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BIOLOGY

Morphological changes in soybean cultivars subjected to apical dominance removal at phenological stages

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ABSTRACT: This study evaluated the effect of removing apical dominance at phenological stages on the agronomic traits of soybean cultivars. The experiment was conducted in the 2020/2021 growing season inthe teaching-experimental area of the Federal Institute of Education, Science and Technology of Rio Grande do Sul, Campus Ibirubá, under a randomized block design in a split-plot arrangement, with three replications. The main plots were composed of five soybean cultivars (DM53i54 IPRO, Zeus IPRO, Lanza IPRO, DM5958 IPRO, and Delta IPRO), and the subplots consisted of the phenological stages of apical dominance removal (control, V2, V4, and V6). Morphological traits were evaluated at different stages. Differences were observed between cultivars, which followed their pre-defined morphologies. Apical dominance removal reduced aspects such as the number of nodes and legumes on the main stem and the first legumeinsertion height. Cultivars developed branching mechanismsas a compensation strategy, increasing the number of legumes on the branches by up to 130%. The removal of the shoot apex can modify morphological aspects in soybean plants,but their yield tends to be maintained.
Key words: pinching, branching, yield components, harvest index, phytohormone.

Alterações morfológicas de cultivares de soja submetidos à remoção da dominância apical em estádios fenológicos

RESUMO: O presente artigo objetiva avaliar o efeito da remoção da dominância apical em estádios fenológicos, nos caracteres agronômicos de cultivares de soja. O experimento foi implantado na área didática-experimental do Instituto Federal de Educação e Tecnologia do Rio Grande do Sul, Campus Ibirubá, na safra 2020/2021, sob delineamento de blocos ao acaso, em arranjo de parcelas subdivididas, com três repetições. As parcelas principais eram compostas pelos cinco cultivares (DM53i54 IPRO, Zeus IPRO, Lança IPRO, DM5958 IPRO e Delta IPRO) e as subparcelas, pelos estádios fenológicos de remoção de dominância apical (testemunha, V2, V4 e V6). As características morfológicas foram avaliadas em diferentes estádios. Como resultados, verificaram-se diferenças entre os cultivares, que seguiram suas morfologias pré-definidas. A remoção de dominância apical, reduziu aspectos como o número de nós e legumes na haste principal, além da altura de inserção do primeiro legume. Como estratégia de compensação, os cultivares desenvolvem mecanismos de ramificação, acrescendo até 130% no número de legumes nos ramos. Verifica-se que a remoção do ápice caulinar é capaz de modificar aspectos morfológicos em plantas de soja, contudo, seu rendimento tende a ser mantido.
Palavras-chave: despontamento, ramificação, componentes de rendimento, índice de colheita, fitormônio.

INTRODUCTION

Soybean (*Glycine max*) is one of the most important crops in Brazil. The growing demand for this product, favorable economic aspects, and the small area of agricultural frontiers to be explored have led to great pressure on breeding programs in the search for high yields (BHUIYAN et al., 2024), tolerance to biotic and abiotic factors (SOUSA et al., 2022; LI et al., 2022), and grains with higher protein content (LIU et al., 2023), among other desired aspects. Plant breeding has been able, in recent years, to create cultivars with taller plants and higher oil and protein contents in the seeds, in addition to changing the days for flowering and maturity, compared to the old cultivars of the South region; although, there are differences between macroregions in Brazil (MILIOLI et al., 2022). However, some of these improved cultivars may be less rustic and have less tolerance to biotic factors, such as pests and diseases, and abiotic factors, such as hail.

The apical meristem, reported at the shoot apex, is an important plant growth point. It produces the auxin, a phytohormone originating from the amino

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acid tryptophan, acting in plant processes such as apical dominance and stem elongation. KERBAUY (2019) calls pinchingor topping the removal of the shoot apex. The shoot apex normally exhibits dominance over the lateral axillary buds during the vegetative growth of plants. If the apex of the stem is cut or broken, the remaining axillary buds are freed from this apical dominance and lateral branches begin to grow. Studies involving the application of plant hormones, such as the direct application of cytokinin on the lateral bud (antagonize the inhibitory effect of auxin) or through strigolactones (negatively affect the synthesis of PIN proteins, involved in auxin transport), have been increasing in soybean and other crops (BERTOLIN et al., 2010).

Plant development depends on a fine adjustment of local auxin gradients (CASSEL et al., 2021).Thus, studies that evaluate the agronomic traits of soybean cultivars in management conditions that change the plant hormonal dynamics are essential. The mechanical removal of the shoot apex has been little reported in the literature although satisfactory production is often reported in commercial plantations even after hail events. From a practical point of view, the mechanical removal of the shoot apex could drive management changesif there is a scientifically proven contribution without affecting crop yield. This may include the selection of genetic materials with the potential to adapt to regional soil and climate conditions, as well as morphological changes that improve the effectiveness of the application of phytosanitary products in the lower third of plants, resulting in better disease control.

In this context, this study evaluated the effect of removing the apical meristem at different phenological stages on the agronomic traits of soybean cultivars.

MATERIALS AND METHODS

The experiment was set up in the 2020/2021 growing season in the teaching and experimental area of the Federal Institute of Education, Science and Technology of Rio Grande do Sul, Campus Ibirubá. The area is located in the physiographic region of the Medium Plateau, Rio Grande do Sul, with a Cfa (humid subtropical) climate (MORENO, 1961), at 416 m above sea level and a south latitude of 28°37′39″ and west longitude of 53°05′23″. The climate data during the field research period showed accumulated precipitation equal to 624.4 mm, while the mean temperature was 22.2 °C. The soil is classified as an Oxisol (Latossolo Vermelho distroférrico típico) (EMBRAPA, 2006). The area used to set up the experiment had been cultivated under the no-tillage system for over 10 years.

The experiment consisted of randomized blocks arranged in a split-plot design withthree replications. The main plots (3.15 m x 16 m) were made up of soybean cultivars and the subplots (3.15 m x 4 m) consisted of soybean phenological stages in which the stem apex of the plants was removed. The plots were composed of seven soybean rows, and the treatments of dominance removal were applied to the three central rows. Only 2 m of these central rows were used for assessments, respecting the border limits.

The evaluated cultivars were DM53i54 IPRO, Zeus IPRO, Lanza IPRO, DM5958 IPRO, and Delta IPRO, which belong to maturation groups 5.4, 5.5, 5.8, 5.8, and 5.9, respectively. The phenological stages of removal of apical dominance, added to a control, were V2, V4, and V6, according to the development scale proposed by FEHR & CAVINESS (1977), referring to the first, third, and fifth trifoliate leaves completely developed, or two, four, and six nodes on the main stem, respectively. This process was conducted through cuts of the shoot apex using scissors, that is, through physical removal.

Sowing was conducted following the population recommended for each cultivar, while fertilization and phytosanitary management practices were carried out according to the technical recommendation for the crop, homogeneously between plots. The cultivars were harvested when they reached physiological maturity, with cuts close to the soil to keep the plants intact for the evaluation of yield components.

The analyses were performed in situ and ex situ (after harvest). Plant height (PH) was evaluated in situ at the R6 phenological stage and consisted of the distance between the soil level to the apex of the stem, in centimeters. The following traits were evaluatedafter final maturation and harvest: first legume insertion (FLI) – distance from the soil level and the insertion of the first legume on the main stem; total number of nodes on the main stem (NMS) – sum of all existing nodes on the main stem; number of legumes on the main stem (LMS) – counting of legumes in the stem; number of legumeson the branches (LB) – counting of legumes in the branches; number of total legumes per plant (TL) – sum of the number of legumes in the branches and main stem of the plant; number of grains per legume (G/L) – the number of grains per plant divided by the number of legumes; number of grains per plant (G/P) – counting of the total number of grains in a plant; thousand-grainweight (TGW) – counting of eight repetitions of 100 grains, averaged and extrapolated to the weight of one thousand grains; and harvest index (HI) – obtained by dividing the grain yield by the biological yield of each replication.

The data were subjected to analysis of variance (ANOVA – F test) at a 5% probability of error and, when significant, the means were compared by the Tukey test at a 5% probability of error.

RESULTS AND DISCUSSION

The differences in the morphological traits of the cultivars were significant for plant height, first legumeinsertion height, number of nodes on the main stem, number of legumes on the main stem and branches, number of legumes and grains per plant, thousand-grain weight,and harvest index (Tables 1 and 2).

These results are due to the predefined morphology of each cultivar, which has different branching habits (ranging from medium to high), in addition to different growth habits and plant heights. HE et al. (2022) emphasized that traits such as the number of legumes (an organ homologous to the leaf) per plant are determinants of grain yield and quality. Therefore, taller plants have more nodes and, consequently, a higher number of legumes, with an increase in the number of grains per plant.

Variables such as thousand-grainweight and the harvest index can influence the yield and efficiency of cultivars in translocating photoassimilates for grain production (PARANHOS et al., 1991). In the present study, these components showed a significant difference between cultivars, in which later cultivars had lower thousand-grain weights and, consequently, lower harvest indices.

Furthermore, the morphology and height of the cultivars are different, significantly affecting the canopy behavior and plant population per hectare. Therefore, these variables can modify the yield of agricultural areas and require further studies regarding the relationships between plant height, production capacity per plant, and density.

The number of grains per legume, thousand-grain weight, and harvest index did not vary statistically considering the phenological stages of apical dominance removal when compared tothe control without pinching (Table 3).

Some of these traits such as the number of grains per legume, are already described as stable within the genetic and phenotypic variations of soybean plants. DURLI et al. (2020) observed no variation in this component regardless of the cultivar or defoliation, corroborating the present study.

The harvest index showed novariation (Table 3). In this sense, plants that had their stem apex removed showed higher branch development but were efficient in grain production, being able to maintain the harvest index. In other words, the plants maintained their biomass through lateral shootseven after pinching, which enabled the maintenance of reproductive organs.

First legume insertion height (cm) was reduced in the most advanced stage of apical dominance removal, reaching a variation of up to 40% relative to the control (Table 3). This component

Table 1 - Summary of the analysis of variance (ANOVA) table for plant height (PH), first legume insertion height (FLI), number of nodes on the main stem (NMS), number of legumes on the main stem (LMS), number of legumes on the branches (LB), number of total legumes per plant (TL), number of grains per legume (G/L), number of grains per plant (G/P), thousand-grain weight (TGW), and harvest index (HI).

SV	DF	---QM---									
		PH	FLI	NMS	LMS	LB	TL	G/L	G/P	TGW	HI
Block	2	92.461*	0.26 ns	27.12*	57.92ns	0.91ns	73.36ns	0.598ns	507.07 ns	1.80 ns	0.009ns
Cultivar (A)	4	1632.21*	42.57*	98.38*	537.44*	993.79*	1081.95*	0.270ns	5683.79*	4563.48*	0.044*
Block*A	8	56.043*	5.07ns	4.24ns	13.57ns	17.15ns	35.53ns	0.226ns	162.81ns	592.30*	0.003ns
Phenological stage (B)	3	37.340*	147.82*	156.06*	1479.53*	1672.92*	329.77*	0.174ns	2311.94*	496.67ns	0.008 ns
A*B	12	41.332*	26.89ns	13.12ns	55.26 ns	262.63*	301.35*	0.274ns	1790.14*	1129.37*	0.024*
Residual	30	12.017	13.47	6.98	48.87	41.15	53.03	0.301	298.23	225.77	0.006
Total	59										

SV = source of variation; DF = degrees of freedom; MS = mean square.
*Significant at a 5% probability of error.
ns Not significant at a 5% probability of error.

Table 2 - Yield components of soybean cultivars DM53i54 IPRO, Zeus IPRO, Spear IPRO, DM5958 IPRO, and Delta IPRO.

Variable	---------------------------Cultivar---------------------------				
	DM53i54 IPRO	Zeus IPRO	Lança IPRO	DM5958 IPRO	Delta IPRO
PH	78.18 e	83.83 d	95.83 c	100.85 b	106.13 a
FLI	11.82 b	13.04 ab	16.49 a	15.40 ab	13.45 ab
NMS	11.40 c	10.21 c	12.74 bc	15.81 ab	16.93 a
LMS	21.03 b	18.14 b	20.53 b	28.14 ab	34.39 a
LB	26.48 b	30.94 b	48.46 a	26.76 b	30.34 b
TL	47.51 b	49.08 b	68.99 a	54.87 b	64.76 a
G/L	2.50^{ns}	2.54	2.47	2.47	2.42
G/P	117.85 b	124.15 b	169.96 a	134.07 a	154.85 a
TGW	202.26 a	203.21 a	183.19 b	183.63 b	155.21 c
HI	0.57 a	0.54 ab	0.54 ab	0.43 c	0.46 bc

Means followed by the same letter in the row do not differ from each other by the Tukey test at a 5% significance.

^{ns}No significant difference between the means by the Tukey test at a 5% significance.

Legend: AP – plant height at R6 phenological stage (cm); FLI – first legume insertion height(cm); NMS – number of nodes on the main stem; LMS – number of legumes on the main stem; LB – number of legumes on the branches; TL – mean number of total legumes per plant; G/L – number of grains per legume; G/P – number of grains per plant; TGW – thousand-grainweight (g); and HI – harvest index.

is directly related to mechanical harvesting, as it determines the adjustment of the cutting height of the combine harvester (MAUAD et al., 2010). In this case, a cutting height below the ideal limit leads to difficulty in collecting the legumes, increasing crop losses. In contrast, plants with very high first legume insertion heights have the production potential reduced, as the lower nodes are only vegetative. REZENDE & CARVALHO (2007) reported that plants suitable for mechanized harvesting have a height between 60 and 120 cm and a first legume insertionheight between 10 and 12 cm.

In addition to the influence of removing apical dominance, other factors are also described as influencing the first legume insertion height. One of them is density, and the higher the density, the higher

Table 3 - Mean yield components of cultivars subjected to apical dominance removal at different phenological stages.

Variable	-----------------Phenological stage of apical dominance removal-----------------			
	Control	V2	V4	V6
PH	92.12 ab	92.80 ab	95.26 a	91.66 b
FLI	16.02 a	16.62 a	13.84 a	9.68 b
NMS	18.03 a	11.09 b	13.26 b	11.30 b
LMS	38.54 a	19.87 b	23.63 b	15.74 b
LB	18.60 c	30.77 b	38.19 a	42.79 a
TL	57.13 ab	50.65 b	61.82 a	58.54 a
G/L	2.48^{ns}	2.48	2.50	2.47
G/P	140.16 ab	123.51b	153.30 a	143.72 a
TGW	189.05^{ns}	190.55	177.71	184.69
HI	0.53^{ns}	0.51	0.52	0.48

Means followed by the same letter in the row do not differ from each other by the Tukey test at a 5% significance.

^{ns}No significant difference between the means by the Tukey test at a 5% significance.

Legend: AP – plant height at R6 phenological stage (cm); FLI – first legumeinsertion height(cm); NMS – number of nodes on the main stem; LMS – number of legumes on the main stem; LB – number of legumeson the branches; TL – mean number of total legumes per plant; G/L – number of grains per legume; G/P – number of grains per plant; TGW – thousand-grainweight (g); and HI – harvest index.

the height at which the legumeis inserted (MAUAD et al., 2010), as plants have higher competition for light, thus tending to higher growth (etiolation) and shading of the lower third (CARMO et al., 2018).

The number of nodes and legumes on the main stem was drastically reduced byremoving the shoot apex (reaching a 38.5% and 59.2% reduction, respectively) (Table 3). In this case, the main stem loses its dominance over the other branches, which showed higher growth capacity and, consequently, higher legume production (130% increase in legume production from the branches). This is a physiological plant response capable of compensating for the reduction in yield in the main stem through increasedyieldin the branches. In this context, TANCREDI et al. (2004) reported that removing apical dominance could stimulate branching in soybean plants grown in pots and increase cultivar yield when conducted at 25 cm in height.

Importantly, the apical dominance exercised over the branches results from the action of the phytohormone auxin. This hormone is produced at the apex and translocated to the base (basipetal transport), causing, in addition to the dominance of the shoot apex over the branches, plant growth and elongation (CASSEL et al., 2021). The plant tends to reduce apical auxin production when the apex is removed and this dominance is overcome, resulting in significant branch growth and a change in plant morphology, which starts to develop grain production mechanisms in the branches seeking to compensate for their reduction in the main stem.

CONCLUSION

Shoot apex removal up to the V6 phenological stage can modify the morphology of soybean plants, requiring further studies to evaluate its influence on yield when it is conducted chemically and/or physically.

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DECLARATION OF CONFLICT OF INTEREST

We have no conflict of interest to declare.

AUTHORS' CONTRIBUTIONS

JLC and DBS conceived and designed the experiments. JLC, GMR, BAM, and DBS performed the experiments. JLC, GMR, BAM, RLL, BDP, and DBS prepared the draft manuscript. All authors critically reviewed the manuscript and approved its final version.

REFERENCES

BERTOLIN D. C. et al. Aumento da produtividade de soja com a aplicação de bioestimulantes. **Bragantia**, v.69, n.2, p.339-347, 2010. Available from: <https://www.scielo.br/j/brag/a/Pq3LJZyT43zwynhCKy7WrXb/?lang=pt>. Accessed: Jun. 25, 2024. doi: 10.1590/S0006-87052010000200011.

BHUIYAN, M. S. H. et al. Increased yield performance of mutation induced Soybean genotypes at varied agro-ecological conditions. **Brazilian Journal of Biology**, v.84, e.255235, 2024. Available from: <https://www.scielo.br/j/bjb/a/zHpbZfjXrLzkY4kFgZrXkZd/?lang=en>. Accessed: Jun. 25, 2024. doi: 10.1590/1519-6984.255235.

CARMO, E. L. et al. Adensamento de plantas e épocas de cultivo de soja em condições de cerrado. **Colloquium Agrariae**, v.14, n.2, p.01-12, 2018. Available from: <https://revistas.unoeste.br/index.php/ca/article/view/2029/2188>. Accessed: Jun. 24, 2024. doi: 10.5747/ca.2018.v14.n2.a201.

CASSEL, J. L. et al. Ação da auxina sobre plantas de soja. **Brazilian Journal of Animal and Environmental Research**, v.4, n.3, p.4628-4643, 2021. Available from: <https://ojs.brazilianjournals.com.br/ojs/index.php/BJAER/article/view/36600>. Accessed: Jun. 24, 2024. doi: 10.34188/bjaerv4n3-142.

DURLI, M. M. et al. Defoliation levels at vegetative and reproductive stages of soybean cultivars with different relative maturity groups. **Revista Caatinga**, v.33, n.2, p.402–411, 2020. Available from: <https://www.scielo.br/j/rcaat/a/WYvmtVh3kpRcFSkdhDnbD4w/?lang=en>. Accessed: Jun. 24, 2024. doi: 10.1590/1983-21252020v33n213rc.

FEHR, W. R. CAVINESS, C. E. **Stage of soybean development**. Ames: Iowa State University os Science and Technology, 11p., 1977. (Special Report, 80). Available from: <https://dr.lib.iastate.edu/entities/publication/58c89bfe-844d-42b6-8b6c-2c6082595ba3>. Accessed: Jun. 24, 2024.

HE, H. et al. A calculation method of phenotypic traits of soybean pods based on image processing technology. **Ecological Informatics**, v.69, e.101676, 2022. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S1574954122001261?via%3Dihub>. Accessed: Jun. 25, 2024. doi: 10.1016/j.ecoinf.2022.101676.

KERBAUY, G. B. **Fisiologia vegetal**. Guanabara Koogan: Rio de Janeiro, 3ed., 430p., 2019.

LI, G. et al. Identification of the soybean small auxin upregulated RNA (SAUR) gene family and specific haplotype for drought tolerance. **Biologia**, v.77, n.4, p.1197-1217, 2022. Available from: <https://link.springer.com/article/10.1007/s11756-022-01010-0>. Accessed: Jun. 25, 2024. doi: 10.1007/s11756-022-01010-0.

LIU, S. et al. Genetic mapping and functional genomics of soybean seed protein. **Molecular Breeding**, v.43, n.4, 2023. Available from:

<https://link.springer.com/article/10.1007/s11032-023-01373-5>. Accessed: Jun. 25, 2024. doi: 10.1007/s11032-023-01373-5.

MAUAD, M. et al. Influência da densidade de semeadura sobre características agronômicas na cultura da soja. **Revista Agrarian**, v.3, n.9, p.175-181, 2010. Available from: <https://ojs.ufgd.edu.br/index.php/agrarian/article/view/75>. Accessed: Jun. 25, 2024.

MILIOLI, A. S. et al. Genetic improvement of soybeans in Brazil: South and Midwest regions. **Crop Science**, v.62, n.6, p.2276-2293, 2022. Available from: <https://acsess.onlinelibrary.wiley.com/doi/10.1002/csc2.20820>. Accessed: Jun. 25, 2024. doi: 10.1002/csc2.20820.

PARANHOS, J. T. et al. Rendimento de grãos, índice de colheita e componentes do rendimento de três cultivares de arroz irrigado. **Ciência Rural**, v.21, n.2, p.169–177, 1991. Available from: <https://www.scielo.br/j/cr/a/XnDZPYXrqS4nsGQqXBdBWck/?lang=pt>. Accessed: Jun. 25, 2024. doi: 10.1590/S0103-84781991000200002.

REZENDE, P. M.; CARVALHO, E. A. Avaliação de cultivares de soja [Glycine max (L.) Merrill] para o sul de Minas Gerais. **Ciência e Agrotecnologia**, v.31, n.6, p.1616–1623, 2007. Available from: <https://www.scielo.br/j/cagro/a/P3BvZcjYffsqY7DdsHKBS5c/?lang=pt>. Accessed: Jun. 25, 2024. doi: 10.1590/S1413-70542007000600003.

SOUSA, C. C. D. et al. Associative mapping for exotic soybean germplasm grain yield in high temperatures. **Revista Caatinga**, v.35, n.3, p.567–573, 2022. Available from: <https://www.scielo.br/j/rcaat/a/NXKsbykgMChtsKddBTGsmrp/?lang=en>. Accessed: Jun. 25, 2024. doi: 10.1590/1983-21252022v35n307rc.

TANCREDI, F. D. et al. Influência da remoção do meristema apical sobre os componentesde produtividade em populações de plantas de soja. **Acta Scientiarum Agronomy**, v.26, n.1, p.113-119, 2004. Available from: <https://periodicos.uem.br/ojs/index.php/ActaSciAgron/article/download/1968/1321/>. Accessed: Jun. 25, 2024.