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Agroproductive performance of three cultivars of *Glycine max* (L.) Merril

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Abstract

Objective: To evaluate the agroproductive performance of three cultivars of *Glycine max* (L.) Merril on a loose brown soil without carbonate.

Materials and Methods: The research was conducted in a farm in the Las Tunas municipality, Las Tunas province, under field conditions. A randomized block design was applied with three treatments and three replicas. Plots with an area of 11,2 m^2 were used. The distance between replicas was 1 m. The seed had 98 % germination. The cultivars Incasoy-1, Incasoy-26 and Incasoy-2 were studied. During the vegetative cycle of the crop, the variables number of pods per plant, number of grains per plant, weight of 100 grains, yield in t ha^{-1}, were evaluated.

Results: The lowest number of pods per plant corresponded to cultivar Incasoy-2 and the highest one was shown by Incasoy-1, which differed statistically from Incasoy-26. The highest yield was obtained in cultivar Incasoy-1 (1,75 t ha^{-1}), which differed from the others, and the lowest value was recorded in Incasoy-2 (0,60 t ha^{-1}). All the cultivars reached profits in their production. The treatment that provided the highest profit was Incasoy-1, with results of 121 250.00 pesos per hectare, and cost of $0,10 per produced peso.

Conclusions: The highest agricultural yield was for cultivar Incasoy-1 (over 1 t/ha) and the lowest yield for Incasoy-2. In turn, the highest net profit corresponded to Incasoy-1, as well as the lowest cost per peso.

Keywords: economic analysis, evaluation, yield

Introduction

From the oil plants produced worldwide, *Glycine max* (L.) Merril occupies first place regarding production and consumption, with more than 50 % in each one of those concepts, compared with the other oil seeds. This is due to its large diversity of uses, derived from its high protein content and oil quality. As average, the dry grain contains 20 % oil and 40 % protein (ASERCA, 2018).

This species contains vitamins, such as thiamine, riboflavin, nicotinic acid, E, K, A, D and C and minerals like iron, phosphorus, magnesium, zinc, copper and calcium. Likewise, it contains between 1 and 5 % lecithin and quality oil (5-25 %), for which it constitutes a source of cheap and highly efficacious protein for human and animal feeding and the grain as well as the plant can be used (Pérez, 2019).

In addition, the oil represents a choice for biodiesel production. The protein of *G. max* contains all essential amino acids for humans, and it is the only protein of plant origin with quality evaluated by the score of its amino acids (100 %), comparable to the proteins of animal origin, although it is limiting in one amino acid (methionine). It is therefore important that it is combined with a cereal or animal protein in order to form a good-quality protein (Rivera-de-la-Rosa and Ortiz-Pech, 2020).

In the current context, with the impact of climate change on agriculture, a state of uncertainty is anticipated regarding how to feed the planet's population and guarantee the availability of species domesticated by different human groups. To promote sustainable productivity growth, strategies must be implemented to ensure increased crop yields, conservation of genetic resources and adoption of innovative crop management practices that generate added value and increase rural incomes (D'Angelo *et al*., 2019).

In Cuba, in recent years, the cultivation of *G. max* is enhanced, mainly due to the limitation of food for human consumption and animal feeding, and because it can be sown practically throughout the year (Pérez, 2019, Roján-Herrera *et al*., 2020).

The search for high yields in the crop implies good management of the different factors that can affect it, such as seed production, irrigation,

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fertilization, existing cultivars and, above all, having cultivars that withstand drought as one of the limiting factors to achieve these objectives (Travieso-Torres *et al.*, 2018).

In Las Tunas, there is a visible need to produce *G. max*, which is proven by its high demand, mainly for animal feeding. At present, its production is still limited due to the lack of cultivars adapted to the edaphoclimatic conditions, a problem that is solved by the research conducted through breeding programs and cultivar selection. Therefore, this study was developed with the objective of evaluating the agroproductive performance of three *G. max* cultivars on a loose brown soil without carbonate.

Materials and Methods

Location. The research was carried out under field conditions, between May and September 10, 2022, in a farm of Las Tunas municipality, Las Tunas province, with a total area of 1 ha. It is located at coordinates 20º 92’ 64’’ LN and 76º 55’ 41’’ LW.

Soil characteristics in the experimental area. Samples were taken from the genetic horizons for the determination of the soil physical and chemical variables (table 1). The samples were gathered at a depth of 20 cm through the experimental sampling technique of square shape (Almendros-Martín *et al.*, 2010) and they were dried and sieved with a 2-mm mesh. The pH (H_2O) was determined through the potentiometric method and the organic matter content by the Walkley and Black (1934) method. The available phosphorus was calculated by the method suggested by Olsen *et al.* (1954), molecular spectrophotometry (EDULST01-13) and the cation exchange capacity (CEC), exchangeable cations (Ca^{2+}, Mg^{+2}, Na^{+}, K^{+}) and the base change capacity (BCC), by the modified Mehlich (1984) method (Norma Cubana NC-65:2000). The soil is classified as loose Brown without carbonate (Hernández-Jiménez *et al.*, 2015)2015.

Performance of the climate variables. During the experiment development period, the performance of the main climate variables that can affect the crop production was taken into consideration. The data were taken from the meteorological station of Las Tunas municipality. The temperature, relative humidity and rainfall during the experiment development period (May-September) were measured. The data are shown in table 2.

Treatments and experimental design. For setting up the experiment a randomized block design was used with three treatments and three replicas. The treatments were T1-Incasoy-1, T2-Incasoy-26 and T3-Incasoy-2. Plots with a surface of 11,2 m^2 (2,8 x 4,0 m) with four rows were used. The two central rows (5,6 m^2) were taken as calculation area. The distance between replicas was 1 m and the cultivars were from the National Institute of Agricultural Sciences (INCA, for its initials in Spanish) with 98 % germination. For the analysis 10 plants per plot were taken, for a total of 30 plants per treatment.

Experimental procedure. The applied plant management was performed according to the technical instruction manual of the crop (Hernández-Martínez *et al.*, 2013).

Seeding took place on May 29, 2022, manually, at 4 cm of depth. Two seeds were placed per nest, with a distance between rows of 0,70 m and 0,10 m between plants.

Table 1. Some components of soil fertility (0-20 cm).

OM	pH	EC	Cmol (+) kg^{-1}				ppm
%	H_2O	dS m^{-1}	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	P_2O_5
3,22	6,43	0,40	26,2	8,38	1,11	1,35	6,26

Table 2. Mean performance of temperature and relative humidity.

Variable	May	June	July	August	September
Mean maximum temperature, °C	31,6	32,4	33	33,5	33,5
Mean minimum temperature, °C	22,1	22,9	23,5	23,1	23,4
Mean temperature, °C	25,8	26,5	27,2	27,2	27,5
Relative humidity, %	79,0	79,0	77,0	78,0	76,0
Rainfall, mm	229,4	357,1	36,6	154,5	103,9

During the drop cycle irrigation was applied seven times through spray technology in the critical periods of water demand, framed in the stages of pre-flowering, flowering-pod formation and grain filling, with an irrigation interval of 7-8 days, depending on the rainy season.

Measurements. After the harvest, the number of pods per plant and the number of grains per pod were evaluated. One hundred grains were weighed (g) with an analytical scale (SARTORIUS, model BS 2202S). In addition, the yield obtained in each plot was estimated. The data were expressed in tons per hectare.

For the economic analysis, the values obtained in yield in t ha^{-1} of the dry seed (14 % humidity) of the experimental variants and the necessary cost to establish one hectare of *G. max* under the conditions adopted by the farmers, were considered. The value of the ton of *G. max* in the market ($77 000.00 CUP), according to the Basic Entrepreneurial Unit (UEB, for its initials in Spanish) Seed, was taken as basis. The economic indicators production value (PV), production cost (PC), profit (P) and cost per production peso (C/P) were evaluated:

- PV ($ ha^{-1}): crop yield multiplied by the sale price of one ton of dry grain at 14 % moisture.
- PC ($ ha^{-1}): summation of the expenses incurred in soil preparation.
- P ($ ha^{-1}): difference between production value and production costs.
- C/P ($): quotient obtained from dividing the production cost and production value.

Statistical analysis. The data of the different measurements were processed through double-classification variance analysis and mean comparison by Tukey's test for 5 % error probability. The information was processed with the statistical program InfoStat® version 2017 (Di-Rienzo *et al*., 2017). For the parametric statistics analysis, the variance homogeneity test was carried out through Bartlett's test and it was tested whether the data were adjusted to a normal distribution through Shapiro-Wilks test.

Results and Discussion

Table 3 shows the yield indicators. The lowest number of pods per plant corresponded to the Incasoy-2 treatment and the highest was shown by Incasoy-1, which differed statistically from Incasoy-26. This component is influenced by several reproductive factors, which can vary according to environmental conditions. There is research showing that high temperatures increase bud and flower production, but also abscission of flower buds, flowers and pods (González-Osorio *et al*., 2020). If *G. max* is grown under adverse environmental conditions, pod development can be affected and, consequently, cause malformations. Grain development can also be affected, resulting in what is known in the literature as empty pods.

According to Jiménez-Zúñiga (2020), yield variations can be explained by the effects of genotype, environment, management and the interaction among these factors. Generally, the environmental effect explains most of the yield variations. The physical and chemical properties of the soil in interaction with climate variables, availability of radiation and water, as well as different thermal regimes, determine different environments for the cultivation of *G. max*.

During the period in which the experiment was carried out, monthly rainfall showed an acceptable performance in the critical stages of the crop. Average temperatures varied between 25 and 27 ºC. This behavior conditioned the stability of the variable during the experiment. In the months of research development, rainfall tended to decrease, which could have caused a decrease in the yields of the evaluated cultivars.

Table 3. Morphoagronomic variables of three *G. max* cultivars.

Treatment	Number of pods per plant	Grains per pod	Weight of 100 grains, g	Yield, t ha^{-1}
Incasoy-1	50,8^{a}	3,0^{a}	14,7^{a}	1,8^{b}
Incasoy-26	43,0^{b}	2,3	11,6^{b}	1,1^{b}
Incasoy-2	37,3^{c}	2,2^{b}	8,6^{c}	0,6^{c}
VC %	3,9	1,0	1,4	9,2
P - value	0,0001	0,0001	0,0001	0,0001
SE ±	0,04	0,01	0,01	0,05

Means with a common letter are not significantly different (p > 0,05)

In a research conducted by Roján-Herrera *et al.* (2020), it is highlighted that the number of pods is the first component to be defined in the stage of pre-flowering and beginning of flowering (R1-R5), which is subject to fluctuations in the environment. Hence the importance of matching the stage at which these components are decided with the best environmental conditions, although this is difficult to manage in practice. In addition, *G. max* has the capacity to fix reproductive structures for a long period. It is shown in this study that an eventual decrease in the number of pods can be partially compensated by the increase in grain mass. This is important, as long as it is noted that each component is affected with different intensity by the environment at each development stage.

No significant differences were found in the number of grains per pod among the cultivars Incasoy-26 and 3 Incasoy-2, but differed from Incasoy-1, which showed the highest results. These results coincide with those reported by Hernández-Tecol *et al.* (2022) in Mexico, who did not find statistical differences regarding the number of grains per pod. According to the report by Albuquerque *et al.* (2022), this species has from 2 to 4 seeds in its pods.

The production of *G. max* grains is linked to the capacity of the crop to capture the available resources (water, nutrients, radiation, CO_2). Temperature regulates the capture intensity of such resources. The moment during the crop cycle in which those resources are available will determine the variations in the yield of this oil plant, because it will affect in a different way the definition of the main two components of crop yield: number of seeds and their weight (Lescay-Batista *et al.*, 2018).

The treatment that showed the highest weight was Incasoy-1, which differed statistically from the others. Incasoy-2 obtained the lowest weight. These results are corroborated with those reported by Romero-Arias *et al.* (2019). These authors referred high weight of 100 grains (between 11,50 and 18,20 g) when evaluating seven *G. max* cultivars in the Majibacoa municipality. This result indicates that there is correspondence among the treatments, regarding grain weight and yields.

The highest yield was shown by cultivar Incasoy-1, which differed from the others. Likewise, the lowest value corresponded to Incasoy-2. The yield per plant was determined, first, by the number of pods per plant and by the seed weight. In the selection for high yield the number of pods can serve as the component of direct selection. However, with the number of formed flowers, the yield does not certainly correlate because the crop loses a large part of its flowers. The seed weight is closely related to the number of seeds per pod (Romero-Arias *et al.*, 2021).

These results do not coincide with the report by Hernández-Tecol *et al.* (2022), who indicated yields from 2,2 to 3 t ha^{-1}. It is considered that the yields of these cultivars were sustainable, because the national mean is de 0,87 t ha^{-1}. If irrigation of 1,02 t ha^{-1} was used, two of the evaluated cultivars would be above the national mean.

There are diverse studies at international level that evaluate the incidence of climate with regards to the planting date. This aspect is important, because most of the meteorological variables, such as temperature and solar radiation, positively or negatively affect crop growth and development. Equally, they modify their environment and disturb dry matter production like yield. Other studies conducted to explain yield variability in the *G. max* crop base their principle on the fact that variations can be consequence of the different radiation availability (Roján-Herrera *et al.*, 2020).

This can be the cause of cultivar Incasoy-2 showing the lowest yield values. In Cuba, agricultural yields vary significantly among planting seasons and dates. In this sense, works conducted in other crops prove that yield is positively and linearly related to planting date, depending on the cultivar and the environment (Maqueira-López *et al.*, 2016).

All the treatments reached profits in their production (table 4). The treatment that provided the highest profit was Incasoy-1, with results of 121 250,00 pesos per hectare and a cost of $ 0,10 per produced peso. Planting the *G. max* crop constitutes a viable alternative for crop production, in order to increase the agricultural yield and sustainability of agroecosystems, as well as their potentialities for human and animal feeding.

The expenses were related to the soil preparation, planting, irrigation, agrotechnical works and harvest. The performance profit was evaluated from the sale price of the ton of *G. max* grain, according to UEB Seed of Las Tunas.

New technologies should be focused on maintaining and preserving the sustainability of the production system through rational exploitation of natural resources and application of pertinent measures to preserve the environment. The *G. max* production contributes to the region improving its

Table 4. Economic appraisal of the studied *G. max* cultivars.

Indicator	Incasoy-1	Incasoy-26	Incasoy-2
Yield, t ha^{-1}	1,75	1,06	0,60
Production value, \$ ha^{-1}	134 750,00	81 620,00	46 200,00
Production cost, \$ ha^{-1}	13 500,00	13 500,00	13 500,00
Profit, \$	121 250,00	68 120,00	32 700,00
Cost per peso, \$ ha^{-1}	0,10	0,17	0,29

insertion in the process of transformation of Cuban economy and, thus, generating alternatives for a possible substitution of the oil plant imports, not only at territorial, but at national scale (Mesa-León, 2023).

Conclusions

The highest agricultural yield corresponded to cultivar Incasoy-1 (over one ton per hectare) and the lowest yield was shown by cultivar Incasoy-2. In turn, the highest net profit, as well as the lowest cost per peso, corresponded to cultivar Incasoy-1.

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Conflicts of interests

The authors declare that there is no conflict of interests.

Authors' contribution

- Aracelis Romero-Arias. Research conception and design, data acquisition and interpretation, manuscript writing and revision.
- Raquel María Ruz-Reyes. Research conception and design, data acquisition and interpretation, manuscript writing and revision.
- Santa Laura Leyva-Rodríguez. Research conception and design, data acquisition and interpretation, manuscript writing and revision.

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