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Productive performance of soybean cultivars grown in southwest goiano

Desempenho produtivo de cultivares de soja cultivadas no sudoeste goiano

Rendimiento productivo de cultivares de soja cultivados en el suroeste de goiano

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Abstract
The development of the soybean crop is influenced by several environmental factors such as temperature, rainfall, relative air humidity, soil moisture and photoperiod. After sowing, the seeds are under pressure throughout the formation and maturation process in the field, which can influence the post-harvest quality. Based on the hypothesis that the behavior of soybean cultivars is expressed by the number of days it takes the plant to reach maturity, and this characteristic influences the plant's capacity for growth and grain production. The aim of this study was to evaluate the productivity of different commercial soybean cultivars from the late maturation group, recommended and cultivated in southwestern Goiás. The experimental design used was a randomized block, with 4 replications in a simple factorial scheme with 5 treatments: T1) SYN 13610; T2) SYN 15600; T3) M 6210; T4) M 7110; T5) ICS 7019. Biometric variables and soybean grain yield were measured. Data were subjected to analysis of variance ($p<0.05$) and the Tukey mean test ($p<0.05$). Cultivar M 7110 presents a higher increase in plant height, number of nodes and number of pods, when compared to other cultivars.
Keywords: *Glycine max*; Growth; Productivity; Cerrado.

Resumo
O desenvolvimento da cultura da soja é influenciado por diversos fatores ambientais como temperatura, pluviosidade, umidade relativa do ar, umidade do solo e fotoperíodo. Depois de semeadas, as sementes estão sob pressão durante todo o processo de formação e maturação no campo, o que pode influenciar a qualidade da pós-colheita. Partindo da hipótese de que o comportamento das cultivares de soja é expressa pelo número de dias que a planta leva para chegar à maturidade, e tal característica influencia na capacidade de crescimento e produção de grãos da planta. Objetivou-se com o presente estudo avaliar produtividade de diferentes cultivares de soja comerciais do grupo de maturação tardio, recomendadas e cultivadas no sudoeste goiano. O delineamento experimental utilizado foi em bloco casualizados, com 4 repetições em esquema fatorial simples com 5 tratamentos: T1) SYN 13610; T2) SYN 15600; T3) M 6210; T4) M 7110; T5) ICS 7019. Foram mensuradas as variáveis biométricas e a produtividade dos grãos da soja. Os dados

foram submetidos a análise de variância (p<0,05) e ao teste de média Tukey (p<0,05). A cultivar M 7110 apresenta um aumento superior na altura de planta, no número de nó e no número de vagens, quando comparadas as demais cultivares.
Palavras-chave: *Glycine max*; Crescimento; Produtividade; Cerrado.

Resumen
El desarrollo del cultivo de soja está influenciado por varios factores ambientales como la temperatura, las precipitaciones, la humedad relativa, la humedad del suelo y el fotoperíodo. Una vez sembradas, las semillas están bajo presión durante todo el proceso de formación y maduración en el campo, lo que puede influir en la calidad poscosecha. Asumiendo que el comportamiento de los cultivares de soja se expresa por el número de días que tarda la planta en alcanzar la madurez, y esta característica influye en la capacidad de crecimiento y producción de grano de la planta. El objetivo de este estudio fue evaluar la productividad de diferentes cultivares comerciales de soja del grupo de maduración tardía, recomendados y cultivados en el suroeste de Goiás. El diseño experimental utilizado fue de bloques al azar, con 4 repeticiones en esquema factorial simple con 5 tratamientos: T1) SYN 13610; T2) SIN 15600; T3) M 6210; T4) M 7110; T5) ICS 7019. Se midieron variables biométricas y rendimiento de grano de soja. Los datos se sometieron a análisis de varianza (p<0,05) y la prueba de la media de Tukey (p<0,05). El cultivar M 7110 muestra un mayor aumento en la altura de la planta, el número de nudos y el número de vainas en comparación con los otros cultivares.
Palabras clave: *Glycine max*; Crecimiento; Productividad; Cerrado.

1. Introduction

One of the sectors of the economy that has been fundamental for the generation of wealth for the country is agribusiness, Brazil stands out as one of the largest producers of soy (Glycine max (L.) Merril) in the world, the productivity of this legume considering their genetic capacity is high (Dourado Neto et al., 2012; Cavalcante et al., 2020). Brazil is the largest soybean producer (Glycine max (L.) Merril) in the world, the national average productivity in the 2019/2020 crop year was 3,379 kg ha-1, in an area of 36,949.7 thousand ha, with a production of 124,844.8 thousand tons (Conab, 2021).

The development of the soybean crop is influenced by several environmental factors such as temperature, rainfall, relative humidity, soil moisture and photoperiod. After sowing, seeds are under pressure throughout the formation and maturation process in the field, which can influence post-harvest quality (Elias; Copeland, 2001; Elias et al., 2012; Marcos Filho, 2015).

The oleaginous cycle varies between 90 and 150 days (from the initial phase to the final phase). The soybean crop has adapted to the edaphoclimatic conditions in Brazil. Cultivars are classified into maturation groups. The maturation group can be denominated in super-early, precocious, medium and late cycles, always admitting the oscillation of the duration of this cycle, according to the region. The variation in the soybean cycle is linked to factors such as soil condition, latitude, altitude, technologies used in management, genetic material and sowing time (Delouche, 2002; Feliceti et al., 2020).

Since the enactment of the "Law for the Protection of Cultivated Plants" in 1997, Brazilian private companies have implemented a soybean breeding program, which introduces a large number of cultivars each new agricultural year and proposes a new classification method for the extension of the developmental cycle (Alliprandini et al., 2009; Feliceti et al., 2020).

Since then, the classic method adopted by Brazil describes the relative maturity of soybeans in super-early, early, medium, medium-late and late cycles (Alliprandini et al., 1994), began to be replaced by a new classification, became classified into Relative Maturity Groups (GMR) developed in the USA.

The reason for this change is that cycle classification only successfully described maturity in a given location, but failed to describe relative maturity within a given environment and latitude of the region where soybeans are grown in Brazil (Alliprandini et al., 2009).

It is understood as GMR, the duration of the soybean development cycle, that is, the number of days from sowing to physiological maturity. The GMR is determined by the response to photoperiod, temperature, precipitation, pest and disease attack, and the sensitivity of both responses to edaphoclimatic characteristics, depending on the genetics of the cultivar. Therefore, varieties are classified as mature groups according to the duration of their cycle (Alliprandini et al., 2009; Feliceti et al., 2020).

In the first scientific article in Brazil using the GMR method, Alliprandini et al. (2009) quantified the genotype x environment interaction according to the duration of the development cycle, the genotype x environment interaction was analyzed quantitatively, and a group of commercial varieties in different locations (different latitudes and altitudes) were evaluated. These varieties are called "standard varieties". Based on this work, soybean breeding programs in Brazil have since used these "standard varieties" to classify varieties introduced each year into the Brazilian soybean market and recommend varieties with the lowest GMR (4.0 to 7.0) in the southern region. Brazil and varieties with GMR from 8.0 to 10.0 indicate areas close to the equator (Bexaira et al., 2018).

It is important to point out that when sowing in areas where GMR is recommended, the development cycle of all GMR is close to 125 to 140 days. However, when cultivars with different GMRs are sown in the same location, it is expected that the higher the GMR, the longer the cultivar development cycle will be (Zanon et al., 2015). However, when the planting time is delayed, the duration of the development cycle decreases regardless of the variety's GMR.

Soybean cultivars differ in terms of perception of sowing time and respond in a unique way for each time (Oliveira, 2010). The economic importance of soybean cultivation on a global scale is consolidated, but tests are constantly needed to verify the ideal sowing time to increase the yield of cultivars. Pedo et al. (2016) showed in their study that seed vigor is interfered with the sowing time as well as the climatic conditions that last during the maturation and subsequent harvest phases.

Every year, the specialized bodies establish a sowing period for the crop, the period varies according to each agricultural year, with the climatic zoning and also to control Asian rust, the main disease of the crop. The sanitary vacuum is essential for soybean crops to start their development without the presence of the Phakopsora pachyrhizi fungus, which causes this very important disease. Thus, with climatic differences and releases of new cultivars, it is necessary to carry out regional studies to assess the impact of environmental factors on crop growth (Kuss et al., 2008; Bahry et al., 2017).

Assuming that the behavior of soybean cultivars is expressed by the number of days the plant takes to reach maturity, and this characteristic influences the growth capacity and grain production of the plant. The objective of this study was to evaluate the productivity of different commercial soybean cultivars of the late maturation group, recommended and cultivated in southwest Goiás

2. Methodology

The experiment was carried out in the experimentation area belonging to the company Tecno Nutrição Vegetal e Biotecnologia Ltda., in the following geographical location 17°44'20.88"S and 50°57'55.79"W, with 860 m of altitude. The soil of the experimental area is classified as Dystroferric Red Latosol (LVdf) (Santos et al., 2018), the physicochemical characteristics are described according to soil analysis (Table 1).

According to the classification by Alvares et al. (2013) and Köppen and Geiger (1928), the climate of the region is classified as Aw (tropical), with rain from October to May, and with drought from June to September. The average annual temperature varies from 20 to 35 °C and rainfall varies from 1,500 to 1,800 mm annually and the relief is gently undulating (6% slope) (Silva et al., 2017).

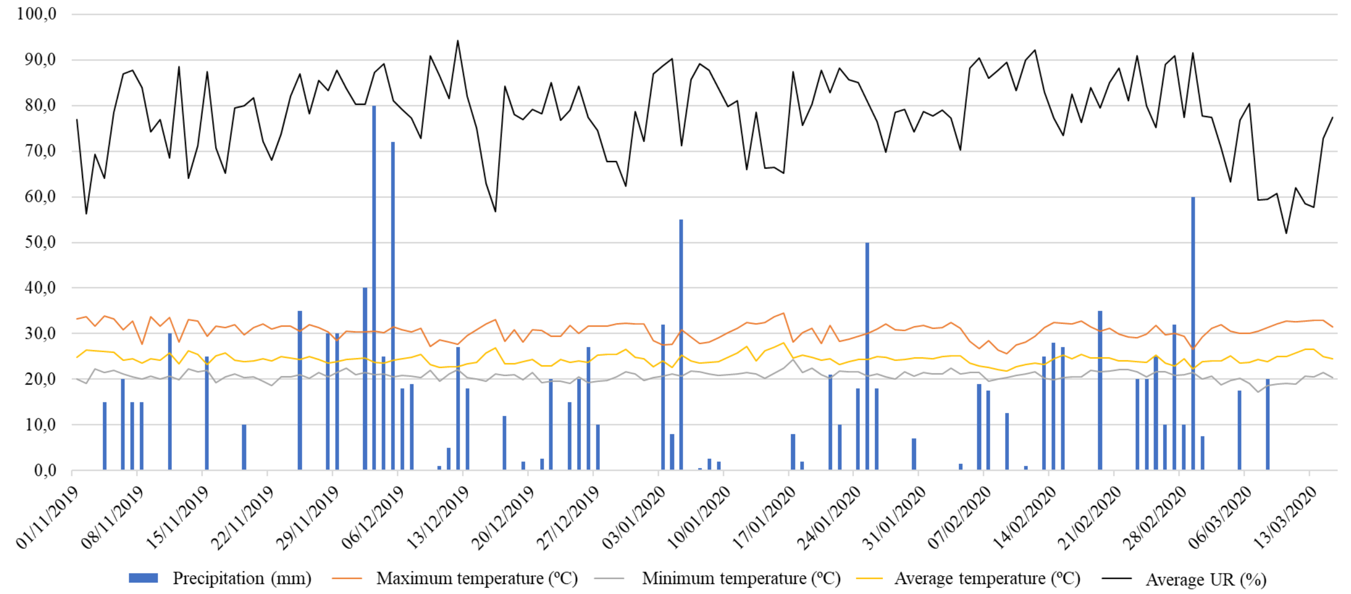
Table 1 - Chemical and granulometric analysis of the soil, 2019-20 season, Rio Verde – GO.

						Macronutrients							
Depth	pH	P	S	K	Ca	Mg	Al	H+Al	M.O.	SB	CTC	V	m
cm	$CaCl_2$	.... mg dm^{-3}				.... cmol$_c$dm^{-3}			g dm^{-3}	cmol$_c$dm^{-3}		%	
0-20	5,18	1,83	3,15	12,81	1,6	1,22	0,00	3,07	37,33	3,15	6,31	49,8	49,6
20-40	5,23	0,83	2,53	4,03	1,2	0,83	0,00	2,5	24,0	2,17	4,17	47,6	52,3
			Micronutrients							Granulometry			
	B	Na	Cu	Fe	Mn	Zn		Sand	Silt	Clay	Textural class		
		.... mg dm^{-3}.....................							%				
0-20	0,11	0,0	1,77	16,9	11,3	1,8		23,4	11,5	65,0	Very Clayey		
20-40	0,0	0,0	0,0	0,0	0,0	1,5		19,6	12,0	68,3	Very Clayey		

pH of the soil solution, determined in calcium chloride solution; MO: organic matter, determination by colorimetric method; P: phosphorus, melhich; K^+: potassium, melhich; Ca^{2+} and Mg^{2+}: exchangeable contents of calcium and magnesium, respectively, in KCl; $S^-SO^4{}_{2-}$: Sulfur in the form of sulfates, extracted with calcium phosphate and determined by colorimetry. Al3+: Exchangeable aluminum, extracted by 1 mol L-1 potassium chloride solution. H+Al: total soil acidity, determined in SMP buffer solution at pH 7.5. SB: sum of bases ($K^+ + Ca^{2+} + Mg^{2+}$). CEC: cation exchange capacity ($K^+ + Ca^{2+} + Mg^{2+}$ + H+Al). V: soil base saturation (SB/CTC ratio). m: aluminum saturation [Al^{3+}/(SB+Al^{3+}) ratio]. Cu, Fe, Mn and Zn: copper, iron, manganese and zinc, extracted by melhich solution. Source: Authors.

During the development of the crop, local climate data were monitored, and the weekly averages are shown in Figure 1.

Figure 1 - Daily data, precipitation, temperature and relative humidity in the period resulting from the experiment, Rio Verde - GO, 2019/20.



Source: INMET Normal Station – 2019-20 Harvest, Rio Verde – GO.

Fertilization was carried out based on soil analysis and in accordance with Sousa and Lobato's (2004) recommendation. The planting fertilization was carried out by broadcast in the total planting area using 400 kg ha-1 of the 02-25-25 formula, aiming at a considerable investment, which justifies the choice of varieties. The sowing of the materials took place on November 9, 2019, with a spacing of 50 cm, following the recommendations of each cultivar.

The experimental design used was a randomized block, with 5 treatments and 4 replications, totaling 20 experimental plots (Table 2).

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Table 2 - Description of treatments, 2019-20 season, Rio Verde – GO.

Treatments	Cultivars	Maturation Group
T1	SYN 13610 IPRO®	7,0
T2	SYN 15600 IPRO®	6,1
T3	M 6210 IPRO®	6,2
T4	M 7110 IPRO®	6,8
T5	ICS 7019 RR®	7,0

Source: Authors.

The experimental plots consisted of 4 lines of 10 meters, totaling 2 m x 10 m = 20 m^2 plot x 20 plots = 400 m^2. During the development of the crop, cultural treatments were carried out via the application of chemical products to control weeds, pests and diseases, as shown in Table 3.

Table 3 - Number of applications and active ingredients used during soybean cultivation, 2019-20 harvest, Rio Verde – GO.

Application	Time	Dose and commercial product and active principles
1ª	Pre-planting	3,0 L ha^{-1} of Crucial (Glyphosate) + 0,5 L ha^{-1} of Zethamaxx (Flumioxazina + Imazetapir) + 0,6 L ha^{-1} of U 46 (2,4-D)
TS	Seeding	0,5 L/100 kg of Cropstar seed (Tiodicarbe + Imidacloprido) + Protreat (Tiram + Carbendazin) + 0,1 L/100 kg of Nodumax seed (*Bradyrhizobium japonicum*)
2ª	20 AED	2,0 L ha^{-1} of Crucial (Glyphosate) + 0,8 L ha^{-1} of Cletodim (Viance)
3ª	40 AED	0,07 L ha^{-1} of Kaiso (Lambda-cialotrina) + 0,4 L ha^{-1} of Fox (Protioconazol + Trifloxistrobina) + 0,25% of Aureo
4ª	60 AED	0,07 L ha^{-1} of Kaiso (Lambda-cialotrina) + 0,4 L ha^{-1} of Fox (Protioconazol + Trifloxistrobina) + 0,25% of Aureo
5ª	70 AED	1,0 kg ha^{-1} of Perito (Acefato) + 0,2 L ha^{-1} of Valio (Óleo of laranja)
6ª	80 AED	0,3 L ha^{-1} of Priori Xtra (Azoxistrobina + Ciproconazol) + 0,5% of Nimbus
Desiccation	110 AED	2,0 L ha^{-1} of Gramoxone (Paraquat) + 0,2 L ha^{-1} of Valio (orange oil)

AED – days after emergence. Source: Authors.

Applications of phytosanitary products were carried out using a backpack sprayer pressurized with CO^2 equipped with a 2 m boom, containing four TT 110.02 spray nozzles (0.45 m between nozzles), applying a volume of spray equivalent to 100 L ha^{-1}. Environmental conditions were always monitored to obtain a favorable condition of average temperature 25ºC, average RH of 78% and average wind speed of 2.5 km h-1. The applications were always carried out between 8:00 am and 10:00 am or from 4:00 pm to 6:00 pm, a period in which it was possible to gather the best climatic conditions for the applications.

The biometric variables: plant height (AP), node number (NN), stem diameter (DC), number of branches (NG) and number of pods (NV), were determined with the aid of a tape measure, ruler and caliper. To obtain biometric data, 2 plants per experimental plot were collected and quantified, totaling 8 plants per treatment at each evaluation in R7.

At the end of the cycle, the experiments were dried and the mass of 100 grains and the grain yield were quantified. Grain productivity was determined by harvesting and threshing the plants, according to the degree of maturation of each one, the water content of the total mass of grains was determined and corrected for 13% moisture, and the values extrapolated to kg ha^{-1}.

Data were submitted to analysis of variance ($p<0.05$) and, in case of significance, they were submitted to the Tukey mean test ($p<0.05$), using the statistical software SISVAR® (Ferreira, 2011).

3. Results and Discussion

In the analysis of variance, it was observed that the variables plant height (AP), number of nodes (NN) and number of pods (NV) were significant depending on the treatments, whereas the variables stem diameter (DC) and number of branches (NG) showed no significant effect depending on the cultivars and treatments (Table 4).

Table 4 - Summary of the analysis of variance for the variables plant height (AP), node number (NN), pod number (NV), stem diameter (DC) and number of branches (NG), depending on the different cultivars, 2019-20 season, Rio Verde – GO.

SV	DF	Mean squares				
		AP	NN	NV	DC	NG
Cultivars	4	$771{,}500^{**}$	$29{,}450^{**}$	$551{,}675^{*}$	$2{,}697^{ns}$	$3{,}175^{ns}$
Blocks	3	$14{,}400^{ns}$	$5{,}916^{ns}$	$120{,}200^{ns}$	$5{,}102^{ns}$	$0{,}733^{ns}$
Residue	12	26,066	4,083	121,075	3,322	1,108
CV (%)		5,87	12,14	20,64	25,41	38,99

ns: not significant; and *; ** Significant respectively at 5 and 1% probability according to the F test. SV – Source of variation; DF – Degree of Freedom; and CV – Coefficient of Variation. **Source:** Authors.

In plant height (AP) cultivar M 7110 (T4) showed a higher increase of 29.29% (24.07 cm) when compared to the other cultivars. The other cultivars did not show statistical differences among themselves by Tukey's test at 5% probability (Table 5).

Again, M 7110 (T4) was the cultivar that had the highest number of nodes (NN), however, it did not show statistical difference from SYN 13610 (T1), but when compared with the other cultivars (T2 – SYN 15600; T3 – M 6210 and T5 – ICS 7019), we can see a respective increase of 40% and 15% in the NN (Table 5).

The same effect can be noticed in the number of pods (NV), where again the M 7110 (T4) presented the highest NN. When we compare the M7110 cultivar with the M 6210 (T3) and ICS 7019 (T5) we can see an increase of 62.22%, however, there is no difference between the SYN 13610 (T1) and SYN 15600 (T2) cultivars that when compared with the cultivars M 6210 (T3) and ICS 7019 (T5) an average increase of 15.26% is observed (Table 5).

Biometric variables are important characteristics in mechanized soybean cultivation systems, as they significantly interfere with the yield and efficiency of mechanized harvesting in large areas (Alcântara Neto et al., 2012).

Similar results were verified by Perini et al. (2012) who found differences in soybean plant height of up to 38%, in addition to observing that plant height had a direct correlation with the final productivity of the crop.

Table 5 - Mean test for plant height (AP) and node number (NN) and pod number (NV), depending on the different soybean cultivars, 2019-20 harvest, Rio Verde – GO.

Treatments	Averages		
	AP	NN	NV
	cm	Ad	Ad
SYN 13610 IPRO®	90,75 b	17,25 ab	53,25 ab
SYN 15600 IPRO®	85,75 b	15,00 b	50,50 ab
M 6210 IPRO®	84,75 b	14,00 b	47,50 b
M 7110 IPRO®	106,25 a	21,00 a	73,00 a
ICS 7019 RR®	67,50 b	16,00 b	42,50 b
Standard error	2,552	1,010	5,501

ns: not significant; and *; ** Significant respectively at 5 and 1% probability according to the F test. SV – Source of variation; DF – Degree of Freedom; and CV – Coefficient of Variation. **Source:** Authors.

In the analysis of variance, it is observed that the variables mass of 100 grains (M100G) and grain yield (PG) were not significant as a function of the treatments (Table 6).

Table 6 - Summary of the analysis of variance for the variables 100-grain mass (M100G) and grain yield (PG), depending on the different soybean cultivars, 2019-20 Harvest, Rio Verde – GO.

SV	DF	Mean squares		
		M100G	PG	PG
Cultivars	4	12,121^{ns}	41345,108^{ns}	11,485^{ns}
Blocks	3	18,652^{ns}	11897,648^{ns}	3,304^{ns}
Residue	12	13,981	30359,109	8,427
CV (%)		23,83	4,72	4,72

ns: not significant; and *; ** Significant respectively at 5 and 1% probability according to the F test. SV – Source of variation; DF – Degree of Freedom; and CV – Coefficient of Variation. **Source:** Authors.

The average weight of 100 grains varies in different locations and sowing times, however the statistical differences in the M100G are not always significant (Seidel; Basso, 2012; Carneiro et al., 2013; Marcos Filho, 2015), soybean is one of the species more sensitive to environmental conditions during and after seed maturation (Marcos Filho, 2015). Menon et al. (1993), when carrying out a study in different locations, observed that the quality and productivity of the seed varied according to the location (Feliceti et al., 2020).

Table 7 - Mean test for mass of 100 grains (M100G) and grain yield (PG), according to different soybean cultivars, 2019-20 harvest, Rio Verde – GO.

Treatments	Averages		
	M100G^{ns}	PG^{ns}	PG^{ns}
	G	kg ha^{-1}	Sc ha^{-1}
SYN 13610 IPRO®	16,83	3630,66	60,51
SYN 15600 IPRO®	15,85	3631,60	60,52
M 6210 IPRO®	16,10	3871,25	64,52
M 7110 IPRO®	16,96	3649,37	60,82
ICS 7019 RR®	12,69	3688,35	61,47
Standard error	1,869	87,119	1,451

ns: not significant. Source: Authors.

The results show that although cultivars are classified in the same maturation group, productivity does not always tend to be different. In view of the controversial results, constant research is needed in order to resolve doubts and corroborate with new results (Feliceti et al., 2020).

The different yields may be linked to genetic characteristics, a study carried out by GRIS et al. (2010) verified the relative contribution of physiological traits to genetic divergence and characterized the response of different cultivars in terms of physiological quality and productivity as a function of the year of cultivation.

4. Conclusion

Cultivar M 7110 has higher plant height, number of nodes and number of pods when compared to other cultivars.

There were no statistically significant differences in the mass of 100 grains or in grain yield in the different soybean cultivars used in the present study.

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