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Agronomic Performance of Three Sunflower Varieties (*Helianthus annuus* L.) in Topes de Collantes Mountain Community, Cuba

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ABSTRACT

Considering the permanent human need to meet the food demands, current efforts are being made to diversify crop productions and foster multipurpose crops. Accordingly, a study was made in Topes de Collantes mountain community, where there is a predominance of farms under agroecological conversion. The aim of this research was to evaluate the morphological and productive indicators of three sunflower varieties for introduction in local agro-forest-grazing systems. The varieties studied were Cubasol 113, Caburé 15, and CIAP JE 94. The treatments for seed germination were dipped in water for 6, 12, and 24 h. The various phenological phases of the crop were determined in the field. Additionally, growth indicators like height, stem thickness, and number of leaves were evaluated; as well as productive indicators capitulum diameter, number of seeds per capitulum, and total seed weight, from which the yields of the three varieties were estimated. Multifactorial and one-way ANOVA analyses were performed for statistical processing. The best treatment was the 12 h dipping, and the best variety was Cubasol 113, with over 70% germination. The height, stem thickness, and leaf number values for the three varieties matched the responses described for them under other edaphoclimatic conditions. The productive values of variety CIAP JE 94 were higher than the values for Cubasol 113 and Caburé 15 under the conditions of the study.

KEY WORDS:/ sunflower, agronomic performance, variety, phenological phases.

INTRODUCTION

Plant oil consumption is one of the human needs to be met by agriculture. These oils are essential for nutrition, due to their fatty acid composition and the absence of certain microcomponents. They are also high calorie foods, with high digestibility coefficients. In Cuba, the strategy to meet the human demands for plant oil consumption is tightly linked to sunflower (*Helianthus annuus* L.). It is presented as a viable alternative for the current conditions, characterized by limited availability of oil, fuel for irrigation equipment, fertilizers, and plant health products (Alemán, 2003a, cited by Ilmi, 2016).

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Sunflower is a fast-growing, remarkably drought-resistant, annual rustic plant, which demands little fertilizing. It can be sown throughout the year in short cycles (100-115 days), which allow the plant to be part of crop rotation schemes, without using the area needed by other important crops (Penichet *et al.*, 2008). This crop is easily adapted to different soil and climate conditions that may not only be used as a source of oil, but also to produce forage (Soares, 2014).

According to Pacheco and Vázquez (2001), this crop has demonstrated to produce considerable amounts of high-quality seeds during several research. Therefore, proper management may lead to high yields of edible oil. In Cuba, it has been sown in heavy, light, and sloppy soils, with acceptable production. There is also the possibility of using saline soils, in mountain and marginal lands; which is also an effective choice for diversification of production on agroecological or conversion farms.

Moreover, Penichet, Alemán, and Carballo (2010) noted that forage sunflower can be sown in Cuba at any time of the year (whenever irrigation is used for germination), aiming at high forage productions during critical events in animal nutrition. The plant has also been said to grow effectively in dry periods at low temperatures. According to Padilla (2006), Cuban Caburé 15 and Cubasol 113 were the most commonly sown varieties nationally in the 1970s, for rudimentary oil production.

These varieties reach 1.8 and 1.4 m high, respectively, in optimum cultivating conditions. Likewise, their cycles are extended to 115 days (Caburé 15) and 100 days (Cubasol 113). Both showed similar yields (up to 3 t. ha^{-1}). In turn, variety CIAP JE 94 can reach 1.8 m high maximum, in a cycle of up to 120 days. The plant yields have been 2.5 $t.ha^{-1}$ in Cuba (Sánchez *et al.*, 2004). Although they are easily adapted to different edaphoclimatic conditions, clay-sandy soils are recommended (pH 5.7-8), with good water retention capacity. The temperatures should be over 15 °C, and below 35 °C, whereas precipitation should be 160-200 mm before, and 200-300 mm after flowering for proper crop development (Pacheco and Alemán, 2003).

In face of the Local Innovation Agricultural Program (PIAL), most farms in Topes de Collantes mountain community are part of the agroecological conversion, which has allowed farmers to diversify their productions, considering the challenge of food safety in the mountains. Sunflower plasticity and multipurpose raise the question of which varieties will produce the best morphological and productive indicators in the area. Therefore, research is needed in order to evaluate the agronomic performance of Caburé 15, Cubasol 113, and CIAP JE 94. The relevance of this study is given by the possibility to determine the variety that can adapt best to the particular local conditions, and to suggest its introduction in the local productive systems.

MATERIALS AND METHODS

Location and general information

This study was conducted at the organoponics of the former Faculty of Mountain, Escambray (now Teaching University of Sancti Spiritus province), located in Topes de Collantes mountain community, municipality of Trinidad (coordinates 21°53′00″N 80°00′00″O).

The edaphic features of the area are shown in Table 1, based on research done by Reyes (2006).

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Table 1. Main features of the soil in the experimental area

Chemical properties	Value	Classification	Physical properties	Value	Classification
pH (H_2O)	4.61	Very acidic	L.I.P (% H.b.s.s)	29.09	
pH (KCl)	3.72	Acidic	L.S.P (% H.b.s.s)	47.15	
OM (%)	3.55	Mean	PI	18.06	Mid-plastic
P_2O_5 (mg.100 g^{-1})	6.87	Mid	E.F. (%)	60.35	Average
K_2O (mg.100 g^{-1})	8.20	Mid	E.A (%)	44.84	Satisfactory
Y_1 (cmol(+) kg^{-1})	4.79	Very high (hydrolytic acidity)	Permeability (log 10 K)	1.97	Adequate
Y_2 (cmol(+) kg^{-1})	0.41	Low			
lA (cmol(+) kg^{-1})	0.11	Low			

Source: Reyes, A. (2006)

During the research, climate variables mean temperature, average relative humidity, and average precipitations were recorded. The values are shown below.

Table 2. Weather variables during the experimental period

Mean temperature (ºC)	22
Average relative humidity (%)	83.6
Average precipitations (mm)	185.3

Source: Weather Station No. 342, Topes de Collantes

Starting plant material

Recently harvested seeds from Cubasol 113 (CBS-113), Caburé-C-15 (C-15), and CIAP JE 94, purchased from the provincial seed company, in Sancti Spiritus, were used.

The varieties were selected (Table 3) according to their productive features, and because they are the most commonly planted and exploited variety by the industry, both in the province and the country (Alemán, 2003a). Sowing took place on September 15, and harvest was performed in December-January, depending on the type of variety and the duration of their phenophases.

Table 3. Features of Cubasol 113, Caburé 15, and CIAP JE 94

Characters	Caburé 15	Cubasol 113	CIAP JE-94
Height (m)	1.6 – 1.8	1.2 – 1.4	1.6 – 1.8
Cycle (days)	110 – 115	90 – 100	100 – 120
Capitulum diameter (m)	14 – 16	12 – 14	20 – 25
Weight 100 kernels (g)	4 – 6	5	7 – 9
Yield (t/ha)	1 – 3	1 – 3	1.0 – 2.5

Source: Sánchez *et al.* (2004)

Seed germination

To ensure high levels of germination and greater homogeneity in the process, and to achieve a suitable number of plants for the research, the seeds were made to germinate in 247-well polyurethane containers (4 cm^3), using a mixture of soil and cattle excreta (2:1) as substrate.

As part of the pregermination treatment, the seeds were dipped in water for 6, 12, and 24 hours. Then each seed was sown in a hole in the soil, 2 cm deep. Every treatment consisted in 24 seeds of each variety (72 seeds/variety). The variable studied was number of germinated seeds accumulated for 16 days (3 days after the number of seeds remained constant). The purpose was to evaluate the percent of germination. The experiment was based on a multifactorial design.

Plantation

All the vegetation existing in the field was totally removed. Then harrowing and raking were performed to condition the soil. The plantation framework was 0.70 x 0.25 m, as recommended by Alemán (2001). A hole was dug 20 cm deep with a pick, and 0.25 kg of worm humus was applied, which is the organic fertilizer most commonly used by the local farmers, then a plant with a root ball was placed in the hole. The average height of the plants at transplantation was 15 cm. A completely randomized design was used in the experiment, 50 plants of each variety (5 rows with 10 plants each) were sown. Tilling consisted in manual removal of undesirable vegetation and manual irrigation when required, depending on the weather conditions throughout the experimental period.

Evaluation of morphological indicators

The stages below were set up to evaluate the main variables linked to plant development:

Plantation-beginning of flowering

Beginning of flowering-flowering

Flowering-physiological maturity

Physiological maturity-harvest maturity

These stages were established considering the fact that subsequent morphological and physiological changes can determine the plant´s phenological stages throughout crop development. These processes are genetically determined and influenced by the environment. Although crop growth and development is a continuous process with overlapping events, several scales have been defined for classification of different phenological stages, which are then correlated to crop response.

Every evaluation was made on a weekly basis; and the variables recorded were,

- Duration of the stage in weeks.
- Plant height: measured with a metric tape (cm), from the base to the apex.
- Stem thickness: measured with a gauge caliper (mm) on the mid area of the stem 30 cm from the soil.
- Average number of leaves: visual count.

Evaluation of productive indicators

Physiological maturity was considered when the flowers began to disappear, exposing the dark kernels on bent down capitula. Harvest maturity was considered when the capitulum was dark, and the kernels were clearly exposed. The kernels were collected manually and air-dried in the shade for 72 hours, until weighing.

The production variables evaluated were,

- Average capitulum diameter (cm): estimated with a measure tape at the time of physiological maturity (flower loss).
- Average of kernels per capitulum: visual count
- Average of kernels per capitulum (g): analytical balance.
- General weight of seeds (g): digital analytical balance. This variable was evaluated when the plants reached harvest maturity, and its value was used to calculate yields in t. ha^{-1}, assuming the criterion of Penichet, Guerra, and Carballo (2008), which states that 1ha of sunflower produces 1.4 t of kernels (300 liters of oil).

Fifteen plants selected at random were measured in the middle of the plantation. They were marked with wooden stakes and a sequential number to prevent measure recording errors. The Excel tabulator was used to record all the data.

Statistical analysis

STATGRAPHICS package, version 5.0, was used to perform statistical processing of the data gathered. Multifactorial analysis was made to the results of germination, and one-way ANOVA was performed to the productive variables. Mean comparison was conducted by the Duncan's multiple ranges (99% confidence).

RESULTS AND DISCUSSION

Seed germination

This physiological process started 72 hours (3 days) in all the treatments and the three varieties after sowing. The number of germinated seeds kept increasing until day 13, when it stabilized. The germination percentage is shown in Table 3.

Table 3. Germination performance of the three *H. annus* varieties with three germinating treatments.

Treat. / Var.	Control (without dipping)	6 hours	12 hours	24 hours	X
Cubasol 113	35.7	64.9	73.2	73.4	61.8[a]
Caburé 15	37.1	48.6	71.4	52.4	52.3[a]
CIAP JE 94	13.5	24.9	30.5	13.5	20.6[b]
X	28.8[b]	46.1[a]	58.5[a]	46.3[a]	

Note: VC var. (%) = 61.61 SE±var.= 0.96** VC treat. (%) = 46.33 SE± treat.=1.71** ($P < 0.001$)

Made by the authors

Generally, seed germination did not show a high percentage, it was higher in treatments where dipping was performed. The percentage of germination did not have a similar performance among the varieties; higher values were observed for Caburé 15 and Cubasol 113 than for CIAP JE 94, with statistically significant differences.

No significant differences were observed among the treatments, except for the control, which means that dipping in water favored germination. Thus, it was inferred that a minimum 12-hour treatment was enough for the seeds to acquire the necessary imbibition levels for germination. Then, enzymatic activity and respiratory metabolism were initiated. After overlapping, the seed reserves are assimilated into sites where the embryos grow, which leads to embryo emergency until the testa is ruptured.

Alemán (2003a) achieved germination percentages above 80% in Cubasol 113, higher than the previous, in flat lands. Likewise, the same author achieved more than 70% germination in 10 days in CIAP JE 94 on brown soil. According to the current study, it was inferred that the germination percentage of recently harvested seeds was influenced by the temperature, humidity, and the edaphic conditions of the mountains in Topes de Collantes. Soares (2014) noted that the seeds were observed to have an adequate germinating capacity, even at temperatures below 5 °C. The optimum temperature interval for seed germination of this species is 15-20 °C, and this process is favored when humidity is high.

Evaluation of morphological indicators

Evaluation results of the first stage (plantation-beginning of flowering).

Cubasol 113= 3 weeks (21 days)

Caburé 15= 7 weeks (49 days)

CIAP JE 94= 4 weeks (28 days)

Continuous and constant increased height dynamics for the three varieties, though the greatest increases were observed from the fourth week on.

Overall, this indicator produced a sigmoidal curve with three, well-defined stages in the experimental conditions. A first stage of slow growth begins in seed germination and ends in flowering (except for Caburé 15). A second, fast growing, stage begins at the onset of flowering and ends at flowering. The third stage begins in flowering and ends in maturation, with an apparent decrease in the speed of growth.

The morphological indicators evaluated showed a normal behavior, according to each variety´s features (Table 4), which are in line with the results of Alemán (2003a), on characterization of Caburé 15 and CIAP JE 94.

Table 4. Behavior of morphological indicators of three *H. annuus* varieties for the conditions of Topes de Collantes mountain area.

Variety	Height (cm)	Stem thickness (mm)	Number of leaves
Cubasol 113	29.5	10.13	29.1
Caburé 15	99.2	18.9	31
CIAP JE 94	27.73	11.6	32.6

Note: Made by the authors

Caburé 15 had the highest values due to its mid-size (may reach 180 cm high), so it requires thicker stems to support the plant, and therefore, more leaves to increase its photosynthetic capacity. These results implicitly showed that this variety grows very fast, reaching heights close to the final height. However, the other two varieties grew more slowly, with a more significant development in further stages.

This stage was characterized by active root development, significantly higher than the aerial part. The plant went from the vegetative to the reproductive stage. After this meristematic change, the number of leaves of the plant is defined, though these processes depend largely on temperature, radiation, and duration of days. In that sense, Ilmi (2016) stated that the number of leaves varied between 12 and 40, depending on the variety. Cerreta (2005) achieved similar values, after evaluation of the same indicators in sunflower hybrids.

The second stage (beginning of flowering-flowering) lasted four weeks in the three varieties. The most significant aspect of the morphological indicators evaluated was the shooting of flower primordium, foliar expansion to increase the photosynthetic capacity, and an increase in stem thickness, which guarantees the assimilation of the elements needed to hold the capitulum and enhance the formation of kernels.

The third stage (flowering-physiological maturity), lasted three weeks for variety Cubasol 113, and four weeks for the other two varieties. The most remarkable event was a reduction of growth, in order to enhance fruit and seed development. Besides, the number of kernels (the basis of yields) was defined. Carbohydrate, fatty acid, and protein accumulation in the kernels was observed, and their weights and oil percentage were determined.

Sánchez *et al.* (2004) achieved similar results in the same varieties, after evaluating the same parameters. Alemán (2003a) also achieved similar results upon evaluation of the morphological indicators in Caburé 15 and CIAP JE 94.

Evaluation of productive indicators

The following stage (physiological maturity-harvest maturity) underwent few changes in each variety in terms of duration, and it behaved as follows:

Cubasol 113= 2 weeks (14 days)

Caburé 15= 4 weeks (28 days)

CIAP JE 94= 3 weeks (21 days)

The productive indicators evaluated on this stage are shown in Table 5.

Table 5. Behavior of productive indicators of three *H. annuus* varieties for the conditions of Topes de Collantes mountain area.

Variety	Capitulum diameter (cm)	Weight of seeds per capitulum (g)	Number of seeds per capitulum
Cubasol 113	18.86b	58.1[b]	1404.2a
Caburé 15	19.66ab	60.06[b]	1250.13[b]
CIAP JE 94	20.4[a]	79.06[a]	1344.8[ab]
VC (%)	7.72	21.15	14.33
SE±	0.39*	3.59*	49.34*

Note: Made by the authors (P <0.001)

Remarkably, a better performance of CIAP JE-94 regarding weight, may be caused by a greater size of the kernel than in the other varieties. The number of kernels per capitulum for this variety was observed not to have significant differences from the other two. Alemán *et al.* (1995), in CIAP JE 94, obtained 2102 and 1015 seeds in different years, and capitulum diameters of 26.28 cm and 18.76 cm, respectively. It meant that the performance observed by this variety in mountain conditions was within the range observed for other edaphoclimatic conditions. These results evidence the importance of the genotype-environment interaction (GxE) when deciding what varieties to choose for sowing.

Differences were observed in terms of cycle duration for the varieties studied. Cubasol 113 accounted for 84 days barely, whereas Caburé 15 and CIAP JE 94 were 133 and 105 days, respectively. In spite of the correspondence of these results to the reports published by Sánchez *et al*. (2004) for these three varieties, Cubasol 113 responded earlier in the Topes de Collantes conditions, which demonstrated that choosing one or another variety by the local farmers will depend on the purpose of crop introduction on their farms.

Determining the total seed weight produced by the three varieties facilitated individual yield estimations. Again, the best results were achieved by CIAP JE 94, with 4 t ha^{-1} (Table 6).

Table 6. Estimation of yields in three *H. annuus* L. varieties for the conditions of Topes de Collantes mountain area.

Variety	Estimation of yields (t. ha^{-1})
Cubasol 113	3.32b
Caburé 15	3.43^{b}
CIAP JE 94	4.02^{a}
VC (%)	21.15
SE±	3.59*

Note: Made by the authors (P<0.001)

The results of yield estimation of the three varieties in the Topes de Collantes conditions fit within the range of previous research done in Cuba under experimental conditions. It is worth recalling that under these conditions, the experimental yield potential (EYP) was determined, which is usually much greater than actual crop yields (CY). In that sense, Soares (2014) noted that EYP was 5.1 t ha^{-1} for CIAP JE 94, whereas the actual crop yield was 2.5 t ha^{-1}.

The best results for CIAP JE 94 were not only supported by larger kernels, but also by better kernel formation. Alemán (2001), achieved similar yields in the same variety, on brown carbonated soils, in Santa Clara, Villa Clara, Cuba.

Moreover, Sánchez *et al.* (2004) reported lower yields (1-3 t. ha^{-1}) than this study in Caburé 15 and Cubasol 113, respectively. The values achieved for CIAP JE 94 were 1 and 2.5 t ha^{-1}, though they differed from the CY.

The results estimated for CIAP JE 94 were higher than the values achieved by Alemán (2003b), after evaluating the influence of sowing dates on oil percentage and yields, in these three sunflower varieties. He concluded that November and December were the best months to establish the crop in flat lands, due to the high yields observed. These results are also better than Leiva, García, and Delgado (2018) who cultivated Caburé 15 on typical rice soils (gley-vertico), estimated yields of 2.36 t ha^{-1}. However, these results were not as remarkable as the results achieved by Morffi *et al.* (1993), cited by Padilla (2006), who reported experimental yields (as in this research) of 4.9 and 3.5 t ha^{-1} in Cuban varieties Caburé 15 and Cubasol 113, respectively.

Lastly, it is important to say that despite the soil acidity of the experimental area (predominant in Topes de Collantes mountain region), and the limitations of the plant for phosphorous, iron, aluminum, and boron uptake, the evidence said these were not limiting factors for the crop.

Instead, its growth seems to have been more influenced by the physical properties of the soil (adequate plasticity, proper permeability, and proper structural factor). Likewise, though precipitations were not abundant during the research, the relative humidity of the area was high, which clearly had a positive influence on crop development. Consequently, favorable results can be achieved under the Topes de Collantes conditions, if the crop is established in September. Nevertheless, further research is recommended, in order to determine the optimum moment to establish the crop in the region.

CONCLUSIONS

The morphological and productive indicators evaluated for sunflower varieties (*H. annuus* L.) Cubasol 113, Caburé 15, and CIAP JE 94 in mountainous conditions showed a behavior similar to other regions of Cuba, which demonstrated the feasibility of introduction in diversified agroecological systems in Topes de Collantes.

Seed dipping in water for 12 hours ensured germination. Variety Cubasol 113 showed the best response (70%) in that respect, in comparison to Caburé 15 and CIAP JE 94.

CIAP JE 94 had better productive values in mountain conditions than Caburé 15 and Cubasol 113, though in all cases the results were similar to or higher than in other regions of Cuba.

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