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Article

Different colors of plastic mulch in the modification of the microclimate, yield and quality of onion

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Abstract

In Sinaloa, one of the causes of the low yield of onion (Allium cepa L.) is that the minimum temperatures do not drop enough to stimulate bulb development. In view of this, looking for an alternative to reduce the temperature in the field, the influence of plastic mulch on the modification of the microclimate and on the quality and yield of this vegetable was evaluated. To this end, during the autumn-winter 2021-2022 cycle, an experiment was conducted under a randomized complete block design with four treatments and four replications. Three colors of plastic mulch were evaluated: black, gray/black, white/black, and the unmulched control. The response variables were soil temperature and moisture, plant development, including weight, bulb diameter, plant height, number of leaves, degrees Brix, and firmness. It was found that the lowest soil temperatures and the highest moisture retention occurred in the white/black plastic mulch, and it was also where the highest weight, bulb diameter, and yield were obtained. Considering the modifications to the microclimate, it was concluded that using white/black plastic mulch is suitable for the conditions of the autumn-winter cycle of the semi-arid and warm climate of the agricultural areas of Sinaloa.

Keywords:

Allium cepa, soil moisture, soil temperature.

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Introduction

Onions are considered one of the main vegetables worldwide, with a production of 106 592 088 t (FAOSTAT, 2022). However, like any crop, there are factors that limit their yield, one of them is temperature, which influences the adaptability, yield, and size of onions (Lescay and Moya, 2006; Kumar and Rawat, 2020). In the state of Sinaloa, low yields are caused, among other aspects, by temperature, which is not low enough during the period of adequate crop development (López-Urquídez et al., 2021).

In this sense, mulching with different colors of plastic is used on the soil surface in different crops, with different objectives, one of which is to modify the radiation balance and reduce the loss of water from the soil. As a result, soil temperature is modified, influencing plant growth, yield, and quality (Amare and Desta, 2021).

The white-on-black mulch in combination used in tomato, pepper, and carrot caused a reduction in the temperature of the root zone compared to the unmulched soil, probably because the black mulch warms and the white mulch cools the soil they cover (Snyder et al., 2020). For their part, García et al. (2018) found that, in greenhouses, the highest total fruit yield per plant occurred for white mulch compared to gray mulch and unmulched soil.

Likewise, Mendonca et al. (2021) report that silver and green mulches showed the highest yields, the highest number of fruits; however, there is currently little recent information regarding the use of colored mulches in onion crops in Mexico. Despite the fact that, in some parts of Mexico plastic mulching of the soil is carried out in the commercial production of onions, there are no studies that indicate what is the best color of plastic for mulching under the conditions of Sinaloa. This work aimed to determine the influence of plastic mulch on the modification of the microclimate and on the yield and quality of onions after being established with different colors of plastic mulch.

Material and methods

Location

This study was conducted in the autumn-winter 2021-2022 cycle on a farm in the Valdez Montoya ejido, located in the central region of the state of Sinaloa, at kilometer 40 of the Navolato-Altata highway. The geographical coordinates of the place are 24° 69' 94" north latitude and 107° 82' 76" west longitude, the altitude is 10 m (Google Earth, 2021). The average minimum temperature is 10.5 °C in January and the average maximum temperatures are greater than 36 °C from May to July (Weather spark, 2021). The texture of the soil is silty loam.

Experimental design

The experiment was made up of four treatments, consisting of three colors of plastic mulch: black, gray/black, white/black, and the unmulched control. The experiment was established by a randomized complete block design with four replications; each experimental unit consisted of four beds 5 m long and 1.2 m wide. Two irrigation tapes with a flow rate of 1 L h^{-1} were installed in each bed.

The bulb was placed in four rows with a separation of 12 cm between rows and 12 cm between bulbs, arranged in zigzag; the estimated population was 207 500 plants ha^{-1}. The plastic was perforated at the time of planting and a bulb was placed for each hole made. The onion variety used was 'Carta blanca' (Nunhems) of short days, with a round white bulb and physiological maturity at 170-175 days after planting.

Irrigation was applied thirty times in a period of 90 days, with a cumulative water level of approximately 45 cm. Fertilization was carried out by the irrigation system with an equivalent dose per ha of 200 kg of nitrogen, 80 kg of phosphorus, 100 kg of potassium and 30 kg of calcium, magnesium and sulfur. The pests that were present in the crop were thrips (Thrips tabaci), beet armyworm (Spodoptera exigua), and common earwig (Forficula auricularia).

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Spinetoram 5.87, Chlorpyrifos 44.5, Malathion 83.7, and Lambda-cyhalothrin 7.8 were applied for control. Likewise, the phytopathogens Peronospora destructor, Stemphylium vesicarium, and Fusarium sp. were also present. They were controlled by applying Captan 50 and Bacillus subtilis through the irrigation system. In addition, during the development of the crop, Propamocarb 47.3+ Fosetyl 27.7, Cyazofamid 34.78 Metalaxyl-M 3.3 + Chlorothalonil 33 were applied to the foliage. The weeds were removed manually.

Variable measurement

To measure soil temperature, a geothermometer was used in each treatment, placed at a depth of 15 cm, recording the information at 8:00 and 15:00 h during the development of the crop. Soil moisture was measured by a moisture sensor in each of the treatments, placed at a depth of 10 cm, readings were taken in the morning and afternoon. The sensors were connected by means of clamps to the Watermark digital meter and the data was measured in kPa.

The harvest took placed when 70% of the onions had their leaves bent, a characteristic sign that the plant has reached its physiological maturity. The plants that remained upright were bent manually. Three days later, the plants were uprooted and placed on the ground to complete bulb curing.

To make the evaluation, 30 plants from each experimental unit were randomly taken to measure the following variables: number of leaves; the length of the leaves was measured with a tape measure, and the equatorial diameter of the bulb was obtained with a Steren Her-411 vernier. To calculate the yield, the weight of the bulb was obtained with a Sunnimix analytical balance. Likewise, the soluble solids content (°Brix) was measured with a hand-held refractometer (Abanopi), whereas the firmness (kgf) of the bulb was measured with a FT-20 analog penetrometer (Wagner).

Data analysis

The Shapiro-Wilk test (Shapiro and Wilk, 1965) was applied to verify the normality of the data and Levene's test to analyze the homoscedasticity of variances (Zar, 2010). Subsequently, the respective analyses of variance (Anova) were performed to evaluate the effect of the different colors of plastic mulch on soil temperature, soil moisture, leaf length, number of leaves, bulb diameter, and bulb weight. Afterwards, a comparison of means was performed [Tukey ($p \leq 0.05$)]. A line regression analysis was also performed to estimate the effect of minimum temperature variation on onion bulb weight. Statistical analyses were carried out using the Xlstat program (Addinsoft, 2022).

Results and discussion

Soil temperature and moisture

There were statistically significant differences ($p \leq 0.05$) between treatments regarding soil temperature at 8:00 and 15:00 h. At both times, the treatment with the lowest temperature was the white/black mulch, followed by the grey/black mulch, compared to the unmulched control (Table 1). These results indicate that the color of the mulch affects the behavior of soil temperature. The black mulch was the only treatment similar to the control without mulch.

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Table 1. Measurement of soil temperature and moisture at a depth of 10 cm in the treatments at 8:00 and 15:00 h.

Mulch	Soil temperature (°C)		Soil moisture (kPa)	
	8:00 h	15:00 h	8:00 h	15:00 h
Black	21.17 (0.15 a	24.57 (0.16 a	17.88 (1.34 a	18.41 (1.36 a
Unmulched	21.12 (0.14 a	24.56 (0.17 a	17.61 (1.38 b	18.27 (1.38 b
Gray/black	20.93 (0.15 b	24.17 (0.16 b	17.8 (1.32 a	18.24 (1.33 b
White/black	19.8 (0.16 c	22.98 (0.16 c	12.78 (1.16 c	13.22 (1.16 c
Significance	<0.0001	<0.0001	0.011	0.014

Means with different letters in columns indicate significant difference according to Tukey test (p≤ 0.05).

This is because black soil increases temperature (Amare and Desta, 2021). This color has a greater capacity to absorb sunlight, raising the temperature of the soil, whereas lighter colors, such as gray and white, have a greater capacity for reflection, causing a decrease in soil temperature (Tarara, 2000). A similar situation is found with Hernández et al. (2021), who, when evaluating different mulch colors, found lower temperatures in the treatment with white mulch compared to the other mulch colors.

In terms of soil moisture, statistically significant differences were also found (p≤ 0.05) between treatments at 8:00 and 15:00 h. In both evaluations, white/black mulch was the treatment with the highest moisture retention (Table 1). White is one of the colors with the lowest absorption of solar radiation, therefore lower thermal conductivity, which allows more moisture to be retained in the soil. In addition to the reduction in temperature, the mulch also functioned as a barrier that prevented the loss of water vapor, which causes it not to escape and return to the surface of the soil (Tarara, 2000).

Plastic mulch conserves soil moisture by not allowing evaporation (Manzoor, 2023). These results coincide with Sarkar et al. (2019), who point out that the white mulch had more moisture in the soil.

Plant height and number of leaves

In the plant height variable, there were no significant differences (p≤ 0.05) between the plastic mulching treatments evaluated (Table 2). This indicates that the plastic mulches did not affect the plant height. This result coincides with what was reported by Ashrafuzzaman et al. (2011), who report that plants with plastic mulch had a height similar to plants established without mulch.

Table 2. Effect of different colors of plastic mulch on plant height and number of leaves in onion ± standard error.

Treatment	Plant height (cm)	Number of leaves
White/black mulch	70.83 (0.69 a	12.93 (0.09 a
Gray/black mulch	70.79 (0.67 a	12.79 (0.09 ab
Unmulched	71.44 (0.64 a	11.98 (0.08 c
Black mulch	69.08 (0.7 a	12.53 (0.08 b
Significance	0.17	<0.0001

Means with different letters in columns indicate significant differences according to Tukey test (p≤ 0.05).

Regarding the number of leaves, significant statistical differences were obtained (p# 0.05). The treatment with the highest number of leaves was white/black plastic mulch, followed by grey/black mulch, compared to the unmulched control. These results indicate that mulch color influences the number of leaves per plant. White is one of the colors with the lowest soil temperature and the highest soil moisture retention, which leads to better plant development. In this regard, Rajablariani et al. (2012) mention that the improved condition of the microclimate due to plastic mulches favors the production of leaves.

Revista Mexicana de Ciencias Agrícolas
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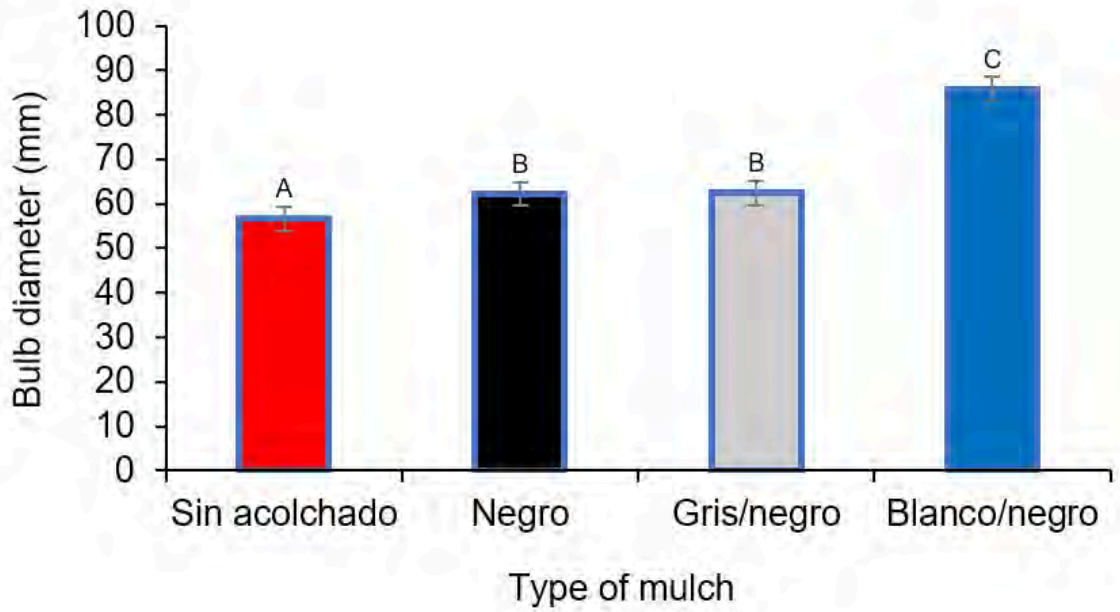
Onion diameter

The diameter of the onions grown with white/black plastic mulch was statistically different from the other treatments, obtaining a maximum of 85.79 mm, followed by the gray/black and black mulches, being statistically the same as observed in Figure 1. These results indicate that the color of the mulch affects the development of the onion diameter since the smallest bulb diameter (56.64 mm) was obtained in the treatment without mulch.

Figure 1. Bulb diameter ± confidence interval under the influence of different colors of plastic mulch. Different letters mean statistically significant differences (p> 0.05) using Tukey's test.



For their part, Kumar and Rawat (2020) mention that plastic mulch increases crop yield, quality, and growth in addition to inhibiting weed growth. Onions from white/black mulch were classified as large size (8.5 cm) and onions from gray and black mulches and unmulched soil are classified as medium (5.6 cm) according to the official Mexican standard NMX-FF-021-SCFI-2003.

The diameter of onion bulbs under colored plastic mulch was larger than bulbs grown in unmulched soil. This positively influenced yield. In this regard, Sarkar et al. (2019) report that the length and diameter of onion bulbs under the influence of colored polyethylene mulch was greater than those of bulbs grown in bare soil.

Yield

Regarding the weight of onion bulbs, there was a significant difference ($p \leq 0.05$) between the treatments, forming two groups. On the one hand, the onions that were harvested from the white mulch had a higher bulb weight, with an average of 386.56 g, whereas the other group was made up of the gray plastic mulch, with a weight of 169.32 g, the black mulch, with 161.62 g, and the bare soil, with 158.7 g (Table 3).

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Table 3. Average weight ± standard error of onion bulbs in different colors of plastic mulch.

Treatment	Average weight (g)
White/black mulch	364.74 (9. 91 a
Gray/black mulch	169.32 (7.64 b
Black mulch	161.62 (7.88 b
Unmulched	158.7 (7.12 b

Means with different letters in columns indicate significant differences according to Tukey's test ($p \leq 0.05$).

This may be due to the influence of soil temperature and moisture availability since white mulch had the lowest temperature and the highest moisture retention, as shown in Table 1. In this regard, Mohammad et al. (2020) mention that using plastic mulch increases water efficiency and therefore increases onion yield.

García et al.'s (2018) study reported that the highest yield in tomato crops was obtained with white mulch compared to gray mulch. On the other hand, Lee et al. (2019) mention that onions grown with black plastic mulch had the highest bulb yield, followed by transparent mulch and unmulched soil. Extrapolating the average weight of the bulb obtained in the treatments, the highest average yield was obtained in the white/black plastic mulch, with 68 t ha^{-1}, compared to the other treatments, which were statistically equal, approximately 29 t ha^{-1}.

These results are consistent with Elsayed-Farag et al. (2018) findings in a study of plastic mulch in tomato. Likewise, in watermelon, Cenobio et al. (2006) report a higher yield under white plastic mulch compared to unmulched treatments. Ramírez (1996) mentions that the white and white/black mulches reflect most of the solar radiation towards the crop foliage, increasing its photosynthetic activity. Therefore, the plant produces more photoassimilates. Likewise, the increase in environmental temperature and solar radiation influence plant growth (Paranhos et al., 2016).

The higher yield is related to temperature since plant growth is remarkably sensitive to temperature; when there is a change of a few degrees, there is a significant change in the growth rate (Salisbury and Ross, 2000). This is observed in Figure 2, where the slope of decrease in the weight of the onion bulb in relation to temperature is very pronounced.

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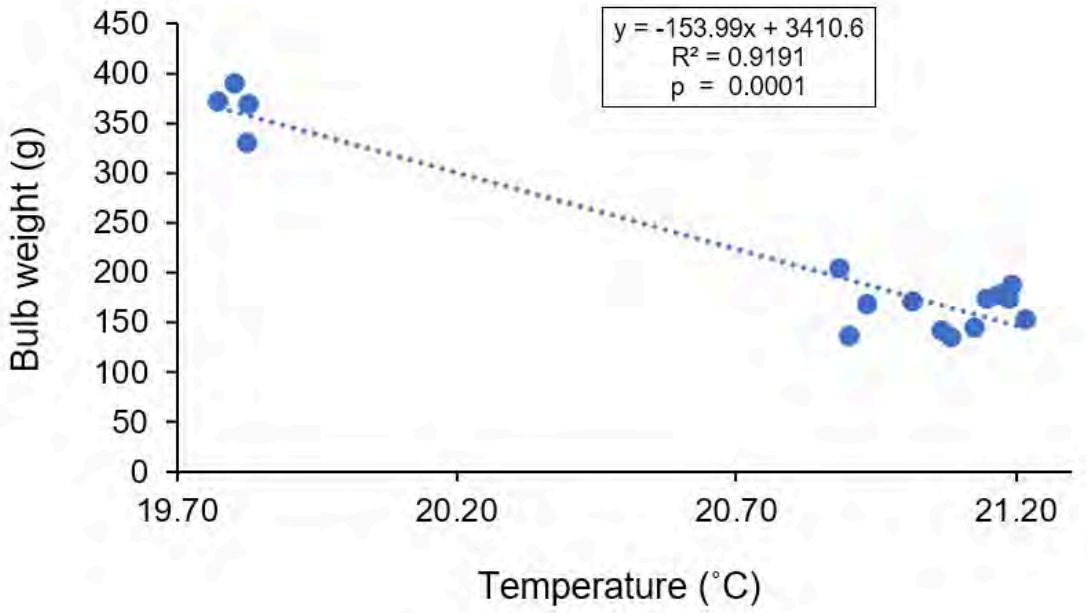
Figure 2. Influence of temperature on onion yields under plastic mulch.



Onion bulb firmness

Onion bulbs grown with white and gray mulches and unmulched soil were the ones that showed the greatest firmness (Figure 3). In contrast, the bulbs with less firmness were those that were grown with black mulch, which may be caused by the high soil temperatures that occurred in this treatment. In this regard, Mallor et al. (2010) report firmness values for mature onions of 3.49 kg cm^{-2}.

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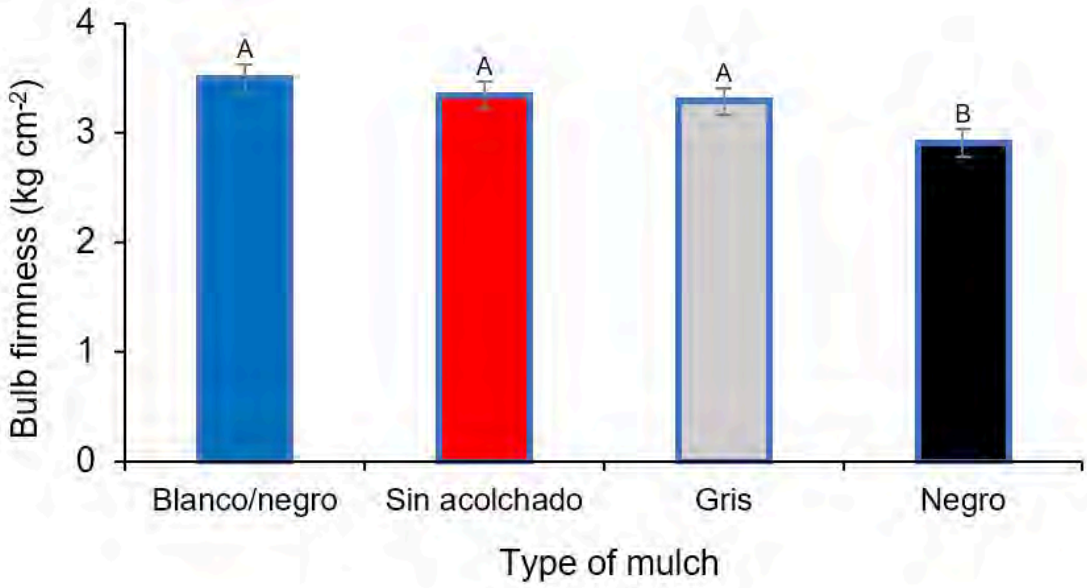
Figure 3. Effect of different colors of plastic mulch on onion firmness ± confidence interval of the mean. Different letters mean statistically significant differences (p> 0.05).



Onion bulb soluble solids

The onion bulbs that were grown with white plastic mulch and bare soil were the ones with the highest concentration of degrees Brix compared to the other treatments, being the gray mulch where the lowest concentration of soluble solids occurred (Figure 4). In this regard, López-Urquídez et al. (2021) documented that onion plants that developed under lower temperature conditions had a higher concentration of degrees Brix, which may be due to the fact that onion plants react by concentrating sugars as a defense mechanism to low temperatures.

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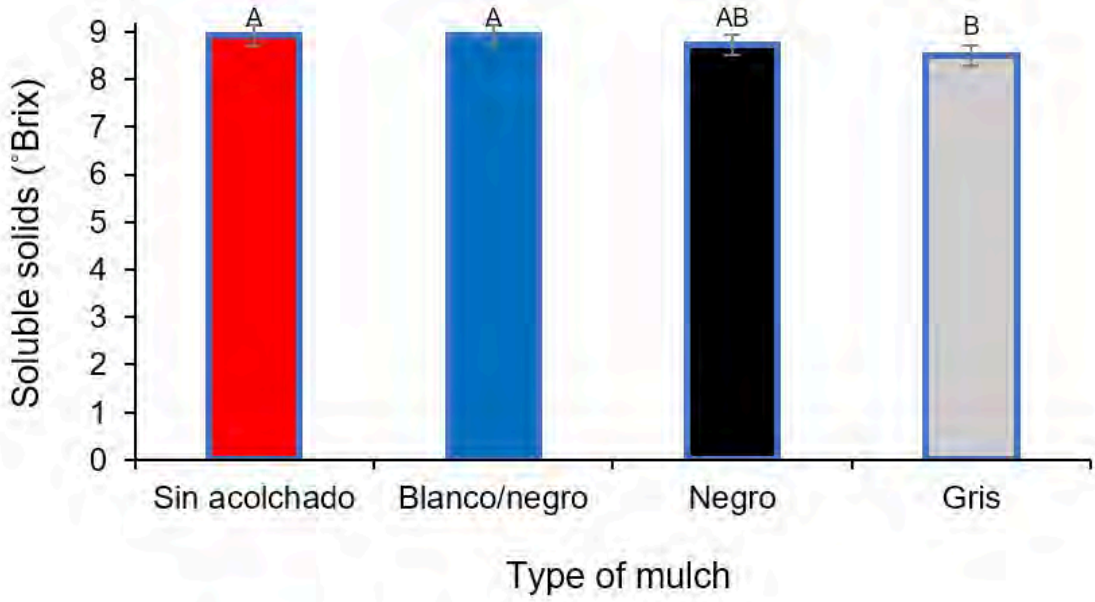
Figure 4. Soluble solids of onion bulbs in different colors of plastic mulch ± confidence interval. Equal letters indicate no significant differences (p> 0.05).



In other studies, the use of gray plastic mulch was the one that presented the highest concentration of total soluble solids, achieving fruits with higher sugar content compared to treatments with black plastic mulch and without mulch (Chaves et al., 2013).

Conclusions

The color of plastic mulch affects the behavior of soil temperature, with the white/black mulch being where the lowest temperatures occur. This causes the soil covered with this mulch to retain more moisture than the soils covered with plastic mulch of the other colors evaluated. The lower soil temperature caused the plants developed under white/black plastic mulch to have a bigger number of leaves, which was reflected in greater diameter, weight and firmness of the bulb, obtaining a higher yield. Therefore, it is considered that white/black plastic mulch is a good option for onion production under warm semi-arid climate conditions.

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soil moisture
soil temperature

Counts

Figures: 4
Tables: 3
Equations: 0
References: 28
Pages: 0