Cultivos Tropicales, Vol. 46, No. 3, July-September 2025, e-ISSN: 1819-4087, p-ISSN: 0258-5936, https://ediciones.inca.edu.cu

Cu-ID: https://cu-id.com/2050/v47n3e05

Original article

Influence of sowing seasons on the agricultural yield of soybean cultivars

Influencia de la época de siembra en el rendimiento agrícola de cultivares de soya

Osmany Roján Herrera[1*], Lázaro A. Maqueira López[1], Miriam Núñez Vázquez[2], Frank E. González Cabrera[3], Luis E. Reinoso Febles[3]

[1]Unidad Científico Tecnológica de Base "Los Palacios", km 1½ carretera La Francia, Los Palacios, Pinar del Río, Cuba. CP 22900

[2]Instituto Nacional de Ciencias Agrícolas (INCA), carretera San José-Tapaste, km 3½, Gaveta Postal 1, San José de las Lajas, Mayabeque, Cuba. CP 32 700

[3]Universidad de Pinar del Río "Hermanos Saiz Montes de Oca", avenida José Martí No. 270, Pinar del Río, Cuba, CP 20100

ABSTRACT: The research was carried out in areas of the Base Scientific and Technological Unit, Los Palacios, Pinar del Río, belonging to the National Institute of Agricultural Sciences, with the objective of analyze the influence of sowing season on the agricultural yield of four soybean cultivars of Vietnamese origin in the town of Los Palacios. Four soybean cultivars (DT-20, DT-22, DT-26 and DT-84), of Vietnamese origin, were evaluated, which were sowing on a Gleysol Nodular Ferruginous Petroferric soil, on three different dates (December 2019, May and July 2020), corresponding to the "winter, spring and summer seasons", respectively. A randomized block experimental design was used with four treatments (cultivars) and three replicates, and crop yield and its components, shoot dry weight and harvest index were evaluated. The results showed a variation between cultivars for the same sowing date and between seasons; in the sowing of May 2020, the cultivars reached a higher value of the total dry mass of the aerial part, as well as of the agricultural yield, while in the sowing of December 2019 the best results were obtained for the harvest index, and in the three sowing dates, analyzed in a general way, the variables most associated with agricultural yield were the number of pods per plant, the number of grains per plant and the total dry mass.

Key words: *Glycine max*, production, harvest index, grains.

RESUMEN: La investigación se desarrolló en áreas de la Unidad Científico Tecnológica de Base, Los Palacios, Pinar del Río, perteneciente al Instituto Nacional de Ciencias Agrícolas, con el objetivo de analizar la influencia de la época de siembra en el rendimiento agrícola de cuatro cultivares de soya, de origen vietnamita, en la localidad de Los Palacios. Se evaluaron cuatro cultivares de soya (DT-20, DT-22, DT-26 y DT-84), de procedencia vietnamita, los que se sembraron sobre un suelo Gleysol Nodular Ferruginoso Petroférrico, en tres fechas diferentes (diciembre 2019, mayo y julio 2020), correspondientes a las "épocas invierno, primavera y verano", respectivamente. Se utilizó un diseño experimental de bloques al azar con cuatro tratamientos (los cultivares) y tres réplicas y se evaluaron el rendimiento agrícola y sus componentes, además de la masa seca total de la parte aérea y el índice de cosecha. Los resultados mostraron una variación entre cultivares para una misma fecha de siembra y entre épocas; en la siembra de mayo 2020, los cultivares alcanzaron un mayor valor de la masa seca total de la parte aérea, así como del rendimiento agrícola, mientras que en la siembra de diciembre 2019 se obtuvieron los mejores resultados para el índice de cosecha, y en las tres fechas de siembra, analizadas de manera general, las variables más asociadas al rendimiento agrícola fueron el número de vainas por planta, el número de granos por planta y la masa seca total.

Palabras Clave: *Glycine max*, producción, índice de cosecha, granos.

* orojan@inca.edu.cu

Received: 05/11/2023

Accepted: 08/12/2024

Conflict of interest: Authors declare no conflict of interest

Authors' contribution: Conceptualization: Miriam Núñez Vázquez. **Research:** Osmany Roján Herrera, Lázaro A. Maqueira López. **Methodology:** Osmany Roján Herrera, Lázaro A. Maqueira López, Miriam Núñez Vázquez, Frank E. Gonzáles Cabrera, Luis E. Reinoso Febles. **Supervision:** Miriam Núñez Vázquez. **Initial draft:** Osmany Roján Herrera. **Writing and final editing:** Osmany Roján Herrera, Lázaro A. Maqueira López. **Data curation:** Osmany Roján Herrera.

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is the fourth largest field crop by volume, a key commodity and the main oilseed produced in the world (1). However, per capita consumption of soybeans is expected to increase by 17 % by 2029; therefore a continuous increase in soybean yield is important not only for grain and animal producers but also for consumers and global agricultural sustainability (2).

However, in order to achieve stable returns over time or increase them, it is necessary to know what the main factors that contribute to determine it, establish the management basis to generate an environment of high productivity and make an adequate selection of cultivars in each sowing season are (3). In this sense, genotype characteristics, different environmental and management conditions influence crop growth, which may help to explain variations in yield response (4).

In Cuba, despite the high demand for soybean cultivation for different forms of processing, it has not been possible to stabilize production (5). However, in order to strengthen the productivity increase of this oilseed in the country, some foreign cultivars have been introduced, specifically from Vietnam (6), and although some attributes of these are known, lack studies that visualize their behavior in different ecosystems. Thus, its response to different environmental conditions may vary according to the date and time of sowing, hence this analysis can be suitable for detecting its adaptability to different environments. Based on the above-mentioned background, this research was developed with the objective of analyzing the influence of the sowing season on the agricultural yield of four soybean cultivars, of Vietnamese origin, in Los Palacios locality.

MATERIALS AND METHODS

The work was carried out in areas of the Scientific and Technological Base Unit, Los Palacios (UCTB-LP), belonging to the National Institute of Agricultural Sciences (INCA), located in the southern plain of Pinar del Rio province, on a Gleysol Nodular Ferruginous Petroferric soil (7). Four soybean cultivars from Vietnam were evaluated (DT-20, DT-22, DT-26 and DT-84), whose general characteristics are presented in Table 1 (8), which were sown on three dates, December 2019, May and July 2020, corresponding to the winter seasons, spring and summer", established for the cultivation of soybeans in Cuba. Some chemical properties that characterize its fertility are presented in Table 2.

Direct seeding was used manually in plots of 30 m^2, with a sowing frame of 0.7 x 0.05 m, with a seed standard of 54 kg ha^{-1}, to ensure 28 plants per m^2. At each sowing date an experimental design of random blocks with four treatments (the cultivars) and three replicates was used.

The phytotechnical work was carried out as recommended in the Technical Manual of soybean cultivation (9). It was always ensured that there were no limitations of any kind for plants. This ensured the availability of water throughout the crop cycle, pest control was carried out in a timely manner to avoid the effects thereof and developed a strict control of herbage plants.

The values of the meteorological variables (global solar radiation, average ten-year precipitation, maximum, minimum and daily mean temperatures) for the period in which the experiments were carried out are shown in Figure 1, those obtained from the Paso Real Weather Station in San Diego, Los Palacios, about 3 km from the experimental area.

In each experimental plot, at the time of harvest, ten representative plants were taken at random, always respecting the edge area, and the following variables were evaluated:

- Total dry mass of aerial part (g) (M total)
- Number of grains per plant (No Grains)
- Number of pods per plant (No Pods)
- Number of grains per pod (No grvai)
- Mass of 100 grains (g) (M 100)
- Harvest index (HI)
- Agricultural yield (t ha^{-1}) at 14 % moisture (Yield)

The total dry mass of the aerial part (Total M) was estimated from the sum of the dry mass of each individual organ (stalks, pods, grains), which were kept in an oven for 72 hours at a temperature of 70 ºC until a constant mass was reached. As for the number of grains and number of pods, we counted the value of each variable in the ten plants per plot and for the amount of grains per pod, we divided the total of grains by the total of pods per plant. From all the grains of the 10 plants sampled, four random samples of 100 grains per plot were taken, which were dried to 14 % moisture and weighed on an analytical balance (KERNPLJ e=0.01g).

Table 1. Some characteristics of the soybean cultivars evaluated.

Characteristics	DT-20	DT-22	DT-26	DT-84
Yield	2.5-3.0 t ha^{-1}	2.5-3.5 t ha^{-1}	2.5-3.5 t ha^{-1}	2.5-3.0 t ha^{-1}
Sowing season	Winter-Summer	Spring- Summer	Winter - Summer	Winter - Spring
Cycle (days)	95-100	90-95	95-100	90-92
Growth habit	Semi-determinated	Determinated	Determinated	Determinated

Table 2. Chemical fertility and pH values of the arable layer (0-20 cm) of the soil where the experiments were carried out.

H_2O (pH)	Ca^{2+}	Mg^{2+}	Na^+	K^+	P_2O_5	OM
	(cmol kg^{-1} soil)				(mg 100 g^{-1} de soil)	(%)
6.49	7.01	3.13	0.16	0.23	20.47	2.72

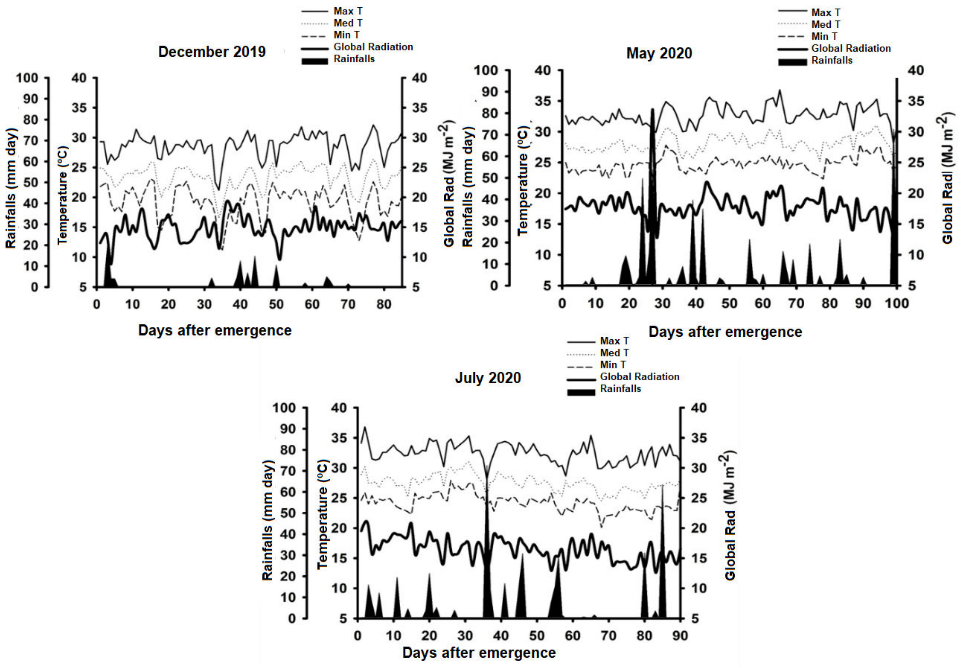

Figure 1. Temperatures (maximum, average, minimum) (ºC), global solar radiation (MJ m^2) and precipitation (mm day) decennial averages taken from the Paso Real San Diego Agrometeorological station during the period of experiment execution.

HI was established as the ratio of the dry mass of grains between the total dry mass of the aerial part of the plant. To determine the agricultural yield (t ha^{-1}), 8 m^2 of the center in each experimental plot were harvested, the plants were threshed and the grains dried to 14 % moisture.

The averages of the evaluated variables obtained by cultivar and date of sowing were subjected to simple variance analysis, and significant differences between the averages of the treatments were verified by the Tukey test at 95 %. In the case of the total dry mass of the aerial part, the harvest rate and agricultural yield and its components, product of the experimental design used, the confidence interval was calculated from the experimental error of the variance analysis. In addition, with the data matrix obtained (sowing date, cultivars, agricultural yield, yield components and growth variables), a multivariate analysis of Main Components was performed by representing a biplot. The statistical package Statgraphics 5.0 (10) was used.

RESULTS AND DISCUSSION

The agricultural yield performance of the soybean cultivars studied, in the different sowing dates, is shown in Figure 2. In the three sowing dates analyzed, the cultivar DT-20 reached the highest yield values, followed by the cultivar DT-26. Also, on the date corresponding to the spring season" (May 2020), it was where the cultivars obtained the highest values, which ranged between 2.7 and 3.6 t ha^{-1}, while the lowest values reached it in the winter season" (December 2019), except the cultivar DT-22 which, on the date corresponding to the summer season" (July 2020), showed a performance lower than that obtained in December 2019, although without significant differences.

These results differ from those described in the literature (8), since, regardless of the time recommended for each cultivar, it was shown that, in spring, they obtained the highest yield values. In this sense, it is worth highlighting the response of cultivars DT-20 and DT-26, which in all sowing dates were superior, especially in spring, when planting is not recommended. Also, the cultivar DT-20 obtained a yield much higher than the maximum described in Table 1, precisely at the non-recommended time (May 2020), with a value of 3.6 t ha^{-1}, while a maximum value of 3 t ha^{-1} has been described.

However, the rest of the cultivars did not obtain values higher than the maximum recorded, although they showed values lower than the minimum described, especially cultivars DT-22 and DT-84, which reached the lowest values at times recommended for sowing. The cultivar DT-22 obtained a yield of 1.7 t ha^{-1} in July 2020, well below the value obtained on the date corresponding to the winter season, while DT-84 at the date of December 2019 obtained a yield of 1.3 t ha^{-1}.

Some authors reported that soybean crop yield was strongly correlated with the daily maximum temperature (30 ºC) during the grain filling stage (R5-R7), i.e., high temperatures are generally associated with a longer duration of this period (11). The above may be related to the response of cultivars at the sowing date corresponding to the spring season", especially those with the best response, since this was the time when the highest temperature values were recorded, above 30 ºC (Figure 1), while in winter they were the lowest and showed greater variability in the summer". However, some studies in Cuba recommend focusing soybean production on the summer season (12), although no consensus has been reached, especially in terms of exploiting certain climatic resources to enhance or stimulate physiological processes that help to obtain a better yield in this crop.

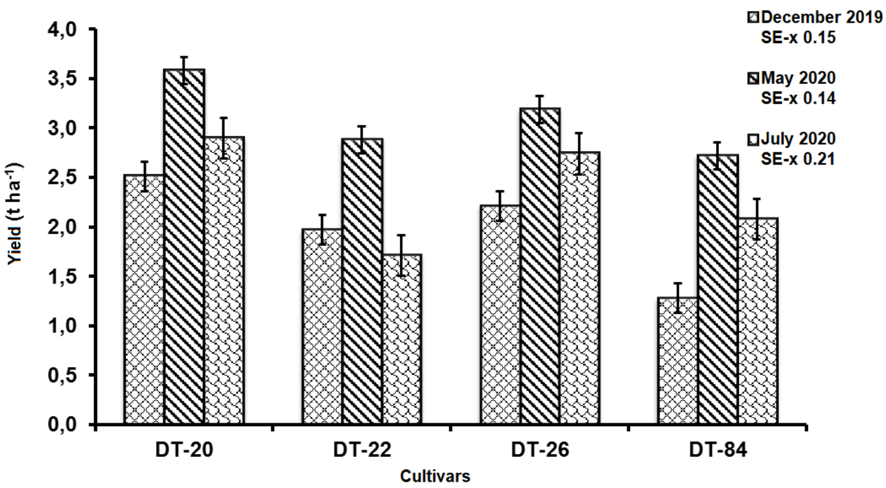

Figure 2. Crop yield (t ha^{-1}) at 14% moisture of soybean grains planted in the three sowing dates under study.

This result reveals the importance of studying the agricultural yield behavior of different soybean cultivars, for certain environmental conditions, especially if one takes into account what some authors with regard to the influence that the behavior of meteorological variables may have on plant growth and development during their cycle depending on the sowing season (13).

When evaluating the yield components (Table 3), differences were found between cultivars for the same sowing date and between them. As for the number of pods and the number of grains, the highest values were obtained by cultivars on the date corresponding to the spring season" (May 2020). However, although several authors define the number of pods as an indirect component (14), together with the number of grains, they may have been important in the expression of yield at this sowing time. The cultivar DT-26 achieved the highest value in the number of pods, although without differences with respect to the cultivar DT-20, while the latter showed the best response in terms of the number of grains.

However, the lowest values of these variables were obtained by cultivars in December 2019. In this sense, previous studies related the number of pods per plant to the prevailing temperature and photoperiod weather conditions, since when temperatures are lower and the photoperiod is shorter, soybean plants reach a lower height, so that they have fewer knots, which consequently decreases the number of pods (2). Although the influence of photoperiod was not evaluated in this study, it should be noted that "winter" is the shortest days of the year (9), coupled with the lowest temperatures during the experiment period (Figure 1), which may have had an impact on the low production of pods, while reducing the number of grains per plant, and thus there is a decrease in yield.

Table 3. Response of the main yield components of soybean cultivars in the different sowing dates studied.

		December 2019		
Cultivars	**No. pods**	**No. grains**	**No. grvai**	**Mass 100**
DT-20	18.4-24.3	31.5-42.9	1.6-1.9	15.7-18.6
DT-22	11.2-17.1	15.4-26.8	1.4-1.6	15.4-18.4
DT-26	9.9-15.7	19.3-30.7	1.8-2.1	15.8-18.8
DT-84	5.5-11.4	6.5-17.9	1.3-1.6	11.4-14.4
Esx.	1.49	2.91	0.07	0.76
		May 2020		
DT-20	60.6-66.6	123.2-141.3	1.9-2.3	10.1-12.2
DT-22	51.5-57.5	101.6-119.5	1.8-2.0	11.3-13.4
DT-26	62.7-68.7	88.4-106.3	1.0-1.4	14.5-16.6
DT-84	57.7-63.7	96.4-114.4	1.5-1.9	10.3-12.4
Esx.	1.53	4.57	0.10	0.54
		July 2020		
DT-20	30.8-49.9	55.4-76.5	1.5-1.8	17.3-18.8
DT-22	9.5-28.6	30.9-52.0	1.9-2.3	14.8-16.3
DT-26	48.9-68.0	73.5-94.6	1.3-1.6	16.2-17.7
DT-84	47.9-67.7	71.5-92.6	1.2-1.5	16.0-17.6
SE-x.	4.88	5.39	0.08	0.38

Confidence interval at 95 % probability calculated from the mean taking into account the experimental error of the variance analysis.

Regarding the number of grains per pod, there was generally little variability between cultivars at all three sowing dates. In December 2019, only cultivar DT-26 differed from the rest of the cultivars, which showed no differences between them. However, at the sowing date of May 2020, cultivar DT-20 reached the highest values of this variable, while in July 2020, the best result was shown by cultivar DT-22.

This result corroborates the literature, which highlights that the variability in the number of grains per pod between genotypes is due more to a genetic character than to prevailing weather conditions (15), although it should not be overlooked that this component can be significantly affected by the exposure of the plant to water stress and temperature, or the combination of both stresses, since they exert a considerable influence during the grain filling process (2).

For the mass of 100 grains, the highest values reached by cultivars coincided with the lowest values obtained in terms of number of pods and grains. This result coincides with those obtained by different authors, who highlight the relationship that exists between the main components of yield, since as the number of pods increases and the number of grains decreases their mass and vice versa, which shows the level of compensation between them (1).

On the other hand, Figure 3 shows the behavior of the total dry mass of the aerial part of soybean cultivars at the different sowing dates studied. It shows that the cultivars reached the highest values in spring" (May 2020), and DT-20 obtained the best response both in spring and at the date corresponding to the winter" (December 2019), although without differences compared to the cultivar DT-26 on this last date. However, at the sowing date corresponding to the summer" (July 2020), the highest dry mass value was achieved by cultivar DT-26, with no differences compared to cultivar DT-20. Once again these cultivars showed the best performance at a time not recommended for planting.

Dates of sowing when the cultivars reached the highest values of total dry mass coincide with the highest values of yield, so this variable must have played an important role in the formation process. Similar results were obtained by other authors, who point out that the yield is positively related to the amount of biomass produced by the plant, and the way in which it divides it towards the various reproductive destinations (15).

According to the literature, the effect of low temperatures and short photoperiods can modify physiological processes during soybean growth, such as dry mass partition (16); therefore, the low dry mass production shown by the cultivars in this study at the planting date corresponding to the winter season" may be a consequence of the effect of temperatures and photoperiod, because the lowest temperatures were recorded during this sowing season (Figure 1), and the shortest days of the year are shown (9).

Other investigations with different soybean cultivars, of national origin, showed that the highest dry mass production was obtained in spring" (17), a result corroborated by this study. Therefore, developing studies with different cultivars and sowing dates remains a major challenge for geneticists, physiologists and plant technologists, all in order to increase the biological productivity of the crop and achieve increases in agricultural yield, that is, to increase the efficiency of the crop in converting economically useful material on the basis of a proper management in each of the phases, where each component of the yield is decided.

On the other hand, when the behavior of the HI was analyzed (Figure 4), for each of the cultivars at the different sowing dates studied, it was possible to appreciate the inverse relation obtained by this variable in comparison with the total dry mass of the aerial part, since on the date corresponding to the winter season" (December 2019), it was where cultivars showed the highest values.

The highest efficiency in converting economically useful dry mass was represented by the cultivar DT-26, which obtained the best results of this variable in the three sowing dates; however, at the date of May 2020, the cultivar DT-84 showed the lowest efficiency, what may be related to the genetic characteristics and response of the cultivar to conditions prevailing during development. Regarding this variability, other authors have shown that HI values can vary between sowing dates for the same cultivar, and between cultivars for the same sowing date (2); therefore, with this result it can be inferred that, the response of cultivars to the harvest rate also depends on the planting season.

Other authors report that high temperatures generally result in low plant efficiency as measured by the HI, because assimilates for growth and yield have to be used in other physiological processes (18), this aspect that may justify the

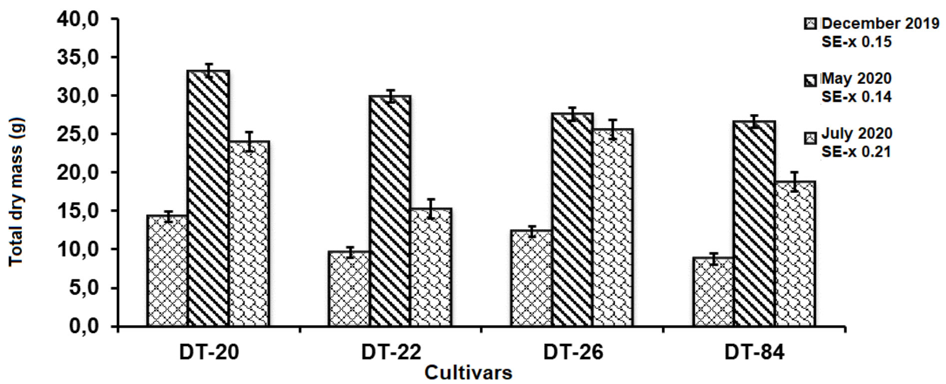

Figure 3. Total dry mass of the aerial part of soybean cultivars at the three sowing dates studied

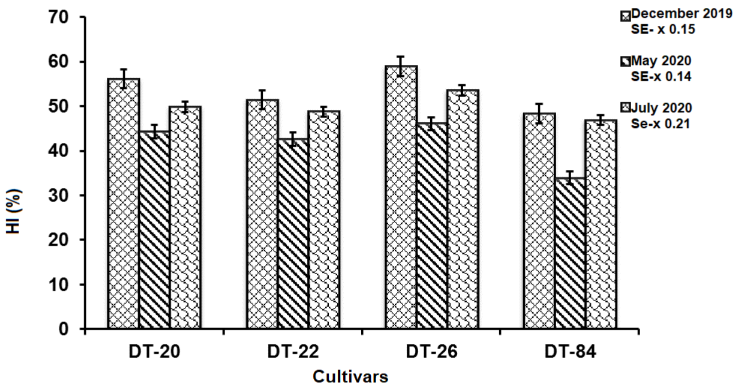

Figure 4. Harvest index behavior of four soybean cultivars, sown on three different dates.

low efficiency values manifested by the cultivars on the date corresponding to the spring" (May 2020), since it is where temperatures were highest. Similar results were reported in other studies, which showed that HI was significantly reduced when soybean genotypes were subjected to high temperatures (16).

However, it is argued that the harvest rate has an inverse relationship with the length of the crop cycle for a given date and time of sowing (1). This statement corresponds to the results obtained in this study, since the cultivars showed a longer duration of the cycle at the sowing date corresponding to the spring season", when they obtained the lowest HI values. In this sowing season they showed values of cycle duration between 110 and 113 days, much higher than reported for these cultivars, especially for the DT-20 and DT-26 cultivars that are not recommended for this season, whereas on the date belonging to the winter season they did not exceed 89 days.

When the degree of association between the variables studied and yield was analyzed (Figure 5), it was observed that those with the greatest influence were the number of pods/plant, the number of grains/plant and the total dry mass of the aerial part, general views for the three sowing dates studied. This result coincides with those obtained by other authors, who affirm that the number of pods and grains, in a wide range of agronomic conditions, are the variables that best explain the variability of yield (15); while other authors give some importance to the dry mass production as an ordered process and positively related to the expression of agricultural productivity (18).

Research conducted for this purpose has reported that modern soybean cultivars produce higher yields as a result of better biomass accumulation (19). Therefore, from the results obtained in this study, it is inferred that a pattern of behavior should not be defined, especially when it comes to explaining physiological responses which depend largely on factors which cannot be managed under natural conditions, as is the case with meteorological variables.

CONCLUSIONS

- The highest values of yield and total dry mass are obtained by cultivars at the sowing date corresponding to the spring season", although not recommended for this sowing season. The cultivars DT-20 and DT-26 stand out, for reaching higher values and in particular, the DT-20 that reaches a yield much higher than the maximum described.
- The highest conversion efficiency of economically useful dry mass is achieved by cultivars at the planting date corresponding to the winter season", related to the shorter duration of the cycle.
- In general, for the three sowing dates evaluated, the variables that most influence the yield are the number of pods/plant, the number of grains/plant and the total dry mass of the aerial part.

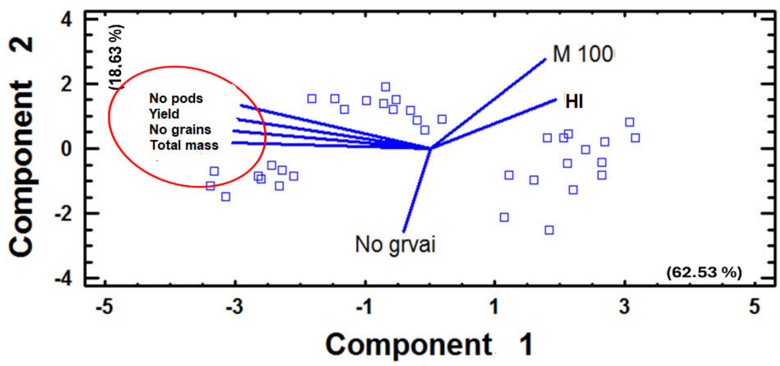

Figure 5. Association of the agricultural yield of soybean cultivars with the variables obtained in the three sowing dates studied.

BIBLIOGRAPHY

1. Lopez MA, Freitas Moreira F, Rainey KM. Genetic Relationships Among Physiological Processes, Phenology, and Grain Yield Offer an Insight Into the Development of New Cultivars in Soybean (Glycine max L. Merr). Front Plant Sci. Frontiers; 2021;12. https://doi.org/10.3389/fpls.2021.651241
2. Vogel JT, Liu W, Olhoft P, Crafts-Brandner SJ, Pennycooke JC, Christiansen N. Soybean Yield Formation Physiology - A Foundation for Precision Breeding Based Improvement. Front Plant Sci. 2021; 12:719706. https://doi.org/10.3389/fpls.2021.719706
3. Andrade JF, Rattalino Edreira JI, Mourtzinis S, Conley SP, Ciampitti IA, Dunphy JE, et al. Assessing the influence of row spacing on soybean yield using experimental and producer survey data. Field Crops Research. 2019; 230:98-106. https://doi.org/10.1016/j.fcr.2018.10.014
4. Wu Y, Wang E, Gong W, Xu L, Zhao Z, He D, et al. Soybean yield variations and the potential of intercropping to increase production in China. Field Crops Research. 2023; 291:108771. https://doi.org/10.1016/j.fcr.2022.108771
5. González F, Hervis G, Cisneros E, Riverol L, Herrera J, Cid G. Fecha óptima de siembra y productividad de la soya ante escenarios de cambio climático. Ingeniería Agrícola [Internet]. 2022 [cited 2025 July 15];12(1):3-13.
6. Toledo-Día D, Osa-Naranjo Y de la, Gonzales-Morera T, Delgado MA, Hurtado Y, Toledo-Día D, et al. SOYIG-20 y SOYIG-22: nuevas variedades de soya (Glycine max L. Merrill) introducidas para las condiciones climáticas de Cuba. Cultivos Tropicales [Internet]. Ediciones INCA; 2020 [cited 2025 July 15];41(1). Available from: http://scielo.sld.cu/scielo.php?script=sci_abstract&pid=S0258-59362020000100007&lng=es&nrm=iso&tlng= es
7. Hernández Jiménez A, Bosch Infante D, Pérez-Jiménez JM, Castro Speck N. Clasificación de los suelos de Cuba 2015 [Internet]. Instituto Nacional de Ciencias Agrícolas. 2015 [cited 2024 Sept 19]. Available from: https://isbn.cloud/9789597023777/clasificacion-de-los-suelos-de-cuba-2015/
8. Van B, Thi V, Hernández B, Vinh T, Alemán M. La colaboración en el cultivo de arroz, maíz, soya Vietnam-Cuba: Resultados y perspectivas. 1st ed. Vietnam: HaNoi, Vietnam: Casa editorial de agricultura; 2015.
9. Esquivel M. El cultivo y utilización de la soya en Cuba. Manual Técnico. Asociación Cubana de Producción Animal; 1997 p. 56.
10. Statistical Graphics Crop. STATGRAPHICS® Plus. [Internet]. 2000.
11. Kumagai E, Yamada T, Hasegawa T. Is the yield change due to warming affected by photoperiod sensitivity? Effects of the soybean E4 locus. Food and Energy Security. 2020;9(1): e186. https://doi.org/10.1002/fes3.186
12. Ortiz R, González R, Ponce M, Martínez J, Fernández C, Batista S. Importancia de la localidad en el comportamiento de variedades de soya durante siembras de primavera en Cuba. Cultivos Tropicales [Internet]. 2004;25(3):67-72.
13. Mwiinga B, Sibiya J, Kondwakwenda A, Musvosvi C, Chigeza G. Genotype x environment interaction analysis of soybean (*Glycine max* (L.) Merrill) grain yield across production environments in Southern Africa. Field Crops Research. 2020; 256:107922. https://doi.org/10.1016/j.fcr.2020.107922
14. Winsor S. Record-Setting Soybeans: What CCAs Should Know. Crops & Soils. 2021;54(4):11-7. DOI: 10.1002/crso.20130
15. Monzon JP, Cafaro La Menza N, Cerrudo A, Canepa M, Rattalino Edreira JI, Specht J, et al. Critical period for seed number determination in soybean as determined by crop growth rate, duration, and dry matter accumulation. Field Crops Research. 2021; 261:108016. https://doi.org/10.1016/j.fcr.2020.108016
16. V R, Alves Silva A, Santos Brito D, Pereira Júnior J. Drought stress during the reproductive stage of two soybean lines. Pesquisa Agropecuária Brasileira. 2020;55. https://doi.org/10.1590/S1678-3921.pab2020.v55.01736
17. Chacón-Iznaga A, Cardoso Romero S, Barreda Valdés A, Colás Sánchez A. Acumulación de materia seca, rendimiento biológico, económico e índice de cosecha de dos cultivares de soya [Glycine max (L.) Merr.] en diferentes espaciamientos entre surcos. Centro Agrícola [Internet]. 2011 [cited 2025 July 15];38(2):5-10.
18. Wei MCF, Molin JP. Soybean Yield Estimation and Its Components: A Linear Regression Approach. Agriculture. Multidisciplinary Digital Publishing Institute; 2020;10(8):348. https://doi.org/10.3390/agriculture10080348
19. Veas REA, Ergo VV, Vega CRC, Lascano RH, Rondanini DP, Carrera CS. Soybean seed growth dynamics exposed to heat and water stress during the filling period under field conditions. Journal of Agronomy and Crop Science. 2022;208(4):472-85. https://doi.org/10.1111/jac.12523