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GROWTH AND VEGETATIVE DEVELOPMENT OF SOYBEAN PLANTS IN SOIL TYPE CONCRECTIONARY PETRIC PLINTHOSOL

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ABSTRACT - The central-north of Brazil is a region with strong presence of concrectionary soil, whose supposed disadvantages from the agronomic point of view, do not prevent their use in agriculture. However, more in-depth information about the behavior of crops of agricultural interest cultivated in this type of soil is few. Due to the observation of agricultural stands in this type of soil, it was hypothesized that plinthite ironstones concretions negatively interfere in the development of crops of agro-economic interest. The objective was to verify the growth and development of soybean cultivated in soil with the presence and absence of plinthite ironstones. Concretionary Petric Plinthosol were collected in the 0-0,20 m layer and part of the soil was sieved so that concretions larger than 3.10 mm in diameter were removed, thus leaving two treatments, soil with and without plinthite ironstones. Morphological evaluations were performed during their phenological phase. Soybean grown in soil without ironstones showed higher growth at 32 and 48 DAE and more leaflets when compared to soy crop grown in soil with ironstones. As for dry matter, soybean grown in soil without ironstones showed more values for aerial, root and total mass as well for aerial root rate when compared to soybean grown in soil with ironstones. Plinthite ironstones interfere with the growth and/or vegetative development of soybeans. Soybean has less vegetative development when grown in soil with plinthite ironstone concretions.
Keywords: annual crops, plinthite ironstones, root restriction.

CRESCIMENTO E DESENVOLVIMENTO VEGETATIVO DE PLANTAS DE SOJA EM SOLO TIPO PLINTOSSOLO PÉTRICO CONCRECIONÁRIO

RESUMO - O centro-norte do Brasil é uma região com forte presença de solo concrecionário, cuja aparente desvantagem do ponto de vista agronômico, não impede seu uso agrícola. Entretanto, informações mais aprofundadas a respeito do comportamento de culturas de interesse agrícola cultivadas neste tipo de solo são poucas. Mediante a observação de estandes agrícolas neste tipo de solo, surgiu a hipótese de que concreções de petroplintita interferem negativamente no desenvolvimento de cultivos de interesse agro-econômico. Diante do exposto, objetivou-se com o presente trabalho verificar o crescimento e desenvolvimento da soja cultivada em solo com a presença e ausência de nódulos de petroplintita. Amostras de Plintossolo Pétrico Concrecionário foi coletado na camada 0-0,20 m e parte do solo foi peneirado de modo que concreções maiores de 3,10 mm de diâmetro fossem retiradas, deixando assim dois tratamentos, solo com concreções e sem concreções petroplintita. Avaliações morfológicas foram realizadas durante o estádio vegetativo. A soja cultivada em solo sem petroplintita teve maior crescimento aos 32 e 48 DAE e maior número de trifólios quando comparado à soja cultivada em solo com petroplintita. Quanto à massa seca, a soja cultivada em solo sem petroplintita teve maiores valores das massas secas da parte aérea, radicular e total, além de maior relação parte aérea radicular que a soja cultivada em solo com concreções de petroplintita. Concreções de petroplintita interferem no crescimento e/ou desenvolvimento vegetativo da soja. A soja tem menor desenvolvimento vegetativo quando cultivada em solo com concreções de petroplintita.
Palavras-chave: culturas anuais, petroplintita, restrição radicular.

INTRODUCTION

Soybean (*Glycine max*) is one of the main sources of vegetable protein, it is a legume widely grown in Brazil, and its agricultural cultivation has increased the most in the last three decades (COLUSSI et al., 2016). According to Hirakuri and Lazzaroto (2014), factors such as high protein content of excellent quality for both animal and human feed, possibility of biofuel production, standardization and uniformity of world commodity, fully mechanized and automated cultivation and significant increase in supply of production technologies that allowed to significantly increase the area and productivity of the oilseed, were responsible for the great increase of soybean crop.

According to Farias et al. (2007), temperature, photoperiod and water availability are the climatic elements that most affect soybean plants development and yield. In Brazil, soybean crop are cultivated from north to

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south on 33.909.400 ha, producing 111.558.600 tons (CONAB, 2018). The main producers are the states of Mato Grosso, with 9.518.600 ha cultivated, followed by Rio Grande do Sul, 5.692.100 ha and Paraná, with 5.464.800 ha.

The amount of grain produced in Tocantins state from 1990 to 2017 had an average annual growth rate of 9.29% (SILVA and DALCHIAVON, 2018). According to CONAB (2018) production in 1990 was 37.600 tons, while in 2017 production exceeded 2.5 million tons.

One of the characteristics of the Tocantins state soil is the large amount of Plinthosols (SEPLAN, 2012). Plinthosols are mineral soils, formed under the condition of water percolation restriction, subject to the temporary effect of excess moisture, usually poorly or imperfectly drained, with significant plinthitization, with or without plinthite ironstones. Plinthite is formed from a mixture of clay, is low in organic carbon and rich in iron, or iron and aluminum, with quartz grains and other minerals. Since is rich in iron oxide, is a distinct material from the soil, found in different shapes, as laminar, nodular, spheroidal and irregular shape, with diameters greater than 2 mm, being firm when wet and very hard when dry, as for plinthite ironstones, after repetitive cycles of wetting and drying, the soil gain an irreversible petric feature (EMBRAPA, 2018).

Despite undesirable characteristics from an agronomic point of view (AZEVEDO and BUENO, 2017), the cultivation of species of economic interest in this soil, such as soybean and common bean crops (NIKKEL and LIMA, 2017) which require considerable agricultural mechanization, is not an obstacle. Farmers, however, have the impression that the productivity of crops grown on soil with ironstone concretions is lower when compared to other soil orders, such as Oxisols, for example. In this regard, it is speculated that plants may be spending more photoassimilates in the root system, because the ironstone concretions, when in concretionary horizon, act as a restrictive environment for free root growth.

Therefore, a study in relation to the interaction of this soil and plants is justified, because phenological characteristics of plants show strong genetic differentiation along natural climatic gradients and relief thus adapting to various biomes and in this sense, abiotic and biotic characteristics of soil has received attention as ecologically important factors in predicting variations of various phenological characteristics (WARE et al., 2019).

Lemes et al. (2018) comment that growth analysis remains the most accessible, inexpensive, and accurate mean for assessing growth and understanding for the contribution of different physiological processes of behavior. These can be influenced by environmental, genetic and agronomic factors (RIBEIRO et al., 2018).

From the growth data, the causes of growth variations between plants submitted to different environment can be studied through measures such as: plant height, length and stem diameter; number of structural units, such as leaf and flower count; surface measurements, such as the determination or estimation of the photosynthetically active surface of plants and dry matter mass, which is the constant mass of a given sample (SILVA et al., 2000; PEIXOTO and PEIXOTO, 2009; PEIXOTO et al., 2011).

Since the influence of plinthite ironstone concretions present in the soil on the development of crops is still uncertain, this work aims to evaluate, through morphological evaluations, the interference of plinthite ironstones on the growth of soybean plants cultivated in Concrecionary Petric Plinthosol.

MATERIAL AND METHODS

The study was conducted at the Universidade Federal do Tocantins (UFT), Brazil, Gurupi University *Campus*, located in the southern region of Tocantins state at 11° 43’ S and 49° 04’ W, at 280 m asl. The local climate, according to the Köppen classification, is Tropical Savannah (Aw) (DUBREUIL et al., 2018). The annual average temperature is 27°C and annual rainfall of 1.500 mm, being rainy summer, dry winter and high water deficit between May and October.

According to Embrapa (2018), the soil is classified as Concretionary Petric Plinthosol (Table 1). Soil samples were collected in a Savannah native area in the arable layer of 0.0 - 0.20 m and dried in the sun. Part of the soil was sieved in sieves with mesh up to 3.10 mm in order to separate the plinthite ironstones, which corresponded to more than 65% of the soil mass. The Table 2 shows values of the granulometry of the soil collected and its composition of concretions in the soil.

Two treatments were then obtained, soil with plinthite ironstones and soil without these concretions. Soil samples were collected in the 0,0 - 0,20 m layer where fractions greater than 2 mm in diameter were removed according to the Manual of Soil Analysis Methods (EMBRAPA, 2017) for physicochemical analyzes (Table 2). The textural analysis showed that the soil has 645 g kg^{-1} of sand, 50 g kg^{-1} of silt and 305 g kg^{-1} of clay. Based on the results of the chemical analysis, the soil was incubated for aluminum neutralization, pH elevation and calcium and magnesium supply in the quantity of limestone of 820 kg ha^{-1}.

It was attempt to fertilize the experiments in a basic way, so that the plants had sufficient conditions to develop, since the objective was not to evaluate production, but the behavior of the species with the least possible interference of the fertilization and to stimulate the growth that could to reflect on the variables evaluated, since higher amounts of nutrients in the soil could mask the experiment. The soil was fertilized based on the recommendation of Ribeiro et al. (1999) with 80 kg ha^{-1} P_2O_5 whose source was single superphosphate and 120 kg ha^{-1} of K_2O with potassium chloride as the source.

Plastic bags with 14 L volume were filled with soil (with and without plinthite ironstones) and later seeded with five seeds of soybean cultivar TMG 1288 per bag, previously inoculated with bacteria of the genus *Bradyrhizobium*. Sowing occurred in May 2017 and three days after the emergency (DAE), thinning was done, leaving only one plant per plastic bag. The irrigation was supplemented, every two days, so that the soil reached 80% of the field capacity. Each treatment (bags with and without ironstones) had seven replications which were placed on the ground on wooden boards at free sky. An application of Thiamethoxam and Lambda-cyhalothrin (33 mL of active ingredient ha^{-1}) at five DAE for control of the larvae (*Liriomyza* spp.) was performed. Morphological evaluation of height was conducted at 16, 32 and 48 DAE, where the measurement was from the soil to the apical meristem of the plant and the summation of trefoil at 48 DAE. Posteriorly the absolute growth rate (AGR) was calculated:

AGR = H2-H1/T2-T1,

Where:

H1 and H2 stand for the height variation obtained in time interval T1 and T2.

TABLE 1 - Morphological characteristics of the studied soil.

Depth (cm)	Hor.*	Texture	Color	Structure			Consistency			Transition
				Type	Class	Grade	Dry	Moist	Wet	
0 - 27	Ag	sandy-clay-loam-gra	7,5YR 3/3	weak	very fine	granular	loose, very friable	slightly sticky	slightly plastic	sharp and smooth
27 - 44	ABg	sandy-clay-gra	7,5YR 4/4	weak	very fine	granular	loose, very friable	slightly sticky to plastic	slightly sticky to sticky	sharp and wavy
47 - 138	Btg	clay-gra	5YR 5/8	weak blocky subangular that crumbles in weak very fine granular			loose, very friable	slightly sticky to slightly plastic	slightly plastic and slightly sticky	-
138 - 150+	F	-	2,5YR 4/4	very much gravel		-	Very hard, to extremely hard, extremely firm	Non plastic, non sticky	very cohesive	-

*Hor. = horizon, gra = gravel, g = presence of gravel.

TABLE 2 - Granulometry of Concretionary Petric Plinthosol collected on layer 0.0 - 0.20 m.

Mesh (mm)	12.00	10.00	7.93	6.39	4.00	3.10	< 3.10
Weight (g 1000 g^{-1})	4.24*	6.64	38.75	103.27	362.40	159.40	325.35
%	0.42	0.66	3.87	10.33	36.24	15.94	32.54

*The values refer to the weight of concretions retained in the sieves.

The experiment was concluded at 55 DAE. The root system and aerial part were separated. After washed in running water, the root system was placed in a drying oven with forced circulation at 65°C for 72 h. The dry masses were then weighed on a precision scale to obtain root dry mass, dry shoot mass, total dry mass and root shoot ratio.

The test to verify the existence of normality of the data were not performed, since it is not advisable to carry out the verification of normality on samples of sizes less than or equal to ten, it was proceed directly to a non-parametric analysis strategy (TORMAN et al., 2012; LE BOEDEC, 2016). The averages were compared using the Wilcoxon test for independent samples at the 5% probability level, using the Actionstat supplement, as calculated by Periotto and Gualtieri (2017) for Excel®.

RESULTS AND DISCUSSION

Table 3 shows the growth averages (cm) of soybean plants at 16.32 and 48 DAE, the absolute growth rate, from 16 to 32 DAE (AGR^1) and 32 to 48 DAE (AGR^2) and the mean of trefoil summation, counted at 48 DAE, cultivated in soil with plinthite ironstones and without plinthite ironstones.

It can be observed statistical difference at 32 and 48 DAE, in the AGR^1 and trefoil count, with greater means of the plants cultivated in soil without plinthite ironstones. At 32 DAE the soybeans cultivated in soil with ironstones presented mean value of 18.92 cm since the soybeans cultivated in soil without ironstones 26.57 cm. At 48 DAE, the soybeans cultivated in soil with ironstones presented mean value of 29.20 cm and the soybeans cultivated in soil without ironstones 42.80 cm. In relation to AGR^1, the soybeans cultivated in soil with ironstones presented growth of 0.31 cm and the soybeans cultivated in soil without ironstones 0.64 cm. As for the trefoil account, the soybeans cultivated in soil with plinthite ironstones presented average of 6.42, on the other hand, soybeans cultivated in soil without plinthite ironstones, 16.28.

The observation of morphological variables, such as plant height, in relation to soil physical attributes is used as a way to verify the interaction between the shoot and root in which it was developed to absorbed nutrients to provide plant support. Silva et al. (2014) in determining the degree of soil compaction, that is, in a root-restricted environment that restricts soybean crop growth, in an Oxisol with 60 g kg^{-1} sand, 370 g kg^{-1} silt and 570 g kg^{-1} of clay in southern Brazil, observed a remarkable decrease in plant height as the degree of compaction increased. Sivarajan et al. (2018) also evaluated height of soybean plants in a study that observed the impact of agricultural mechanization, by soil compaction, on different soils.

TABLE 3 - Mean of height (in cm) measured at three times, absolute growth rate (AGR) and trefoil summation of soybean plants grown in soil with and without plinthite ironstones.

Soils	16 DAE*	32 DAE	48 DAE	AGR^1	AGR^2	Trefoil
Soil with ironstones	13.81 a	18.92 b	29.20 b	0.31 b	0.64 a	6.42 b
Soil without ironstones	16.23 a	26.57 a	42.80 a	0.64 a	1.03 a	16.28 a
VC (%)	18	30	29	64	66	50

*DAE = days after emergence, trefoil counted at 48 DAE, AGR^1 = interval (16 DAE to 32 DAE), AGR^2 = interval (32 DAE to 48 DAE), Means followed by equal letters in the column do not differ statistically from each other by independent Wilcoxon test at 5% probability.

Santos et al. (2017), when evaluating the initial development of soybean crop as a function of different sowing velocities of the seeder in soils of different textural classes, one with 140 g kg^{-1} and the other with 350 g kg^{-1} of clay, observed that plants sown in clayey soil showed higher plant height. Soil physical properties such as texture, distribution and average pore diameter and structure are directly linked to the variation in the amount of water stored in the soil, however, Mezzomo et al. (2018) comment that texture is considered one of the main factors affecting soil water retention as it determines the contact area between water and solid particles.

Since the soil of this experiment is concretionary, the amount of plinthite ironstone gravels larger than 3.10 mm in diameter in relation to the total soil volume exceeds 67% (Table 2), which implies a reduction in water retention and may be an explanation for the difference in height between soybean grown on soil with plinthite ironstones and without plinthite ironstones: lower amount of water retained in the soil and lixiviation.

Gava et al. (2015) when studying the water stress on soybean crop, both, deficit and excess of water application in sandy loam soil, observed that the occurrence of deficit reduced the height of soybean plants, however, it was not observed when in excess of irrigation. Beutler and Centurion (2004) when evaluating the height of soybean plants in soil compaction and water content levels in two Oxisols, one sandy, with textural analysis of 687 g kg^{-1} of sand, 42 g kg^{-1} of silt and 271 g kg^{-1} of clay and the other more clayey soil, with 227 g kg^{-1} of sand, 256 g kg^{-1} of silt and 517 g kg^{-1} of clay, observed that in both soils, the height of the plants was higher in plants grown in soil with higher available water content.

When observing the values of Table 3, it can be noted that in the first measurement there was no statistically significant difference, but there was in the second and third measurement, this may be an indication that the root system of soybean plants cultivated in soil with plinthite ironstones developed in a similar way to soybeans grown in soil without plinthite ironstones in the first weeks of the experiment, however, later had greater difficulty to develop, as shown by measurements at 32.48 DAE and AGR^1 and which is corroborated by the number of trefoil counted at 48 DAE, consequently with lesser green phytomass for photosynthetically active radiation absorption.

Table 4 presents the values of dry mass of the aerial part (DMA), dry mass of the root part (DMR), total dry mass (TDM) and shoot root ratio (DMA DMR^{-1}) of soybean plants. It can be observed that there was statistical difference in all evaluated variables. Soybean plants cultivated in soil without plinthite ironstones presented higher DMA value than those cultivated in soil with plinthite ironstones with means of 18.92 g and 12.61 g, respectively. In relation to the DMR, soybean plants cultivated in soil with plinthite ironstones presented a value of 11.57 g, whereas plants cultivated in soil without plinthite ironstones, weighed 13.96 g. Still in Table 4, soybean plants cultivated in soil without plinthite ironstones presented higher TDM average than those cultivated in soil with plinthite ironstones with value of 24.19 g and 32.88 g, respectively. Regarding the DMA DMR^{-1}, soybean plants grown in soil with plinthite ironstones presented a 1.09 ratio and plants grown in soil without plinthite ironstones presented a ratio of 1.35.

TABLE 4 - Mean (in g) of dry mass of the aerial part (DMA), dry mass of the root part (DMR); total dry mass (TDM) and shoot root ratio (DMA DMR^{-1}) of soybean (*Glycine max*) plants at 55 DAE grown in soil with and without plinthite ironstones.

Soils	DMA	DMR	TDM	DMA DMR^{-1}
Soil with ironstones	12.61 b*	11.57 b	24.19 b	1.09 b
Soil without ironstones	18.92 a	13.96 a	32.88 a	1.35 a
VC (%)	23	11	18	13%

*Means followed by equal letters in the column do not differ statistically from each other by independent Wilcoxon test at 5% probability.

Similar behavior were observed by Beutler and Centurion (2004), higher values of dry mass, aerial and root dry mass of cultivated plants in a more favorable environment for development, in the case, less compacted soil and larger amount of water. Silva et al (2014), when determining the degree of compaction that restricts soybean crop growth in potted clay soil, also found that the height of soybean plants decreased in a restrictive environment, compaction of 82%, which interfered with root and shoot dry matter production.

Generally, root systems evaluated in an environment with restriction, compaction, for example, present higher root mass, compared to a system developed without restriction, which was observed in the work of Silva et al. (2014). Relating the previously discussed variables, lower growth in the last two evaluation periods and lower number of trefoil, with lower values of shoot dry mass and total dry mass, the values corroborate the indications that soybean plants cultivated in soil with plinthite ironstones had more difficult to adapt to the environment in which their root system was inserted.

By relating the values of root dry mass and root shoot ratio, the root system of soybean crops grown in soil without plinthite ironstones was able to develop more adequately, reflected in a larger amount of trefoil and possibly reflected in a higher DMA DMR^{-1} value. Given this, there is strong evidence that plinthite ironstones in the soil cause developmental interference in soybean plants.

CONCLUSIONS

Plinthite ironstones interfere on soybean plants on growth and/or vegetative development.

Soybean plants have lower vegetative development when cultivated in soil with plinthite ironstones.

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