potato in the Andean region of Peru.

The research was carried out in a family property, located at 3 425 masl, in the province of Huari, Ancash-Peru region, located at the coordinates 9° 22’ 10” SL and 77° 01’ 04” WL, from October 2019 to March 2020. The climate of the region is classified as Dwb according to the Köppen classification, characterized by cold or temperate and dry winters with cool and rainy summers. The soil with loam texture has a pH of 6.64, organic matter of 1.248%, nitrogen of 0.062%, phosphorus of 13 mg kg^{-1} and potassium of 78 mg kg^{-1}. Prior to the installation of the experiment, the analyses of the organic sources were carried out and the results are shown in Table 1.

Table 1. Chemical characteristics of organic sources.

Source	pH	N (%)	P_2O_5 (%)	K_2O (%)	EC (dS m^{-1})
Sheep manure	9.16	1.35	2.07	1.39	1.78
Chicken manure	8.62	8.15	7.4	3.08	10.22
Island guano	8.16	11.05	10.68	2.75	26.4

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The statistical design of randomized complete blocks was implemented with a 3 x 3 factorial arrangement plus one additional treatment (control) and in four blocks. Two factors were studied: organic sources (sheep manure, chicken manure and island guano) and three levels of application (5, 10 and 15 t ha^{-1}). The additional treatment (control) did not receive any type of fertilization. The area of the experimental unit was 10.94 m^2. The preparation of the land was carried out with a team, the weeding was manual, and the presence of pests and diseases was not noticeable. The experiment was conducted under rainfed conditions.

In five plants of the central furrow per each experimental unit, the number of stems and tubers per plant, total yield and the category extra (tubers with weights between 321 and 710 g) were evaluated. The data obtained for the variables evaluated were subjected to the analysis of variance by the F test ($p< 0.05$) and the means were compared with the Tukey test ($p< 0.05$). The data were analyzed with the statistical software R.

According to the analysis of variance, Table 2, there is interaction between organic sources and levels of application for number of stems per plant, yield and category extra. For the number of tubers per plant, significant differences have only been shown between organic sources, but not between levels of application. Likewise, for the set of variables evaluated, there have been significant differences between the control treatment and the mean of the factorial.

Table 2. Summary of the analysis of variance for the number of stems per plant (NStP), number of tubers per plant (NTuP), yield and category extra.

Sources of variation	Degrees of freedom	Mean squares			
		NStP	NtuP	Yield (t ha^{-1})	Extra (t ha^{-1})
Block	3	0.043 ns	49.666 ns	2.485 ns	4.511 ns
Organic source (S)	2	4.828 **	358.083 **	2576.306 **	985.754 **
Levels (L)	2	1.693 **	57.583 ns	39.562 ns	60.207 **
SxL	4	0.456 *	41.291 ns	465.761 **	175.149 **
Factorial vs control	1	4.533 **	115.6 *	885.788 **	416.995 **
Error	27	0.1486	25.129	12.286	4.064
Total	39				
Coefficient of variation (%)		11.74	26.24	18.8	13.13

ns= not significant; *= significant at 0.05; **= significant at 0.01.

Comparing the control treatment and the factorial treatment, Table 3, the application of organic sources promoted a greater number of stems, tubers per plant and yield.

Table 3. Comparison of means between the control and the mean of the factorial for the number of stems per plant (NStP), number of tubers per plant (NTuP), yield and category extra.

Treatment	NStP	NTuP	Yield (t ha^{-1})	Extra (t ha^{-1})
Control	2.28 b	14 b	13.26 b	5.77 b
Factorial	3.4 a	19.67 a	28.95 a	16.44 a

Means with a common letter are not significantly different, according to the Tukey test ($p> 0.05$).

With regard to the interaction between organic sources and levels of application for the number of stems per plant, Table 4 shows that, at the three levels of application, island guano and chicken manure were significantly superior to sheep manure; while within each source, the application of 10 and 15 t ha^{-1} of chicken manure and sheep manure promoted greater stem formation, a response that was not observed in island guano. The increase in the number of stems per plant can be explained by the increase in the availability of nutrients in the soil (Ghemam *et al*., 2016), thus favoring the growth of new dormant shoots in the seed tuber.

Table 4. Interaction between organic sources and levels of application for the number of stems per plant.

Organic source	Levels of application (t ha^{-1})		
	5	10	15
	No. of stems per plant		
Island guano	3.73 Aa	3.73 Aa	3.7 ABa
Chicken manure	3.13 Ab	4.13 Aa	4.18 Aa
Sheep manure	2.05 Bb	2.85 Ba	3.1 Ba

Means followed by the same uppercase letter in the same column and lowercase in the row do not differ from each other, according to the Tukey test at the level of 5% probability.

For the number of tubers per plant, Table 5, the highest values were obtained with the application of island guano, which were significantly higher than the other organic sources.

Table 5. Analysis of main effects for organic sources.

Organic source	No. of tubers per plant
Island guano	25.25 a
Chicken manure	19.42 b
Sheep manure	14.33 c

Means with a common letter do not differ from each other, according to the Tukey test at the level of 5% probability.

Evaluating the interaction between organic sources and levels of application for yield and category extra, Tables 6 and 7 show that, at the levels of 5 and 10 t ha^{-1}, island guano surpassed the other organic sources; while within organic sources, in island guano, the highest yield was obtained with the application of 5 t ha^{-1}, while in chicken manure and sheep manure, yields increased as the amount applied increased.

Table 6. Interaction between organic sources and levels of application for yield (t ha^{-1}).

Organic source	Levels of application (t ha^{-1})		
	5	10	15
	Yield (t ha^{-1})		
Island guano	56.84 Aa	45.5 Ab	32.75 Ac
Chicken manure	22.46 Bb	18.09 Bb	35.78 Aa
Sheep manure	12.42 Cc	17.38 Bb	19.28 Ba

Means followed by the same uppercase letter in the same column and lowercase in the row do not differ from each other, according to the Tukey test at the level of 5% probability.

Table 7. Interaction between organic sources and levels of application for the category extra (t ha^{-1}).

Organic source	Levels of application (t ha^{-1})		
	5	10	15
	Category extra (t ha^{-1})		
Island guano	27.88 Aa	29.34 Aa	21.96 Ab
Chicken manure	12.47 Bb	6.18 Bc	24.08 Aa
Sheep manure	6.48 Cb	8.65 Bab	10.87 Ba

Means followed by the same uppercase letter in the same column and lowercase in the row do not differ from each other, according to the Tukey test at the level of 5% probability.

In general, it can be seen that the application of 5 t ha^{-1} of island guano has promoted better results for the variables under study. This result is explainable because this source has a high concentration of nutrients compared to the other sources; however, it shows as a disadvantage the high content of salts (Table 1) which raise the electrical conductivity of the soil and end up negatively affecting the yields, as observed in the application levels of 10 and 15 t ha^{-1}. The fact that island guano has stood out above the other organic sources is due to the immediate availability of nutrients for the crop (Minagri, 2018).

It is possible that the high content of nutrients, mainly nitrogen, has favored to keep the leaf area functional for a longer time, directly causing a greater photosynthetic activity and consequently, a greater transfer of photosynthates to the storage organs, a situation that has not been observed with the application of sheep manure, which due to its low coefficient of mineralization (Gaham *et al*., 2016) obtained the lowest yield. Chicken manure stood out in second place, obtaining better yield characteristics with the application of 15 t ha^{-1}, this result being explainable by the lower nutrient content compared to island guano (Table 1).

In the case of sheep manure, the lower values obtained for the set of characteristics evaluated can be explained by the low nutrient content in its composition (Table 2) and the resistance it presents to decomposition due to the presence of a membrane that covers it (Célio *et al*., 2012).

Conclusions

The application of 5 t ha^{-1} of island guano, under the conditions of the experiment, has directly affected the productive characteristics of the crop, by favoring a greater formation of stems and tubers per plant, characteristics that ultimately influenced the highest yields, both in the total and in the category extra. With respect to chicken manure and sheep manure, higher doses favored the obtaining of better productive and yield characteristics.

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