Aplication of Worm Castings in an Aridisol Soil to Achieve Maximum Production of Wine Grapes

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ABSTRACT

*The productive activity of vine (Vitis vinifera L.) in the Ica Region (Southern Peru), is developed in an ecosystem with a predominance of aridisol-type soil, which leads to the use organic fertilizer that improves soil fertility. The objective of the work is to determine the maximum productive of Vitis vinifera L. cv. Malbec with the application of worm castings (Eisenia foetida). The randomized complete block experimental design was used with four treatments and four replications in an aridisol soil. When estimating the production function based on econometrics, a positive maximum yield is obtained, as a response of the grapevine cv. Malbec to their nutritional needs***.**

Keywords: *Vitis vinifera*, ecosystem, organic fertilizer, yield

1. INTRODUCTION

The grapevine (*Vitis vinifera* L.) belongs to the Vineaceae family, which is an important economic crop and is widely planted throughout the world. It has a high nutritional value and is rich in sugar, vitamins, anthocyanins, and amino acids that are known to have a protective role against cancer, oxidation, and cardiovascular disease[1]. In the Ica Region there is the largest installed area of grapevines with 16 966 ha with an average yield of 19 377 kg ha^{-1}[2], being below the national average of 23 460 kg ha^{-1}[3], it should be noted that in the case of Ica, although it is the largest producer, it does not have the best yield[4]. According to USDA Soil Taxonomy[5] aridisols have a very low concentration of organic matter, reflecting the paucity of vegetative production on these dry soils. It is proven that planting sites influence the yield and quality of berries in grapevine varieties[6].

Continuous cultivation of grapes can affect the productive potential of the soil, resulting in decreased yields[1]. Unbalanced water and fertilizer systems have limited grape yield and quality in extremely arid areas. The combined application of organic and inorganic fertilizers has been shown to be one of the practical approaches to improving yield and quality[7].

Approximately 97% of the nutrients in worm castings (WC) are in the form that can be absorbed by plants, mainly nitrogen, phosphorus, and potassium[8]. Excessive inorganic fertilizer input can lead to soil compaction, soil acidification, and accumulation of heavy metal ions[9]. Therefore, some alternatives have been recommended, such as organic fertilizers, which provide nutrients for crop growth and contain a large amount of organic matter and valuable trace elements vital for crops[10].

The productivity of land depends on various natural resources namely climate, slope of land, chemical and biological properties of the soil, rainfall, etc. All these factors are considered to be the basis of production; land is considered to be the most important basis of agriculture[11]. In general, the efficient utilization of natural resources and economic inputs in agricultural production is not a linear but a multifaceted process, influenced by various aspects such as water and soil conditions[12].

The yield of the grapevine (expected product) will depend on the agricultural input WC supplied to the Aridisol Soil in variable doses under investigation. For these considerations, the reason is to determine the maximum productive yield with the application of worm castings (*Eisenia foetida*) in the conditions of an aridisol soil.

2. MATERIALS AND METHODS

2.1 Site description

The experimental work was carried out in the Ica Region, Peru, District of Salas Guadalupe, in the demonstration fields of the Universidad Privada San Juan Bautista - UPSJB, located at an altitude of 405 m above m.s.l. at the geographical coordinates of 13°59'17"S 75°46'33"W. Grapevine plantations occupy spaces of aridisols soil, that are common in the ecosystem. The environmental conditions represented mainly by temperature and humidity influence the growth rates of the grapevine; in the study area, a minimum temperature of 11°C and a maximum of 31°C[13] and an average relative humidity of 53%[14].

2.2 Experimental conditions of the treatments

As research materials we have worm castings (WC) from the Universidad Nacional Agraria La Molina and grapevine cv. Malbec in production, subject of the study originally from France with a characteristic of its purple fruit adapted to the environmental conditions of Peru with an orientation to the industrial production of red wines. The vineyard of 4 years of vegetative period since planting at a distance of 3.00 meters between lines and 1.50 meters between plants. There were four WC treatments, including the control: Zero (0); 1.5; 2.5; and 3.5 t ha^{-1} distributed in four blocks and with four randomized replications in experimental units of 27 m^2 composed of 6 strains of grapevine cv. Malbec in each experimental unit (plot), in total there are 96 grapevines occupying 432 m^2, area of the research field. Near plants on the soil were cover applied of worm castings (WC) characterized by the following: pH 6.9; electrical conductivity (E.C.) dS/m 6.01; organic matter contents 31.66%; nitrogen 1.39%; phosphorus contents 1.74%; potassium 0.81%; calcium 6.69%; magnesium 1.7%; and, a humidity of 29.73%.

2.3 Aridisol soil agroecosystem

The aridisol soil, in which the vineyard agroecosystem under study is installed, has the following characteristics: Sandy texture (93% sand), low organic matter content (0.05%), slightly alkaline (pH 7.85) and high salt represented by content electrical conductivity (EC: 9.12 dS m^{-1}). Aridisols (or desert soils) are a soil order in USDA Soil Taxonomy[5], form in an arid or semi-arid climate, dominate the deserts and xeric shrublands, which occupy about one-third of the Earth's land surface. The study zone in which are included areas such as: The Valley of Ica, Pisco, Nazca and Palpa configure an arid zone with limitations of soil fertility.

In order to determine the maximum productive yield and generate a mathematical model that relates the variables under study, the econometric method was used with the support from the spreadsheet software program of Microsoft Excel as a tool to estimate a production function for a single input in its quadratic form with its corresponding coefficient of determination R^2[15]. The application of the econometric method allows us to follow an operating procedure for the estimation of data from the variables under investigation and to create the model[16].

A production function can be expressed using the following equation:

$$y = f(x_i) \tag{1}$$

Where y: is the quantity produced; x_i: is the variable factors of production.

3. RESULTS AND DISCUSSION

The results of this experiment in terms of production of *Vitis vinifera* L. cv. Malbec are presented as average yields in kg per experimental plot (Table 1). These experimental data allow estimating the production function based on the principle of least squares[15].

Table 1. Average yields of *Vitis vinifera* L. cv. Malbec expressed in kg $plot^{-1}$ *.

Block Number	Treatments	Total Block	Average Block

	T1	T2	T3	T4		
I	25.2	39.14	28.61	31.94	124.89	31.22
II	37.61	24.24	36.52	23.55	121.92	30.48
III	17.53	21.31	32.48	33.74	105.06	26.27
IV	17.15	36.41	40.71	21.54	115.81	28.95
Total Treatments	97.49	121.1	138.32	110.77	467.68	29.23
Averages	24.3725	30.275	34.58	27.6925	29.23	

*kg $plot^{-1}$: Kilograms per plot

3.1 Production function estimation specification

To estimate the production function, was used the linear regression model, which is a mathematical model that allows estimating the effect of one variable on another[17]. The production function is a quadratic model for a single agricultural input, represented by the following equation:

$$Y_i = \beta_0 + \beta_1 X_i + \beta_2 X_i^2 \quad (2)$$

Where Y_i: A dependent variable, which is estimated based on a given value of X_i[18,]; also called an endogenous or returning variable[17]; the predicted or estimated value of the variable Y_i for a selected value of an independent or explanatory variable X_i[19]; called regressor[20, 21]; β_0, β_1 and β_2 are estimators of the parameters of the specified regression model[22].

For our study, the aforementioned general model represents a function of production, input-output relationship, which allows us to analyze and model the decision processes that are addressed by Econometrics[22]. For this purpose, we based ourselves on the 16 observations detailed in Table 1 that allowed us to find the parameters of the regression that minimizes the sum of the squares of the deviations between the observed values of the dependent variable, Y_i, and the estimated values of the same, $\hat{Y}_i$. The procedure consists of finding the parameters using the following matrix equation[17]:

$$B = (X' X)^{-1} X' Y \quad (3)$$

Where B: Column vector that includes β_0, β_1 and β_2 (of order 3 by 1); X: Matrix of the independent variables including the intercept (of order 16 by 3); Y: Column vector of the dependent variable (of order 16 by 1).

The production function is estimated developing the equations formulated with the data from Table 1, using Microsoft Excel software, resulting in the following equation:

$$Y = 8.870684 + 3.167642 X - 0.768195 X^2 \quad (4)$$

This mathematical model of quadratic equation (Eq. 4) is represented in Figure 1, showing the increase in grapevine production, as the doses of organic fertilization with WC increase, until reaching a maximum yield.

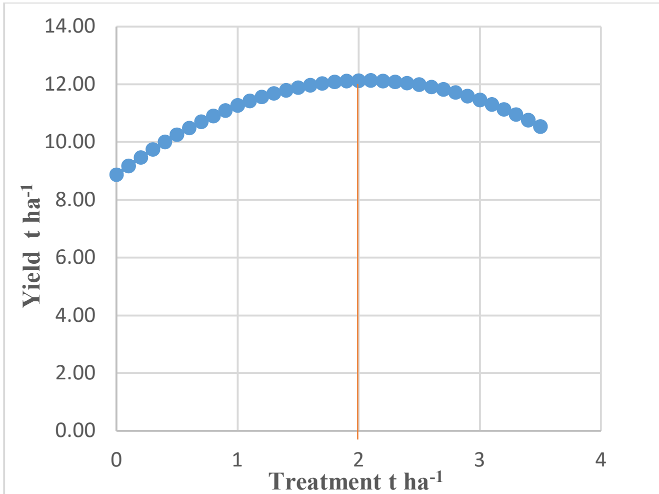

Figure 1. A production function as a result in the study of application of worm castings.

3.2 Goodness of fit statistical test

Statistical goodness of fit tests is used to test whether the data in the sample can be considered to come from a certain distribution or Probability Model[23]. Goodness of fit tests are hypothesis tests to verify whether the data observed in a random sample fit with some level of significance to a certain probability distribution (uniform, exponential, normal, Poisson, or any other). Table 2 shows the main indicators of the goodness of fit of the regression of the Production Function[17]; these statistical estimates were made with the support of software program Microsoft Excel.

Table 2. Indicators of the linear regression goodness of fit of the production function.

Regression estimators		Statistic "t"		Probability
β_0 =	8.870684	Tβ0 =	6.432801	0.0000
b_1 =	3.167642	Tβ1 =	1.749792	0.1037
b_2 =	-0.768195	Tβ2 =	-1.526567	0.1508
		R^2 =	0.2023	

According to the indicators of the regression estimators (Table 2), it can be inferred that the application of 1 t ha^{-1} of WC impact changing the yield. For increments per ton of fertilizer WC up to before the range of 0 to 2.0 t ha^{-1} increases at decreasing but positive rates, with more WC continues to be added to levels above 2.0 t ha^{-1} the productive yields per hectare decrease, this implies that the maximum yield of grapevine is 12 t ha^{-1} with the application of 2.0 t ha^{-1} of WC, just when marginal yields are zero.

The results of the linear regression analyses carried out with the experimental data of the present research work reflect the positive response of the vine plant to the application of WC, coinciding with other similar research works with this organic fertilizer; Among them from[6, 24, 25] achieved the response of cultivated plants in productive yields, improving yields and soil fertility; also consistent with the research results of[26] evaluated the efficacy of cow dung and WC on seed germination, seedling growth, and vegetative development parameters of *Viola wittrokiana* (pansy); they found that WC not only improved seed germination and pansy growth, but also enhanced soil health. Consequently, they argued that WC can be used as a potent biofertilizer in soil improvement. This confirms our assertion, in light of our results, of the benefits of WC as an organic fertilizer considered as a biotechnological factor in the production process and development of sustainable agriculture; coinciding with the postulate that “in the modern path of economic development of agriculture, interest is being taken in technology, the role of natural resources, sustainability and food security” [27].

In our study, when the agricultural input fertilizer WC is increased by one unit, the production of grapevine (*Vitis vinifera*) cv. Malbec up to the maximum level 12 t ha^{-1}; hence the yield decreases in the production process; this fact, according to economic theory and microeconometric tools that lead to a set of measurement and modeling techniques[28], can determine the marginal returns also called diminishing marginal returns based on the principle of the Law of Diminishing Returns; explained extensively by[29].

The coefficient of determination $R^2 = 0.2023$ (Table 2) means that 20.23 % of the variation in the productivity of grapevine cv. Malbec under study is due to the variation in the application doses of WC fertilizer. The difference of 79.77% is due to other random factors (climate, water, soil texture, soil salinity...).

CONCLUSION

The application of worm castings resulting from a biotechnological process, a natural organic fertilizer, is of benefit to the productive activity of the cultivation of *Vitis vinifera* L. cv. Malbec and an alternative for sustainable agricultural development. A maximum acceptable yield was achieved in the conditions of an aridisol soil predominant in the Ica Region (Peru). With their respective inference tests indicate that there is a significant impact of the application of worm castings on yields per unit area of land. The study carried out leaves the possibility of carrying out other experimental research work with soluble organic fertilizers.

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