Scientia Agraria Paranaensis – Sci. Agrar. Parana.
ISSN: 1983-1471 – Online
DOI: https://doi.org/10.18188/sap.v19i4.25335

# PERFORMANCE OF SOYBEAN PLANTS SUBJECT TO WATER DEFICIT IN DIFFERENT DEVELOPMENT STAGES

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SAP 25335 Received: 12/06/2020 Accepted: 20/10/2020
Sci. Agrar. Parana., Marechal Cândido Rondon, v. 19, n. 4, oct./dec., p. 373-3, 2020

**ABSTRACT** - Soybean plants are constantly exposed to abiotic stresses that compromise production, among these, in areas of Brazilian Cerrado, mainly in the northeast region, periods of drought can occur due to irregular and summer rainfall. Thus, the objective of this work was to determine the physiological response of Monsoy 9350 soybean at different stages of development, when subjected to water stress. The experiment was conducted in a greenhouse, in the experimental area of the campus of the Universidade Federal do Piauí (UFPI) in Bom Jesus-PI, assembled in a 3x3 factorial scheme, with water in the soil at three levels (50% VTP; 75% VTP and 100% VTP) and three phenological phases, budding to bloom (BF); bloom to complete grain filling (FE) and budding to complete grain filling (BE), the experiment consisted of 9 treatments, in a randomized block design, containing 4 replications. The evaluation of the experiment was standardized according to the phenological stages and not according to the time. The following variables were evaluated: plant height, internode length, internode thickness, number of branches, chlorophyll index, number of flowers, insertion of the first pod and number of pods. According to the evaluated results, the water stress in soybean for cultivating Monsoy 9350 mainly affects the period from budding to bloom, interfering negatively in height, chlorophyll and number of pods.
**Keyword:** *Glycine max* L., water stress, physiological parameters, soil moisture.

# *DESEMPENHO DE PLANTAS DE SOJA SUBMETIDO À DÉFECIT HÍDRICO EM DISTINTOS ESTÁDIOS DE DESENVOLVIMENTO*

**RESUMO** - As plantas de soja estão expostas constantemente a estresses abióticos que comprometem a produção, dentre esses, em áreas de cerrado do país, principalmente na região nordeste, podem ocorrer períodos de seca decorrentes de precipitações pluviométricas irregulares e veranicos. Com isso, objetivou-se com esse trabalho determinar a resposta fisiológica de soja Monsoy 9350 em distintos estádios de desenvolvimento, quando submetido ao estresse hídrico. O experimento foi conduzido em casa de vegetação, na área experimental do campus da Universidade Federal do Piauí (UFPI) em Bom Jesus-PI, montado em esquema fatorial 3x3, com a água no solo em três níveis (50% VTP; 75% VTP e 100% VTP) e três fases fenológicas, o botoamento até à floração (BF); florescimento até o enchimento completo dos grãos (FE) e botoamento até o enchimento completo dos grãos (BE), o experimento constou de 9 tratamentos, em delineamento experimental em blocos casualizados, contendo 4 repetições. A avaliação do experimento foi padronizada em função dos estádios fenológicos e não em função do tempo. Sendo avaliado as seguintes variáveis: altura da planta, comprimento do entrenó, espessura do entrenó, número de ramos, índice de clorofila, números de flores, inserção da primeira vagem e número de vagens. De acordo com os resultados avaliados, o estresse hídrico em soja para cultivar Monsoy 9350 afeta principalmente o período que compreende do botoamento ao florescimento, interferindo de forma negativa na altura, clorofila e número de vagens.
**Palavra-chave:** *Glycine max* L., estresse hídrico, parâmetros fisiológicos, umidade do solo.

## INTRODUCTION

The Brazilian Cerrado stands out as a new dimension in the agricultural scenario. It is responsible for a large part of the arable area in the country. The region predominates as demanding crops for soybeans, upland rice, cotton and corn. However, scientific progress in relation to the production of soybean cultivars, the development and yield of this crop can be limited by water deficit during different stages of development (ZANDONÁ et al., 2015).

Soybean is the main source of income for the country and for rural producers, as it has led the ranking of the most exported products for over 22 years, that is, since Brazil started to register and disclose sales data abroad. In recent years, the crop has been gaining even more space, due to the almost guaranteed profitability of crops. Its production chain is responsible for one third of the agribusiness of the country, which is the second largest producer of the world and exporter of grains of this oilseed and accounts for 31.7% of world production, preceded

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only by the United States (AGRIANUAL, 2019; CONAB, 2019).

The water availability is considered the climatic factor with the greatest effect on agricultural productivity (FIOREZE et al., 2011). The soybean culture is usually, during some period of its cycle, subject to water stress, which can affect its mechanisms of capture and use of resources at different stages of development. Several works have been developed aiming to know the interaction between the availability of water and agricultural crops, especially with the intention of differentiating sensitive and drought-tolerant cultivars, seeking better adaptation of these to the most diverse environments.

In the soybean culture, several studies prove that the reproductive period is the most sensitive to water deficit. However, there is no consensus among the authors as to the most critical stage/ stages for low soil moisture. The need for water in soybean increases with the development of the plant, reaching the maximum in flowering-filling of grains and decreases after this phenological stage. Expressive water deficits during such stages cause physiological changes in the plants, causing premature fall of leaves and flowers and miscarriage of pods, in addition to reducing grain productivity (GAVA et al., 2015). Thus, the search for soy cultivars that are more tolerant to drought as well as a better understanding of the mechanisms of tolerance to water stress has been a constant focus of current research.

The studies of water relations in plants and the interactions caused by temporary water deficit in physiological processes are such important, since water deficit has effects on several physiological processes in plants, many of which reflect adaptation mechanisms. Knowing the variation of water consumption by a crop in its different stages of development, it is possible to infer about the physiological aspects involved in the process, as well as about its consequences. (PEIXOTO et al, 2006).

The effect of water deficit in cultivated plants affects, in complex ways, practically all aspects of growth, including anatomical, morphological, physiological and biochemical changes. However, the damage depends on its duration and severity, as well as the stage of development at which it occurs. The most critical period of some legumes (beans and soybeans) to water deficiency coincides with the phase of greater water consumption by the plant.

Given the above, the objective was to determine the physiological response of Monsoy 9350 soybean at different stages of development, when subjected to different levels of water stress.

## MATERIAL AND METHODS

The experiment was conducted in a greenhouse with an arc roof and galvanized iron structure, covered with shade (50% shading), arranged in the East-West direction, in the experimental area of the Universidade Federal do Piauí (UFPI) campus in Bom Jesus-PI, at 09º04’28” South latitude and 44º21’31” West longitude and with an average altitude of 277 m. The climate of region is Aw type according to the Köppen global climate classification, with two seasons well defined. A drought that lasts from May to September and another rainy one that lasts from October to April.

The soybean plants, cultivar Monsoy 9350 were grown in a greenhouse, in 10 L pots, containing Oxisol as substrate. According to the analysis of the soil samples, the substrate contained: 76 g $kg^{-1}$ of clay, availability of exchangeable bases of 14.8 cmolc $dm^{-3}$; 13% base saturation; availability of 2.1 mg $dm^{-3}$ phosphorus; cation exchange capacity of 115.8 mmolc $dm^{-3}$; 10 g $dm^{-2}$ of organic matter; 2.1 mg $dm^{-3}$ of phosphorus; 1.2 mmol $dm^{-3}$ of potassium; 10 mmol $dm^{-3}$ of calcium; 3 mmol $dm^{-3}$ of magnesium; 3 mmol $dm^{-3}$ of aluminum; 0.1 mg $dm^{-3}$ of copper; 28 mg $dm^{-3}$ of iron and 0.3 mg $dm^{-3}$ of zinc.

Fertilization for planting and covering was carried out according to the liming and fertilization recommendation manual for the state of Ceará. The soil was broken up, sieved and physically characterized (TEIXEIRA et al., 2017). The average values, resulting from four repetitions for particle density, soil density, total porosity and soil moisture for the calculation of water levels, were 2.35 kg $dm^{-3}$; 1.15 kg $dm^{-3}$; 51.06% and 12.31%, respectively.

To establish water stress, three water levels N1-50%, N2-75% and N3-100% of the total pore volume (VTP) were used, defined from the total porosity of the soil, according to the methodology described by Freire et al. (1980). The three phenological phases were: budding to bloom (BF); bloom to complete grain filling (FE) and budding to complete grain filling (BE).

The experiment was carried out in a 3x3 factorial scheme, with water in the soil at three levels (50% VTP; 75% VTP and 100% VTP) and the development stages at three levels (BF; FE and BE), in a block design randomized with 4 repetitions. The experiment consisted of 9 treatments (Table 1). At sowing, four soybean seeds were placed per pot and all treatments with 100% VTP occupied by water, to guarantee germination. One week after germination, thinning was done, leaving two plants per pot by cutting the plants close to the soil.

The water deficit levels started, from the moment when 50% of the plants were in the beginning of the appearance of the first flower buds. Once the stage of development of each treatment was completed, the water level was returned and maintained at 100% of the VTP. For this, the vessels were weighed, daily on a scale with a sensitivity of one gram to replace evapotranspirated water, according to Freire et al. (1980). The distribution of plants in the pots was in line, with a spacing of 0.10 m between plants in the line and 0.40 m between lines, resulting in a density of 9.55 plants per linear meter and 238,853 plants per hectare. This value is within the range of 180,000 to 240,000 plants per hectare, the range used by farmers.

The evaluation of the experiment was standardized according to the phenological stages and not according to the time. The following parameters were evaluated: plant height (AP), internode length (CEN), internode thickness (EEN), number of branches (N°RAM), chlorophyll index (IC), number of flowers (N°FL), insertion of the first pod (IPV), number of pods (N° VG).

The data were submitted to analysis of variance by the "F" test, for diagnosis of significant effect, and the treatments compared to each other by the Tukey test, at 5% probability of error. For interaction between the factors, simple regression analysis was applied following the recommendations of Banzatto and Kronka (2006). The SISVAR® statistical programs (FERREIRA, 2014) were used for the purpose of comparing means.

**TABLE 1 -** Characterization of treatments, that is, combinations between water levels and crop development stages.

| Treatments | Soil water levels | Development stages |
|---|---|---|
| 1-N1BF | 50% VTP | Budding to Bloom |
| 2-N2BF | 75% VTP | Budding to Bloom |
| 3-N3BF | 100% VTP | Budding to Bloom |
| 4-N1FE | 50% VTP | Bloom to complete grain filling |
| 5-N2FE | 75% VTP | Bloom to complete grain filling |
| 6-N3FE | 100% VTP | Bloom to complete grain filling |
| 7-N1BE | 50% VTP | Budding to complete grain filling |
| 8-N2BE | 75% VTP | Budding to complete grain filling |
| 9-N3BE | 100% VTP | Budding to complete grain filling |

## RESULTS AND DISCUSSION

According to the results of the analysis of variance presented in Table 2, significant differences were observed between water levels for the variables plant height, chlorophyll and number of flowers. Since for the analysis of development stages, significance was also observed for the same variables mentioned above. According to the table of analysis of variance, it was found that there was a significant interaction between the water levels and the stages of development of the plant, it is represented in Figure 1, the interactions.

**TABLE 2 -** Height of plants (AP), internode length (CEN), internode thickness (EEN), number of branches (N°RAM), chlorophyll index (IC), number of flowers (N°FL), insertion of the first pod (IPV), number of pods (N°VG). Phytotechnical and productive analysis of soybean plants as a function of water levels and different phenological stages.

| Variations | AP | CEN | EEN | N°RAM | IC | N°FL | IPV | N°VG |
|---|---|---|---|---|---|---|---|---|
| | ($cm^{-1}$) | ($cm^{-1}$) | ($cm^{-1}$) | ---- | (%) | ---- | ($cm^{-1}$) | ---- |
| Levels (N)("f") | 35,23** | $0.06^{ns}$ | $0,12^{ns}$ | $2,37^{ns}$ | 46,23** | 105,42** | $0,73^{ns}$ | $3,54^{ns}$ |
| N1 | 68,40b | 36,15a | 13,55a | 9,64a | 26,62c | 14,94b | 14,62a | 17,65a |
| N2 | 77,34a | 35,72a | 13,37a | 9,58a | 33,80b | 24,57a | 14,13a | 23,98a |
| N3 | 77,98a | 35,61a | 13,47a | 10,37a | 37,57a | 26,69a | 13,58a | 25,08a |
| DMS | 3,18 | 4,05 | 0,91 | 1,01 | 2,88 | 2,15 | 2,15 | 7,51 |
| Stages (E)("f") | 41,53** | $1,22^{ns}$ | $0,24^{ns}$ | $2,75^{ns}$ | 19,53** | $35,53^{ns}$ | $0,09^{ns}$ | $0,23^{ns}$ |
| E1 | 73,60b | 35,02a | 13,59a | 9,65a | 30,50b | 18,53c | 13,94a | 21,63a |
| E2 | 80,81a | 35,17a | 13,47a | 10,41a | 30,66b | 21,88b | 14,07a | 23,42a |
| E3 | 69,30a | 37,29a | 13,33a | 9,53a | 36,84a | 25,79a | 14,32a | 21,66a |
| DMS | 3,18 | 4,05 | 0,91 | 1,01 | 2,88 | 2,15 | 2,15 | 7,51 |
| CV (%) | 4,19 | 11,12 | 6,66 | 10,06 | 8,67 | 9,57 | 15,00 | 33,16 |
| (N) x (E) | 12,37** | $1,30^{ns}$ | $0,53^{ns}$ | $0,61^{ns}$ | 2,95* | 10,59** | $1,04^{ns}$ | $0,51^{ns}$ |

* e ** = significant at 5 and 1% probability, respectively, ns = not significant, DMS = minimum significant difference, CV = coefficient of variation, N = levels, E = stages.

In the BF stage, the levels of 75% and 100% significantly affected the plant height, so it is not necessary to raise the water level to obtain an average height of 77 cm, so the same value was found when comparing the two levels 75% and 100%. The reduction of water availability to the level of 50% significantly reduced, when compared to the other treatments, the height of the plant 66 cm in the BF. In the phonological stage of FE, the level of 100% had the highest height 89% followed by the level of 75%. For the BE stage, the level of 75% obtaining a larger size for the analyzed variety.

The effect of water deficit on the plant is quite dynamic, affecting practically all aspects of growth. In the soybean culture, several researches prove that the reproductive period is the most sensitive to the water deficit. However, there is no consensus among the authors as to the most critical stage/stages. The need varies according to the development of the plant, confirming the effects of the treatments applied in the present work.

In a condition of water deficit, one of the primary effects triggered in plants is cellular dehydration, which consequently causes a reduction in the pressure potential (turgor) and in the cell volume. This condition triggers side effects, such as the accumulation of ion concentration in the cytosol, becoming cytotoxic, as they cause protein denaturation and membrane destabilization, which can culminate in cell death (TAIZ et al., 2017). Furthermore, height is a variable of great importance for mechanized agriculture, affecting the regulation of equipment for harvesting, since plants of irregular size can cause significant losses in the harvest (BARDHI et al., 2013).

When analyzing the variable number of branches, according to the analysis of variance (Table 2), it was found that, there was no interaction between water levels and the stages of plant development, that is, regardless of the water level used, the studied variety showed a similar performance in terms of number of branches, being probably a genetic characteristic of the variety.

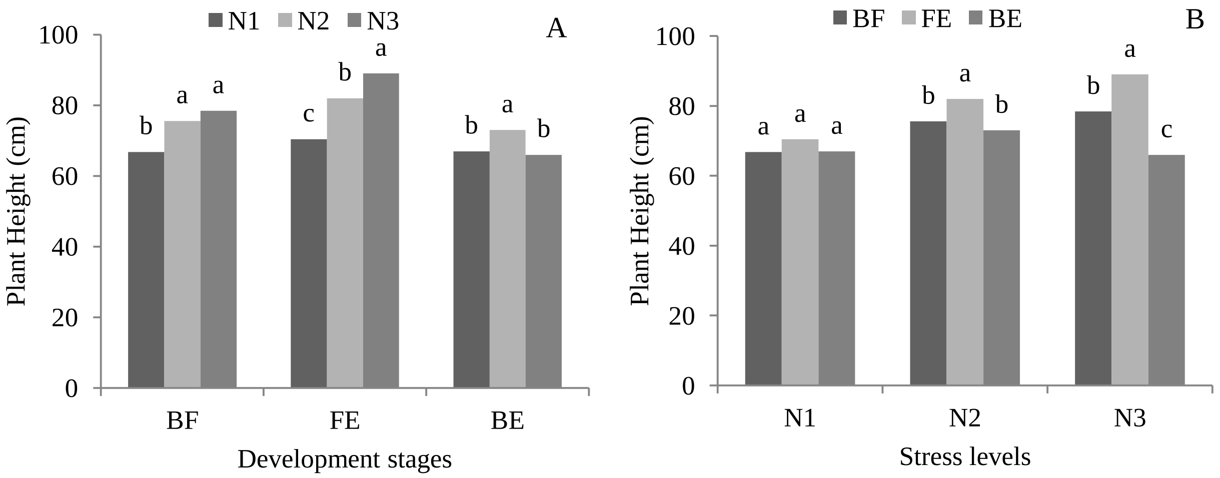


**FIGURE 1 -** Significant interactions of the analysis of variance regarding the height of the soybean plant. N1 = 50%, N2 = 75% and N3 = 100% of the total pore volume. Budding to bloom (BF); bloom to complete grain filling (FE) and budding to complete grain filling (BE). Bars with the same lowercase and uppercase letters do not differ.

In view of the chlorophyll index (Figure 2), it was observed that all stages were influenced by the water levels applied in each treatment. It is noticeable that regardless of the stages of development, in the treatments containing 100% of the VTP there were significant differences in relation to the others, and it can be diagnosed that the level presented an ideal value for the development of the soybean plant in all physiological stages. The water deficit is characterized as one of the environmental stresses responsible for the loss of pigments in the leaves, causing the cycle and life of the plant to be altered. In addition, the relationship between chlorophyll a and b in terrestrial plants can be used as an indicator of response to shading and premature senescence, and the relationship between chlorophyll and carotenoids is used to a lesser extent to diagnose the senescence rate under water stress (TAIZ et al., 2017).

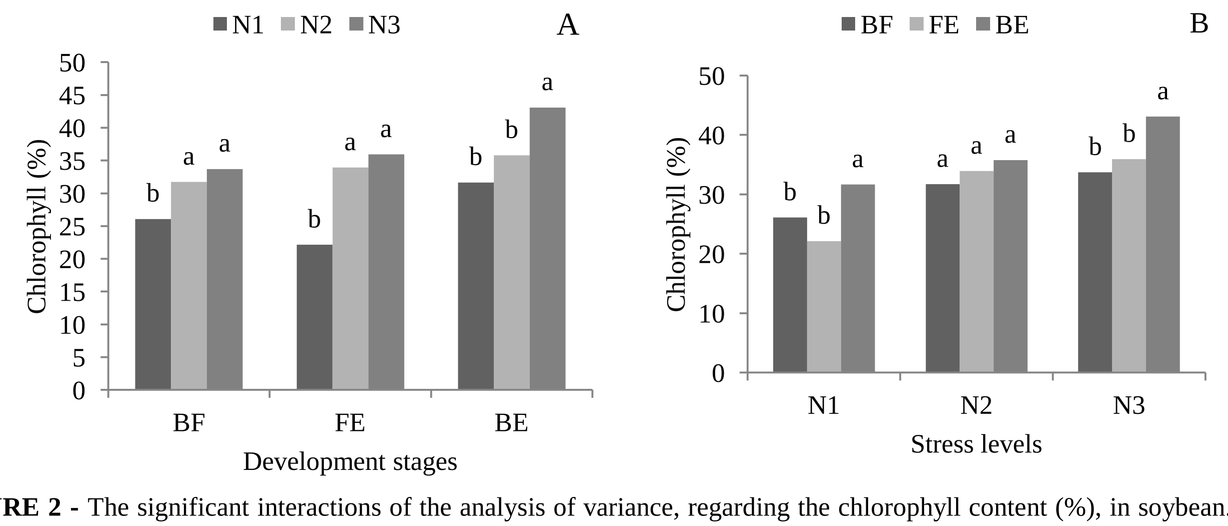


**FIGURE 2 -** The significant interactions of the analysis of variance, regarding the chlorophyll content (%), in soybean. N1 = 50%, N2 = 75% e N3 = 100% of the total pore volume. Budding to bloom (BF); bloom to complete grain filling (FE) and budding to complete grain filling (BE). Bars with the same lower and upper case letters do not differ.

For the variable number of flowers, it was observed that from budding to bloom, there was a reduction in the values of this variable when the most severe stress (N1) was used (Figure 3A). However, the other two levels of applied stress did not differ statistically. However, the other two levels of applied stress did not differ statistically. Water stress reduces cell expansion and, consequently, leaf expansion and flowers, promoting a smaller leaf area, aiming at decreasing the rate of transpiration, thus conserving a limited water supply in the soil for a longer period (TAIZ et al., 2017).

In the stage from bloom to grain filling, there was a proportional reduction in the number of flowers according to the decrease in the amount of water available to the plant (Figure 3A). Similar results were found by Rodrigues et al. (2018), when they evaluated water stress in soybean and observed a reduction in the number of reproductive structures. When the whole soybean cycle (BE) is observed, there is a reduction in flowers when the greatest water stress (N1) is applied, however, the two levels that follow, N2 and N3, did not differ significantly.

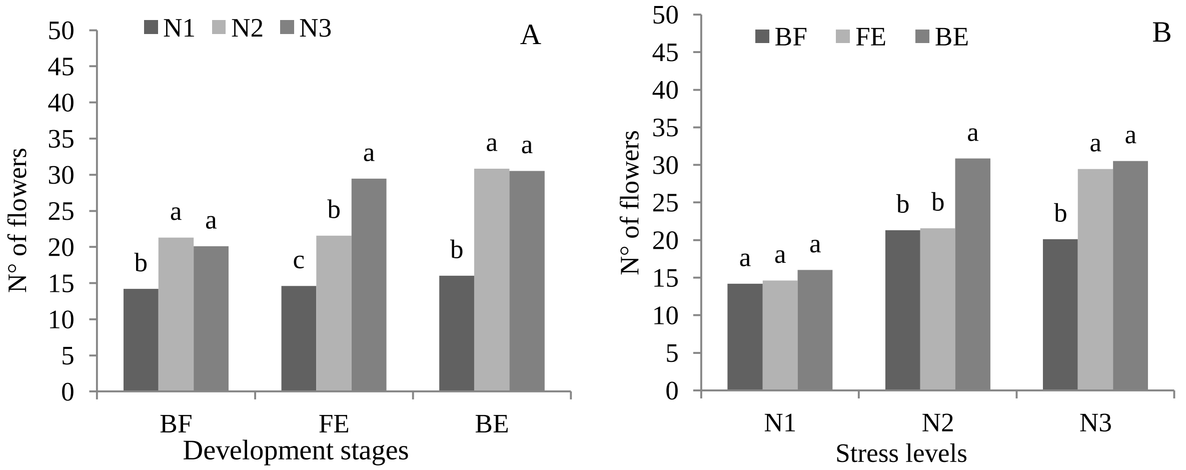


**FIGURE 3 -** Breakdown of the significant interactions of the analysis of variance, referring to the number of soybean flowers. N1 = 50%, N2 = 75% and N3 = 100% of the total pore volume. Budding to bloom (BF); bloom to complete grain filling (FE) and budding to complete grain filling (BE). Bars with the same lowercase and uppercase letters do not differ.

When analyzing the stages of development within each stress level, it is clear as a whole that greater availability of water in the soil favored the formation of flowers. In N1, there was no difference between the stages (Figure 3B), when observing N2, a significant difference was observed in the BE stage, in relation to the other two stages, BF and FE, which did not differ between them. The treatments that received 100% of VTP had the values of number of flowers increased in the stage of bloom to the filling of grains (FE), as well as in (BE), period that comprises the entire cycle of the plant (Figure 3B).

According to Fietz and Urchei (2002), the stage in which the plant needs more water is from bloom to grain filling, and expressive water deficits during such stages cause physiological changes in the plants, causing premature fall of leaves and flowers. Water stress causes changes in the anatomy, physiology and biochemistry of plants, with intensity depending on the type of plant and the degree of duration to which they have been subjected to stress (ARAÚJO et al., 2010), which can affect all their stages of development, starting from the germination of the seeds and, consequent stabilization of the stand (BALARDIN et al., 2011), until the development and productivity (TAIZ et al., 2017; BILIBIO et al., 2010).

In general, water stress causes reduction in development and productivity when applied to the total soybean crop cycle. However, the study and applicability of different levels of water deficit can be evaluated, through new works, favoring more responses and thus more possibilities in the production strategy and in the conduction of plants in the field exposed to water stress, due to the prolonged summer periods more frequent, mainly in the cerrado region.

## CONCLUSION

The water stress in soybean for the cultivar Monsoy 9350 mainly affects the period from budding to bloom, interfering negatively in height, chlorophyll and number of pods.

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