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RURAL ENGINEERING

Technologies for reducing water consumption by pineapples in the semi-arid region

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ABSTRACT: In irrigated systems, the adoption of management methods like soil cover, polymers which absorb the water present in the soil and the utilization of shading screens can decrease the water consumption by the plants. This is achieved as these means protect the plant and soil against radiation and wavelengths of light undesirable for cultivation. However, for pineapple cultivation in the semi-arid climate regions, very little study has been done regarding these technologies. Hence, the present study conducted to assess the pineapple growth, production and quality when various kinds of soil cover, red shading screen and water absorption polymers are employed. To accomplish this, a field trial was performed utilizing four types of soil cover in the plots (plastic mulching; organic matter; organic matter + red shading screen 50%; plastic mulching + red shading screen 50% and the control (no cover).Two treatments were included in the subplots namely, either the absence or presence of a water-absorbing polymer in the planting hole (0.5 g per plant), arranged in subdivided plots. We adopted the Randomized Complete Block (RCB) , with three replications. The following aspects of the plants were studied: naturally flowering, stem diameter; leaf area index; D-leaf area and total leaf area; fruit weight with crown; fruit weight without crown; fruit length with crown; and fruit length without crown, as well as the traits of the post-harvest fruit, soluble solids, titratable acidity, pH and the soluble solids/titratable acidity ratio. Further, the productivity in t ha^{-1} and efficiency of water use (EUA) were ascertained. It was evident that the plastic mulching + 50% red shading screen favored the vegetative development and productivity of the 'IAC Fantástico' pineapple plants. The characteristics of the quality of the postharvest fruit were unaffected by the treatments. The shading screen reduced the percentages of natural flowering in the treatments which included organic matter + red shading screen 50% and plastic mulching + red shading screen 50%.
Key words: *Ananas comosus*, Fantastic IAC, shading screen, hydrogel, mulching.

Tecnologias para redução do uso de água no abacaxizeiro em região semiárida

RESUMO: A utilização de práticas de manejo com cobertura do solo, uso de polímeros de absorção de água no solo e telas de sombreamento podem diminuir o consumo de água em sistemas irrigados, por proporcionarem proteção da planta e solo contra a presença de radiação e comprimentos de onda (luz) indesejados para o cultivo, no entanto essas tecnologias são pouco estudadas no cultivo de abacaxizeiro em regiões de clima semiárido. Assim, o trabalho foi realizado com o objetivo de avaliar o crescimento, produção e qualidade do abacaxizeiro em resposta a utilização de diferentes tipos de cobertura de solo, tela de sombreamento vermelha e polímeros de absorção água. Para isso, desenvolveu-se ensaio de campo composto por quatro coberturas de solo nas parcelas (mulching plástico; matéria orgânica; matéria orgânica + tela de sombreamento vermelha 50%; mulching plástico + tela de sombramento vermelha 50% e o controle (sem cobertura) com dois tratamentos nas subparcelas referentes a ausência e presença de polímero absorvedor de água colocado na cova de plantio (0,5 g por planta), dispostos em parcelas subdivididas, no delineamento experimental em blocos ao acaso, com três repetições. Foram avaliadas a porcentagem de plantas com florescimento natural; diâmetro do talo; índice de área foliar; área foliar de folha D e área foliar total; peso do fruto com coroa; peso do fruto sem coroa; comprimento do fruto com coroa; e comprimento do fruto sem coroa, bem como as características pós-colheita de frutos, sendo sólidos solúveis; acidez titulável; pH e relação sólidos solúveis/acidez titulável. Foram determinadas a produtividade em t ha-1 e eficiência do uso da água (EUA). O mulching plástico + tela de sombramento vermelha 50% apresentou-se mais favorável ao desenvolvimento vegetativo e produtividade das plantas de abacaxizeiro 'IAC Fantátisco'. Os tratamentos não influenciaram nas características de qualidade pós-colheita de frutos. A tela de sombreamento proporcionou menores porcentagens de florescimento natural nos tratamentos matéria orgânica + tela de sombreamento vermelha 50% e mulching plástico + tela de sombreamento vermelha 50%.
Palavras-chave: *Ananas comosus*, IAC Fantástico, tela de sombreamento, hidrogel, mulching.

INTRODUCTION

While the pineapple cultivar has a relatively low water requirement, one of the principal drawbacks in raising this crop is the inefficient water usage in the irrigated systems, arising from the paucity of research on technologies which focus on lowering the water loss via evaporation and leaching that occurs in the soil, as well as boosting the efficiency of the plants in terms of water usage.

To ensure that the pineapple crop achieves its full productive potential, it becomes crucial that the cultivation is done in an area receiving well-distributed annual precipitation

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(1,000 to 1,500 mm) and temperatures in the range of 22 to 32º C and thermal amplitude from 8 to 14º C (REINHARDT et al., 2013).

Some of the main technologies include employing ground covers, shading screens and water-absorbing polymers. When these technologies are used either individually or in combination in pineapple cultivation, they are found to heighten both the production and fruit quality, as well as decrease the use of water, apart from other inputs.

Plastic mulching is seen to affect soil temperature. Due to the higher levels of heat absorption, darker colors raise the soil temperature, while the lighter colors reflect greater amounts of solar radiation, causing the temperature to drop, thus enhancing the irradiance under the plant canopy (JAHAN et al., 2018).

The use of shading screens is steadily rising in popularity in a variety of crops as a means of lowering the intensity and raising the distribution of the radiant energy that directly reaches the plants. These shading screens are available in a range of colors (blue, red, yellow, gray, black) with specific functions for their usage.

The red screens were observed to have the ability of transferring more light from the spectrum into red and Far-red waves, as well as diffuse the light passing through the mesh, and raising the efficiency of plant development (LI, 2006). Besides, irrespective of the shading factor, the red mesh transmits more of the photosynthetically active radiation (PAR) into the cultivation area (GAMA et al., 2017). Further, the light transmitted through this layer of materials encourages the differential stimulation of a few of the light-controlled physiological responses, namely photosynthesis as a function of photosynthesis photon flux density and leaf chlorophyll content (ILIĆ et al., 2017).

When there are conditions of adequate light supply, together with the adoption of other technologies like the addition of water-retentive polymers to the soil, the irrigation efficiency is raised, as they facilitate the retention of the available water for plant growth thus boosting both the quality and quantity of the yield (NAVROSKI et al., 2015).

In light of the above, the present study was performed to assess the growth, production and quality of the pineapple cultivar when water-absorbing polymers, a variety of soil covers and a red shading screen were used.

MATERIALS AND METHODS

The present research was performed in an experimental site, present in the municipality of Janaúba, MG, with the geographic coordinates of 15° 43’ 48” S, 43° 19’ 23” W and an altitude of 533 m and climate type “Aw” (typical of the rainy tropical savannah and dry winter). The types of weather conditions confirmed through the duration of the experiment are shown in figure 1.

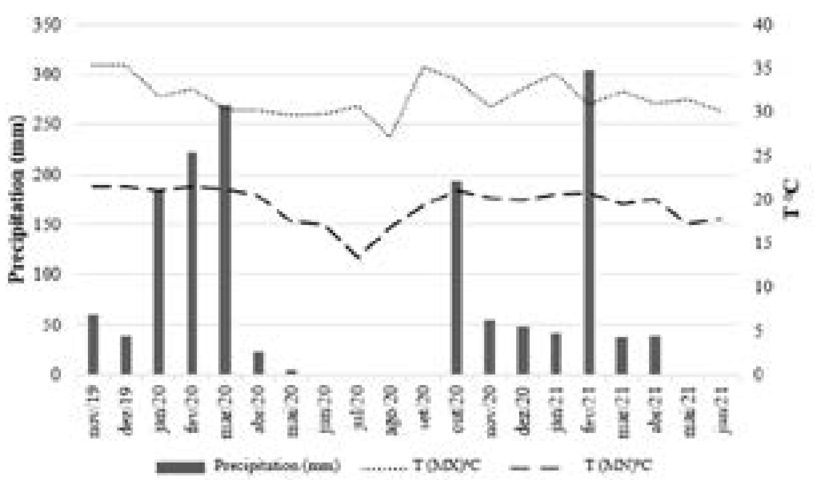

Figure 1 - Precipitation, minimum temperature-T(MN) and maximum temperature-T(MX) recorded in the course of the experimental period (Janaúba, MG).

At the selected site of the study, the soil was classified as Eutrophic Red Latosol (EMBRAPA, 2013). First, 10 simple samples were drawn to make a composite sample from 0-20 cm depth in order to ascertain the physical and chemical features cited here: pH (H2O) = 7.2; MO = 1.5 dag kg-1; P = 12.9 mgdm-3; K= 202 mgdm-3; Al3+= 0 cmolc dm-3; Ca2+= 4.2 cmolc dm-3; Mg= 1.0 cmolc dm-3; Zn = 31.1 mg/dm-3; Fe = 19.3 mg/dm-3; Mn = 67.8 mg/dm-3; Cu = 0.6 mg/dm-3; B= 0.3 mg/dm-3; H+Al = 0.9 cmolc dm-3; SB = 6.4 cmolc dm-3; V(%) = 87; m(%)= 0; effective CTC 5.5 cmolc dm-3; Total CTC 6.8 cmolc dm-3 and P-rem 33.3 mgL-1.A field trial was conducted in the plots which included four soil covers (plastic mulching; organic matter; organic matter + 50% red shade cloth cover; plastic mulching + 50% red shade cloth cover and the control (no cover), which involves two treatments in the subplots (having the absence and presence of a water-absorbing polymer placed in the planting hole (0.5 g per plant), in accordance with manufacturer's recommendations; they were placed in order, in the subdivided plots of the experimental design, in randomized blocks, with three replications. The experimental plot included two double rows, each of which was 3 m in length, ensuring 0.9 x 0.4 x 0.3 m spacing. To accomplish the evaluation, eight central plants were selected from each subplot.

The organic mulch was spread evenly to 5 cm height above the ground in all the treatments. For each treatment, the red shading screen was installed on four wooden posts, placed to a height of 1.20 m above the ground, confirming that the entire plot and its sides were covered.

Planting was done using the pup type seedlings, and pup-sprout of the '*IAC Fantástico*' cultivar, about 30 cm in height. Irrigation was performed using a fixed conventional sprinkler, at a height of 1.60 m above the soil, maintaining a spacing distance of 0.6 x 0.6 m between the emitters, throughout the experimental site. Approximately 15 mm of water was used per week, irrespective of rainfall, for roughly 60 mm in total per month.

The soil was prepared using the conventional method, which involves one plowing and two harrowing procedures. At the time of planting, micronutrients were added per plant using 4 g of P2O5 as monoammonium phosphate (MAP) and 8 g FTE BR12 as the source. During the vegetative phase of the pineapple, N and K supplements were added as fertilizer, as monthly applications, for a total of 20 g plant-1 of N and 15 g plant-1 of K2O, as urea and KNO3, respectively, until floral induction, according to CARDOSO et al. (2013).

The date of floral induction was set earlier at 14 months post planting, which was April 2021, and was performed 484 days after planting was done. At that time, 50 mL of Ethrel® (1% a.i.) for every 20 L of water from a backpack pump was mixed with calcium hydroxide (lime) and added in a dose of 0.35 g L-1 of water. Next, 50 mL of this solution was applied per plant to the leaf rosette of the pineapple plant.

The fruits growing in the plots not provided with a shade cloth were protected using a paper sheet instead, 60 days post floral induction, to decrease the degree of burning due to solar radiation. The fruits were harvested when at least 50% of the skin turned yellow in color.

The variables cited here were determined: percentage of plants with natural flowering, stem diameter, leaf area index, leaf area of leaf D and total leaf area, weight of fruit with crown, weight of fruit without crown, length of fruit with crown and length of fruit without crown.

Between 10:00 and 14:00 h, the leaf area index was estimated using the AccuPAR model LP-80 ceptometer, employed by carefully following the manufacturer's specifications. For each subplot three readings were taken, below and above the canopy of each healthy plant. The stalk diameter was measured with digital calipers and the data was noted in centimeters (cm). The percentage of natural flowering was assessed from the number of plants that flowered in the absence of the addition of any flowering inducer. Leaf area of leaf D and total leaf area were estimated using the methodology described by SANTOS et al. (2018).

In order to assess the fruit weight, a semi-analytical scale, having 0.001 g precision, was used. The productivity in t ha^{-1} was estimated by multiplying the average fruit weight, with and without the crown, respectively, by the plant density.

Water Use Efficiency (WUE) was calculated as the relationship between the yield and known gross irrigation depth, and given in kg ha-1mm-1, as adopted by SANTOS et al. (2016).

US= Productivity/LBA

In which,

USA: water use efficiency (kgha-1mm-1)

Productivity: fruit productivity for each treatment (kgha-1);

LBA: gross applied depth related to evapotranspiration of the crop in each treatment, in terms of irrigation days (mm). Soluble Solids (SS) analysis was performed on the pulp drawn from the sampled fruits, and determined by refractometry with the use of a digital refractometer. The results were cited in °Brix; the Titratable Acidity (TA) was assessed based on the technique advised by the AOAC (1992). The titration itself was performed in a burette, which was agitated, using the juice from the selected fruits from each repetition, after the extraction, crushing and homogenization of 10 g of the pulp in 90 mL of distilled water, to which 0.1N NaOH was added. The indicator used was 1% phenolphthalein. The results were given in terms of grams of citric acid per 100 g of pulp. The pH was noted using a bench potentiometer, having a glass membrane electrode calibrated with the solutions of pH 4.0 and 7.0 (AOAC, 1997); the soluble solids/titratable acidity ratio (ratio) was determined by dividing the percentage of the total soluble solids by the titratable acidity. Univariate and multivariate analyses of variance were done on the data collected with respect to the characteristics assessed in the present research. The Tukey test at 5% significance was performed on the means in the univariate analysis. In the case of the multivariate analysis, the 10 characteristics cited here were defined earlier: weight and length of the fruit with crown, soluble solids, titratable acidity and Brix/acidity ratio of the pulp, stem diameter, total leaf area, leaf area index and SPAD on sheet D. The dispersion of scores derived from the analysis of canonical variables enabled the identification of the characteristics that had the highest relative importance in a two-dimensional scatter plot. Statistical analysis was done utilizing the statistical software R (ExpDes.pt and Multivariate Analysis packages).

RESULTS AND DISCUSSION

The canonical correlation between the characteristics assessed and the dispersion of the five treatments (which stemmed from the combination of the three soil cover types and the two conditions, with the addition and in the absence of the water-absorbing polymer) arising from the canonical variables of the characteristics, are listed in figure 2 and table 1.

With respect to the canonical variable 1 (VC1), a high positive correlation was evident between the variables of natural flowering, soluble solids/titratable acidity relationship and soluble solids. This implies that the greater the value of VC1 in the scatter plot, the higher are the values of these traits estimated. However, the results were contrary for the variables like weight of fruit with crown, weight of fruit without crown, fruit length, fruit length, titratable acidity, stem diameter, leaf area D, total leaf area and index of leaf area. Regarding the canonical variable 2 (VC2), higher correlations were recorded, which were negative for the SPAD and FLOR variables. Therefore, the higher the VC2 value, the lower will be the values of these variables.

From the outcomes of the correlation three groups of treatments could be formed in the two-dimensional scatterplot. The first group included the plastic mulching treatments + 50% red shade cloth, with and without the polymer (MPS:COM and MPS:WITHOUT). A second intermediate group was noted which included the treatments that had organic mulching + 50% red shade cloth, with and without the polymer (MOS:COM and MOS:WITHOUT). Finally, the other treatments composed a third group: organic mulching, with and without the water-absorbing polymer (MO: WITH and MO: WITHOUT), plastic mulching with and without the polymer (MP: WITH and MP: WITHOUT), control with and without the water-absorbing polymer (TEST: WITH and TEST: WITHOUT).

Soil covered with white plastic mulching with the additional 50% red shade cloth, and with and without the polymer, induced higher leaf area index, weight and length of the fruits with crown, total leaf area, stem diameter and titratable pulp acidity. However, it caused a drop in values of the SPAD index of leaf D, soluble solids and the Brix/acidity ratio of the pulp and natural flowering. These variables were, hence, more evident in the control plants (without coverage), provided with plastic mulching and organic mulching, with and without the water-absorbing polymer. While intermediate values were recorded for all the variables studied, the plastic mulching treatments linked to the use of the red shade cloth with and without the water-absorbing polymer are note-worthy.

The mulching used in combination with the shade cloth may have induced a microclimate with improved conditions for the pineapple plants to develop, enhancing the characteristics that promote agronomic interest.

The mulching applied enhanced the plant growth, by controlling the soil moisture regimen, minimizing temperature fluctuations, as well as reflecting root development, ensuring efficient water and nutrient usage, and aiding in climate resilience, as cited by Acharya, Bandyopadhyay and Hati (2018). The completely uncovered treatments received direct irradiance, and this greater exposure to high temperatures and luminosity could exert a negative effect on the traits investigated when compared with the plants that were provided with the shade cloth. The slow development of plants is linked to the soil

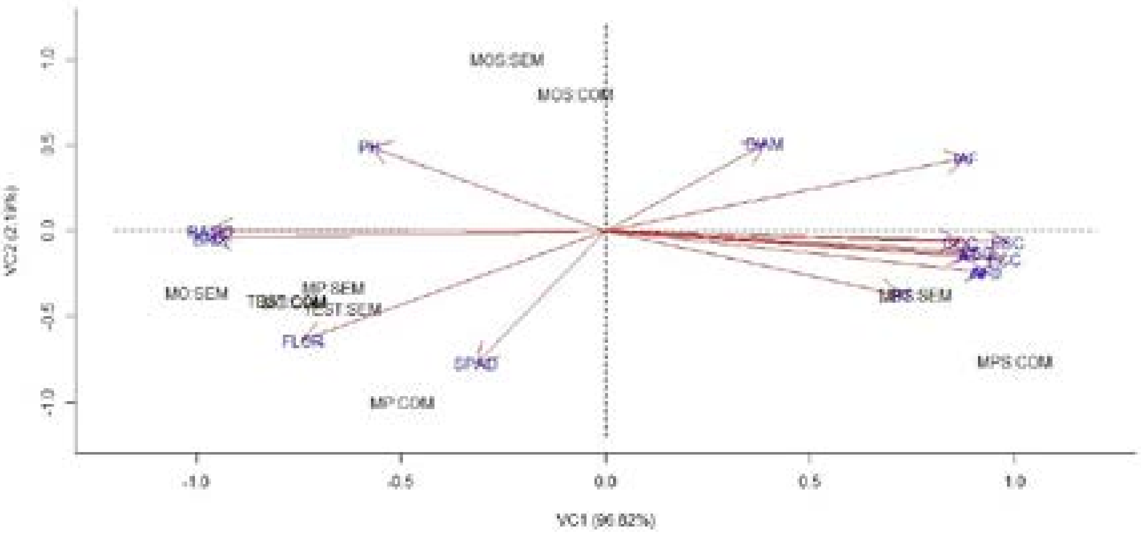

Figure 2 - Graphical representation of the distribution of the pineapple plants raised under a variety of technologies to decrease the water consumption in terms of it being related to the first and second canonical variables (Canonical variables 1 and 2, respectively), on the basis of the variables cited here: flowering, weight of the fruit including the crown, weight of the uncrowned fruit length, crowned fruit length, uncrowned fruit length, leaf area index, D-leaf leaf area, total leaf area, spad, ratio and °Brix. The Figure displays the treatments performed TEST:COM = Control with polymer; TEST:WITHOUT = Control without polymer; MP:COM = White plastic mulching with polymer; MP:SEM = White plastic mulching without polymer; MO:COM = Organic mulching with polymer; MO:SEM = polymer-free organic mulching; MPS:COM = White plastic mulching + 50% red shade cloth with polymer; MPS:SEM = White plastic mulching + red shade cloth 50% polymer-free; MOS:COM = Organic mulching + 50% red shade cloth with polymer; MOS:SEM = Organic mulching + 50% polymer-free red shade cloth.

and climate conditions that do not encourage crop growth in the semi-arid parts of Minas Gerais, with its prevailing high temperatures, which are around 25ºC and exceed 28ºC.

The red screen used was observed to enrich the plant canopy with diffused light, believed to have greater efficiency photosynthetically than direct light, as it can gain better entry into the plant (ILIĆ et al., 2017).

The decreased application of water linked to the treatments of plastic mulching + 50% red shade cloth, organic mulching + 50% red shade cloth, plastic mulching and organic mulching in the pineapple cultivation demonstrated positive responses in relation to the depth of water in the conventional methods of raising this crop. Mulching most likely supported the availability of soil water for a longer time duration for the plants, lowering the water lost through evaporation.

The water-absorbing polymers were found to have no effect on the percentage of plant flowering (Table 1). The treatments that yielded the least natural flowering averages were organic matter + 50% red shade cloth and plastic mulching + 50% red shade cloth, and with no statistical difference between the two. The control plants (having no coverage), plastic mulching and organic mulching revealed the highest percentages of natural flowering and the results are listed in table 1.

The resultant inhibition or decrease in natural flowering in the treatments where the red shade screen was used, is perceived as the phytochrome-response to the wavelengths of light (quality of irradiance) that actually land on the leaves and are recognized by these pigments.

The 50% red shading screen has been deduced to raise the amount of red light available for the plants which the phytochromes absorb, thus inducing greater accumulation of the Fver light. This inhibits flowering in the pineapple plants (short-day plants). Flowering usually occurs under Fv light which is accumulated during the night, although this process stopswhen the conditions include long days and short nights.

Phytochromes act like keys. In the Fv form, the phytochrome absorbs the red light and changes it to Fve, which in turn absorbs the light in

Table 1 - Percentage of natural flowering in pineapple plants that were treated with mulching, water-absorbing polymers and red shade screening.

Treatments	---------------------------Natural flowering (%)---------------------------	
	With polymers	Without polymers
Test	58.3 Aa	50 Aa
MP	50 Aa	41.6 Aa
MOS	4.1 Ba	0 Ba
MPS	12.5 Ba	8.3 Ba
MO	50 Aa	45.8 Aa
CV%	28.2	20.1

Means followed by the same letters shown in uppercase in the columns and in lowercase in the rows, showed no difference from each other according to the Tukey test ($P < 0.05$). Treatments: Test = control; MP = plastic mulching; MO = organic mulching; PMS = plastic mulching + red shade cloth 50%; and MOS = organic mulching + red shade cloth 50%.

the Far-red area. In the Fve form, when it absorbs the Far-red light, the phytochrome transforms it into Fv which then absorbs the light in the red region - a phenomenon called photoreversibility (HILTBRUNNER et al., 2007).

Contrary to the others, which demonstrated higher percentages of natural flowering, the red shading screen was seen to support vegetative development and cell expansion in the treatments with the organic mulching + red shading screen 50% and plastic mulching + red shading screen 50%, which are likely the physiological responses to the stimuli the phytochrome had assimilated. This process enables the plants to adapt to the prevailing conditions, thus encouraging the vegetative development. This occurs as the increased shading of the plants can raise the leaf area that is seeking sunlight, thus resulting in an imbalance in the light uptake.

No significant interactions were observed between the main treatments and the addition of the polymers, for any of the variables namely, stem diameter (stem), leaf area of leaf D and total leaf area, barring for the leaf area index. The findings are revealed in table 2.

With respect to stalk diameter, only the plastic mulching + 50% red shading screen treatment showed a higher mean from the other treatments and with statistical difference, when the polymer was added at the time of planting. In the absence of the polymer application, the plastic mulching treatment + red shading screen 50% was found to be better than only the organic mulching treatment + red shading screen. No significant differences were seen, regardless of whether the polymer was used or not, when compared within the same main treatment. This effect can be understood as the response of the plastic mulching related to the red shading, which caused the plant growth to escalate.

Plastic mulching helps maintain the soil moisture and affects the reflection of sunlight, lowering the soil temperature and, thus reducing evaporation, when compared with the uncovered soils. These are positive benefits that affect plant development and growth. This finding corresponds to the researches done by OLIVEIRA et al. (2021), as these authors reported that mulching exerted a positive effect on the ‘Vitória’ pineapple, in terms of the growth and vegetative development. It is; therefore, understood that the addition of mulching promotes plant growth, by controlling the soil moisture regimen and reducing the temperature variations, inducing more root development and efficiency of the usage of water and nutrients, thus leading to the adaptability to climatic fluctuations (OLIVEIRA et al., 2021).

It has been observed that the red shading screens can transform more spectrum light into red and Far-red waves. They are able to diffuse the light that travels through the mesh, thus supporting plant development (LI, 2006). Plastic mulching most likely encouraged the retention of soil humidity, lowering the soil temperature. This offered more conducive conditions for the root system in the plants to develop well. Besides significantly reflecting the irradiance that lands on the white plastic surface, it causes this irradiance to return to the plant canopy, thus boosting the light absorption efficiency and, therefore, the photosynthetic process.

The plastic mulching, together with the shading screen, was finally observed to provide conducive conditions and establish the microclimate in which the plants could take root. It was seen to offer a ventilated environment, reduce the temperature and

Table 2 - Vegetative features of the pineapple after using mulching and water, polymers and red shading screen.

Treatments	------------------Stalk Diameter (mm)------------------		---------------------------------*IAF-------------------------------	
	With polymers	Without polymers	With polymers	Without polymers
Witness	66.7 Ba	69.3 ABa	4.9 Bb	5.1 Ca
MP	66.6 Ba	69.1 ABa	5.1 Ba	4.9 Ca
MOS	64.8 Ba	67.1 Ba	6.6 Aa	6.1 Bb
MPS	77.1 Aa	77.8 Aa	6.4 Ab	6.7 Aa
MO	66.1 Ba	71.1 ABa	5 Ba	4.6 Cb
CV%	6.4	4.2	4.7	2.1
	------------------------‘D’ Leaf area---------------------		-------------------------Total Foliar Area------------------------	
	With polymers	Without polymers	With polymers	Without polymers
Witness	710.3 Ba	690.4 Ba	12743.5 Ba	12397.05Ba
MP	685.4 Ba	702.9 Ba	12310.9 Ba	12614.7 Ba
MOS	710.1 Ba	694.1 Ba	12740.2 Ba	12462.1 Ba
MPS	895 Aa	820.7 Ab	15962.7 Aa	14667.9 Ab
MO	694.2 Ba	658.6 Ba	12462.9 Ba	11843.4 Ba
CV%	8.9	5.1	8.7	5

Means followed by equal letters, expressed in the uppercase in the columns and in lowercase in the rows, showed no difference from each other based on the Tukey test ($P < 0.05$). Treatments: Control (TEST); plastic mulching = MP; MO = organic mulching; organic mulching + 50 % red shade cloth (MOS); plastic mulching + 50 % red shade cloth (MPS) and organic mulching (MO). *Significant effect for the interaction between the treatments and polymers.

prevent the direct incidence of radiation falling onto the leaves, thus supporting vegetative development. The microclimate of the soil surface in the systems where mulching is adopted, has lower soil temperature and moisture when compared to the plots that lack mulching and where more intense solar radiation is present (NAJAFABADI et al., 2012; HOMEZ & AROUIEE, 2016).

Plastic mulching + 50% red shade cloth demonstrated greater averages of the leaf area of leaf D and total leaf area, showing statistical differences when compared with the other main treatments. It is; therefore, noteworthy to emphasize that in this treatment (plastic mulching + red shade cloth 50% - MPS) the added polymer also helped to boost the values of the leaf area of leaf D and total leaf area. On comparison between the use or otherwise of the polymer while maintaining the main treatments unchanged, this technology was observed to raise leaf area index value to a higher level in the plastic mulching, organic mulching + 50% red shade cloth and organic mulching treatments. On the other hand, the leaf area index was reduced because of the addition of the polymer to the control plants (without coverage) and plastic mulching + 50% red shade screen.

Regarding the leaf area index, the highest values were noted when the polymer was used in the treatments organic mulching + 50% red shade cloth and plastic mulching + 50% red shade cloth, the latter showing superiority to the others when the polymer was not applied. The best responses in the treatments with the added polymers and without them, showed statistical difference from the other treatments.

The leaf area is directly related to the plant size; therefore, the bigger plants possess greater leaf area. Plants raised with the red shade cloth displayed much better growth when compared to plants that lacked the added shade cloth, reiterating that the leaf area is directly proportional to the plant size. Both the leaf area D and leaf area are directly related to the photosynthetic activity and pineapple growth, which are the important traits in plant productivity (FRANCISCO et al., 2014).

Plants raised in the treatments where plastic mulching + 50% red shade cloth and organic mulching + 50% red shade cloth were used showed 6.55 and 6.33, as the average indices respectively, and which under conditions of low light revealed greater leaf area. This was perhaps induced by the influence exerted by the better light quality, higher proportion of red light, reduction in the excess light energy, circumventing any possible photodamage and a drop in the temperature extremes that are harmful to the plant, thus producing greater shading. In the shade plants, larger leaf area is a common occurrence, with variations noted in the stomatal density and size, which in turn will affect the photosynthetic process and stomatal conductance based on the species (HOLLAND & RICHARDSON, 2009).

The physical features of the fruits included, weight of fruit with crown, weight of fruit without crown, length of fruit with crown, length of fruit without crown, as listed in table 3. The interaction between the treatments and absorption polymers revealed a significant effect for all the variables, barring for the weight of fruit with crown. The variable diameter was not affected by the treatments and the polymers usage.

For the weight of fruits with crown, no significant effect of the interaction between treatments and absorption polymers was observed. Plants cultivated with plastic mulching + 50% red shading screen showed a higher average, differing from the other treatments with and without polymers, respectively. Conversely, the uncrowned fruits were influenced by the treatments and use of the polymers revealing a significant effect that the interaction induced, after which the highest average was noted in the treatment which included the plastic mulching + 50% red shading screen and the added absorption polymers.

The treatment which included organic mulching + 50% red shading screen showed lower efficiency than the one in which plastic mulching + 50% red shading screen were used. This was likely caused by the differences in the materials used and their reciprocal actions with the soil. Organic residues are known to have interactions with the soil, and as they decompose in time, they may immobilize some of the soil nutrients; further, the biological decomposition of the residues like N, P and S, affect the soil nutrients by temporarily decreasing their availability to the plants. The plant residues also encourage and raise the water retention of the soil by minimizing evaporation, as reported by LONGHINI et al. (2019) in their work in which they used plant residues as soil cover. Employing organic residues having a high C/N ratio, like sawdust, can case a temporary drop in the availability of nitrogen, phosphorus and sulfur for the plants by inducing immobilization of the microbial soils (BARROS & CAVALCANTE, 2021).

As plastic mulching is made up of synthetic material (polyethylene) it cannot decompose like plant residues. Besides, by decreasing the quantity of water lost via evaporation, it induces a lower degree of salt leaching and therefore raises the nutrient availability in the functional root absorption zone of the plant (BRAGA et al., 2017). The treatment using plastic mulching + red shading screen showed 50% more efficacy as it supported the development and growth of the plants because the plastic mulching most likely helped dissipate the solar radiation and conserve the soil moisture. Besides the advantages evident by applying the plastic mulching as soil cover, several studies showed a boost in the productivity. Therefore,

Table 3 - Fruit weight with and without crown, length with and without crown of pineapple fruits treated with mulching, water absorption polymers and red shade cloth in Janaúba/MG.

Treatments	----------------Fruit weight with crown (g)--------------		--------------*Weight of fruit without crown (g)--------------	
	With polymers	Without polymers	With polymers	Without polymers
Test	1059.6 Ca	1057.1 Ba	979.2 Ba	969.1 Ca
MP	1119.7 Bca	1105.3 Ba	1023.3 Ba	1021.2 Ba
MOS	1160.1 Ba	1119.3 Ba	1070.6 Ba	1092.4 Ba
MPS	1480.5 Aa	1419.6 Ab	1374.4 Aa	1297.9 Ab
MO	1070.4 Ca	1046.1 Ba	976.3 Ba	959.9 Ca
CV%	3.32	2.08	4.2	2.3
Treatments	-------------*Fruit length without crown (cm)----------		------------*Fruit length with crown (cm)------------	
	With polymers	Without polymers	With polymers	Without polymers
Test	15.7 Ba	15.03 Bb	27.03 Aa	26.0 Bb
MP	15.8 Ba	16.2 Aba	26.5 Aa	27.2 Aba
MOS	16.1 Aba	15.6 Ba	27.5 Aa	26.6 Ba
MPS	17.3 Aa	17.4 Aa	28.5 Aa	29.1 Aa
MO	15.4 Ba	14.8 Ba	26.9 Aa	26.2 Ba
CV%	4.6	2	3.8	1.8

Means followed by equal letters, shown in lowercase in rows and uppercase in columns, show no difference from each other by Tukey's test ($P < 0.05$). Treatments: Control (TEST), plastic mulching (MP), organic mulching + red shading screen 50% (MOS), plastic mulching + red shading screen 50% (MPS) and organic mulching (MO). *The effect for the interaction of treatments and polymers was significant.

adopting this technology induced a rise in the dry and fresh mass of roots, diameter and productivity (ARAÚJO et al., 2019).

One more inference that can be drawn is that the 50% red shading screen caused alterations in the luminosity present in the environment, thus sparking some stimuli in the plants via the photoreceptor pigments, which in turn exerted a positive response, boosting both fruit size and vigor, and thus producing better developed and hence heavier fruits.

All plants possess the inherent capacity to alter their developmental model as a response to the light present in their specific environments (LARCHER, 2004). Particular pigments, like phytochromes and cryptochromes, are known to absorb specific wavelengths of radiation, which in turn will spark a series of changes in the development of each plant (DIGNART et al., 2009). The pineapple plant size is a good indicator of fruit weight and size. In light of this, it can be deduced that the more vigorous plants will yield heavier fruits.

From a market perspective, the large and heavy fruits are more sought after, as these are the quality parameters for commercial use, either to be consumed fresh or for industry.

In terms of the length of fruit with crown and without crown, an observation was made significant influence of the interaction between the treatments and absorption polymers. With respect to the use of polymers, no significant differences were noted between the treatments; some of the results were higher than those reported by OLIVEIRA et al. (2021), where an average of 20 cm was achieved. In their work, BARKER et al. (2018) reported fruit size of 8.79 cm, while KÜSTER et al. (2017) varied the planting in their rainfed cultivation in July and September and produced a yield, with average fruit size of 11.51 cm. Unlike treatments without the use of polymers, plastic mulching and plastic mulching + red shade cloth 50% presented higher averages, differing from the other treatments. In their studies SILVA et al. (2020) arrived at similar results, where the values of fruit length without crown reached up to 15.5 cm.

The variable length of the uncrowned fruits showed the best outcomes in the treatments where organic mulching + red shading screen and plastic mulching + red shading screen 50% with the polymers and plastic mulching and plastic mulching + red shading screen 50% without the polymers were used. Differences like these were attributed most likely to the heightened efficiency induced by the soil coverings when compared with treatments that lacked such coverings. Keeping this fact in mind, it was noted that fruits having larger mass also grew to longer lengths.

The variable of fruit diameter was not affected either by the polymer-treatment interactions or by the influence of the treatments and polymer usage; here, diameters in the 114 to 179 mm range were found, which were better than those reported by BERILLI et al. (2014) who recorded fruit diameter of 108 mm for the ‘Vitória’ cultivar.

The variables of productivity and efficiency in the use of water with applied depth USA 1 showed no significant effect caused by the influence exerted by the interaction between the treatments and the application of absorption polymers (Table 4). In the case of the plastic mulching treatment + red shading screen 50% with and without the use of the absorption polymers for both the variables investigated, higher averages were observed, which differed from the other treatments (control (no cover), plastic mulching, organic mulching and organic mulching + 50% red shading), in which the plastic treatment mulching + 50% red shading screen revealed a higher average values after the addition of the absorption polymers. Thus, the plastic mulching treatment + red shading screen 50% showed it was effective in boosting the productivity and improving the water usage.

The ever-increasing water scarcity in several regions and the charges levied for its usage make it an urgent necessity to assess the efficiency with which the plants are utilizing this vital resource. In light of the findings observed, the plastic mulching treatment + 50% red shading screen indicates the higher productive potential of this cultivar in irrigated systems having the highest value for water usage.

The yield and EUA 1 were greater in the plastic mulching treatment + red shading screen 50% after the added hydrogel, when compared to not adding it (Table 4); it is likely that the added absorption polymer permitted the water absorbed by the plant during its lifecycle to be distributed in a better manner, which in turn helped to raise the nutrient absorption efficiency. Hydrogel has found wide usage in improving the water availability for the cultivar, by raising the water retention capacity of the soil and growing media, thus also enhancing the water and fertilizer use efficiency and augmenting the physical properties of the soil (2018).

The polymer helps in the water retention either from rainfall or irrigation and slowly makes it available for the plant. This enables the root system to reduce the root desiccation process that usually occurs during the drought seasons, thus

Table 4 - Productivity, Efficiency of water use with applied depth of water (USA 1) in pineapple treated with mulching, water-absorption polymers and red shading screen, in Janaúba/MG.

Treatments	-----------------------Productivity t/ha----------------------		-------------USA 1 kg-fruit/mm (applied layer)-------------	
	With polymers	Without polymers	With polymers	Without polymers
Test	54338.9 Ca	54210.8 Ba	45.2 Ca	45.1 Ba
MP	57424.5 Ca	56684.3 Ba	47.8 Ca	47.2 Ba
MOS	59490.8 Ba	57403.8 Ba	49.5 Ba	47.8 Ba
MPS	75926.0 Aa	72802.0 Ab	63.2 Aa	60.6 Ab
MO	54890.5 Ca	53648.0 Ba	45.7 Ca	44.7 Ba
CV%	3.32	2.08		

The means followed by equal letters, shown in lowercase in the rows and uppercase in the columns, reveal no difference from each other using the Tukey test ($P < 0.05$). Treatments: Test = control; MP = plastic mulching; MO = organic mulching; MPS = plastic mulching + red shade cloth 50%; and MOS = organic mulching + red shade cloth 50%.

permitting the plant to develop even under adverse water deficit conditions (MINOSSO et al., 2021).

The addition of the absorption polymers and plastic mulching were found to exert a direct effect on the characteristics displayed by the plants in terms of the parameters of commercial productivity for the treatment involving plastic mulching + 50% red shading screen treatment, and with no significant influence being noted in the other treatments. For some time now, polymers have been contributing in a significant way to agriculture, as they can enhance the moisture conservation in the root system, improve and establish conducive conditions for the salt and mineral absorption by the roots and which, related to the addition of plastic mulching, can boost the yield, as is true in the present study.

The application of hydroretentive polymers (hydrogel) has been an alternative which can enhance the retention of soil water and make it available to the plants during the dry spells (SILVA et al., 2019); besides, they improve the soil aeration, the ability for cation exchange and they lower the degree of nutrient leaching (KONZEN et al., 2017). Several benefits have been attributed to the usage of polymeric materials (hydrogel) in agriculture, such as the enhancement of the physicochemical features of the soil, water conservation, water and nutrient retention and availability, apart from a boost in the yield of the agricultural cultivars (TIAN et al., 2020).

In the studies done by LAMBERT et al. (2017) the use of mulching was reported to induce a boost in the yield, internode number and branch length in watermelon. In the pepper crop, the plastic cover use caused an escalation in the productivity with higher efficiency of water use (ROCHA et al., 2018).

CONCLUSION

The red shading screen used along with the plastic and organic mulching was observed to decrease the natural flowering of the 'IAC Fantástico' pineapple cultivar.

The treatment in which plastic mulch was added and a red shading screen used was found to raise the vegetative growth of pineapple 'IAC Fantástico'; in fact, the inclusion of the water absorbent polymer to this treatment produced heavier fruits.

The treatments used were generally not seen to affect the postharvest quality traits of the 'IAC Fantátisco' pineapple; however, the application of plastic mulching along with a red shading screen lowered the value of the titratable Brix/acidity ratio.

The treatment in which plastic mulching was used with the red shading screen and the added water-absorbing polymers increased the water use efficiency and induced greater yield.

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DECLARATION OF CONFLICT OF INTEREST

The authors have no conflict of interest to declare. The sponsors/founders played no part in the study design, data collection, analysis or interpretation, or in writing the manuscript and the decision to publish the results.

AUTHORS' CONTRIBUTIONS

All the authors made equal contributions to the conception of the manuscript and its writing. All the authors critically reviewed the manuscript and gave their approval for the final version.

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