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Ecophysiological aspects and biomass production of soybean genotypes under soil flooding stress conditions[1]

Aspectos ecofisiológicos e produção de biomassa de genótipos de soja sob condições de estresse por alagamento do solo

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HIGHLIGHTS:
PELBR 17-46 and PELBR 15-7016 genotypes are more sensitive to flooding stress in the vegetative and reproductive stages.
Soil flooding negatively affects the biomass production of soybean genotypes.
The 75I77RSF IPRO genotype is the most suitable for cultivation under flooding stress conditions.

ABSTRACT: The objective of this study was to evaluate the ecophysiological aspects and biomass production of three soybean genotypes subjected to soil flooding in the vegetative and/or reproductive stages. The design adopted was completely randomized with 5 replications, in a 3 x 3 factorial arrangement, with three soybean genotypes: PELBR 17-46, PELBR 15-7016, and 75I77RSF IPRO; and three water treatment conditions: soil flooding for 10 days in the vegetative period + 10 days in the reproductive period; soil flooding for 10 days only in the reproductive period, and the control treatment, where the soil was maintained at 70% of field capacity. There was a reduction in the relative water content for the PELBR 15-7016 and PELBR 17-46 genotypes in the vegetative/reproductive stages and in the reproductive stage, while for the 75I77RSF IPRO there was no difference. The levels of chlorophyll a, chlorophyll b, and total chlorophyll were reduced only for the PELBR 15-7016 and 75I77RSF IPRO genotypes. The dry matter in the leaves and roots was lower for PELBR 17-46 and PELBR 15-7016 when subjected to stress in the R2 soybean stage and for the grain production. PELBR 17-46 and PELBR 15-7016 genotypes are more susceptible to stress, while the 75I77RSF IPRO showed mechanisms to overcome waterlogging stress.

Key words: *Glycine max* (L.) Merr., hypoxia, morphophysiological adaptation, abiotic stresses, waterlogging

RESUMO: O objetivo deste trabalho foi avaliar aspectos ecofisiológicos e produção de biomassa de genótipos de soja submetidos ao alagamento do solo nas fases vegetativa e/ou reprodutiva. O delineamento adotado foi o inteiramente casualizado com 5 repetições, em arranjo fatorial 3 x 3, com três genótipos de soja: PELBR 17-46, PELBR 15-7016 e 75I77RSF IPRO; e três condições de tratamento de água: alagamento do solo por 10 dias no período vegetativo + 10 dias no período reprodutivo; alagamento do solo por 10 dias apenas no período reprodutivo, e o tratamento testemunha, onde o solo foi mantido a 70% da capacidade de campo. Houve redução no teor relativo de água para os genótipos PELBR 15-7016 e PELBR 17-46 no vegetativo/reprodutivo e no reprodutivo, enquanto para 75I77RSF IPRO não houve diferença. Os teores de clorofila a, b e total foram reduzidos apenas para os genótipos PELBR 15-7016 e 75I77RSF IPRO. A matéria seca nas folhas e raízes foram menores para PELBR 17-46 e sensíveis quando submetidos ao estresse no estádio R2 da soja e para a produção de grãos. Os genótipos PELBR 17-46 e PELBR 15-7016 são mais suscetíveis ao estresse, enquanto o 75I77RSF IPRO apresentou mecanismos para superar o estresse por encharcamento.

Palavras-chave: *Glycine max* (L.) Merr., hipóxia, adaptação morfofisiológica, estresses abióticos, alagamento

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Introduction

Soybean plants constitute an important source of protein and oil for humans, animals, and various industrial products, with a total grain production of approximately 341 million tons worldwide (USDA, 2019).

Agriculture around the world is constantly challenged by the increasing incidence of adverse weather events, as a consequence of global warming. Extreme events that alter water availability, such as droughts and floods, pose major threats to food security (Balasundram et al., 2023). Thus, temporary or permanent conditions of flooding (formation of a water layer) or waterlogging (saturation with water) of the soil are global problems that can bring serious damage to agricultural development.

The negative impacts of flooding on soybean crops are mainly a consequence of the slow diffusion rates of gases and the relatively low solubility of O_2 in water (Zhou et al., 2020). One of the most serious problems faced by plants subject to soil waterlogging is the energy deficit as a result of the inhibition of root respiration caused by the lack of O_2; in this situation, plant development is impaired. Because of the lack of oxygen, a series of disturbances in the metabolism of plants occur, which are manifested through alterations in growth and development. These alterations seem to be related to tolerance mechanisms, leading to a metabolic, anatomical and/or morphological adjustment, which allows plants to survive for longer periods under these conditions (Yang et al., 2021). Chandra et al. (2020) analyzed 28 soybean genotypes in the reproductive stage (R1 stage) under flooding conditions and observed that some genotypes tested showed potential and desired characteristics to tolerate flooding stress.

Therefore, the objective of this study was to evaluate the ecophysiological aspects and biomass production of three soybean genotypes subjected to soil flooding in the vegetative and/or reproductive stage.

Material and Methods

The experiment was carried out in a greenhouse (height of 4 m and sides closed with shades), located in the experimental garden of the Universidade Federal do Acre - UFAC, located in the city of Rio Branco - Acre, Brazil (9°53′16″S, 67°49′11″W), from November 2020 to February 2021. Climatic data were collected daily inside the greenhouse using a digital thermo-hygrometer, recording an average air temperature of 25.2 °C and relative air humidity of 86.1% during the experiment.

The design adopted was completely randomized (CRD) with 5 replications (one plant per plot), in a 3 x 3 factorial arrangement, with three soybean genotypes: PELBR 17-46, PELBR 15-7016, and 75I77RSF IPRO; and three water treatment conditions: soil flooding for 10 days in the vegetative period + 10 days in the reproductive period; soil flooding for 10 days only in the reproductive period, and the control treatment, where the soil was maintained at 70% of field capacity throughout the plant cycle.

The field capacity for water treatments was previously established as the water content retained by the dry substrate after undergoing saturation and subsequent drainage of the excess water. The physicochemical analysis of the substrate used is presented in Table 1. The mass of water retained in the substrate was considered as 100% of the field capacity - FC (Cairo, 1995). Based on this parameter, 70% of the FC was established for the irrigation of the pots. Irrigation management was carried out by weighing the pots daily and replacing the volume of transpired water, using a digital scale (ELGIN DP-15 Plus).

Sowing was performed in pots with capacity of 8 L, containing substrate of a mixture of vegetable soil and washed sand, in the proportion of 1:1 (v/v). Before sowing, the seeds were inoculated with the commercial product Peat Inoculum Masterfix Soja® at a dose of 100 g in 50 kg of seeds, at a concentration of 5 x 109 colony forming units (CFU) of *Bradyrhizobium japonicum* and *Bradyrhizobium elkanii* per gram. During the crop cycle, up to the V2 stage, second node, the pots were maintained at 70% of field capacity. No fertilizers were provided during the execution of the experiment.

The application of the water layer was carried out in two moments of the plant: at the phenological stage V2, repeating in the same plots, later for more ten days at stage R2; and other plots received substrate flooding only at the R2 stage, for ten days.

During the flowering period, leaf discs were collected and the relative water content, damage to the membrane and levels of photosynthetic pigments (chlorophyll a, chlorophyll b, total chlorophyll, and carotenoids) were evaluated. At the end of the experiment, the dry matter production was evaluated.

To determine the relative water content (RWC) (Cairo, 1995), 10 discs were removed from the youngest fully developed leaf and immediately weighed on a precision scale (FM), then placed to saturate by immersing in deionized water for 48 hours at 4 °C and in the dark. After this period, the discs were weighed again to obtain the turgid matter mass (TM). Subsequently, these discs were placed in a forced air circulation oven at 65 °C and kept until reaching constant mass, and, after this period, they were weighed to determine the dry matter mass (DM).

The RWC was obtained from the formula:

$$\mathrm{RWC} = \frac{\mathrm{FM} - \mathrm{DM}}{\mathrm{TM} - \mathrm{DM}} \times 100$$

where:

FM - fresh mass;

Table 1. Physicochemical characteristics of the substrate used in the experiment

Physical	Value	Fertility	Value
Sand (kg kg^{-1})	0.81	pH in water (1: 2.5)	7.11
Silt (kg kg^{-1})	0.14	P (mg dm^{-3})	104.7
Clay (kg kg^{-1})	0.05	K^+ (mg dm^{-3})	177.4
		Na^+ (mg dm^{-3})	16.4
		Ca^{2+} ($cmol_c$ dm^{-3})	3.20
		Mg^{2+} ($cmol_c$ dm^{-3})	1.10
		Al^{3+} ($cmol_c$ dm^{-3})	0.00
		H+Al ($cmol_c$ dm^{-3})	0.00
		BS ($cmol_c$ dm^{-3})	4.83
		CEC ($cmol_c$ dm^{-3})	4.83

BS - Sum of bases; CEC - Cation exchange capacity

DM - dry mass; and,
TM - turgid mass.

The result was expressed as a percentage and the methodology described is in accordance with Cairo (1995).

Membrane damage (MD) was estimated from electrolyte leakage using ten leaf discs (diameter of 10 mm) obtained from the same leaf used for RWC determination. These discs were immersed in 18 mL of deionized water for 24 hours. Subsequently, the electrical conductivity of this suspension was measured using a benchtop conductivity meter (mCA-150), and the first conductivity (C1) was obtained. Soon after, the material was placed in a water bath at 100 °C and kept for 1 hour and, after cooling, a new measurement of electrical conductivity was performed, obtaining the second conductivity (C2). To obtain the MD, the measurements were inserted into the formula:

$$MD = \frac{C1}{C2} \times 100$$

where:
C1 - first conductivity; and
C2 - second conductivity.

Chlorophyll and carotenoid contents were determined using the methodology described by Lichtenthaler & Wellburn (1983), in which discs (diameter of 10 mm) from the same leaves used for RWC and MD determination were removed and cut into small pieces. Then, they were placed in test tubes protected from light (wrapped with aluminum foil) containing 7 mL of 80% acetone. The tubes were placed in a refrigerator at 4 °C and kept for 48 hours for pigment extraction. Subsequently, the acetone with the extracted pigments was taken to a spectrophotometer (JENWAY 6705 UV/Vis) to read the absorbance at wavelengths 663, 647 and 470 nm.

From the readings observed in the respective wavelengths, the pigment contents were determined using the equations according to Lichtenthaler & Wellburn (1983):

$$\text{Chlorophyll a (Chl a)} = 12.21A_{663} - 2.81A_{647}$$

$$\text{Chlorophyll b (Chl b)} = 20.13A_{647} - 5.03A_{663}$$

$$\text{Total chlorophyll} = 17.3A_{647} - 2.81A_{663}$$

$$\text{Carotenoids} = \frac{1000A_{470} - 3.27\text{Chl a} - 104\text{Chl b}}{229}$$

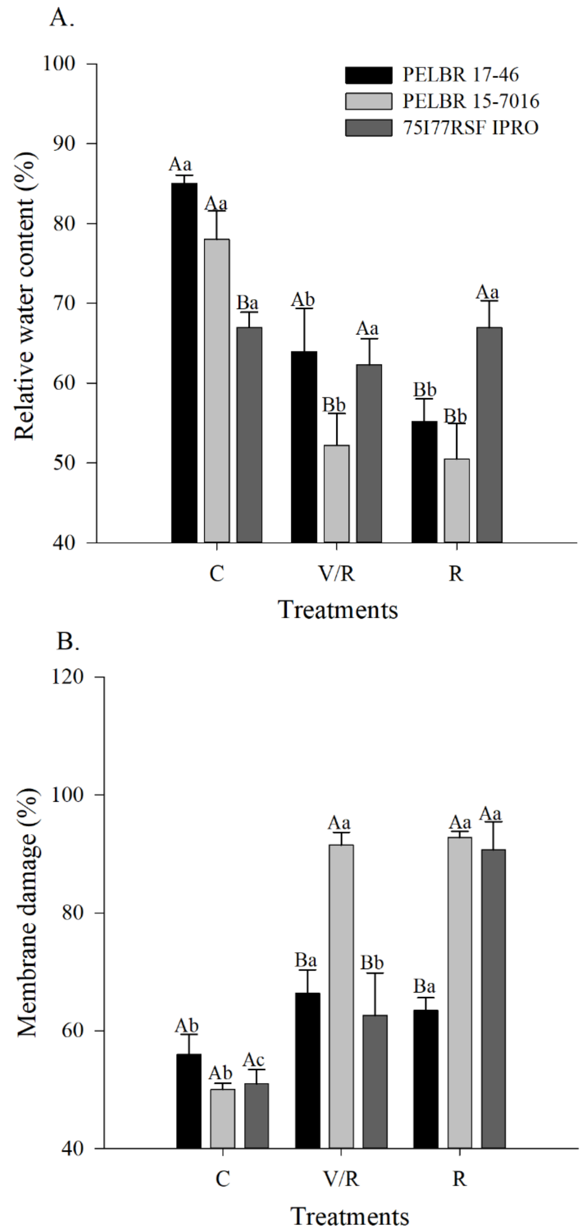
The results obtained were expressed in mg L^{-1} and later transformed into mg g^{-1} of fresh matter mass.

For the determination of dry matter, at the end of the cycle (74 days after sowing), the plants were cut and separated into: leaf, root, stem, and pod/grain. Then, the organs were placed separately in paper bags and taken to an air circulation oven at 65 °C until they reached constant weight. Subsequently, all material was weighed on a balance (resolution of 0.001 g) and the dry matter mass was obtained. With these data it was possible to calculate the biomass partition for each organ (Benincasa, 2003.).

The data obtained were subjected to analysis of variance (ANOVA) and, when there was a significant difference at $p \leq 0.05$ probability, a Tukey test was performed to compare means, with the aid of the statistical software SISVAR 5.0 (Ferreira, 2011).

Results and Discussion

For relative water content and membrane damage, there was an interaction between genotypes and flooding stress (Figure 1). The 75I77RSF IPRO genotype showed no



Different uppercase letters indicate a significant difference between genotypes and different lowercase letters indicate a significant difference between water treatments, by Tukey's test ($p \leq 0.05$). Vertical bars above each soybean bar represent the standard error of the mean
C - control in which the soil was maintained at 70% of field capacity throughout the crop cycle; V/R - soil flooding for 10 days in the vegetative period + 10 days in the reproductive period; and R - soil flooding for 10 days only in the reproductive period

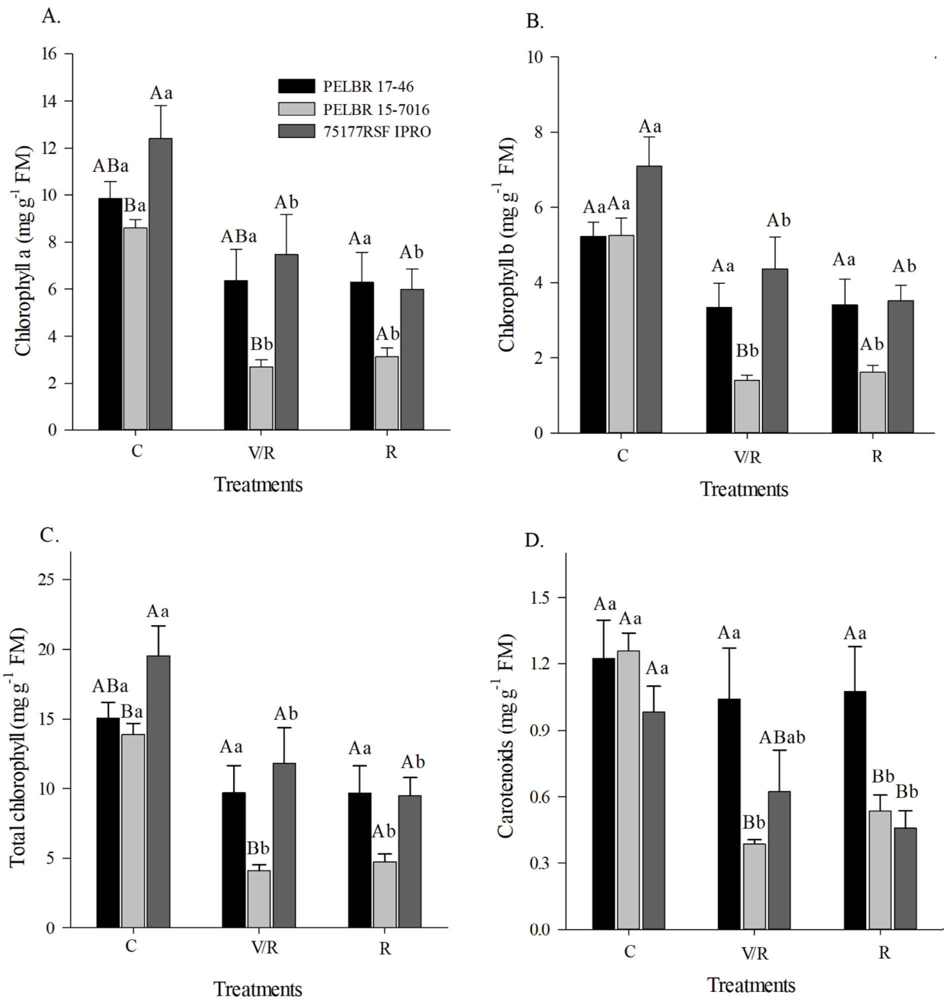
Figure 1. Relative water content (A) and membrane damage (B) in soybean genotypes (PELBR 17-46, PELBR 15-7016, and 75I77RSF IPRO) as a function of water treatment conditions

reduction in relative water content (RWC) when subjected to water treatments, while the PELBR 17-46 genotype suffered a reduction of 25 and 35% when subjected to flooding in the vegetative/reproductive and reproductive stages, respectively (Figure 1A). The PELBR 15-7016 genotype showed a greater reduction in RWC at the same stages, of 33 and 37% (Figure 1A). Under flooding stress conditions, membrane damage was 84% higher in the PELBR 15-7016 genotype in both plant stages, while damage in PELBR 17-46 and 75I77RSF IPRO increased by 27 and 19% with flooding in the vegetative/reproductive stages, respectively. In the reproductive period, the PELBR 15-7016 and 75I77RSF IPRO genotypes showed greater electrolyte leakage, while the PELBR 17-46 genotype was more resilient to stress (Figure 1B).

As a result of the applied water stress, the PELBR 15-7016 and PELBR 17-46 genotypes had their relative water content reduced in the two moments of soil flooding, vegetative/reproductive and reproductive. However, the 75I77RSF IPRO genotype showed no change (Figure 1A). The decrease in RWC in the PELBR 15-7016 and PELBR 17-46 genotypes indicates an insufficient supply of water for cell expansion, which may occur due to the prevalence of hypoxia or anoxia, limiting water permeability in the roots (Katerji et al., 1997). Leaf cell membranes were strongly affected by periods of stress for all genotypes, with less damage for the PELBR 17-46 (Figure 1B). By means of changes in the relative water content, it is possible to obtain information regarding the water conditions of the cells, since under stress conditions the plant tends to reduce water absorption and, consequently, cell turgor. Thus, abiotic stresses, such as flooding, also affect the hydraulic conductance of tissues, altering their resistance to water flow.

As a result, plants in flooded soils have greater difficulty in absorbing water, as this factor increases resistance to absorption, causing water deficiency and reduction in plant cell turgor, limiting tissue growth (leaf expansion), in addition to causing a deficiency in the translocation of nutrients from the soil to the root system (Garcia et al., 2020). Thus, even when plants are in flooded soil, there is difficulty in absorbing water, generating a condition of physiological drought (Barickman et al., 2019). As for the observed increase in electrolyte leakage, it is probably due to disruption of the membrane as a result of injuries caused by flooding stress (Dong et al., 2019).

For chlorophyll a, chlorophyll b, total chlorophyll, and carotenoids there was an interaction between the factors (genotypes and stress) (Figure 2). The PELBR 17-46 genotype had no statistical difference between the control and stress



Different uppercase letters indicate a significant difference between genotypes and different lowercase letters indicate a significant difference between water treatments, by Tukey's test ($p \leq 0.05$). Vertical bars above each soybean bar represent the standard error of the mean

C - control in which the soil was maintained at 70% of field capacity throughout the plant cycle; V/R - soil flooding for 10 days in the vegetative period + 10 days in the reproductive period; and R - soil flooding for 10 days only in the reproductive period

Figure 2. Chlorophyll a (A), chlorophyll b (B), total chlorophyll (C) and carotenoids (D) in soybean genotypes (PELBR 17-46, PELBR 15-7016, and 75I77RSF IPRO) as a function of soil flooding water treatment conditions

treatments, in chlorophylls a, b and total. However, PELBR 15-7016 and 75I77RSF IPRO were strongly affected by the water treatments applied, with reductions of 69 and 40.3% in the vegetative/reproductive stage and 64 and 47.6% in the reproductive stage, respectively (Figure 2A). The PELBR 15-7016 genotype showed less chlorophyll a than 75I77RSF IPRO with flooding in the vegetative/reproductive stages, while in the reproductive stage all genotypes were statistically equal. The behavior of chlorophyll b (Figure 2B) and total chlorophyll (Figure 2C) was similar to that of chlorophyll a, with the exception of the treatment with flooding in the vegetative/reproductive stage, in which the PELBR 15-7016 genotype was different from the others.

Carotenoids showed a reduction, in the PELBR 15-7016 and 75I77RSF IPRO genotypes, of 70 and 58% in the vegetative/reproductive treatment, respectively; and 37 and 54% in the treatment with stress applied only in the reproductive stage of soybean, while PELBR 17-46 showed no change, in any of the moments of water treatment (Figure 2D).

The PELBR 17-46 genotype showed no change in photosynthetic pigments, chlorophyll a, chlorophyll b, total chlorophyll, and carotenoids, under waterlogging. However, PELBR 15-7016 and 75I77RSF IPRO were more susceptible to stress conditions in the vegetative/reproductive and reproductive stages. According to Wang et al. (2022), the reduction in leaf chlorophyll content (Figure 3) and plant growth (Figure 4) and the increase in electrolyte leakage (Figure 2) is an index of sensitivity of genotypes to soil flooding, results observed in this experiment. Probably, the reduction in chlorophyll contents in plants under flooding, in a certain way, must be related to the decrease in the amount of O_2 available to plants in flooded environments, causing restrictions in metabolism. According to Dong et al. (2019), one of the factors linked to the photosynthetic efficiency of soybean plants and, consequently, to growth and adaptability to different environments is chlorophyll. Thus, the chlorophyll content can be used as a tool to assess the level of adaptation of plants in an adverse environment.

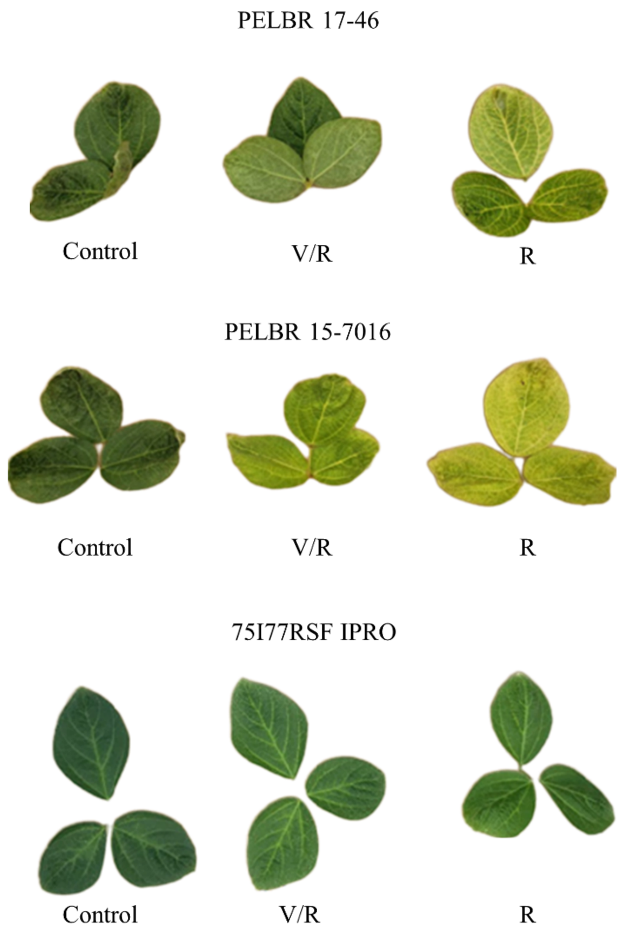
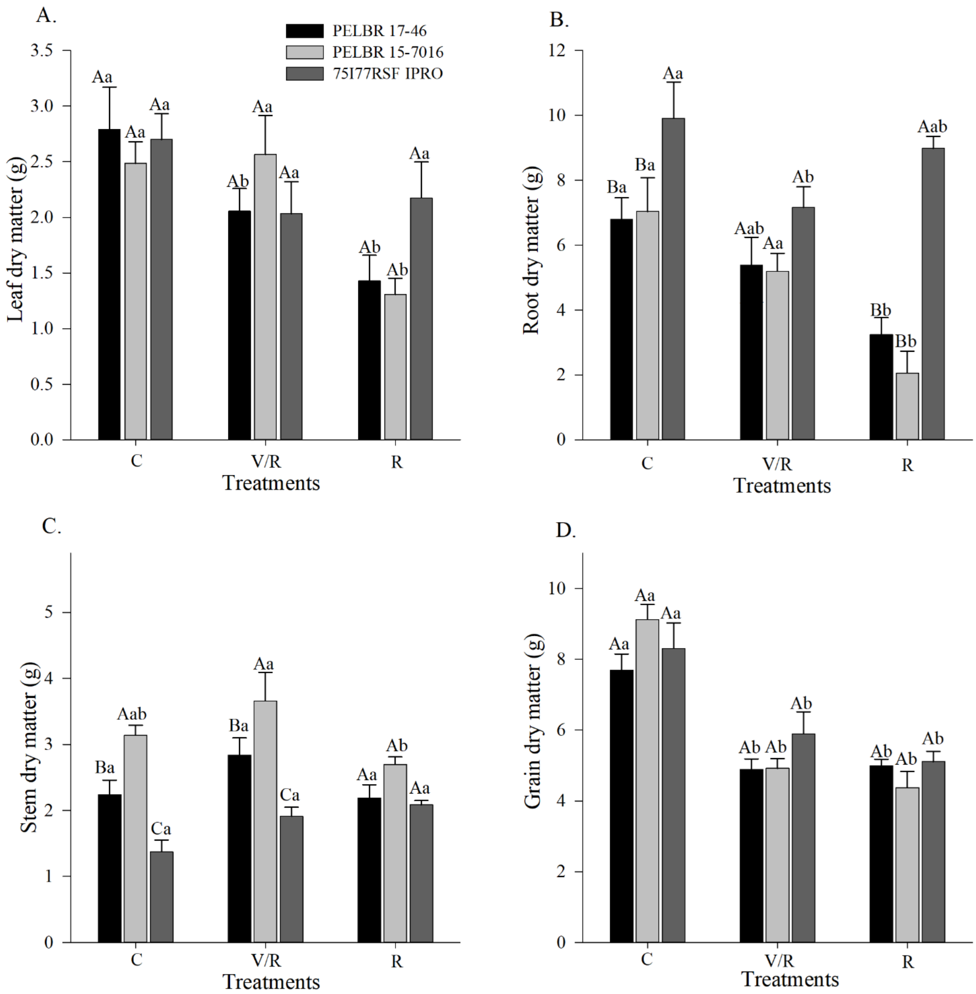


Figure 3. Images of PELBR 17-46, PELBR 15-7016, and cv. 75I77RSF IPRO genotypes at the end of the experiment, after being subjected to soil flooding in the vegetative/reproductive and reproductive stages

Chlorophyll may be the main pigment responsible for capturing the light energy used in the photosynthesis process; it is one of the factors related to the photosynthetic efficiency of plants and also in their growth and adaptability to different environments. However, leaf chlorophyll content is associated with N content, which can be influenced by environmental conditions that restrict N_2 fixation, such as hypoxia (Loreti & Striker, 2020). Thus, oxygen deficiency in the root system of the soybean plant, in addition to inhibiting symbiotic fixation, also impairs the absorption of nitrogen and other minerals, negatively affecting root growth and nodulation (Chandra et al., 2022). Consequently, transport of N and/or minerals to the shoot may be inadequate, resulting in stunted and chlorotic plants.

The production of leaf dry matter and grain dry matter showed an isolated effect only for flooding stress, while for stem dry matter there was an effect between genotypes and flooding stress (Figure 4). For root dry matter, there were interactions between genotypes and flooding stress (Figure 4). For dry matter, it is observed that in the leaves there was no statistical difference between the genotypes in relation to the water treatments applied in any of the periods of the plants (Figure 4). The PELBR 17-46 genotype showed 26% less dry matter accumulation in the leaves in the vegetative/reproductive stage and 49% in the reproductive stage; the PEL 15-7016 genotype was affected only in the reproductive stage with approximately 48%, while 75I77RSF IPRO remained stable during hypoxic stresses (Figure 4A). In the root, the PELBR 17-46 and PELBR 15-7016 genotypes had smaller masses, 52 and 71% respectively, in the reproductive stage. 75I77RSF IPRO was the genotype that initially showed the highest biomass in the root, and even under soil flooding, under hypoxic conditions, it maintained high dry matter masses in all treatments (C, V/R and R) (Figure 4B). As for the stem, a difference in the accumulation between the genotypes was observed in the control, which was repeated in the vegetative/reproductive stage, in which PELBR 15-7016 had a greater contribution, followed by PELBR 17-46 and 75I77RSF IPRO (Figure 4C). Despite not showing difference between genotypes, grain dry matter was strongly affected by the water treatments applied in the two soybean stages, with average production 49, 36, and 34% lower for the PELBR 17-46, PELBR 15-7016, and 75I77RSF IPRO, respectively (Figure 4D).

Although the PELBR 17-46 and PELBR 15-7016 genotypes suffered greater reduction of dry matter in the leaf (only in the reproductive stage) and root under soil flooding condition in



Different uppercase letters indicate a significant difference between genotypes and different lowercase letters indicate a significant difference between water treatments, by Tukey's test (p ≤ 0.05). Vertical bars above each soybean bar represent the standard error of the mean

C - control in which the soil was maintained at 70% of field capacity throughout the plant cycle; V/R - soil flooding for 10 days in the vegetative period + 10 days in the reproductive period; and R - soil flooding for 10 days only in the reproductive period

Figure 4. Leaf (A), root (B), stem (C) and grain (D) dry matter production in soybean genotypes (PELBR 17-46, PELBR 15-7016, and 75I77RSF IPRO) as a function of soil flooding water treatment conditions

the vegetative/reproductive and reproductive stages, it did not cause severe limitation in the accumulation of plant biomass. This allows us to infer that the response to these variables was differential for the greater tolerance or sensitivity of the three genotypes, since 75I77RSF IPRO was the least affected by soil flooding. Similar results were found by Garcia et al. (2020), in which soybean genotypes subjected to flooding for seven days showed a reduction in organ dry matter, but without drastic damage, and were able to overcome the waterlogging stress. In general, it can be stated that the genotypes exhibited moderate tolerance to flooding through different mechanisms to overcome hypoxia.

According to Rymaszewski et al. (2017), when plants are subjected to water stress, whether from lack or excess of water in the soil, several changes may occur at the morphophysiological level, resulting from phenotypic changes, which allow plants to mitigate the effects of stress. The first traits affected by stress are normally shoot and root organs, as observed for the PELBR 17-46 and PELBR 15-7016 genotypes (Figure 4A and 4B). For Barickman et al. (2019), the limitation in plant growth can be influenced by the lower absorption of water by the roots, a result found in Figure 1, in which the relative water content, for the same genotypes, was found to decrease during stress.

For biomass allocation in roots and grains, there was an interaction between genotypes and flooding stress, while for biomass allocation in the stem, there was only the isolated effect of the factors (Table 2). With regard to the distribution of total dry matter among the various plant organs, except the leaf, there was a statistical difference between genotypes and water treatments (Table 2). Allocation in the leaves did not change at any moment of the treatments. Considering the allocation of stem and grain biomass, a pattern of behavior was observed for the PELBR 17-46 and PELBR 15-7016 genotypes, with lower values of grain biomass in the vegetative/reproductive stage and greater accumulation in the stem in the two stages of flooding imposition. In the stem, the highest increments were found for PELBR 17-46, 71% for the vegetative/reproductive stage and 64% for the reproductive stage and for PELBR 15-7016, 53 and 86%, respectively. The 75I77RSF IPRO genotype allocated the highest fraction of biomass in the stem, 84% in the two stages of soil waterlogging; and less accumulation in the grain, 25%, when the stress was applied only in the reproductive stage of the plant. It is also noteworthy that the PELBR 15-7016 genotype was the only one that reallocated root dry matter, redistributing 43% of its biomass with the imposition of water treatment in the reproductive stage.

Table 2. Allocation of dry matter in the leaf, root, stem, and grain of soybean genotypes, PELBR 17-46, PELBR 15-7016), and 75I77RSF IPRO, subjected to soil flooding stress

		Grain	Leaf	Stem	Root
		(%)			
PELBR 17-46	Control	39.75 Aa	14.31 Aa	11.39 Ab	34.54 ABa
	V/R	31.36 Ab	13.88 Aa	19.52 Aa	35.22 ABa
	R	42.75 Aa	11.73 Aa	18.66 Ba	26.86 Ba
PELBR 15-7016	Control	42.32 Aa	11.36 Aa	14.54 Ab	31.78 Ba
	V/R	30.64 Ab	15.45 Aa	22.19 Aa	31.72 Ba
	R	42.22 Aa	12.88 Aa	26.87 Aa	18.02 Bb
75I77RSF IPRO	Control	37.45 Aa	12.28 Aa	6.18, Bb	44.08 Aa
	V/R	34.56 Aab	11.74 Aa	11.37 Ba	42.32 Aa
	R	27.89 Bb	11.63 Aa	11.41 Ca	49.06 Aa

Different uppercase letters indicate a significant difference between genotypes and different lowercase letters indicate a significant difference between water treatments, by Tukey's test ($p \leq 0.05$)

The periods of soil flooding, in the vegetative/reproductive and reproductive stages of soybean, caused the redistribution of dry matter among the plant organs, preferably to the stem. The investment of biomass in certain parts can be a strategy to overcome stress caused by excess water in the soil, due to hypoxic or anoxic conditions. This mechanism determines whether or not a genotype is tolerant. After submersion or flooding, tolerant plants tend to respond quickly to oxygen limitation, investing in adventitious rooting and in stem nodes, a result similar to those found in this study, while in sensitive plants, hypoxia causes the interruption of root growth (Fukao et al., 2019). Avelino et al. (2021) state that plants under flood conditions seem to experience strong competition between the biomass allocated to leaves and the biomass allocated to stems and roots, thus developing a strategy of great importance for the adaptation and acclimatization of plant species to different growth environments.

The physiology of plant response to water stress is highly complex and involves deleterious and/or adaptive changes (Ozturk et al., 2020). Plant species adapt to flooding conditions through various physiological, biochemical, anatomical, and morphological changes (Jia et al., 2021). In general, flooding produces characteristic responses such as reduced growth rate, swelling of the base of the stem, epinasty, senescence, and early abscission of the leaves, formation of adventitious roots, development of aerenchyma, reduction of transpiration, decreasing the flow of nutrients to leaves, and low biomass production in soybean genotypes (Mueller et al., 2021; Smith et al., 2021; Sathi et al., 2022). Based on the above, the need for studies that seek to understand the physiological responses of soybean genotypes as a function of the variation in water availability in the soil, especially with regard to cultivation under flooded soil conditions, is evident.

Conclusions

1. Soil flooding affected the cellular integrity and relative water content of the PELBR 17-46 and PELBR 15-7016 genotypes and the biomass production of all soybean genotypes in the vegetative and reproductive stages;

2. The 75I77RSF IPRO genotype shows the best responses under soil flooding conditions, being the most suitable for cultivation under these conditions.

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