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Weed control by solarization and mulching in cowpea development

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ABSTRACT

Weeds are a serious threat to agriculture because they compete with crops, thereby interfering in production. As such, this study aimed to assess weed control using soil solarization and mulching on the growth and yield of cowpea. A completely randomized design was used, with eight treatments and four repetitions. The treatments consisted of a combination of two management practices, namely soil solarization (with and without) and three mulches (castor bean, rattlepod and spontaneous vegetation), as well as no mulching. Non-solarized soil and without mulch increased the number and dry weight of weeds, while the main stem length of the cowpea plants decreased. Mulching increased the pod length and number of seeds per pod regardless of solarization, as well as shoot dry weight and moisture content. By contrast, root dry weight increased in the absence of mulching, particularly in non-solarized soil. Soil solarization reduces weed infestation in cowpea crops, especially when associated with mulching.

Keywords: competition, soil management, pod yield, *Vigna unguiculata* L.

Controle de plantas daninhas por solarização e cobertura morta no desenvolvimento de feijão-caupi

RESUMO

A interferência de plantas daninhas tem causado sérios prejuízos à agricultura por competir com as culturas, afetando a produção. Assim, este estudo teve como objetivo avaliar o controle de plantas daninhas utilizando a solarização e a cobertura morta do solo sobre o crescimento e o rendimento do feijão-caupi. O delineamento experimental foi o inteiramente casualizado, com oito tratamentos e quatro repetições. Os tratamentos consistiram em uma combinação de duas práticas de manejo, a solarização do solo (com e sem) e três coberturas (mamona, crotalária e vegetação espontânea), bem como sem cobertura morta. O solo não solarizado e sem cobertura morta aumentou o número e o peso seco de plantas daninhas, enquanto o comprimento do ramo principal das plantas de feijão-caupi diminuiu. A cobertura morta aumentou o comprimento de vagens e o número de sementes por vagem, independentemente da solarização, bem como o peso da parte aérea e o teor de umidade. Por outro lado, o peso seco das raízes aumentou na ausência de cobertura morta, principalmente em solos não solarizados. A solarização do solo reduz a infestação de plantas daninhas na cultura do feijão-caupi, principalmente quando associada à cobertura morta.

Palavras-chave: competição, manejo do solo, rendimento de vagem, *Vigna unguiculata* L.

1. Introduction

Weed infestation in crops is a major problem in agriculture and causes serious economic losses due to competition for natural resources such as light, water, space and nutrients (Tavares et al., 2013; Lima et al., 2016). The cowpea in particular has a limited ability to compete with weeds, and depending on the interference caused by their interaction, yield losses can range from 67 to 76% (Salgado et al., 2007; Osipitan, 2017), making weed control a vital part of successful crop production (Pessôa et al., 2017). In this respect, different crop management strategies have been adopted to eliminate or control weed including soil solarization (Candido et al., 2011) and mulching (Monquero et al., 2009).

Solarization is a preventive, non-chemical form of weed control that helps deplete reserves of dormant weed seeds in the soil by increasing its temperature (Khan et al., 2012; Ghosh and Dolai, 2014), as observed in peanut (Soumya et al., 2004) and lettuce crops (Candido et al., 2011). Khan et al. (2012) observed in cauliflower cultivation that the solarization technique reduced fresh and dry biomass of weeds compared to control during two years of cultivation.

Already the mulching involves applying organic or non-organic material to the soil surface in order to reduce the amount of light that reaches it and decrease weed (Meschede et al., 2007; Khalid et al., 2018), as reported in cowpea (Flôres et al., 2017) and castor bean crops (Ferreira et al., 2015). Guerrero et al. (2019) observed in artichoke that biosolarization can be recommended as an effective management strategy for the control of weeds and fungal diseases transmitted by soil, as well as improved soil fertility and agricultural crop production.

As such, this study aimed to assess weed control using soil solarization and mulching on cowpea growth and yield.

2. Material and Methods

The experiment was conducted in a greenhouse of the experimental unit at the Agricultural Science Center of the Federal University of Alagoas (UFAL), in the municipality of Rio Largo (AL) (09° 28’ S, 35° 49’ W and altitude of 127 m), where the climate is characterized as warm and humid (Souza et al., 2004).

Pots were filled with 8 kg of cohesive yellow sandy clay loam latosol (oxisol), which had been broken up, sieved and solarized. Solarization was performed with soil irrigated close to field capacity, covering a 10 cm layer in 100 μm transparent plastic sheeting and exposing it to the sun for 20 days. In this method the soil temperature varies from 40 to 50 ºC (Katan, 1981).

Simultaneously to solarization, three types of mulch were tested: castor bean (*Ricinus communis*), rattlepod (*Crotalaria ochroleuca*) and spontaneous vegetation, obtained in uncultivated areas.

The study was carried out from April to July 2017, using a completely randomized design with eight treatments and four repetitions, totaling 32 plots, each corresponding to one plant per pot. The following treatments were used: T1 (solarized soil with castor bean mulch), T2 (solarized soil with rattlepod mulch), T3 (solarized soil with spontaneous vegetation mulch), T4 (solarized soil without mulch), T5 (non-solarized soil with castor bean mulch), T6 (non-solarized soil with rattlepod mulch), T7 (non-solarized soil with spontaneous vegetation mulch) and T8 (control: non-solarized soil without mulch).

The seeds were planted directly in the nursery pots containing soil in line with the treatments (solarized or non-solarized), with three seeds per nursery pot. Thinning was performed at seven days after planting (DAP), leaving only one plant per pot. Next, mulch (100 g pot^{-1}) was added according to each treatment and the soil was irrigated every three days to keep it close to field capacity.

The weed species in each experimental unit were analyzed at 80 DAP. Material was collected using a 0.25 m^2 quadrant thrown randomly into the plot (Braun-Blanquet, 1979) to determine the number of weeds (NW) and weed dry weight (WDW).

The following growth and yield traits were assessed for cowpea plants: Main stem length (MSL), number of leaves (NL), number of pods per plant (NPP), pod length (PL), number of seeds per pod (NSP), shoot fresh weight (SFW), shoot dry weight (SDW), root dry weight (RDW), and shoot moisture content (SMC).

The dry weight of the weeds and cowpea plants was obtained after drying in a drying chamber at 65 ºC for 48 hours. Next, the material was weighed on a precision balance (0.001 g). Shoot moisture content was determined based on the ratio between shoot fresh and dry weight, according to the method described by Borges et al. (2014).

The data were submitted to analysis of variance using the F-test and means compared with the Scott-Knott test. Pearson’s correlation was used to verify the relationship between weed occurrence and cowpea development.

3. Results and Discussion

All the cowpea traits studied were affected by the soil management treatments, except for NL and NP (Table 1).

Table 1. F-values for weed infestation and cowpea growth and yield traits under solarization and mulching.

Variables	*F* value
NW- Number of weeds	14.90**
WDW- Weed dry weight	7.84**
MSL- Main stem length	15.88**
NL- Number of leaves	2.70ns
NP- Number of pods	1.90ns
PL- Pod length	4.38**
NSP- Number of seeds per pod	5.45**
SDW- Shoot dry weight	2.96*
RDW- Root dry weight	57.46**
SMC- Shoot moisture content	4.84**

* and ** significant at 5 and 1% probability, respectively; ns = no significant.

The number of weeds (NW) was lower in all treatments with solarization and mulching (T1-T3), followed by those without solarization and with mulching (T5-T7) and with solarization and no mulching (T4), but higher in the treatment without solarization or mulching (T8), reaching 10.7 individuals (Figure 1A). The same behavior was observed for WDW, with a maximum of 7.2 g in T8 (Figure 1B). Thus, both solarization and mulching favored castor bean cultivation by reducing weed infestation, especially when these two management practices were combined.

The NW was negatively correlated with cowpea growth and yield traits, except for RDW, which showed a positive correlation (Figure 2). This demonstrates that greater weed infestation, particularly in T8, significantly affected the growth and yield of cowpea plants. Weed reductions have also been observed due to solarization in vegetables (Ricci et al., 2000; Khan et al., 2012) and peanut crops (Soumya et al., 2004). Similarly to our results, the authors also reported that solarization did not completely eradicate weeds, but significantly reduced their number when compared to non-solarized soil. This was likely due to the high solarization temperatures, which affect the seeds and propagules of weeds (Khan et al., 2012). Mulching also contributed to weed control, particularly when associated with solarization. Monquero et al. (2009) studied the use of different mulches for weed suppression and found they were effective at reducing the weed community, although the level of control varied among weed species. As such, it can be inferred that mulching inhibits the germination and emergence of some weed species, in addition to reducing their initial growth and dry weight (Meschede et al., 2007; Khan et al., 2012).

Main stem length (MSL) was greater in treatments using castor bean mulch with and without solarization (T1 and T5), at approximately 163.2 and 151.7 cm, respectively, followed by the remaining mulches with or without solarization and solarization alone (T2, T3, T6, T7 and T4); however, an MSL of 98.7 cm was observed in non-solarized soil without mulching (Figure 3A).

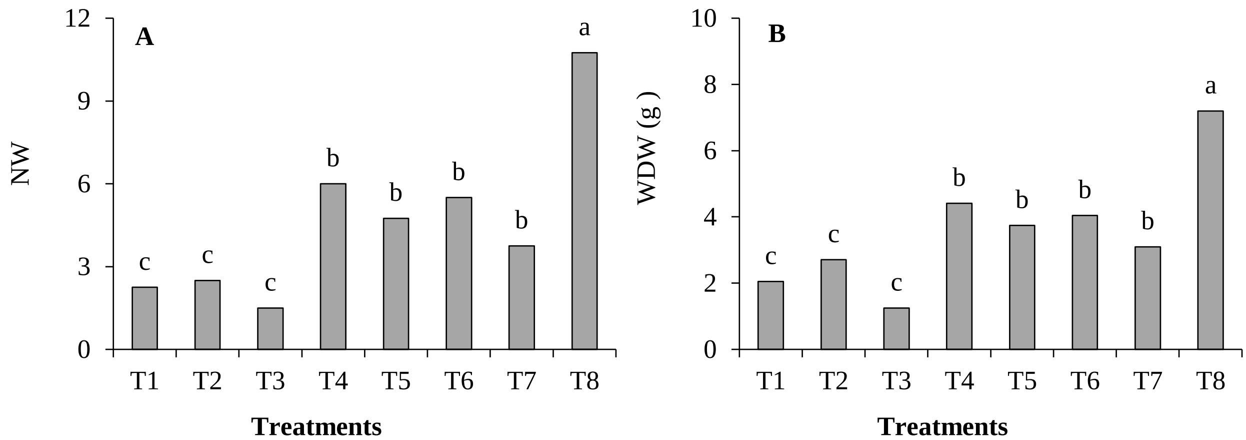

Figure 1. Number weeds – NW (A) and total weeds dry weight – WDW (B) in cowpea plants submitted to soil solarization and mulching. Mean followed by the same letter do not differ by Scott-Knott test at the 5% probability level. T1: solarized soil with castor bean mulch, T2: solarized soil with rattlepod mulch, T3: solarized soil with spontaneous vegetation mulch, T4: solarized soil without mulch, T5: non-solarized soil with castor bean mulch, T6: non-solarized soil with rattlepod mulch, T7: non-solarized soil with spontaneous vegetation mulch and T8: non-solarized soil without mulch.

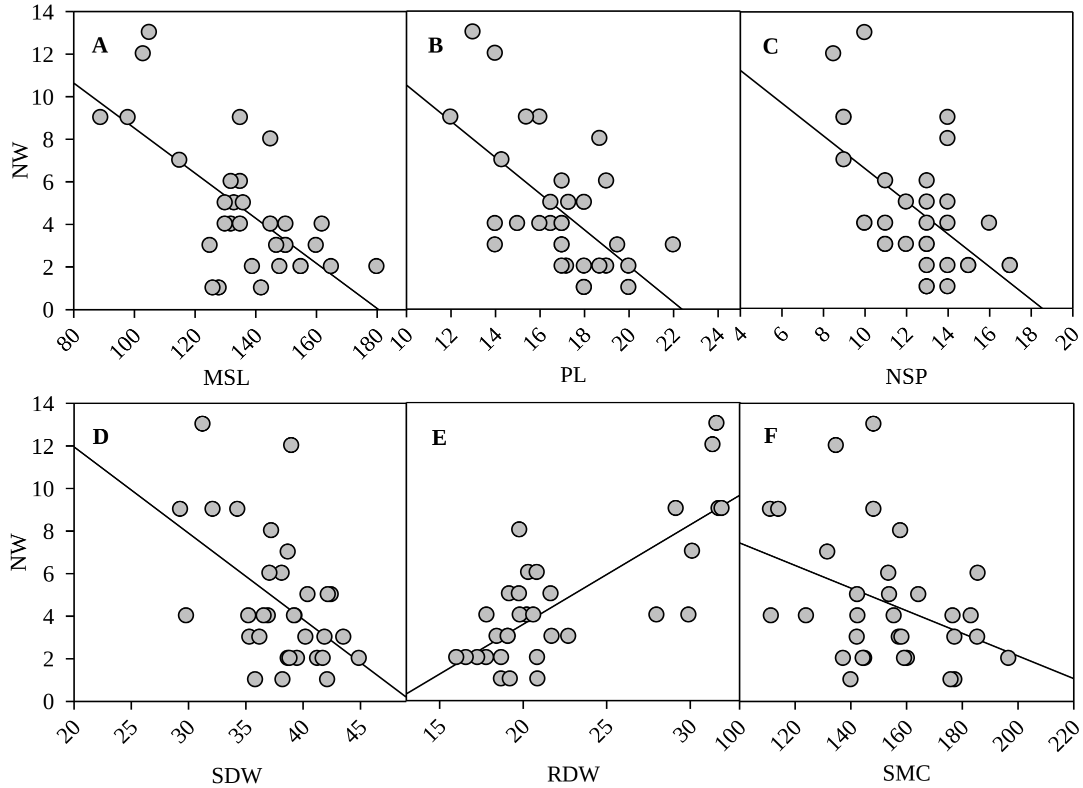

Figure 2. Correlation between weed occurrence and the development of cowpea plants submitted to soil solarization and mulching. NW: Number weeds; MSL: Main stem length; PL: Pod length; NSP: Number of seeds per pod; SDW: Shoot dry weight; RDW: Root dry weight and SMC: Shoot moisture content.

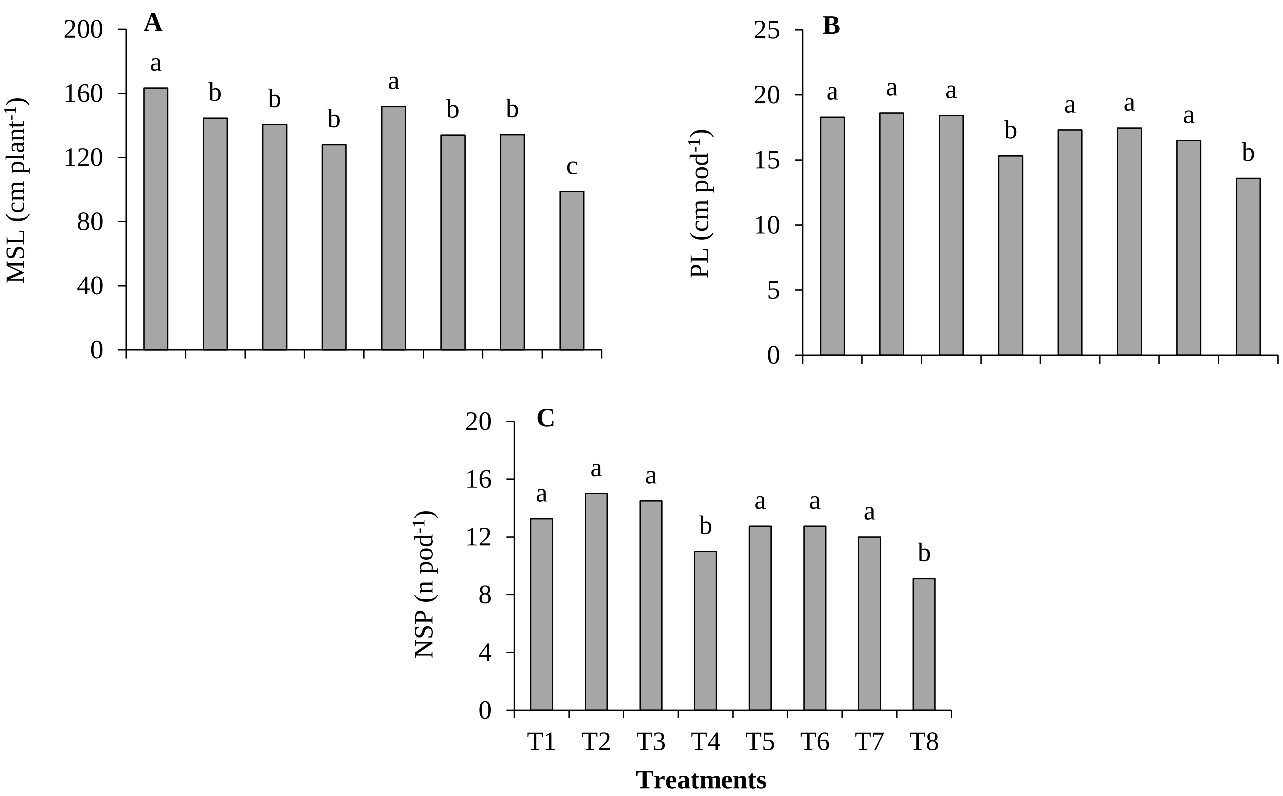

Figure 3. Main stem length – MSL (A), pod length – PL (B) and number of seeds per pod – NSP (C) in cowpea plants submitted to soil solarization and mulching. Mean followed by the same letter do not differ by Scott-Knott test at the 5% probability level. T1: solarized soil with castor bean mulch, T2: solarized soil with rattlepod mulch, T3: solarized soil with spontaneous vegetation mulch, T4: solarized soil without mulch, T5: non-solarized soil with castor bean mulch, T6: non-solarized soil with rattlepod mulch, T7: non-solarized soil with spontaneous vegetation mulch and T8: non-solarized soil without mulch.

The longer main stems observed in cowpea plants submitted to mulching, particularly with castor bean, is largely due to the greater uniformity of the mulch layer, which helped maintain soil moisture (Ferreira et al., 2015) and favored plant growth (Ziech et al., 2014; Flôres et al., 2017; Khalid et al., 2018). On the other hand, the low plant growth observed in non-solarized soil without mulching likely occurred because of the larger number of weeds (NW) competing with cowpea plants, as reported in peanut crops grown in non-solarized compared to solarized soil (Soumya et al., 2004), and bean plants without mulching (Pessôa et al., 2017).

The PL was higher in plants without mulching in both solarized and non-solarized soil (T1-T3 and T5-T7), and lower in treatments without mulch regardless of solarization (T4 and T8), with 15.3 and 13.6 cm, respectively (Figure 3B). Similar behavior was observed for NSP, where by treatments without mulching (T4 and T8) had only 11 and 9 pods, respectively (Figure 3C).

The PL and NSP are characteristics important in assessing the productivity of cowpea plants, since they contribute directly to the crop yield. As such, the higher values recorded for these variables in treatments without mulch, irrespective of solarization, indicates that mulching may have benefitted the cowpea plants in two ways: first, by suppressing weed growth and thereby reducing competition and increasing yield (Monquero et al., 2009; Pessôa et al., 2017), and second, by raising soil moisture retention and promoting more efficient water use (Teófilo et al., 2012; Ferreira et al., 2015), which improved pod yield. Shoot dry weight (SDW) was lower in cowpea plants grown in solarized or non-solarized soil without mulch (T4 and T8), at only 34.2 and 34.1 g, respectively, but was higher in the remaining treatments, reaching 41.7 in T3 (Figure 4A).

Similar to pod yield, SDW was higher in treatments with mulching, irrespective of soil solarization. In addition to mitigating weeds, mulch can improve the physical and biological characteristics of soil (Meschede et al., 2007; Ziech et al., 2014) and enhance plant performance, as reported by Pessôa et al. (2017), who found that weed control methods increased photosynthesis in cowpea plants, raising dry matter production. On the other hand, the soil not submitted to mulching was exposed to more sunlight, resulting in a larger number of weeds and ultimately damaging the crop, which was unable to fully realize its genetic potential (Meschede et al., 2007).

Root dry weight (RDW) was higher (31.6 g) in non-solarized soil without mulching (T8), followed by solarized soil without mulch (T4) at 29.3 g, but lower in the remaining treatments, with the lowest value (18 g) recorded in T1 (Figure 4B). In addition, it was observed that RDW correlated positively with the number of weeds (Figure 2E).

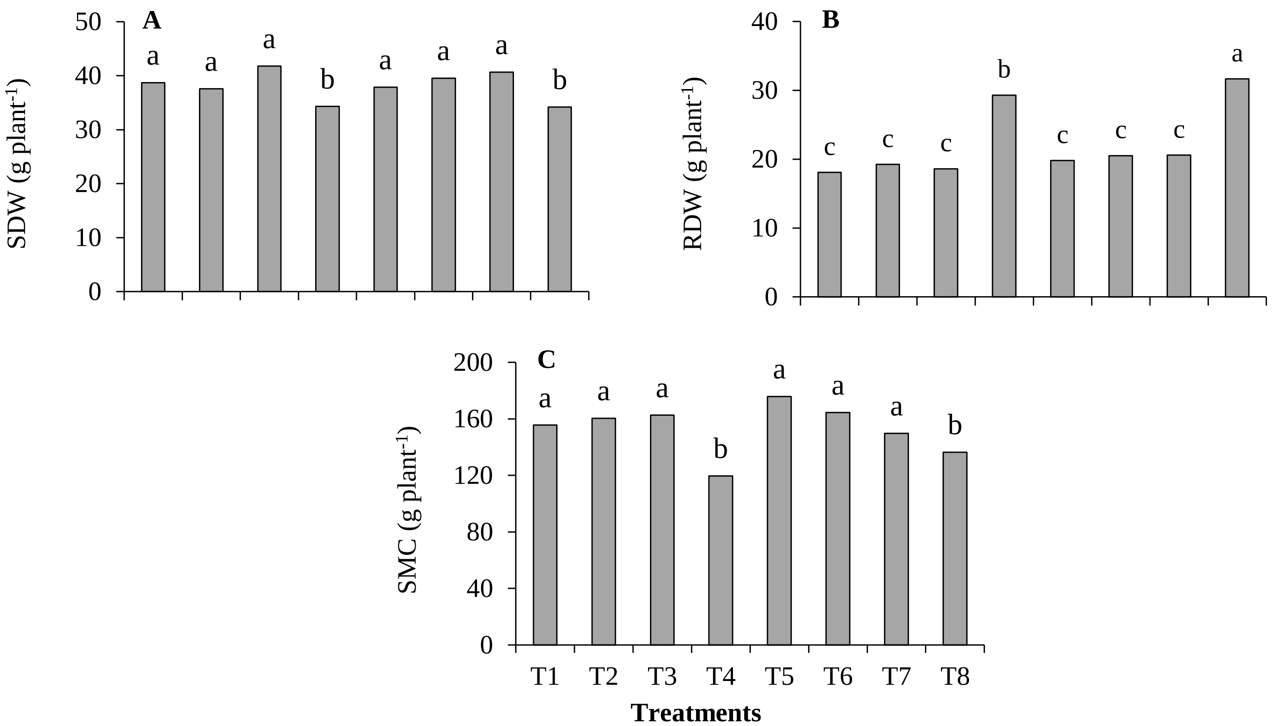

Figure 4. Shoot dry weight – SDW (A), root dry weight – RDW (B) and shoot moisture content – SMC (C) in cowpea plants submitted to soil solarization and mulching. Mean followed by the same letter do not differ by Scott-Knott test at the 5% probability level. T1: solarized soil with castor bean mulch, T2: solarized soil with rattlepod mulch, T3: solarized soil with spontaneous vegetation mulch, T4: solarized soil without mulch, T5: non-solarized soil with castor bean mulch, T6: non-solarized soil with rattlepod mulch, T7: non-solarized soil with spontaneous vegetation mulch and T8: non-solarized soil without mulch.

Root growth differed from that of shoots and was greater in plants grown in non-solarized soil without mulch. In this treatment, greater light exposure due to the absence of mulch likely resulted in higher evaporation and lower soil moisture levels, prompting the expansion of the root system in search of water (Polania et al., 2017). Additionally, RDW was lower in solarized than non-solarized soil, suggesting that the greater weed infestation observed without solarization increased competition with the crop, reducing water availability, inducing root expansion and raising RDW values. In fact, although solarization is somewhat efficient at controlling weeds, it is more effective than non-solarization (Ricci et al., 2000), as observed in the present study.

As observed for SDW, SMC was lower in plants cultivated without mulching regardless of solarization, whereas moisture content was higher in plants treated with mulch (Figure 4C). The different types of mulch used contributed to the growth of cowpea plants, both by suppressing weeds and favoring sustained moisture levels in the soil, which contributed to greater plant hydration, evident in the higher SMC values recorded under these conditions. Borges et al. (2014) found that plants with a higher moisture content were taller, had a larger leaf area and produced more biomass, which is consistent with the high PL, NSP, SDW and SMC values observed in cowpea plants submitted to mulching. Furthermore, treatments without mulching exhibited greater weed infestation, which competed with the cowpea plants for water and resulted in lower SMC values. Teófilo et al. (2012) found that weed interference affects the water consumption and yield of crops.

4. Conclusions

Soil solarization reduces weed populations in cowpea crops, especially when associated with mulching. Mulching favors the yield traits of cowpea plants, irrespective of solarization. The absence of solarization and mulching results in greater weed infestation, which affects the main stem and root growth of cowpea plants.

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