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Original Article

Productivity of soybean cultivars in two planting seasons

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ABSTRACT

The research was developed in areas of the Scientific and Technological Base Unit, Los Palacios, Pinar del Rio, belonging to the National Institute of Agricultural Sciences, with the objective of analyzing the productivity of soybean cultivars in two planting seasons. Cultivars DT-20, DVN-5, DT-26, DVN-6 of Vietnamese origin were used, which were sown on a Ferruginous Petroferric Nodular Gley Hydromorphic soil, on two different dates (January and May 2013), corresponding to the cold and spring seasons, respectively. A randomized block experimental design with four treatments (cultivars) and three replicates was used, and growth and agricultural yield variables were evaluated. The results showed variation among cultivars for the same planting date and between seasons. At sowing in May 2013, cultivars achieved a higher value of total aerial dry mass as well as agricultural yield. However, the best results in terms of harvest index were obtained in the January sowing. It should also be noted that in general for the two sowing dates, the variables most associated with agricultural yield were the number of pods and the number of grains per plant.

Key words: *Glycine max*, yield, harvest index

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is the major oilseed crop produced worldwide, with an area of about 130 million hectares and a total production of 360 million tons [(1)]. Different environmental, genotypic, and management conditions (maturity group, sowing date, climate, and soil) affect the growth of this crop, and thus may help explain variations in yield response under different environmental conditions [(2)]. Thus, it is possible that different genotypes can obtain similar or different yields in the same environment and that one genotype can achieve different yields in different environments [(3)].

In turn, the response of soybean growth and yield to planting date has been extensively evaluated by many researchers [(4)], since it is one of the most important and least costly production decisions affecting soybean yield and seed quality [(5)]. Some studies show that the sowing date, through variations of different meteorological variables, is one of the most influential factors that affect the agronomic traits of soybean, depending on the growth stage in which the crop is found [(6)].

In Cuba, the industrial processing of soybeans makes it possible to obtain various products of strategic value for humans, such as milk, yogurt and oil, in addition to obtaining flour for animal feed [(7)]. However, despite the fact that this crop has been known since the beginning of the 20th century, its production has not yet been stabilized [(8)]. Likewise, in order to increase the production of this grain in the country, some foreign cultivars have been introduced, specifically from Vietnam, which should be evaluated to maximize its utilization.

For all these reasons, the study of factors that limit the growth and yield of these new soybean cultivars is of utmost importance. Knowledge of these factors determines the yield at different planting times contributes to the selection of more appropriate management practices for the crop and guides the breeder in the selection of cultivars with higher yield potential and more adapted to the environment. Therefore, the present work was developed with the aim of analyzing the productivity of soybean cultivars in two planting seasons.

MATERIALS AND METHODS

The experiments were carried out at the Scientific and Technological Base Unit, Los Palacios, (UCTB-LP), belonging to the National Institute of Agricultural Sciences, located in the southern plains of Pinar del Río province, at 22°44' North latitude and 83°45' West latitude, at 60 m a.s.l., with an approximate slope of 1 %, in the period from January to August 2013. Four soybean cultivars (DVN-5, DVN-6, DT-84, D-2101), of different vegetative cycles, from the Socialist Republic of Vietnam, were evaluated, which were sown on two sowing dates, in January and May, corresponding to the cold and spring seasons, respectively.

The soil of the experimental area is classified, according to the New Version of Genetic Classification of Cuban Soils (9), as Ferruginous Petroferric Nodular Gley Hydromorphic. As a result of the soil sampling of the experimental area, some properties that characterize its fertility are shown in Table 1.

Table 1. Some properties of the arable layer (0-20 cm) that characterize the fertility of the soil where the experiments were carried out

H_2O (pH)	Ca^{2+}	Mg^{2+} (cmol kg^{-1} soil)	Na^+	K^+	P_2O_5 (mg 100 g^{-1} of soil)	OM (%)
6,49	7,01	3,13	0,16	0,23	20,47	2,72

The main characteristics of cultivars under study are presented in Table 2 (8). Direct sowing was used manually at a distance of 0.7 x 0.07 m with a seed standard of 54 kg ha^{-1}, to ensure at least 28 plants per m^2. A randomized block experimental design with three replications and four treatments (cultivars) was used for each sowing date. The experimental plots had an area of 30 m^2.

Table 2. Main characteristics of the soybean cultivars studied in experiments

Characteristics	DT-20	DVN-5	DT-26	DVN-6
Yield	2,5-3,0 t ha^{-1}	3,0-3,5 t ha^{-1}	2,5-3,5 t ha^{-1}	3,0-3,5 t ha^{-1}
Season sowing	Winter-Summer	Spring-Summer	Winter-Summer	Spring-Summer
Cycle (days)	95-100	92-100	95-100	95-100
Growth habits	Semi-determined	Determined	Determined	Determined

The phytotechnical work was carried out as recommended in the Technical Manual of Soybean Cultivation (10). It was always ensured that there were no limitations for the plants.

The values of the meteorological variables (maximum, minimum and average temperatures, and average decennial rainfall) for the period in which the experiments were carried out are shown in Figure 1, which were obtained from the Paso Real de San Diego Meteorological Station, in Los Palacios, approximately 3 km from the experimental area.

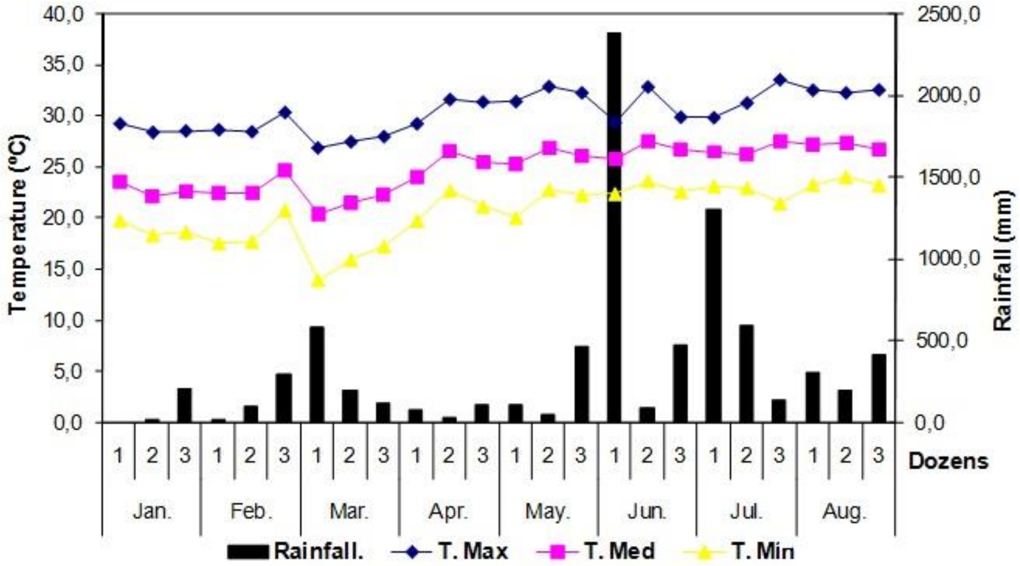

Figure 1. Temperatures (maximum, mean, minimum) and decadal average rainfall taken from the Paso Real de San Diego Agrometeorological Station, during the period of experiments

In each experimental plot, at the time of harvest, ten representative plants were taken at random, always respecting the border area. The following variables were evaluated in each plant:

- Total dry mass of aerial part (g) (M total).
- Dry mass of stems (g) (M stems)
- Dry mass of pods (g) (M pods)
- Dry mass of grains (g) (M Grains)
- Mass of 1000 grains (g) (M 1000)
- Number of grains per plant (No Grains)
- Number of pods per plant (No Pods)
- Number of grains per pod (No GrPod)
- Crop index (CI)
- Agricultural yield (t ha^{-1}) at 14 % moisture content (yield)

For the dry mass of the plant parts (M stems, M pods, M grains), each part was separated and kept in an oven for 72 hours at a temperature of 70 ºC until constant mass. The total mass of the aerial part (M total) was estimated from the sum of the dry mass of each individual organ. The CI was established as the ratio of the dry mass of grains to the total dry mass of the aerial part of the plant.

To determine the agricultural yield (t ha^{-1}), 8 m^2 were harvested from the center of each experimental plot, the plants were threshed and the grains were dried to 14 % moisture. For the number of grains and number of pods, the value of each variable was counted in the ten plants per plot and for the number of grains per pod; the total number of pods per plant divided the total number of grains. From all the grains of the 10 plants sampled, four random samples of 1000 grains per plot were taken. These were dried until the grains reached 14 % moisture and then the samples were weighed on an analytical balance ($KERN_{PLJ}$ e=0.01 g) to obtain the mass value in grams.

The means of the evaluated variables obtained by cultivar and sowing date were subjected to a simple analysis of variance and the significant differences between the means of the treatments were verified by Tukey's test at 95 %. In the case of the total dry mass of the aerial part, harvest index and yield, product of the experimental design used, the confidence interval was calculated from the experimental error of the analysis of variance. In addition, with the data matrix obtained (cultivars, yield, yield components and growth variables), a multivariate Principal Component analysis was performed, using a Biplot representation, to identify the variables most associated with yield. The statistical package Statgraphics 5.0 (11) was used.

RESULTS AND DISCUSSION

Figure 2 shows the total dry mass response of the aerial part of the soybean cultivars in the different planting dates studied (January and May 2013). In general, cultivars reached the highest values of this variable on the date corresponding to the spring season (May 2013). Likewise, the DT-20 cultivar obtained the best response on both sowing dates, although without differences with respect to the DT-26 cultivar on the date corresponding to the cold season (January 2013).

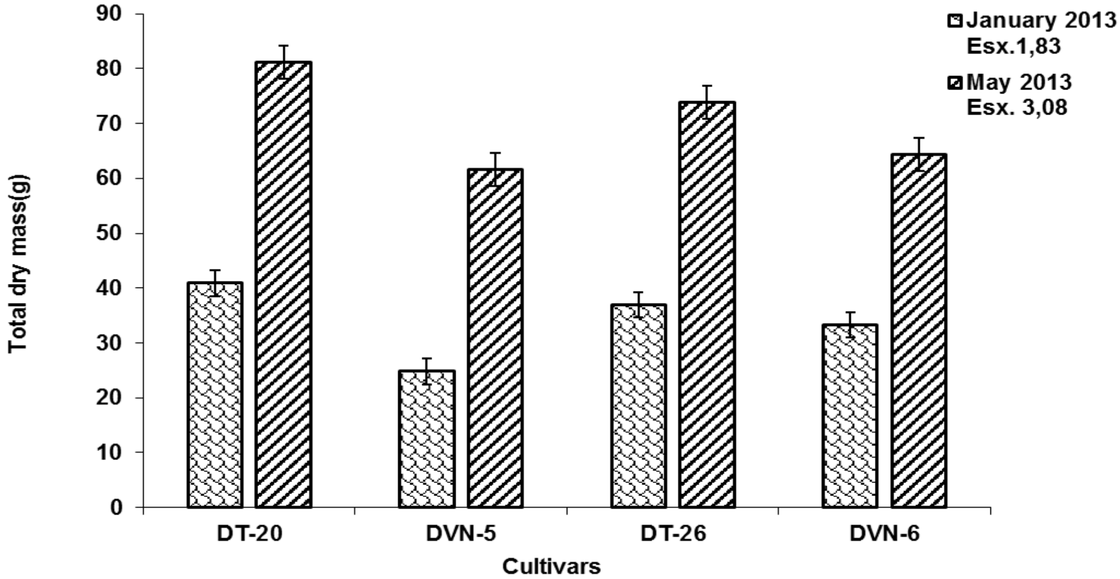

Figure 2. Total dry mass of the aerial part of the soybean cultivars in the two planting dates studied

In this sense, some authors emphasize that in Cuba, in the spring season, is where most of the soybean cultivars achieve a higher biomass production (7,12). In addition, this difference, both between cultivars and between sowing dates for this variable, could be a consequence of the response of the genotypes to environmental conditions, fundamentally, to temperatures (13). In the spring, plants were exposed to higher temperatures (Figure 1), a condition that favored greater plant growth.

It is important to emphasize that the distribution of dry matter among the different organs of a plant is the final result of an ordered set of metabolic and transport processes that govern the flow of assimilates through a source/sink system (14). Therefore, the proportion of biomass assigned to leaves, stems and fruits at each moment of development depends on growth kinetics and distribution rate, which are governed by leaf area, meteorological variables and nutrient availability (15).

The production of dry matter in the soybean crop depends fundamentally on the duration of the period between the emergence phase (Ve) and the beginning of seed formation (R_5) (16). The biomass production of a crop is a function of the amount of incident photosynthetically active radiation, the proportion of this that is intercepted and the conversion efficiency of this intercepted radiation (17,18). Therefore, in this study the response of cultivar DT-20, is related to what was suggested by these authors. Although this cultivar presents a similar cycle to the other cultivars studied, it has as a particular characteristic, that the period from Ve to R_5 tends to be more lasting (8). Therefore, the phase in which the highest biomass production is decided, was exposed to a longer time of incident radiation, at the same time that the conversion efficiency of this cultivar should be more efficient than the rest of the cultivars. Evidently, although the amount of incident radiation is not easily managed in agricultural practice, it is of vital importance to coincide the critical period of the crop with the periods of greater probability of high radiation.

When analyzing the behavior of the harvest index (Figure 3), it could be seen that this variable obtained an inverse response to the total dry mass, since it was on the date corresponding to the cold season (January 2013), where the cultivars reached the highest values. Cultivar DT-20 obtained the best results for this variable on both sowing dates; however, on the May 2013 date, cultivar DT-26 showed the lowest efficiency in the conversion of economically useful dry mass, which may be closely related to the genetic characteristics and the response of the cultivar to the prevailing conditions during cultivar development. Previous studies have shown that the values of harvest index can vary between sowing dates for the same cultivar, and between cultivars for the same sowing date (19); therefore, with this result it can be inferred that the response of genotypes to harvest index not only depends on the cultivar, but also on the sowing time.

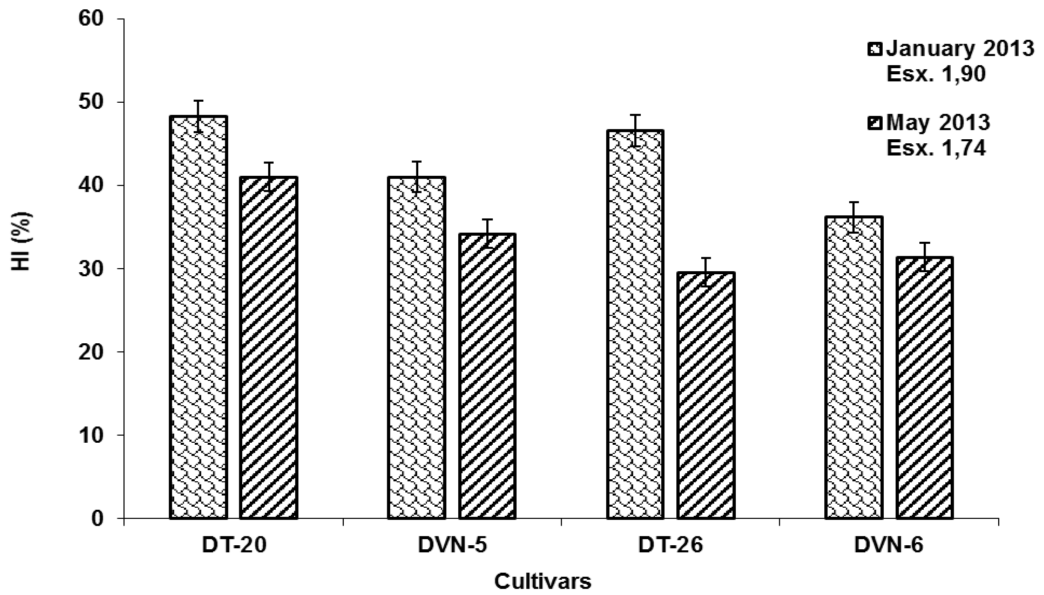

Figura 3. Performance of the harvest index (HI) of four soybean cultivars planted on two different dates (January and May 2013)

On the other hand, literature states that high temperatures generally result in a lower harvest index, due to the fact that the assimilates destined to growth and yield have to be used in other physiological processes such as maintenance respiration, osmotic adjustment and root growth (20). In this study, the lowest values of the harvest index coincided with the period where temperatures were highest, so it could be an influential factor in the response of the cultivars to this variable. Similar results were reported by other authors, where the harvest index was notably reduced when soybean genotypes were subjected to high temperatures [21]. From this study, it is clear that there must be sufficient genetic variability among soybean genotypes for selection and evaluation based on harvest index estimates to be meaningful.

Table 3 shows the results of the main yield components, where differences in these variables between cultivars for the same planting date are evident. On the date corresponding to the cold season (January 2013), cultivars DT-20 and DT-26 reached highest values in the number of pods without significant differences between them; however, when the number of grains was analyzed, it was observed that cultivar DT-20 was the one with the best response. Similar results were obtained at the spring sowing date, although in the number of grains, the DT-26 cultivar reached the highest values. The results obtained in this study help to explain how some cultivars respond better than others to different soil and climatic conditions. In this sense, the literature highlights the role played by the number of pods and the number of grains as direct components in yield formation [3]. In addition, it is affirmed that each component is affected by the different meteorological variables in each of the development stages through which the crop passes, fundamentally, in the grain filling stage [22]. Hence, the low response achieved by the DVN-5 cultivar in the number of grains.

Table 3. Response of the main yield components of the soybean cultivars at the different planting dates studied

Cultivars	No. pods	No. grains	No. Gra/pod.	Mass 1000 (g)
January 2013				
DT-20	58,06 a	105,86 a	1,83 ab	175,07 b
DVN-5	29,80 b	46,06 d	1,56 b	289,52 a
DT-26	49,66 a	92,26 b	2,27 a	186,58 b
DVN-6	32,03 b	63,93 c	1,93 ab	200,05 b
Se x.	3,77	7,10	0,08	14,05
May 2013				
DT-20	80,73 a	154,6 ab	1,91 b	175,53 b
DVN-5	55,66 b	101,86 c	1,91 b	216,49 a
DT-26	88,8 a	170,93 a	1,93 b	147,79 c
DVN-6	57,73 b	146,02 b	2,55 a	159,66 bc
Se x.	4,49	7,94	0,09	8,21

Means with letters in common per column, not significantly different for $p \leq 0.05$ according to Tukey's test

As for the number of grains per pod, there was generally little variability among cultivars at both sowing dates. In January 2013 only cultivar DVN-5 differed from the rest of the cultivars, which showed no differences among them. However, on the May 2013 planting date, the DVN-6 cultivar reached the highest values for this variable. This result corroborates what was stated by some authors, who emphasize that the variability in the number of grains per pod among genotypes is due more to a genetic character than to the prevailing meteorological conditions [23], although the influence exerted by these

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conditions during the grain filling process should not be overlooked. On the other hand, when the response of cultivars to the mass of 1000 grains was analyzed, it was obtained as a result that the highest values of this variable were reached by the cultivar DVN-5 in the two sowing dates studied. In this sense, some authors emphasize the contradiction that exists between the main yield components, that is, as the number of pods and the number of grains increases, the mass of grains decreases and vice versa, which demonstrates once again the compensatory level between these components (6).

Similarly, this variability became even more evident when the response of cultivars to agricultural yield was analyzed at the different sowing dates studied (Figure 4). The highest yield values were obtained by the cultivars on the spring sowing date, a result that corresponds to the sowing date on which the highest dry mass production was achieved. In this regard, some authors point out that yield is positively related to the amount of biomass produced by the plant, and the way in which it is partitioned to the different reproductive destinations (24).

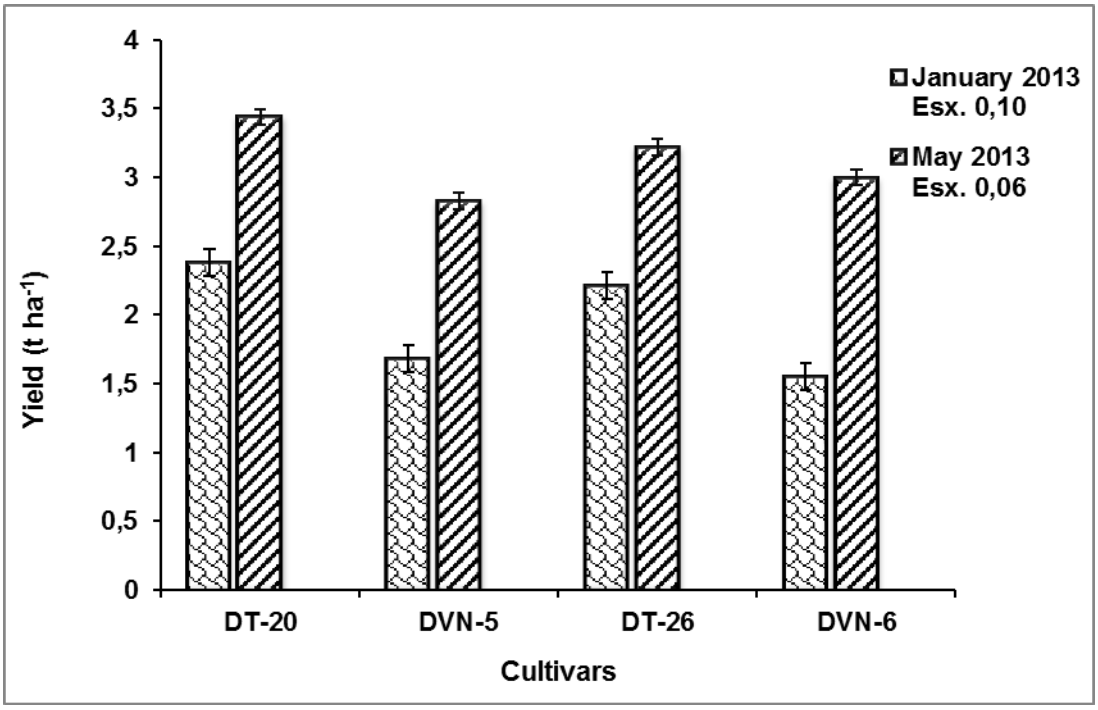
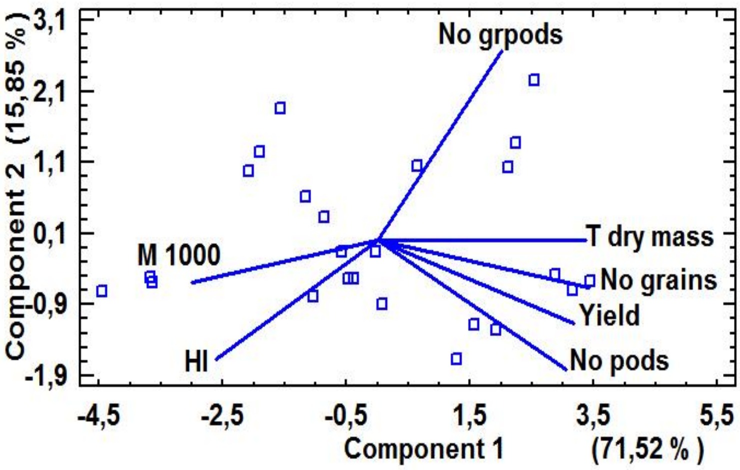


Figure 4. Agricultural yield (t ha^{-1}) at 14% grain moisture of soybean cultivars planted at the two planting dates under study

On both planting dates the DT-20 cultivar reached the highest yield values, although on the January 2013 date it showed no differences with respect to the DT-26 cultivar. Some authors reported that soybean crop yield was strongly correlated with the maximum daily temperature (≤ 30 ºC) during the grain filling stage (R_5-R_7), that is, high temperatures are generally associated with a longer duration of the period, which leads to a greater availability of incident radiation (6,16). In general, the highest values of agricultural yield achieved by soybean cultivars in this study correspond to the period where temperatures were higher, therefore, the availability of incident radiation was higher and there was a better utilization by cultivars, especially the cultivar with the best response. These results show that the meteorological environment is also an important factor for high yields, as it is reaffirmed once again that planting date is one of the most important factors to be taken into account when explaining variations in the main agronomic traits of soybean.

Evidently, it is demonstrated that of the variables analyzed in this study, some had a greater contribution than others to yield increase. In this sense, when the degree of association of these variables with yield was analyzed (Figure 5), it was observed that the most influential were the number of pods/plant and the number of grains/plant, seen in general for the two sowing dates studied, although it was observed that the total dry mass had a certain association, which is why it played a fundamental role in the expression of yield.



M 1000: mass of thousand grains (g). Yield: Agricultural yield (t ha-1). No grains: Number of grains per plant. No pods: Number of pods per plant. No grpods: Number of grains per pod. M total: Total dry mass of the aerial part (g). HI: Harvest index (%)

Figure 5. Association of the agricultural yield of soybean cultivars with the variables obtained on the first and second components in the two planting dates studied

Studies carried out with soybean cultivars of different maturity groups showed that the increase in yield was attributed to the considerable increase in the number of pods/plant and the number of grains/plant (6). Furthermore, it is stated that these variables constitute the main components of yield, and can only be compensated, to a certain extent, by grain mass (25). On the other hand, modern soybean cultivars have been reported to produce higher yields because of better biomass accumulation [14]. This shows that to examine the key trait that can improve the yield of soybean cultivars, more attention should be paid to the grain-filling period, with a strong emphasis on traits related to dry mass dynamics.

CONCLUSIONS

- The results indicated that the best response of the soybean cultivars studied was obtained on the spring planting date (May 2013).
- Cultivars DT-20 and DT-26 were the best performers at both planting dates studied, regardless of growth habit and recommended planting time.
- The number of pods/plant and number of grains/plant proved to be the variables that most influenced yield expression at both planting dates studied.

BIBLIOGRAPHY

1. Carciochi WD, Schwalbert R, Andrade FH, Corassa GM, Carter P, Gaspar AP, et al. Soybean seed yield response to plant density by yield environment in North America. Agronomy Journal [Internet]. 2019;111(4):1923–32. Available from: https://acsess.onlinelibrary.wiley.com/doi/full/10.2134/agronj2018.10.0635
2. Corassa GM, Amado TJ, Strieder ML, Schwalbert R, Pires JL, Carter PR, et al. Optimum soybean seeding rates by yield environment in Southern Brazil. Agronomy Journal [Internet]. 2018;110(6):2430–8. Available from: https://acsess.onlinelibrary.wiley.com/doi/full/10.2134/agronj2018.04.0239
3. Enrico JM, Conde MB, Martignone RA, Bodrero ML. Soja: evaluación de la estabilidad del rendimiento según fechas de siembra. Para mejorar la producción [Internet]. 2013;50:71–8. Available from: https://inta.gob.ar/sites/default/files/script-tmp-inta-soja-evaluacion-estabilidad-rendimiento-segun-fe.pdf
4. Junior CP, Kawakami J, Schwarz K, Umburanas RC, Del Conte MV, Müller MML. Sowing dates and soybean cultivars influence seed yield, oil and protein contents in subtropical environment. J. Agric. Sci [Internet]. 2017;9:188. Available from: https://pdfs.semanticscholar.org/8c35/dd42c7255b14bb8e00646f23ebf84ad06e9d.pdf
5. Boyer CN, Stefanini M, Larson JA, Smith SA, Mengistu A, Bellaloui N. Profitability and risk analysis of soybean planting date by maturity group. Agronomy Journal [Internet].

2015;107(6):2253–62. Available from: https://acsess.onlinelibrary.wiley.com/doi/full/10.2134/agronj15.0148

6. Andrade JF, Edreira JIR, 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 [Internet]. 2019;230:98–106. Available from: https://www.sciencedirect.com/science/article/abs/pii/S037842901831414X
7. Romero A, Ruz R, González M. Evaluación de siete cultivares de soya (*Glycine max*) en las condiciones edafoclimáticas del municipio Majibacoa, Las Tunas. Pastos y Forrajes [Internet]. 2013;36(4):459–63. Available from: http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0864-03942013000400006
8. Díaz-Solis SH, Morejón-Rivera R, Maqueira-López LA, Echevarría-Hernández A, Cruz-Triana A, Roján-Herrera O. Selección participativa de cultivares de soya (*Glycinemax*, (L.)) en Los Palacios, Pinar del Río, Cuba. Cultivos Tropicales [Internet]. 2019;40(4). Available from: https://scielo.sld.cu/pdf/ctr/v40n4/1819-4087-ctr-40-04-e02.pdf
9. Hernández-Jiménez A, Pérez-Jiménez JM, Bosch-Infante D, Speck NC. La clasificación de suelos de Cuba: énfasis en la versión de 2015. Cultivos Tropicales [Internet]. 2019;40(1). Available from: http://scielo.sld.cu/scielo.php?pid=S0258-59362019000100015&script=sci_arttext&tlng=pt
10. Esquivel MA. El cultivo y utilización de la soya en Cuba. Manual Técnico. Asociación Cubana de Producción Animal. 1997;56.
11. Crop SG. STATGRAPHICS® Plus [Internet]. 2000.(Profesional) [Internet]. Available from: http://www.statgraphics.com/statgraphics/statgraphics.nsf/pd/pdpricing
12. Iznaga AC, Romero SC, Valdés AB, Sánchez AC, Pérez RA, Valdés GR. 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;38(2):5–10. Available from: http://cagricola.uclv.edu.cu/descargas/pdf/V38-Numero_2/cag022111784.pdf
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 [Internet]. 2020;256:107922. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0378429020312065
14. Kawasaki Y, Tanaka Y, Katsura K, Purcell LC, Shiraiwa T. Yield and dry matter productivity of Japanese and US soybean cultivars. Plant Production Science [Internet]. 2016;19(2):257–66. Available from: https://www.tandfonline.com/doi/pdf/10.1080/1343943X.2015.1133235

15. Barrientos Llanos H, del Castillo Gutiérrez CR, García Cárdenas M. Análisis de crecimiento funcional, acumulación de biomasa y translocación de materia seca de ocho hortalizas cultivadas en invernadero. Revista de Investigación e Innovación Agropecuaria y de Recursos Naturales [Internet]. 2015;2(1):76–86. Available from: http://www.scielo.org.bo/scielo.php?pid=S2409-16182015000100010&script=sci_arttext
16. Saryoko A, Fukuda Y, Lubis I, Homma K, Shiraiwa T. Physiological activity and biomass production in crop canopy under a tropical environment in soybean cultivars with temperate and tropical origins. Field Crops Research [Internet]. 2018;216:209–16. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0378429017313928
17. Lopez-Pereira M, Connor DJ, Hall AJ. Intercepted radiation and radiation-use efficiency in sunflower crops grown at conventional and wide inter-row spacings: Measurements and modeled estimates of intercepted radiation. Field Crops Research [Internet]. 2020;246:107684. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0378429019311748
18. Tao Z, Wang D, Yang Y, Zhao G, Chang X. Light interception and radiation use efficiency response to tridimensional uniform sowing in winter wheat. Journal of integrative agriculture [Internet]. 2018;17(3):566–78. Available from: https://www.sciencedirect.com/science/article/pii/S2095311917617155
19. Maqueira-López LA, la-Noval WT de, Roján-Herrera O, Pérez-Mesa SA, Toledo D. Respuesta del crecimiento y rendimiento de cuatro cultivares de soya *Glycine max* (L.) Merril) durante la época de frío en la localidad de Los Palacios. Cultivos Tropicales [Internet]. 2016;37(4):98–104. Available from: http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0258-59362016000400009
20. Chaves-Barrantes NF, Gutiérrez-Soto MV. Respuestas al estrés por calor en los cultivos. I. Aspectos moleculares, bioquímicos y fisiológicos. Agronomía Mesoamericana. 2017;28(1):237–53.
21. Allen Jr LH, Zhang L, Boote KJ, Hauser BA. Elevated temperature intensity, timing, and duration of exposure affect soybean internode elongation, mainstem node number, and pod number per plant. The Crop Journal [Internet]. 2018;6(2):148–61. Available from: https://www.sciencedirect.com/science/article/pii/S2214514118300035
22. Egli DB. Crop growth rate and the establishment of sink size: a comparison of maize and soybean. Journal of Crop Improvement [Internet]. 2019;33(3):346–62. Available from: https://www.tandfonline.com/doi/abs/10.1080/15427528.2019.1597797

23. Monzon JP, La Menza NC, Cerrudo A, Canepa M, Edreira JIR, 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 [Internet]. 2021;261:108016. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0378429020313009
24. Nico M, Miralles DJ, Kantolic AG. Natural post-flowering photoperiod and photoperiod sensitivity: Roles in yield-determining processes in soybean. Field Crops Research [Internet]. 2019;231:141–52. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0378429018311237
25. Wei Y, Jin J, Jiang S, Ning S, Liu L. Quantitative response of soybean development and yield to drought stress during different growth stages in the Huaibei Plain, China. Agronomy [Internet]. 2018;8(7):97. Available from: https://www.mdpi.com/2073-4395/8/7/97