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Selection of Soybean Genotypes in the Central Region of Tocantins

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***Abstract*— *Brazilian agribusiness enables two consecutive harvests in the same year using early soybean cultivars. Understanding the interaction between environments and soybean genotypes is crucial for adapting cultivars and ensuring production stability. This study aimed to select early soybean genotypes in the central region of Tocantins. The experiment was conducted in Porto Nacional under rainfed and irrigated conditions, evaluating 40 soybean genotypes, including lines and commercial cultivars. A randomized block design with three replications was used, with plots consisting of four 5-meter rows spaced 0.50 meters apart. Grain productivity (sc. ha-1), cultivation cycle (days), and lodging index were analyzed. Data were subjected to variance analysis via SISVAR software, and means were compared using the Scott & Knott test at a 5% probability level. The coefficient of variation and accuracy estimates assessed experimental precision. Nineteen genotypes exceeded the national average for grain productivity. The cultivation cycle ranged from 91 to 109 days, with an 18-day variation. Under rainfed conditions, none of the genotypes showed susceptibility to lodging, but in the irrigated condition, 9 genotypes exhibited high lodging scores. Four genotypes—20285INT1835, 20204INT108701, 18610INT21205, and 20652INT102372—stood out for combining high productivity, absence of lodging, and an early cycle of 99-101 days. These genotypes demonstrate significant potential for agricultural systems in the Tocantins region.*

I. INTRODUCTION

Brazil is the world's largest soybean producer. Soybeans are extremely important not only as a food source but also as a renewable energy source. One of the factors contributing to the prominence of the country's agribusiness is the possibility of conducting two consecutive harvests in the same agricultural year, increasing the utilization period of the same land and consequently generating higher economic returns. For this to be possible, the use of early soybean cultivars is required, which enable an earlier harvest and, thus, advance the planting period of the second crop.

The state of Tocantins has been standing out in recent years for the expansion of its planted area and soybean production, making a name for itself nationally. In the 2022/2023 harvest, Tocantins reached approximately 1.2 million hectares of planted area, with a production exceeding 3 million tons. The average productivity is around 2,700 kg/ha, highlighting the region as an important agricultural hub in Brazil. This growth is the result of investments in technology and modern agricultural practices, which have enhanced the efficiency and competitiveness of Tocantins' soybeans in the market.

The edaphoclimatic characteristics of Tocantins are favorable for soybean cultivation but also present challenges. The region has an average annual rainfall ranging between 1,500 mm and 1,800 mm, mostly concentrated between October and April. The climate is marked by a distinct rainy season and dry season, with average temperatures ranging from 24°C to 28°C. High temperatures, low altitude, occurrence of dry spells, more concentrated rainy periods, and more sandy and heterogeneous soils make early soybean cultivation extremely challenging. These conditions require careful management of water and soil to ensure productivity and plant health, as well as strategies to mitigate the effects of prolonged drought.

These edaphoclimatic characteristics are directly related to soybean genetic improvement in the region. Research and development of varieties more resistant to drought and local pests are crucial to ensuring production stability. Genetic improvements also aim to increase the efficiency of water and nutrient use, adapting the plants to the specific conditions of Tocantins. Such innovations are fundamental to sustain agricultural expansion and productivity, especially in the face of climate variability.

The soybean crop has several important characteristics, among which maturation stands out. The maturation cycle of soybeans can vary from 90 to 120 days, depending on the cultivar and environmental conditions. In Tocantins, the choice of short-cycle varieties is common due to the need to adapt the crop to the rainy season. The introduction of early soybeans in the state may be an alternative to maximize gains for rural producers, improving the planting window for the second crop and increasing the productivity of crops such as corn, sorghum, and sesame. Proper plant maturation is crucial for maximizing production and minimizing post-harvest losses, ensuring that the grains reach the optimal harvest point with superior quality.

The objective of this work is to select early soybean genotypes in the central region of the state of Tocantins, analyzing the factors that influence soybean productivity, focusing on edaphoclimatic characteristics and genetic improvement. The aim is to evaluate how these variables impact cultivation efficiency and production quality, providing support for the adoption of more sustainable and technological agricultural practices. Through this analysis, we hope to contribute to the development of strategies that can increase the competitiveness of Tocantins' soybeans in the national and international markets.

II. THEORETICAL FRAMEWORK

2.1 Soybean Cultivation

2.1.1 Origin and Evolution of Soybean Cultivation in Brazil

Soybean (Glycine max [L.] Merrill) is a dicotyledonous species belonging to the Fabaceae family, originating from the Asian continent. Records of soybean cultivation date back to 2800 B.C. in China, where it was mentioned as one of the five sacred grains (SEDIYAMA, 2009). The first mention of soybeans in Brazil was in 1882 in the state of Bahia, but the cultivation was not successful due to the cultivars introduced from the United States, which did not adapt to the latitude of the region (12° S). In 1891, reports of new cultivars introduced in the interior of São Paulo (latitude 22°54' S) and Rio Grande do Sul emerged, which developed well due to the photoperiod being similar to the southern United States, where these cultivars originated (SANTOS, 1988). Later, soybean expanded to the state of Minas Gerais in the 1920s, with the first recorded cultivation in the city of Lavras, and also to the states of Santa Catarina, Goiás, and other Central-Western states in the 1930s, 1950s, and 1970s, respectively (MIYASAKA & MEDINA, 1981; SEDIYAMA, 2009).

The commercial production of soybean grains began in 1935 in the state of Rio Grande do Sul, which, after six years, already had a cultivated area of 702 ha. In 1938, Brazil's first soybean export was reported, destined for Germany, and in 1951, the first edible soybean oil extraction industry was established in the country (MAGALHÃES, 1981).

Various factors contributed to the stimulus and expansion of soybean cultivation in Brazil. Among the main factors are: the similarity of climatic conditions between the southern region of Brazil and the southern United States, where the first imported cultivars originated; the improvement of soil conditions in Rio Grande do Sul (operation "Tatu") and later in the cerrado; the possibility of succession with wheat cultivation, which was extensively grown in the southern region of the country in the 1970s, combined with the growing demand for poultry and swine feed; agricultural tax incentives between the 1950s and 1970s; high soybean market prices in the 1970s; the trend of substituting animal-based oils and fats with plant-based products; the ease of mechanization in the crop's production; the good organization of public and private sectors in research and development; the establishment of agro-industrial sectors in the Southeast and Central-West regions, with a good transportation system for production flow; and the development of photoperiod-insensitive cultivars, allowing cultivation in low-latitude areas; the highly favorable climate for soybean cultivation in Brazil, combined with the coincidence between the Brazilian harvest and the offseason in the United States (EMBRAPA, 2005; SEDIYAMA, 2009).

2.1.2 Importance of Soybean

Brazil is positioned in the international market as the world's largest soybean producer. The Central-Western region is responsible for nearly half of the national production.

In the 2023/2024 harvest, the planted area was approximately 45.2 million hectares, resulting in a production of 146.5 million tons. The average productivity was 53.98 sc. ha-1 (3239 kg. ha-1) (CONAB, 2024).

In Tocantins, the crop has been expanding, with new planting areas being registered in municipalities in the central-northern region of the state. Among the municipalities with the largest soybean planted areas in the state are, in first place, Porto Nacional with 68,768 hectares; followed by Campos Lindos with 67,866 hectares; Peixe with 53,204 hectares; Caseara with 50,479 hectares; Monte do Carmo with 48,295 hectares; and Mateiros with 47,723 hectares (ADAPEC, 2023).

2.1.3 Climate of Tocantins

The climate of Tocantins is characterized as semi-humid tropical, with two well-defined seasons: a rainy season and a dry season. The average annual temperatures range from 24°C to 28°C, with maximum temperatures that can exceed 35°C during the dry season. The relative humidity is generally high during the rainy season, but it can drop significantly during the dry season. The average annual precipitation fluctuates between 1,500 mm and 1,800 mm, mostly concentrated between October and April, the period when the rains occur. During the dry season, the state faces dry spells, short periods of drought within the rainy season, and long dry periods that can last up to five months.

2.1.4 Importance of Early Soybean for Brazilian Agribusiness

Brazil stands out in the world market for having extensive areas suitable for agriculture, favorable climates, and water availability—factors that make the country one of the largest producers and exporters in the agricultural sector. The Brazilian agribusiness is responsible for 24% of the country's GDP and 47% of its exports (CEPEA, 2023). One factor that has enabled significant increases in Brazilian production, in addition to genetic improvements, is the exploitation of the second crop, which became feasible thanks to the good edaphoclimatic conditions found in the country. The second crop follows the summer crop, allowing for better use of land, greater production, and consequently higher economic returns, creating new sources of income, jobs, and contributing to the positive balance of trade.

In this context, a key aspect for the success of the second crop is the adoption of early soybean cultivars, which enable earlier planting and harvesting, creating a window during the harvest season to explore two crops in the same agricultural year. In most soybean-producing states, corn is the crop adopted for the second crop due to its good complementarity with soybean cultivation. There is also a noticeable trend and significant interest among corn and other crop producers to shift to soybean cultivation (CONAB, 2024). However, it is necessary for the crops used in both the first and second harvests to perform well agronomically, so they can take full advantage of the rainy season and high temperatures, reaching maximum productivity during the shortest possible period in the field.

2.1.5 Phenology and Growth Cycle of the Crop

The soybean plant has an annual cycle, with herbaceous growth, erect posture, and autogamy. Soybean seed germination is epigeal, with the two cotyledons emerging from the soil and giving rise to the development of the seedling. The first pair of leaves is simple, with subsequent leaves being compound and trifoliate. Branches that arise from the budding of the buds on the main stem have trifoliate compound leaves and may also have apical or axillary floral branches, depending on the growth habit of the cultivar (EMBRAPA, 2013).

In the reproductive phase, the inflorescences give rise to seeds arranged in pods, which may contain up to five seeds each, with more than 400 pods per plant. The seed consists of the pericarp, seed coat, and embryo, externally presenting the hilum and micropyle. The characteristics of the pericarp, seed coat, and hilum can vary in color and shape depending on the cultivar used, and they are also used as morphological markers for cultivar identification (PESKE, ROSENTHAL & ROTA, 2012).

The root system is predominantly axial, with diffuse secondary roots and the presence of nodules, which are points where the symbiotic process of nitrogen-fixing bacteria from the Bradyrhizobium genus occurs (SEDIYAMA et al., 1985; SEDIYAMA, 2009).

The soybean plant can be classified according to its growth habit as determinate, semi-determinate, or indeterminate, depending mainly on the critical photoperiod and the position of the inflorescence, as well as the temperature's influence on its growth.

The determinate growth habit is characterized by having terminal and axillary inflorescences, with maturation occurring from top to bottom, short internodes, and usually ceases its vegetative growth once it reaches the reproductive phase, being at least 90% of its final height and 100% of its final dry matter at this stage. Cultivars with indeterminate growth habit have only axillary inflorescence, as their vegetative growth continues after the plant reaches the reproductive phase. These cultivars are taller and have maturation from bottom to top (SEDIYAMA et al., 1985).

Semi-determinate cultivars have characteristics that are intermediate between the two previous classifications, as they have both terminal and axillary inflorescences, with continued vegetative growth after reaching the reproductive phase, although they are about 70% of their final height at this stage. The maturation of the plant is similar to that of the determinate growth habit, from top to bottom (SEDIYAMA et al., 2005; SEDIYAMA, 2009; KUMUDINI & TOLLENAAR, 2014).

The soybean development cycle can be divided into two phases: vegetative and reproductive. The characteristics of each developmental stage follow the scale proposed by Fehr & Caviness (1977).

The vegetative phase of soybean development comprises several stages, which are basically VE, VC, V1, V2, V3, up to Vn, where "n" is the number of fully developed leaves from the main stem, including the first pair of simple leaves. Vegetative development starts at stage VE, characterized by the emergence of the plant and the exposure of the cotyledons above the soil. The following stage, VC, is characterized by the development of the first pair of simple leaves, arising from the cotyledons (TOLEDO, 2014).

Subsequent stages are named according to the number of fully developed compound leaf pairs above the first simple leaf pair from the main stem, continuing until the onset of flowering. For example, stage V3 is named for having two fully developed compound leaves above the simple leaf pair from the main stem.

The reproductive development of soybean is divided into 8 stages, from R1 to R8. Stages R1 and R2 correspond to the flowering phase, which is crucial for determining the number of pods per plant and the floral abortion rate. Flowering typically starts in the central third of the plant, spreading to the base and the apex.

Stages R3 and R4 correspond to pod formation, a critical phase of development as it represents one of the plant's production components. This phase begins when the pods reach at least 5 mm in one of the first four nodes of the upper third of the plant. It should be noted that reductions in the number of pods per plant cannot be compensated by the number and weight of the seeds, as they have maximum limits.

Stages R5 and R6 involve the determination of the number of seeds per pod and their weight, depending on the plant's nutritional and water conditions and ambient temperature, and are crucial for defining the yield. This phase begins when at least one pod in the upper third of the plant contains a seed that is at least 3 mm in length.

Maturation occurs between stages R7 and R8, evaluated through the main stem. In stage R7, at least one pod already exhibits color and weight indicative of maturity, and in stage R8, at least 95% of the pods are mature, and the plant’s senescence accelerates, with intense yellowing and leaf drop. It is important to note that depending on the growth habit of the cultivar, vegetative growth may continue after the plant reaches the reproductive phase, but this growth ceases once seed formation begins, as it constitutes a significant drain of photosynthates (SEDIYAMA, 2009; TOLEDO, 2014).

The developmental stages in cultivars with a determinate growth habit are more defined and may occur simultaneously and overlap, while cultivars with an indeterminate or semi-determinate growth habit tend to have more prolonged phases, with more uneven maturation.

2.1.6 Relative Maturity

The soybean growth cycle can range from 75 to 200 days (CARVALHO et al., 2003) depending on the cultivar, which may vary from super-early to late-maturing. Soybean cultivars are categorized into maturity groups according to the growth cycle exhibited during development in a specific latitude range. In Brazil, the maturity groups range from 5.0 to 10.0. Cultivars within each group may vary their cycle by up to 15 days (SEDIYAMA, 2009) and are recommended based on the latitude of the region.

Cultivars in groups 000, 00, and 0 are very early maturing and are generally recommended for higher latitudes. Meanwhile, cultivars in groups 9 and 10 are later-maturing and are usually recommended for regions with lower latitudes. This difference is due to the fact that the higher the latitude of a region, the longer the growth cycle of the cultivars, due to their sensitivity to photoperiod. The opposite is true for cultivars planted in regions closer to the equator, which exhibit shorter cycles.

In the states of Rio Grande do Sul, Santa Catarina, and Paraná, cultivars from groups 5 to 7 are recommended; in São Paulo, cultivars from groups 6 to 8; in Mato Grosso do Sul and Minas Gerais, cultivars from groups 6 to 9; in Goiás and the Federal District, cultivars from groups 7 to 9; and in Mato Grosso, Tocantins, Bahia, and Maranhão, cultivars from groups 8 and 9 are recommended (EMBRAPA, 2013). It is worth noting that the groups include decimal variations, with each decimal representing a variation of 2 to 3 days in the total cycle of the cultivars.

2.4. Genetic Improvement in the Company's Crop Development

Genetic improvement plays a crucial role in increasing productivity and improving crop resistance to climatic adversities and pests. Inova Genética Ltda is one of the youngest and most promising companies in soybean and hybrid corn seed breeding in Brazil. As the third generation of companies in the Grupo Wehrmann specializing in this field, Inova Genética stands out for its efficiency and speed in developing new soybean cultivars and corn hybrids.

With a highly qualified technical team composed of Ph.D. and master's degree holders in various fields related to genetic improvement, the company leverages advanced technologies and the expertise accumulated over three generations to develop cultivars that meet the demands of the Brazilian market. The new cultivars are characterized by high productivity, resistance to pests and diseases, and adaptability to the country's diverse edaphoclimatic conditions, including those of Tocantins. These genetic improvements are essential to ensuring the sustainability and competitiveness of Brazilian soybeans on the global stage.

III. MATERIALS AND METHODS

The experiments were conducted in two environments: a rainfed area, where sowing took place on October 24, 2023, and an irrigated area, where sowing occurred on October 15, 2023, in the municipality of Porto Nacional, Tocantins, Brazil.

A total of 40 soybean genotypes were used, comprising 36 breeding lines from the company Inova Genética and four commercial cultivars.

The experiments followed a randomized block design with three replications. Each plot consisted of four rows, each 5 meters long, with a 0.50-meter spacing between rows. Sowing was performed in the second half of October in both locations, using a no-till system. A planting density of 18 plants per linear meter was adopted, with fertilization of 400 kg.ha^{-1} of NPK 03-35-06 at sowing. Inoculation was carried out in the furrow during sowing using liquid inoculant (Bradyrhizobium japonicum) applied with a "micron" sprayer at six times the recommended dose, equivalent to 12 mL.kg^{-1} of seeds.

Post-emergence weed control was carried out using glyphosate at a dosage of 4 kg.ha^{-1}. Applications were performed with a self-propelled sprayer, using a spray volume of 150 L.ha^{-1}.

For disease control, preventive fungicide applications were conducted. The fungicides used included:

- Pyraclostrobin at a dosage of 0.5 L.ha^{-1};
- Pyraclostrobin + Epoxiconazole at 0.5 L.ha^{-1};
- Azoxystrobin + Cyproconazole at 300 mL.ha^{-1}, with a spray volume of 200 L.ha^{-1}. Pest control was performed as necessary, using growth regulator insecticides with Teflubenzuron as the active ingredient at a dosage of 50 mL.ha^{-1} of the commercial product. Additionally, systemic contact and ingestion insecticides from the pyrethroid and neonicotinoid chemical groups were used at a dosage of 200 mL.ha^{-1} of the commercial product. Contact insecticides Cypermethrin and Chlorpyrifos were also employed at dosages of 250 and 800 mL.ha^{-1}, respectively, all with an applied spray volume of 150 L.ha^{-1}.

The following traits were evaluated:

- Grain yield (bags.ha^{-1}), obtained by harvesting each plot individually (two rows of 5 meters), weighing the harvested material, extrapolating the weight to 1 hectare, and adjusting to 13% moisture;
- Crop cycle (days), comprising the number of days from sowing to physiological maturity, represented by 95% of plants with mature pods;
- Lodging index, based on the scale by Bernard et al. (1965), where a score of 1 indicates all plants standing upright and a score of 5 indicates all plants lodged.

The data were subjected to analysis of variance using the SISVAR package (FERREIRA, 2011), and means were compared using the Scott & Knott test at a 5% probability level. Experimental precision was analyzed through the coefficient of variation (CV) (PIMENTEL GOME009) and accuracy estimates (RESENDE & DUARTE, 2007).

IV. INDENTATIONS AND EQUATIONS

The coefficient of variation (CV), according to Pimentel Gomes (2009), can be classified as follows: low when less than 10%; medium when between 10% and 20%; high when between 20% and 30%; and very high when above 30%. In this study, the CV was classified as low for the crop cycle (2.04), medium for grain yield (10.99), and very high for lodging (34.34) (Table 1).

Table 1. Joint analysis of variance for grain yield (bags. ha⁻¹), crop cycle (days), and lodging.

Source of Variation	Mean Square Grain Yield	Cycle	Lodging
Genotypes	209.85*	121.04*	1.93*
Location	17562.02*	881.67*	244.37*
Genotypes × Location	137.44*	55.70*	4.37*
Block (Location)	31.38	0.27	1.40
General Mean	55.83	101.87	1.68
Accuracy	0.82	0.96	0.83
CV	10.99	2.04	34.34

*Significant at 5% probability by the F-test. Source: Author, 2024

For the lodging trait, a higher CV estimate was observed. A possible explanation for this low precision is that the magnitude of the mean is inversely related to the CV estimate; that is, a lower mean tends to result in a higher CV.

On the other hand, the evaluation of experimental precision through accuracy estimates eliminates the effect of the mean. Accuracy reflects both the precision of the experimental execution and the presence of variability. Accuracy estimates above 70% are considered of high magnitude (RESENDE & DUARTE, 2007), as was observed for all evaluated traits (Table 1).

From the analysis of variance table, significant variation was observed among genotypes for all evaluated traits. The results also demonstrate a significant difference between locations.

The significant genotype × location interaction indicates that there were differences in the behavior of cultivars across the two environments. This can be attributed to differences in management conditions between the two areas, with the main difference being that one area was irrigated.

Table 2. Phenotypic means for grain yield (bags. ha⁻¹) of 40 soybean genotypes in irrigated and rainfed areas in Porto Nacional, Tocantins.

Genotype	Porto Nacional Irrigated	Porto Nacional Rainfed	Mean
18626INT21777	68.97 a	60.86 a	64.91 a
20283INT355	75.96 a	51.95 a	63.95 a
20285INT1835	69.35 a	56.51 a	62.93 a
WS 069	69.98 a	54.91 a	62.44 a
20161INT127104	73.47 a	50.62 a	62.05 a
182033INT19473	71.84 a	51.62 a	61.73 a
20283INT330	66.3 a	54.1 a	60.2 a
18224INT31266	64.24 a	56.1 a	60.17 a
... *(and so on for all genotypes)*			

Means followed by the same letter belong to the same group according to the Scott-Knott test at 5% probability. Source: Author, 2024

For grain yield, the range of variation in the overall mean was 30.95 bags.ha⁻¹, with 19 genotypes from group "a" standing out as the most productive, showing averages above the national mean of 53.98 bags.ha⁻¹ (CONAB, 2024).

A comparison between the environments (irrigated and rainfed) reveals lower grain yield in the rainfed environment. According to Sentelhas et al. (2016), 77% of potential, attainable, and actual yield losses are associated with water deficits, while 23% are due to poor management.

Table 3. Phenotypic means for crop cycle (days) of 40 soybean genotypes in irrigated and rainfed areas in Porto Nacional, Tocantins.

Genotype	Porto Nacional Irrigated	Porto Nacional Rainfed	Average
20056INT83388	92 a	89 a	91 a
20069INT83970	93 a	88 a	91 a
20046INT6748	93 a	95 b	94 b
18182INT29304	96 a	93 b	95 b
20121INT123637	94 a	98 c	96 b
20355INT237	94 a	102 d	98 c
20285INT1835	95 a	103 d	99 c
20652INT102372	96 a	102 d	99 c
TMG 2379 IPRO	97 b	104 d	100 c
20234INT151467	97 b	102 d	100 c
18610INT21205	97 b	102 d	100 c
20698INT106175	99 b	101 d	100 c
20204INT108701	95 a	106 e	101 c
18224INT31266	97 b	104 d	101 c
20283INT330	99 b	103 d	101 c
HO GUAPÀ I2X	98 b	104 d	101 d
20476INT115870	99 b	104 d	101 d
20021INT5328	99 b	104 d	102 d

20261INT168604	100 b	105 e	102 d
217509I2X263774	100 b	104 d	102 d
182094INT21698	100 b	104 d	102 d
216776I2X266008	99 b	107 e	103 d
WS 070	102 c	104 d	103 d
NEO 790 IPRO	102 c	105 d	103 e
18626INT35452	102 c	105 e	103 e
182033INT19473	101 c	106 e	104 e
20161INT127104	101 c	106 e	104 e
18626INT35452HMC	104 c	105 d	104 e
WS 069	104 c	103 d	104 e
182033INT19349	101 c	108 e	105 e
182056INT41228	102 c	107 e	105 e
20283INT355	102 c	107 e	105 e
BMX Olimpo IPRO	103 c	107 e	105 e
215981I2X264129	97 b	117 f	107 f
217231I2X266546	106 c	108 e	107 f
18388INT10333	108 d	105 d	107 f
20267INT1216	113 e	104 d	108 g
216524I2X266884	97 b	121 g	109 g
18626INT21777	111 e	107 e	109 g
18372INT9826	112 e	105 e	109 g

Mean: **104 a** (irrigated), **100 b** (rainfed).

Means followed by the same letter belong to the same group according to the Scott-Knott test at a 5% probability level.
Source: Author, 2024

A general average variation of 18 days was observed among the genotypes. The genotypes 20056INT83388 and 20069INT83970 were the earliest, with a cycle of 91 days, while genotype 18372INT9826 was the latest, with 109 days. The genotypes tended to be earlier in the rainfed environment.

It was noted that as the average crop cycle decreased, there was also a decline in the overall average productivity (Tables 1 and 2).

The phenotypic correlation test supports this observation. Correlation reflects the degree of association between traits, and understanding it is crucial as it indicates how much one trait influences the expression of others (CRUZ, REGAZZI & CARNEIRO, 2012).

Gesteira et al. (2018) conducted phenotypic correlation tests between grain yield and crop cycle, showing a significant and high correlation (0.7417). This indicates that later cultivars were more productive, although cultivars with shorter cycles and good performance can still be identified.

Choosing early cultivars for soybean-maize succession or second-crop maize after soybean is essential, as early harvesting increases the planting window and optimizes soil and environmental resource use (SILVA NETO, 2011).

Table 4. Phenotypic averages for lodging in 40 soybean genotypes under irrigated and rainfed conditions in Porto Nacional – TO

Genotype	Irrigated	Rainfed	Average
20652INT102372	1.0 a	1.0 a	1.0 a
217231I2X266546	1.0 a	1.0 a	1.0 a
18182INT29304	1.0 a	1.0 a	1.0 a
20069INT83970	1.3 a	1.0 a	1.2 a
18388INT10333	1.3 a	1.0 a	1.2 a
20056INT83388	1.3 a	1.0 a	1.2 a
20355INT237	1.3 a	1.0 a	1.2 a
20161INT127104	1.3 a	1.0 a	1.2 a
20121INT123637	1.3 a	1.3 a	1.3 a
216776I2X266008	1.7 a	1.0 a	1.3 a
20261INT168604	1.7 a	1.0 a	1.3 a
...	...	...	...
HO GUAPÓ I2X	3.3 c	1.0 a	2.2 b
WS 069	3.3 c	1.0 a	2.2 b
18224INT31266	3.7 c	1.0 a	2.3 b
20234INT151467	4.3 d	1.0 a	2.7 c
20267INT1216	5.0 d	1.3 a	3.2 c

Average: **2.3 b (Irrigated) | 1.1 a (Rainfed)**

Note: Means followed by the same letter belong to the same group according to the Scott-Knott test at 5% probability.
Source: Author, 2024.

For lodging, there was no significant variation among the genotypes tested under rainfed conditions. In this case, all genotypes remained upright enough to allow for mechanized harvesting. However, under irrigated conditions, significant variation in this trait was observed. Genotypes in groups "c" and "d" displayed higher lodging scores, which could result in losses during mechanized harvesting due to plant tipping.

When considering the overall lodging average, genotypes belonging to group "a" showed scores that enable mechanized harvesting in both evaluated environments.

Soil type, moisture, fertility, wind, and plant genetics are some of the factors that can directly influence this characteristic. Clayey, wetter, and more fertile soils generally exhibit higher lodging levels compared to other soil types. This characteristic significantly impacts soybean harvesting. As lodging intensifies, harvesting losses increase directly due to the difficulty in collecting lodged plants (MARTINEZ, 2013).

V. CONCLUSION

The earliest genotypes were 20056INT83388 and 20069INT83970, but they did not stand out among the most productive.

The genotypes 20285INT1835, 20204INT108701, 18610INT21205, and 20652INT102372 excelled by combining high grain productivity, absence of lodging, and a crop cycle of 99 to 101 days, which is considered early.

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