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Technical feasibility of geotextile fabric in bell pepper production under different irrigation levels

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Abstract – The Soiltain® DW geotextile fabric, used in water treatment plants, has a service life of three months, presenting itself as a solid residue, whose characteristics provide high strength and longevity, and can be an alternative mulching product in agriculture. This research aimed to evaluate the technical viability of geotextile fabric and mulching (synthetic and organic) in the production of bell pepper, Kolima F1 cultivar, under three irrigation levels. The experiment was carried out in Arapiraca, Alagoas – Brazil, in subdivided plots, with three irrigation levels in the main plots (60, 100 and 150% ETc) and four mulches in subplots (geotextile blanket, uncovered soil, white and organic mulching), with five replicates. Four evaluation cycles were carried out between 10/2019 and 03/2020. In general, agronomic variables were influenced by irrigation levels and mulching. Soil temperature was the variable that most negatively influenced plants, while white mulching associated the 150% ETc water level reduced plant performance. Geotextile blanket showed maximum water use efficiency (average 28.8 kg m^{-3}), average productivity (52.2 Mg ha^{-1}) and higher profitability (R$ 180.33), being a solid residue soil cover alternative, which must be associated with a 100% Etc water level.

Keywords: *Capsicum annuum*. Dripping. Mulching. Solid residue. Soiltain® DW.

Viabilidade técnica da manta geossintética na produção de pimentão em função de diferentes lâminas de irrigação

Resumo - A manta geossintética Soiltain® DW, utilizada em estações de tratamento de água, tem vida útil de três meses, apresentando-se como resíduo sólido, cujas características conferem alta resistência e longevidade, podendo constituir um produto alternativo na cobertura do solo na agricultura. Esta pesquisa objetivou avaliar a viabilidade técnica da manta geossintética e de coberturas do solo (sintético e orgânico) na produção de pimentão, cultivar Kolima F1, sob três lâminas de irrigação. O experimento foi conduzido em Arapiraca, Alagoas - Brasil, em parcelas subdivididas, estando nas parcelas principais três lâminas de irrigação (60, 100 e 150% da ETc) e, nas subparcelas, quatro coberturas do solo (manta geossintética, solo descoberto, mulchings sintético branco e orgânico), com cinco repetições. Foram realizados quatro ciclos de avaliação entre os meses de 10/2019 e 03/2020. Em geral, as variáveis agronômicas foram influenciadas pelas lâminas de irrigação e pelas coberturas do solo. A temperatura do solo foi a variável que mais exerceu influência negativa sobre as plantas. O mulching branco associado a lâmina de 150% ETc reduziram o desempenho das plantas. A manta geossintética apresentou máxima eficiência no uso da água (média 28,8 kg m^{-3}), produtividade média (52,2 Mg ha^{-1}) e maior lucratividade (R$ 180.33), consolidando-se como um resíduo sólido alternativo na cobertura do solo, devendo ser associado à lâmina de 100% ETc.

Palavras-chave: *Capsicum annuum*. Gotejamento. Mulching; Resíduo sólido; Soiltain® DW.

Viabilidad técnica de la manta geosintética en la producción de pimiento según diferentes profundidades de riego

Resumen - La manta geosintética Soiltain® DW, utilizada en plantas de tratamiento de agua, tiene una vida útil de tres meses, presentándose como un residuo sólido, cuyas características le confieren alta resistencia y longevidad, pudiendo constituir un producto alternativo para la cobertura de suelo en agricultura. Esta investigación tuvo como objetivo evaluar la viabilidad técnica de la manta geosintética y cobertura terrestre (sintética y orgánica) en la producción de pimiento, cultivar Kolima F1, bajo tres profundidades de riego. El experimento se realizó en Arapiraca, Alagoas - Brasil, en parcelas subdivididas, con tres profundidades de riego en las parcelas principales (60, 100 y 150% ETc) y en las subparcelas cuatro coberturas de suelo (manta geosintética, suelo desnudo, mantillos sintéticos blancos y orgánicos), con cinco repeticiones. Se realizaron cuatro ciclos de evaluación entre el 10/2019 y el 03/2020. En general, las variables agronómicas fueron influenciadas por la profundidad del riego y la cobertura del suelo. La temperatura del suelo fue la variable que más influyó negativamente en las plantas. El acolchado blanco asociado con una hoja de ETc al 150% redujo el rendimiento de la planta. La manta geosintética mostró máxima eficiencia en el uso de agua (promedio 28,8 kg m^{-3}), productividad promedio (52,2 Mg ha^{-1}) y mayor rentabilidad (R$ 180.33), consolidándose como una alternativa de residuos sólidos en cobertura vegetal, la cual debe estar asociada con una lámina de agua 100% ETc.

Palabras clave: *Capsicum annuum*. Goteo. Mantillo. Residuo sólido. Soiltain® DW.

Introduction

Irregularities in rainfall distribution and higher temperatures in the Northeastern region of Brazil promote significant evapotranspiration rates, which correspond to water lost to the atmosphere (mm or m^3 H_2O m^{-2} or ha^{-1} day^{-1}), so that irrigation water management and the use of techniques that aim to minimize water losses through evaporation are key factors to ensure productivity and sustainability of agricultural activities in rural properties (Wang et al. 2020). When it comes to the production of fruits, irrigation management must be considered important practice to obtain high productivity and quality products (Bernardo et al. 2013), because the water deficit induce the reduction of fruit size, moisture content, and production dry matter during different phases of development(Medyouni et al. 2021).

Supplementing water through irrigation is an important factor that promotes increased productivity and reduced risks, influencing the quality and quantity of fruits (Lima et al. 2006). Azevedo et al. (2005) observed maximum yield (18.9 Mg ha^{-1}) in 120% of the irrigation level. However, Kabir et al. (2020) observed no statistical difference between the 67 and 100% ETc levels in the yield of bell pepper fruits. This information indicates that the choice of irrigation level considers the geographic location, the agricultural species and the irrigation system.

Among methods, the drip irrigation system presents advantages, such as saving water, energy and labor, greater application uniformity, soil and topography flexibility, and less severity of shoot diseases (Marouelli and Silva 2012). When efficient irrigation system is linked to the monitoring of meteorological data and crop evapotranspiration calculations, it allows the application of the irrigation levels to be ideal for crop development at each development stage (Silva et al. 2018).

Associated with irrigation, soil cover has been widely used in agriculture with the aim of controlling weeds, reducing soil water losses through evaporation, facilitating harvesting and marketing (Hernández-Aranda et al. 2021), since the product is cleaner and healthier. Soil cover can be carried out by means of synthetic or organic materials, highlighting polyethylene mulching of different colors or natural residues, respectively (Jayawardana et al. 2019). In addition, solid residues, which would be disposed of in landfills, dumps or burned in the environment, can be used, being an ecologically correct practice, also reducing costs.

Soiltain® DW geotextile blanket, used in water treatment plants, is made of polypropylene fabric, 14 mm in thickness with high resistance and tonicity, with UV protection, inert to biological degradation and resistant to chemical attacks (alkalis and acids), which allows water to flow through its pores, retaining sludge and sediment, taking 25 years for its degradation in the environment (Guimarães et al. 2017). Blankets have useful life of three months and, considering their characteristics, they have been used by horticulturists from Arapiraca, and can be reused for several cultivation cycles. However, there is no scientific information to validate its agricultural efficiency.

Bell pepper (*Capsicum annuum* L.) is an annual species of tropical climate belonging to the *Solanaceae* family of economic importance in Brazil, being among the ten most cultivated vegetables (Trecha et al. 2017), with estimated production of 253 thousand tons of fruits, the Southeastern region being the region with the highest production, with 124 thousand tons. The Northeastern region concentrates 25.5% of the national production, especially states of Bahia, Ceará and Pernambuco, with the highest production (IBGE 2020). According to this Institute, the municipality of Arapiraca, located in the semi-arid region of Alagoas, is responsible for diversified production of vegetables, accounting for 43.9% (933 Mg year^{-1}) of bell pepper produced in the state.

It is estimated that 9.5% of Arapiraca properties use irrigation (IBGE 2017) and that 47% have dimensioned irrigation system (Silva et al. 2013). This information indicates that large part of properties use water without considering irrigation frequency and intensity, reflecting reduction in the water volume of the region's hydrographic basin, worsening in the driest periods of the year.

For these reasons, this research aimed at evaluating the technical viability of the Soiltain® DW geotextile blanket and mulching (synthetic and organic) under three irrigation levels in the cultivation of bell peppers in Arapiraca, Alagoas – Brazil.

Materials and methods

The research was conducted on a farm located in the community of Batinga at coordinates 9°47'44.8" S and 36°37'00.0" W, altitude of 247 m a.s.l, rural area of Arapiraca, between 10/25/2019 and 03/27/ 2020, totaling 152 days. During the experimental period, the average rainfall was of 324.9 mm and minimum, average and maximum temperatures were of 19.8, 25.8 and 37.2°C, respectively. The soil was classified as YELLOW LATOSOL with sandy loam texture (Embrapa 2018).

The experiment was installed in a completely randomized design in subdivided plots, considering as main plots the three irrigation levels (60, 100 and 150% ETc) and as subplots, four soil covers (SoilTain® DW geotextile blanket, uncovered soil, white polyethylene mulching and organic mulching), totaling 12 treatments, with five replicates. Plots had 6.0 m^2, containing 24 plants, of which 16 composed the experimental unit (19.0 m^2).

SoilTain® DW geotextile blanket was selected because it is a solid residue that is intended to be tested regarding its viability as alternative mulching. Uncovered soil was evaluated as one of the management practices adopted in the region. White waterproof mulching of 20 microns in thickness has been used by producers, without previous research. Dry non-commercial leaves of tobacco (*Nicotiana tabacum*), residue generated on property after harvesting the leaves for marketing, were used as organic mulching.

Hybrid bell pepper 'Kolima F1' cultivar was used, which presents green color, average fruit weight of 240 g, and widely grown in the micro region of Arapiraca. Seedlings were prepared using 200-cell trays with Bioplant® commercial substrate. The soil preparation was carried out with the aid of a rotating hoe coupled to a 6.5 CV tractor, at 0.15 m of depth. Subsequently, the beds were leveled and prepared in dimensions 6.0 x 1.0 m, under 0.4 x 0.4 x 1.0 m double row spacing, totaling initial stand of 55,555 plants ha^{-1}. At 35 days after planting, seedlings with four pairs of leaves were transplanted to the final location, placing one plant per pit. Planting was carried out on 10/25/2019.

Soil analysis (0 – 20 cm depth) showed the following characteristics: pH 7.5 (H_2O); P: 246 mg dm^{-3} (Mehlich); Na and K (Mehlich), Ca + Mg (KCl 1N) and H + Al (calcium acetate pH 7.0): 0.30, 0.25, 8.6 and 0.4 $cmol_c$ dm^{-3}, respectively; organic matter: 2.48%; Fe, Cu, Zn and Mn (Mehlich): 107.1, 5.57, 2.38 and 34.19 mg dm^{-3}, respectively. Soil physical composition was: coarse sand, fine sand, silt and clay: 301, 298, 235 and 166 g kg^{-1}, respectively. Following recommendations of Cavalcanti (2008), doses of 30 kg N ha^{-1} were used in foundation and 120 kg in cover, divided into doses of 40 kg N ha^{-1}, applied at 20, 35, 50 and 65 days after planting, with urea in fertigation as source. For potassium fertilization, 40 kg K_2O ha^{-1} in the foundation and 40 kg in cover (40 days after planting) as potassium chloride was used, with manual application.

For water management, classified as C1S1 (low salinity and sodicity levels), the system used was the drip. In impulsion line (50 mm), for a nominal flow of 20 m^3, were used filters of 2-inch disc, type 120 mesh, in fiberglass reinforced polypropylene, with a set of 198 mm discs and diameter of a set of 86 mm discs. The drip tapes had a nominal diameter of 16 mm, 8,000 μm of internal wall, with an operating pressure of up to 8.0 mca, allowing a flow of 1.6 L h^{-1}. The spacing between drippers was 0.20 m along side lines, with two emitters per plant, forming a continuous wet strip. For geotextile blanket, white mulching and organic matter treatments, the drip tapes were arranged under soil covers.

In the first fifteen days, irrigations were carried out uniformly at 100% crop evapotranspiration (ETc) in all plots, daily, with the objective of standardizing soil water content and favoring initial seedling growth. After the 15th day of transplant, different irrigation levels were applied, daily, with irrigation time calculated based on ETc, according to Allen et al. (1998), in which reference evapotranspiration (ET_0) was daily determined by the method of Hargreaves e Samani (1985) and solar radiation from the top of the atmosphere was calculated for the local coordinate. Throughout the cycle, three crop coefficient (Kc) values were used, 0.4 in phase I, 0.8 in phase II and III and 1.0 in phase IV (Marouelli and Silva 2012).

Irrigation time was calculated according to recommendations of Santos and Brito (2016). In the event of rain, the amount of rain was subtracted from the ETc to obtain the irrigation time and when rains were greater than ETc, irrigation was suspended and restarted when the actual soil water storage was depleted. The location coefficient (Kl) adopted for the calculation of the irrigation time was equal to 1.0, because irrigation in the bell pepper culture was continuous (Fereres 1981). Gross irrigation level for each treatment, per evaluation cycle, was: 1st cycle: 166.5, 259.21 and 375.09 mm; 2nd cycle: 107.26, 178.77 and 268.16 mm; 3rd cycle: 85.25, 142.09 and 213.13; 4th cycle: 79.38, 132.30 and 198.45 mm, for levels 60, 100 and 150% ETc, respectively.

Weed control in the uncovered soil treatment was carried out manually, four times during the experiment, with the aid of a hoe. Pest control was carried out according to incidence and to the level of damage, using chemical control (Rumo WG®).

Four evaluation cycles were performed, at 50, 96, 124 and 152 days after seedling transplant (DAT). Evaluations were carried out according to the harvest period adopted by the producer. The following variables were evaluated: plant height with the help of a measuring tape (cm), measured from the soil to the apical plant height; stem diameter with the aid of a caliper (mm), measuring close to the ground; and leaf width, measured with the aid of a caliper (mm), with leaves being collected from the median plant height at four ends.

The following productivity-related variables were also analyzed: number of fruits/plant; fruit length (caliper, in mm); fruit width (caliper, in mm); commercial fruit weight (scale, in g); commercial fruit productivity (number of commercial fruits/plant x fruit weight x stand; in Mg ha^{-1}); plant stand. Eight measurements per week of the soil temperature, measured with the aid of digital infrared thermometer (model GM400, in °C), was carried out at 0.10 m from the soil, close to the stem, in each treatment. Water use efficiency (WUE) was calculated for all treatments and considered productivity and applied gross water level according to Santos et al. (2015).

To evaluate the economic viability of each treatment, total cost (fixed costs + variable costs) and per treatment (bell pepper sale, R$) were considered. Viability was calculated by subtracting revenue from total costs, according to CONAB (2010), dividing into fixed and variable costs, with each item being calculated by treatment. Thus, in accounting terms, variable costs were separated into crop costs, post-harvest expenses and financial expenses, in which the latter was related to the working capital used. Likewise, fixed costs were differentiated into depreciation of the fixed capital and other fixed costs involved in production and remuneration of land and fixed capital factors.

Item values were determined in Reais (Brazilian currency, R$) based on the following specifications, adapted from CONAB (2010): a) fertilizers and pesticides: total used (kg and L) multiplied by the market price; b) 'Kolima F1' hybrid seedlings: total seedlings acquired multiplied by their unit value; c) labor: total hours worked in the culture multiplied by the working time value of the region; d) irrigation expenses: sum of all equipment acquisition costs multiplied by the unit value; e) electric energy: sum of the time of pump use multiplied by the kWh value; f) type of soil cover: sum of the area to be covered multiplying by the m^2 value of the material used; g) operation with machines and implements: sum of hours worked multiplied by the hour/machine value in the region; h) depreciation of the irrigation system: depreciation = {[(value of a new equipment - residual value)/useful life] x hours worked}. To obtain revenues, the values of all harvests in the production period were added and multiplied by their market value at the time (R$ 3.17 kg^{-1}; US$ 1.0 = R$ 5.48; April/2020).

Agronomic data were submitted to analysis of variance, applying the Scott-Knott test in the grouping of means (P <0.05). Considering that productivity is the main response variable in this research, the minimum number of measurements necessary to predict the real value was estimated based on the repeatability coefficient, using the principal component method (covariance matrix), considering R^2 of 99%. For the economic analysis, the average value (R$) for each treatment was used. Multivariate analysis was performed, using the principal component analysis, with standardized data.

Results and discussion

The presence of significant interactions (P<0.05) among factors irrigation levels (IL), soil cover (SC) and evaluation cycles (EC), indicate that the variation of factors influence the development of plants. Interactions between IL x SC (plant height, stem diameter and leaf width), IL x EC (fruits number/plant and WUE) and SC x EC (stand, fruits number/plant, temperature and WUE) were observed. No interaction was observed for the variables of the fruit length, width, weight and productivity and, no triple interaction (IL x SC x EC) was observed (P>0.05).

The experimental variation coefficient varied from 2.7% for fruit width, indicating excellent precision, up to 19.7% for productivity, considered acceptable in field research (Ferreira, 2018). Based on the repeatability coefficient, four evaluation cycles (R^2 = 99%) were sufficient to accurately predict the real productivity value, indicating that the increase in the number of evaluations would generate little accuracy gain. Bell pepper plantations in the region of Arapiraca last, on average, six months, using intensive management. In this sense, the increase in the number of measurements for the other variables would not have an impact on accuracy.

In general, the SoilTain® DW geotextile blanket promoted results superior to white mulching in relation to plant height, stem diameter and leaf width in the three irrigation levels, together with uncovered soil and organic mulching treatments (Table 1). White mulching promoted the lowest performance in bell pepper plants, probably due to the thermal stress in the root tissue, compromising the absorption of water and nutrients, with reflexes on growth-related variables (Gasparim et al. 2005).

Table 1. Irrigation level x soil cover interaction for morphological variables of bell pepper grown in Arapiraca, Alagoas.

Soil covers	Irrigation levels (% ETc)		
	60	100	150
	Plant height (cm)		
Geotextile blanket	29.4 aA	31.6 aA	27.5 bB
Uncovered soil	28.9 aB	27.8 bB	31.7 aA
White mulching	23.8 bB	26.7 bA	27.4 bA
Organic mulching	31.5 aA	29.8 aA	30.9 aA
	Stem diameter (mm)		
Geotextile blanket	13.7 aB	14.6 aA	13.5 aB
Uncovered soil	13.2 aA	13.1 bA	13.0 aA
White mulching	12.2 bB	12.8 bA	11.9 bB
Organic mulching	13.8 aB	14.3 aA	13.4 aB
	Leaf width (mm)		
Geotextile blanket	48.5 aA	48.7 aA	47.9 aA
Uncovered soil	47.8 aB	47.4 aB	48.7 aA
White mulching	46.6 bA	47.7 aA	47.4 aA
Organic mulching	48.5 aA	48.0 aA	48.3 aA

Means followed by equal letters, lower case in column and upper case in row, belong to the same group by the Scott-Knott test (P>0.05).

Among irrigation levels, that corresponding to 100% ETc promoted larger diameter stem (P<0.05), highlighting the geotextile blanket with higher values (Table 1). Unlike these results, Padrón et al. (2015) evaluated 'Tirano' pepper hybrid in San Juan Lagunillas/Venezuela did not observe effect of irrigation levels (60, 80 and 100% ETc) on stem diameter (average 17.7 mm). White mulching showed smaller leaf width in 60% ETc water level. When grown in uncovered soil, 'Kolima F1' hybrid required more water to obtain larger leaf width (Table 1), probably due to greater evapotranspiration in this cultivation system.

Irrigation level of 100% ETc showed the best results (P<0.05) for the agronomic variables of bell pepper (Table 2). This behavior is associated with the maintenance of adequate water levels in soil in the field capacity, allowing greater absorption of nutrients, greater distribution of photoassimilates transferred from leaves to plant organs, leading to better development (Carvalho et al. 2012).

Table 2. Effect of irrigation level on morphological variables of bell pepper grown in Arapiraca, Alagoas.

Levels (% ETc)	Variables				
	Stand	Width fruit (mm)	Length fruit (mm)	Fruit weight (g)	Productivity (Mg ha^{-1})
60	50,510 a	78.0 b	59.1 b	203.9 b	51.9 a
100	51,106 a	79.2 a	60.7 a	209.0 a	54.2 a
150	47,417 b	79.7 a	61.6 a	212.1 a	48.1 b
Mean	49,678	78.9	60.5	208.3	51.4

Means followed by equal letters in column belong to the same group by the Scott-Knott test (P>0.05).

Irrigation level of 150% ETc favored higher plant mortality during the crop development period, thus reducing plant stand and productivity. However, it favored greater fruit weight (Table 2), probably due to the lower intra and interplant competition provided by the lproarger spatial arrangement (Slam et al. 2011). Monge-Pérez (2016), evaluated 'Vikingo' hybrid in Alajuela/Costa Rica, at different densities, and observed increase in fruit weight (6.4%) and reduction in productivity by 13.6% (equivalent to 9.3 Mg ha^{-1}) with reduction in plant stand.

Treatment with white mulching obtained the lowest productivity (Table 3) due to its smaller plant stand. The average productivity observed in this research (51.4 Mg ha^{-1}) was next to the average (58.2 Mg ha^{-1}) of 15 bell pepper genotypes (minimum of 44.3 and maximum of 77.3 Mg ha^{-1}), obtained by Elizondo-Cabalceta and Monge-Pérez (2017) in Alajuela/Costa Rica.

Table 3. Effect of soil cover on agronomic variables of bell pepper grown in Arapiraca, Alagoas.

Soil cover	Variables	
	Fruit length (mm)	Produtivity (Mg ha^{-1})
Geotextile blanket	79.7 a	52.2 b
Uncovered soil	78.5 b	55.9 a
White mulching	78.7 b	40.3 c
Organic mulching	79.1 b	57.2 a
Mean	79.0	51.4

Means followed by equal letters in column belong to the same group by the Scott-Knott test (P> 0.05).

The increase in plant height, stem diameter and leaf width as a function of plant age (Table 4) reflects changes in the growth phases of bell pepper crop. Silva et al. (2010) studied the growth of 'Atlantis' bell pepper hybrid in different spatial arrangements in Baraúnas/RN and observed increases in the leaf area index up to 98 days after transplant, with tendency to slower growth with increasing plant age. With the end of this research in the fourth evaluation (152 DAT), stabilization of the sigmoidal plant growth was not observed. However, the productivity, main response-variable, stabilized (Table 4) and the repeatability analysis was efficient in identifying such stabilization, indicating four evaluation cycles, in which, additional cycles would not increase the accuracy.

Table 4. Effect of evaluation cycles on the morphological variables of bell pepper grown in Arapiraca, Alagoas.

Evaluation cycles (DAT)	Variables			
	Plant heigth (cm)	Stem diameter (mm)	Leaf length (mm)	Produtivity (Mg ha^{-1})
50	10.5 d	9.9 d	35.5 d	43.6 b
96	27.6 c	12.3 c	39.8 c	53.1 a
124	33.9 b	14.3 b	50.1 b	54.2 a
152	42.7 a	16.6 a	66.2 a	54.7 a

Means followed by equal letters in column belong to the same group by the Scott-Knott test (P>0.05). DAT: days after transplant.

'Kolima F1' hybrid showed low growth rates at 50 DAT, reflecting on productivity (Table 4). The number of fruits/plants was influenced by irrigation levels (Table 5). With growth at 96 DAT, demand increased and the volume provided by the 100% ETc water level favored the number of fruits (P<0.05). In the latest assessments, there was no effect of irrigation levels due to rainfall.

Table 5. Irrigation levels x evaluation cycles interaction for the number of bell pepper fruits/plants and WUE, Arapiraca, Alagoas.

Levels (% ETc)	Evaluation cycles (DAT)			
	50	96	124	152
	Fruits number/plant			
60	4.1 aC	4.9 bB	5.5 aA	5.8 aA
100	3.9 aB	5.3 aA	5.5 aA	5.5 aA
150	3.4 bB	5.4 aA	5.4 aA	5.5 aA
	Water use efficiency (WUE, kg m^{-3})			
60	36.5 aB	22.2 aC	50.2 aA	38.8 aB
100	25.3 bC	18.1 bD	37.1 bA	30.7 bB
150	18.9 cB	12.2 cC	23.5 cA	22.3 cA

Means followed by equal letters, lower case in column and upper case in row, belong to the same group by the Scott-Knott test (P> 0.05). DAT: days after transplant.

Regarding water use efficiency (WUE), at any evaluation stage, 60% ETc water level showed the highest efficiency (Table 5), that is, lower water level was needed to produce bell pepper fruits. Similar results were obtained by Carvalho et al. (2011), who studied 'Konan R' red bell pepper and obtained the best WUE results with 75% ETc water level in greenhouse in Lavras/MG. Souza et al. (2019) also observed greater efficiency in 60% ETc (55.6%), in Maringá/PR.

Significant reduction (P<0.05) in plant stand was observed for all soil covers (Table 6). However, reduction was more expressive for white mulching and geotextile blanket, respectively, due to the soil temperature in the initial seedling growth phase. Even though it is porous, it is likely that the black color of the blanket associated with its thickness (14 mm) promotes increase in temperature and stress in plants, promoting their mortality. Rodrigo and Goto (2016) observed that the soil temperature was higher (P<0.05) in treatments with plastic mulching when compared to uncovered soil. Although some authors have observed positive effect of increased soil temperature on plants, in this research, considering the semiarid climate conditions in the region, temperature increased seedling mortality, especially in the initial growth phase. However, it is possible that the increase in soil temperature may benefit plants in the winter.

Table 6. Soil cover x evaluation cycles interaction for plant stand, number of fruits/plants, soil temperature and WUE in Arapiraca, Alagoas.

Soil covers	Evaluation cycles (DAT)			
	50	96	124	152
	Stand			
Geotextile blanket	55,555 aA	47,743 bB	47,453 bB	47,453 bB
Uncovered soil	55,555 aA	52,950 aA	51,794 aA	51,794 aA
White mulching	55,555 aA	38,773 cB	38.,194 cB	38,194 cB
Organic mulching	55,555 aA	53,530 aA	52,372 aA	52,372 aA
	Fruits number/plant			
Geotextile blanket	3.8 bB	5.4 aA	5.4 aA	5.7 aA
Uncovered soil	4.3 aB	5.3 aA	5.4 aA	5.6 aA
White mulching	2.7 cC	4.9 bB	5.6 aA	5.5 aA
Organic mulching	4.4 aC	5.2 aB	5.5 aA	5.5 aA
	Temperature (°C)			
Geotextile blanket	50.5 aA	40.0 aB	38.3 aB	37.0 aB
Uncovered soil	47.5 bA	37.6 bB	38.7 aB	37.1 aB
White mulching	53.6 aA	42.7 aB	41.0 aB	38.0 aB
Organic mulching	41.3 cA	36.2 bB	35.7 bB	35.4 bB
	Water use efficiency (WUE, kg m^{-3})			
Geotextile blanket	28.0 aB	17.9 aC	37.5 aA	31.8 aB
Uncovered soil	26.3 aC	19.4 aD	39.9 aA	33.6 aB
White mulching	26.9 aB	14.0 bC	30.3 bA	24.4 bB
Organic mulching	26.4 aC	18.6 aD	39.9 aA	32.5 aB

Means followed by equal letters, lower case in column and upper case in row, belong to the same group by the Scott-Knott test (P>0.05). DAT: days after transplant.

When grown under uncovered soil conditions and organic mulching, 'Kolima F1' hybrid, in addition to presenting the highest stands ($P<0.05$), presented the highest number of fruits/plants in all evaluations (Table 6) and, consequently, the highest productivity values (Table 3). Organic mulching showed the lowest soil temperature among the different types of cover ($P<0.05$) in all evaluations. This is due to the fact that the use of mulching reduces the thermal amplitude and protects soil from direct solar radiation (Borges et al. 2015). It was also found that shoot growth favored soil cover. As plant increased its leaf area (Table 4), solar energy interception by its canopy also increased, reducing soil temperature from 96 DAT (Table 6).

Regardless of evaluation period, geotextile blanket, uncovered soil and organic mulching showed higher water use efficiency than white mulching (Table 6). Considering that white mulching was the treatment that obtained the highest soil temperatures, reflecting in reduced plant stand and, consequently, the productivity, it presented the lowest WUE.

From the economic viability point of view, geotextile blanket used as alternative mulching showed the best results, as it is a product free from cost and requires less maintenance and eliminates the use of weeding, thus resulting in lower production costs, reflecting in income gains. At the end of the experiment, considering the area cultivated with each treatment (useful plot area of 19 m^2), the geotextile blanket produced profit of R$ 180.33, followed by organic mulching, with R$ 121.33, and white mulching and uncovered soil, with R$ 43.77 and R$ 36.33, respectively.

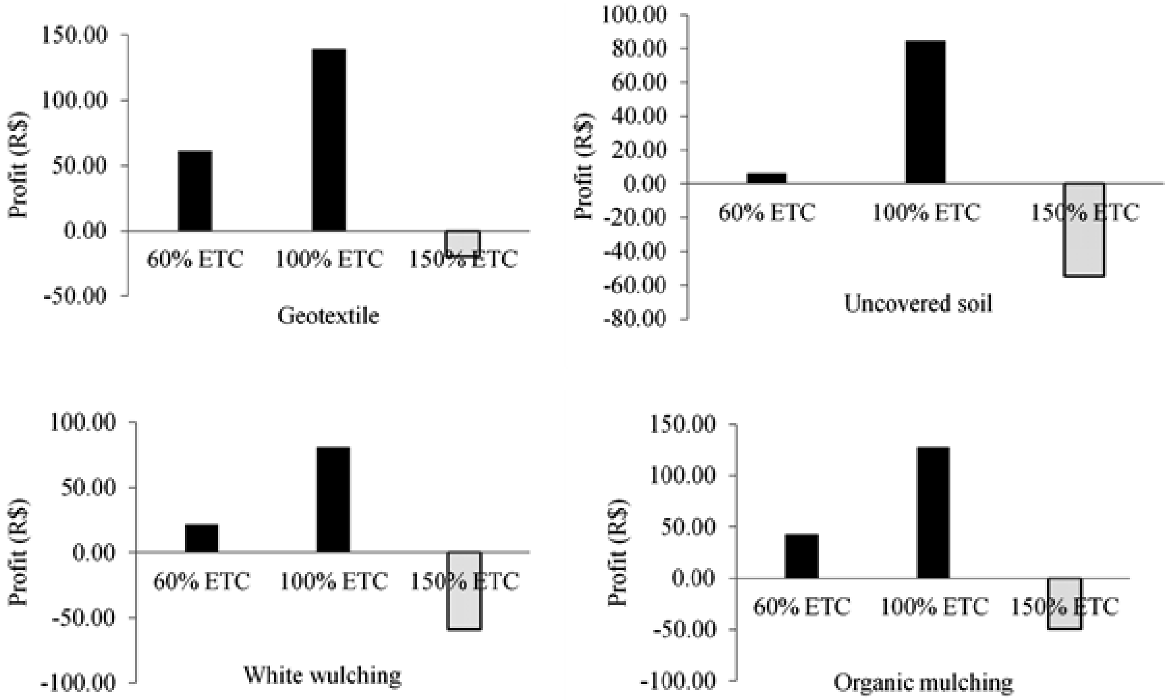
In the uncovered soil treatment, there was a need to carry out four manual weeding, directly impacting profitability. Regarding white mulching, in addition to requiring more careful handling to avoid physical damage (fragile material), additional care in its disposal is necessary after use, considering that some producers burn this product.

Uncovered soil had higher cost than the other treatments in terms of implementation and maintenance per unit area (R$ 39.70 m^{-2}) due to the greater labor applied in the crop cultivation such as weeding and maintenance of beds, thus increasing cost in relation to the other treatments. Geotextile blanket had the lowest implementation and maintenance cost, with R$ 33.70 m^{-2} because it is a product free from cost, requiring lower maintenance, reducing labor cost. Organic and white mulching had costs of R$ 38.80 and R$ 36.20 m^{-2}, respectively.

White mulching, despite having low implementation costs, acquisition costs associated with low productivity (Table 3) increased the implementation cost. Regarding organic mulching, despite having no or low acquisition cost, requires implementation and maintenance labor, being necessary, during the cycle, to carry out manual weeding and maintenance of beds, increasing labor cost.

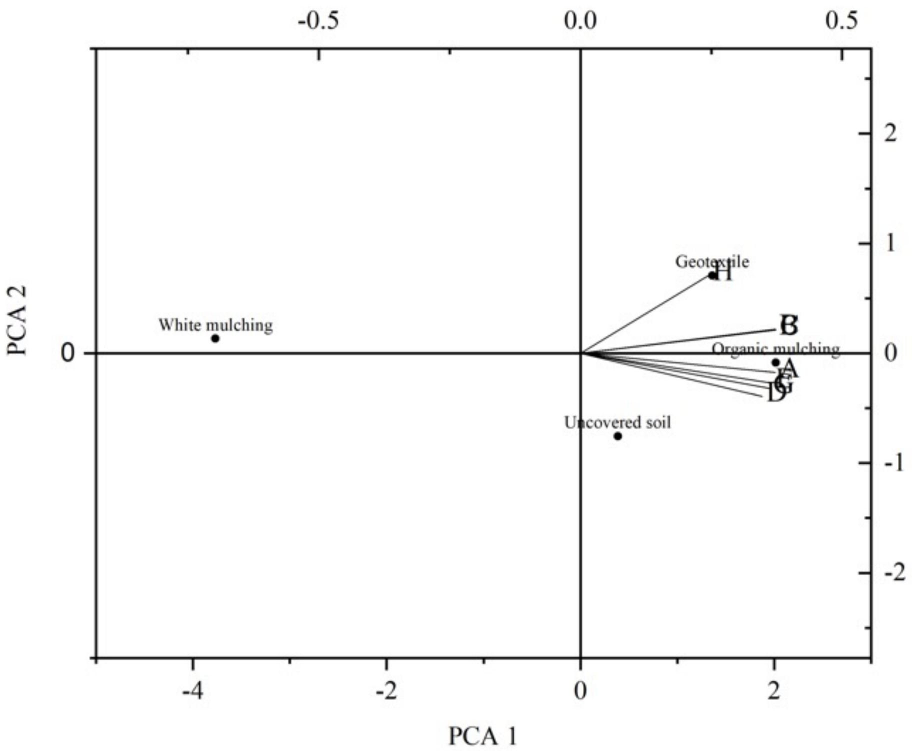
Irrigation level of 100% ETc showed greater profitability in the four soil covers, highlighting geotextile blanket (R$ 139.10). On the other hand, white mulching presented the lowest profitability (R$ 80.90) in this irrigation level. Irrigation level of 150% ETc showed negative results, with R$ -19.58, R$ -49.24, R$ -54.72 and R$ -58.76 for geotextile blanket, organic mulching, uncovered soil and white mulching, respectively (Figure 1).

Figure 1. Profit for the soil cover and applied irrigation level interaction.



The sum of the accumulated variation in the first two principal components was 99.4%, indicating that the analyzed variables were important to accurately explain the results. The direction and proximity of the lines in the graph (Figure 2) to each variable indicates a strong positive correlation.

Figure 2. Dispersion biplot (PCA 1 x PCA 2) graph of treatments and variables evaluated. A: plant height; B: stem diameter; C: leaf width; D: stand; E: fruits number/plant; F: width fruit; G: productivity; H: profit.



Considering all variables, it is possible to propose the formation of three groups, in which treatments uncovered soil and organic mulching presented similar characteristics, remaining in the same group (Figure 2), indicating that the adoption of anyone of the production systems will provide similar results. On the other hand, geotextile blanket and white mulching were different from each other and from other treatments, remaining in different groups. The white mulching is the production system that promotes unfeasible results if adopted by the producer (PCA 1). The geotextile blanket presented superior results in relation to the others, mainly in terms of profitability (H, Figure 2), being the most suitable system.

In general, agronomic variables were influenced by irrigation levels and soil cover. Soil temperature was the variable that most negatively influenced plants. White mulching and 150% ETc water level reduced plant performance. Multivariate analysis confirmed the results obtained, in which it was possible to observe the formation of three groups, highlighting white mulching, which presented the most unfavorable characteristics. On the other hand, geotextile blanket, compared to other treatments, presented satisfactory results for variables under study, mainly in relation to productivity, which, when associated with its gratuity and reduced crop management, presented the best economic return, especially when associated with 100% ETc water level.

Conclusions

Soiltain® DW Geotextile blanket, a solid residue from water treatment plants, when associated with 100% ETc water level, is an economically viable alternative in the production of drip irrigated bell pepper.

The agronomic variables of 'Kolima F1' bell pepper hybrid are influenced by irrigation levels and soil cover. Soil temperature is the variable that most negatively influences production components, especially regarding plant stand and, consequently, productivity. In this sense, producers should adopt 100% ETc water level as a management strategy.

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