Article

# Effect of mulching on cabbage grown in the Mexicali Valley

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## Abstract

The use of mulch in soil to produce vegetables increases the yield and quality of harvested products; however, these increases are conditioned by the type of mulch, whether plastic or organic. An experiment was performed in cabbage (*Brassica oleracea* L. var Capitata) culture during the 2021-2022 season, with the aim of evaluating its response on water use efficiency, mineral nutrition and yield to four types of mulches in the soil. Four treatments were evaluated (soil with black plastic mulch, white plastic mulch, mulch with wheat straw and a control without mulching), distributed under a randomized block design with four repetitions. The results showed that white plastic mulch increased the total biomass, cabbage weight and leaf weight, compared to the rest of the treatments. The use of both plastic mulches (black and white) increased the concentration of nitrates in the cell extract of the midrib. The leaf temperature increased only due to the use of black plastic mulch. Finally, the efficiency in the use of water was higher in the treatments with plastic mulch and lower in the soil without mulching. Considering the greater efficiency in the use of water, yield and mineral nutrition, it was concluded that the soil with plastic mulch is the most recommended to produce cabbage in the Mexicali Valley, Mexico.

**Keywords:** *Brassica oleracea* L, irrigation water, mineral nutrition, plasticulture.

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# Introduction

Currently in the Mexicali Valley in northwestern Mexico, there is a dynamic of crop reconversion, due to the low profitability in crop production. Crops such as cotton (*Gossypium hirsutum* L.), wheat (*Triticum aestivum* L.) and alfalfa (*Medicago sativa* L.) have gradually been replaced by horticultural crops. Of all the vegetables grown, those produced during the winter stand out. Among them, the following cruciferous vegetables stand out: broccoli (*Brassica oleracea* var Italica), cauliflower (*Brassica oleracea* var Botrytis L.), brussels sprouts (*Brassica oleracea* var Gemmifera) and cabbage (*Brassica oleracea* L. var Capitata) (Atlas-Agroalimentario, 2020) (Robinson, 2010). In general, these vegetables are managed under a pressurized irrigation system, mostly drip irrigation, although the plasticulture technique has recently been introduced.

This technology allows modifying the growth medium and increase the yield and quality of the harvested products. In this regard, the modification of the soil environment through mulches directly impacts the development and growth of crops (Kader *et al*., 2017). This is a result of the fact that, depending on the type of mulch, temperature, humidity and some physical and biological properties of the soil are modified (Mulumba and Lal, 2008). Plastic mulches of different colors (Amare and Desta, 2021) and organic mulches from harvest residues (Li *et al*., 2013), are usually used. In Mexicali, Baja California, Mexico, there is a growth in the area established in a group of crops belonging to the cruciferous vegetables.

Among them, the production of cabbage stands out. This is because it is one of the most promising in terms of obtaining high yield per unit of water applied. However, there is no local information that quantifies the effect that the use of different types of mulches has on the crop. The objective of this research was to evaluate the efficiency in the use of water, the yield and quality and the nutritional status of cabbage culture due to the effect of different types of mulches.

# Materials and methods

### Location of the study

The study was conducted in the experimental field of the Institute of Agricultural Sciences of the Autonomous University of Baja California, located in the ejido Nuevo León, Mexicali, Baja California, Mexico (32° 24’ north latitude and 115° 11’ west longitude). In this agricultural region, a warm desert climate, extreme in excess, and a rainfall regime in winter (BW [h’] hs [x´] [e’]) (García, 1970) prevail. Temperature conditions were taken from a weather station located 450 m from the experimentation site (Figure 1). At this site, the soil has a clay texture of the calcaric hyposalic Vertisol type. The chemical characteristics of water and soil are presented in Table 1.

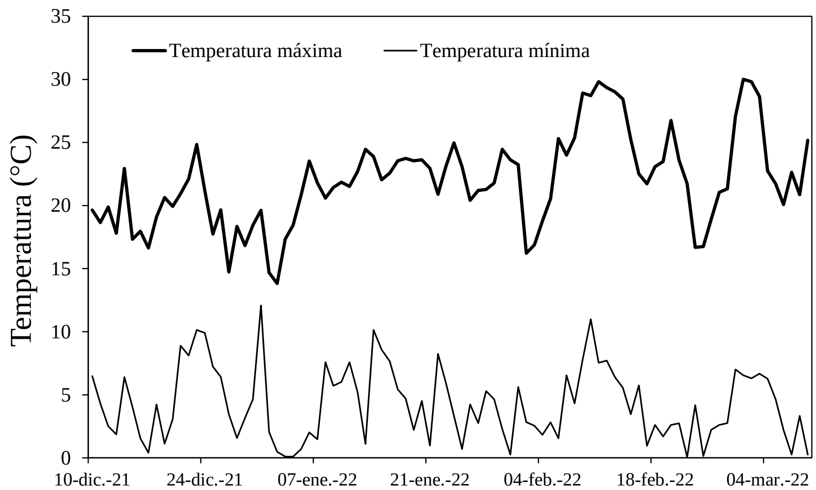


**Figure 1. Evolution of maximum and minimum temperatures in cabbage culture (Mexicali, BC).**

**Table 1. Chemical characteristics of the water and soil in which the experiment was carried out†.**

| Parameters in soil | Value | Parameters in water | Value |
|---|---|---|---|
| Potential hydrogen | 8.4 | Potential hydrogen | 8.01 |
| Electrical conductivity | 4.5 dS $m^{-1}$ | Electrical conductivity | 4.5 dS $m^{-1}$ |
| Total nitrogen | 3.3 mg $kg^{-1}$ | Potassium | 0.12 meq $L^{-1}$ |
| Olsen phosphorus | 7.9 mg $kg^{-1}$ | Sodium | 5.65 meq $L^{-1}$ |
| Potassium | 733 mg $kg^{-1}$ | Calcium | 5.9 meq $L^{-1}$ |
| Calcium | 175 mg $kg^{-1}$ | Magnesium | 1.79 meq $L^{-1}$ |
| Magnesium | 315 mg $kg^{-1}$ | Bicarbonates | 2.49 meq $L^{-1}$ |

†= determinations according to NOM-021-RECNAT (2000).

## Establishment and experimental design

Sowing was carried out on October 19, 2021, under greenhouse conditions. Polystyrene trays of 200 cavities were used. Canadian sphagnum peat moss (LM-GPS Canada) was used as a substrate for sowing. The variety of the plant was Charmant (F1 Hybrid) [Sakata Seed America, Inc. USA]. Subsequently, in the field, planting beds oriented from north to south were raised, with a separation of 1.6 m and with a height of 20 cm. An irrigation system with double tape [Toro, Aqua-Traxx, San Nicolás de los Garza, NL, Mexico (expenditure per dropper: 1 L $h^{-1}$; 20 cm apart)] was installed.

The transplantation was performed on December 14, 2021, at a density of 3.1 plants $m^{-2}$. Four treatments were evaluated: soil with black plastic mulch, soil with white plastic mulch, soil with wheat straw mulch and bare soil as a control. For the treatment of wheat straw, this was placed just two weeks after transplantation, using an approximate amount of 500 g of straw per each linear meter of each bed. The treatments were distributed using a randomized block experimental design with four repetitions.

From transplantation to 35 days after it, an irrigation sheet of 100 mm was applied to all treatments. Subsequently, each treatment was irrigated separately considering readings from moisture tensiometers (Irrometer Co. Riverside, CA. EU) placed at a depth of 30 cm. From 35 to 45 days after transplantation (dat), each irrigation was performed when the tensiometer reached readings of 20 kPa after 45 dat, when the tensiometer reached readings between 10 and 15 kPa.

## Agronomic management

During the experiment, a dose of 320, 90, 200, 38 and 15 kg $ha^{-1}$ of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) was applied on a fractional weekly basis. Urea ($CO_2$ $[NH_2)_2]$, potassium nitrate ($KNO_3$), calcium nitrate [Ca $(NO_3)_2$] and magnesium sulfate ($MgSO_4$) were used as fertilizer sources. The pests that were present were thrips (*Thrips tabaci*) and larvae of the diamondback moth (*Plutella xylostella*). Both were controlled with weekly applications of Acetamiprid (Aval; Potecin, SA, Qro., Mexico) and herbaceous extracts of natural origin [(*Capsicum frutenses*, *Allium canadense* and *Anemone multifida*) (Senvicid, EDOCA, Querétaro, Mexico)].

Likewise, in the control treatment (bare soil), two foliar sprays of the herbicide Clethodim [(5RS)-2-[(E)-1-[(2E)-3-chloroallyloxyimino]propyl]-5-[(2RS)-2-(ethylthio)propyl]-3-hydro xycyclohex-2-en-1-one] [Arysta Life Science Mexico, SA de CV]) were carried out with the aim of controlling Bermuda grass (*Cynodon dactylon*). In the case of broadleaf weeds such as *quelite* (*Amaranthus* spp.) and mallow (*Malva sylvestris*), they were controlled manually by hoeing.

## Variables evaluated

At 55, 80 and 90 dat, samplings of the midrib of the leaves of cabbage plants were carried out with the aim of measuring the concentration of nitrates ($NO_3$) and potassium (K) in the cell extract (CE). The samplings consisted of collecting five ribs of the most recently matured leaves per treatment. The samples were frozen (-1 °C) for further analysis. At the end of the study, they were thawed and had the CE removed using a garlic press. The determinations of $NO_3$ and K were made using a portable ion meter (LAQUAtwin B-743, Horiba, Kyoto, Japan).

At 85 dat (0March 7, 2022), a temperature measurement was made right at the head of the cabbage plant. This variable was obtained from 12:00 to 13:00 h of the day. The measurement was made in ten plants per each treatment. A thermometer was used (Fluke 574, Fluke Co., Everett, WA, USA). Additionally, the environmental temperature during the development of this activity was considered (Erdem *et al*., 2010). The harvest was made at 100 dat. An area of 3.5 $m^2$ of the central part of each experimental plot was selected and the plants were harvested.

The entire plant was weighed. The leaves that covered the head or cabbage (commercial harvest) were then removed and both parts were weighed separately. The harvest index was obtained with both data. Efficiency in the use of water was obtained for the entire plant, the head or cabbage and for the leaves of the plant. This variable was obtained after dividing the biomass of the crop expressed as kg $ha^{-1}$ by the irrigation sheet expressed in millimeters (Pascale *et al*., 2011).

### Statistical analysis

All data obtained were subjected to analysis of variance with Minitab 17 (Minitab, 2017). The mean difference was made using the Tukey test ($p < 0.05$).

## Results and discussion

### Climate conditions

Figure 1 shows the temperature conditions that occurred during the experiment. In general, temperatures were optimal for the growth and development of the crop (Criddle *et al*., 1997). The maximum temperatures remained in the order of 14 to 30 °C, while the minimums were from 0 to 12 °C, with an average of 16 °C. These temperature conditions are very common in the Mexicali Valley and have been prevalent for the last forty years (Ruiz-Corral *et al*., 2006).

### Nitrates and potassium in CE

The concentrations of $NO_3$ in the CE of the midrib were the only ones that varied due to the effect of the type of mulch (Table 2). At 55 dat, the highest concentration of $NO_3$ was found in the soil mulched with black plastic, while the lowest were found in the control. At 80 dat, soils with plastic mulch were higher than the treatments with wheat straw and the control. In the case of K concentration in CE, there were no significant changes between treatments or between sampling dates. K concentrations in the CE of the midrib were in the order of 2 250 to 3 675 mg $L^{-1}$.

**Table 2. Concentration of nitrates ($NO_3$) and potassium (K) in the cell extract of the midrib of cabbage culture due to the effect of different types of mulch.**

| Treatment | $NO_3$ | K | $NO_3$ | K | $NO_3$ | K |
|---|---|---|---|---|---|---|
| | 55 dat (mg $L^{-1}$) | | 80 dat (mg $L^{-1}$) | | 90 dat (mg $L^{-1}$) | |
| Black plastic | 6 875 (±861) a[†] | 2 975 (±206) | 6 250 (±378) a | 2 775 (±95) | 6 825 (±925) | 3 675 (±262) |
| White plastic | 5 500 (±326) bc | 2 900 (±115) | 6 975 (±596) a | 2 800 (±182) | 6 000 (±476) | 3 325 (±250) |
| Wheat straw | 5 900 (±365) ab | 3 100 (±81) | 5 325 (±419) b | 2 575 (±125) | 6 150 (±675) | 3 350 (±238) |
| Control | 4 775 (±298) c | 3 000 (±115) | 4 275 (±309) c | 2 550 (±173) | 6 925 (±457) | 3 300 (±270) |
| Significance | 0.001 | 0.28 | < 0.001 | 0.068 | 0.168 | 0.184 |

[†]= different letters within the same column mean significant differences according to the Tukey test ($p < 0.05$).

In this regard, Llanderal *et al*. (2020) report that factors such as crop evapotranspiration, vapor pressure deficit and leaf area index have a wide impact on $NO_3$ and K concentrations in crops. These factors are important to consider because crops have different development and growth due to the use of different types of mulch (Tarara, 2000; Kader *et al*., 2017). In this regard, Amare and

Desta (2021) mention that vegetables grown during the winter with soil with black mulch have a greater growth than those grown with other types of mulches, which consequently modifies the parameters indicated above.

On the other hand, recent studies on corn culture (*Zea mayz* L.) show that the presence of nitrates in soil as well as the absorption of nitrogen by plants grown in soils with plastic mulch are greater than in plants grown in soils without mulching (Wang *et al*., 2018a). For example, in soils mulched with plastic, the concentration of nitrates in the profile of 20 cm increases by about 30% (Ma *et al*., 2018b), which consequently causes these plants to increase the absorption and distribution of nitrates in their tissues (Wang *et al*., 2018a).

**Plant temperature**

Knowledge of leaf temperature is an indirect way of knowing the water status of the plant with respect to soil moisture. This theoretically means that, if at noon a plant has a leaf temperature close to the environmental temperature, it is a plant that suffers stress from lack of irrigation (Katimbo *et al*., 2022). In this study, the temperature of the plants was in the order of 17.9, 14.6, 13.5 and 11.6 °C, for the mulches of black and white plastic, wheat straw and bare soil respectively. Likewise, the average environmental temperature was in the order of 20.3 °C (Figure 2).

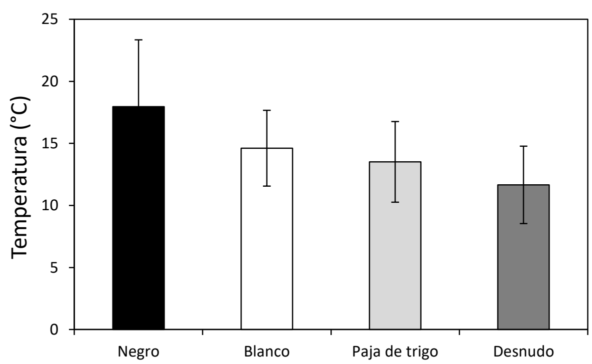


**Figure 2. Foliar temperature of cabbage culture due to the effect of different types of mulches.**

Although the temperature of plants mulched with black plastic was close to the environmental temperature, this is not considered harmful to the crop, since it is within the optimal temperatures for the development of the crop (5 to 32 °C) (Warland *et al*., 2006; Ji *et al*., 2017). On the contrary, considering the values of 17.9 °C, the growth of the plants with black plastic mulch showed a growth rate higher than those of the rest of the treatments. Paranhos *et al*. (2016) indicate that the increase in environmental temperature and solar radiation received by cabbage plants greatly influences their growth.

On the other hand, the difference in the degree of hydration of the plants between the treatments could be explained by the different environments provided by each treatment in the development of the root of the plants. This is because their root development is conditioned by the environment in which they grow (Amare and Desta, 2021). Studies show that plants grown in autumn on bare soil and on soils with plastic mulch have different fluctuation of minimum and maximum temperatures in the soil during the day (Díaz-Pérez, 2009), which brings as an effect that the development and root growth may be different between the plants (Luo *et al*., 2020). In such a way that depending on root development, there is an effect on the degree of hydration of plants (Comas *et al*., 2013).

## Yield

The yield in cabbage culture was affected by the mulch of the plants (Table 3). In general, plants grown with white plastic mulch had the highest yield of total fresh biomass, of cabbage (head), of leaves and of individual cabbage weight than the treatment with wheat straw. The highest cabbage (head) yield was in the order of 51.21 to 45.82 t $ha^{-1}$, while the lowest was 44.53 t $ha^{-1}$. These yields are higher than those published in the Atlas Agroalimentario 2020 (Atlas-Agroalimentario-2020, 2020), which indicates that the yield is 33 t $ha^{-1}$ for the Mexicali Valley region.

**Table 3. Yield of fresh biomass, cabbage weight, leaf weight and harvest index in cabbage culture due to the effect of different types of mulches.**

| Treatment | Total yield | Cabbage | Leaves | Harvest index | Weight per cabbage |
|---|---|---|---|---|---|
| | (t $ha^{-1}$) | | | | (kg) |
| Black plastic | 69.91 (±4.74)bc[†] | 45.82 (±2.24)ab | 24.13 (±2.59)bc | 0.65 (±0.05) | 1.432 (±0.7)ab |
| White plastic | 76.52 (±4.49)a | 51.21 (±2.38)a | 25.32 (±2.82)a | 0.66 (±0.05) | 1.6 (±0.74)a |
| Wheat straw | 65.41 (±12.59)c | 44.53 (±10.67)b | 20.81 (±3.97)c | 0.68 (±0.07) | 1.39 (±0.64)b |
| Control | 67.23 (±11.07)c | 45.22 (±10.69)ab | 22.01 (±3.4)bc | 0.67 (±0.07) | 1.414 (±0.7)ab |
| Significance | < 0.001 | 0.035 | 0.018 | 0.319 | 0.034 |

[†]= different letters within the same column mean significant differences according to the Tukey test ($p < 0.05$).

Other crops in which plastic mulch is used have the same tendency when reporting yield. In potato (*Solanum tuberosum*) and cucumber (*Cucumis sativus*), the color of the mulch increases the temperature in the soil in relation to the bare soil, especially at the beginning of the growing season of the crop (Ibarra-Jiménez *et al*., 2011; López-Tolentino *et al*., 2017). On the other hand, in reference to crops mulched with wheat straw, reports indicate that sometimes these can yield less than those grown in soils without mulch, especially those grown in winter. This is because the straw on the soil prevents its heating, keeping it cool for a longer time (Kosterna, 2014).

## Water use efficiency

Due to the importance of irrigation water in crop yields, it has recently been proposed to consider the bioproductivity of crops per unit of water applied and not per harvested sowing area (De Pascale *et al*., 2011). This implies knowing the water balance in the soil, the type of mulch used (organic or inorganic), the color, biodegradability, population density of the crop in question and the measurement of water applied to the soil during the growing season of the crop (Tarara, 2000; Kader *et al*., 2017; Biswas *et al*., 2022).

In this study, the treatment with black plastic mulch was the one that received the smallest irrigation sheet, followed by the treatment with wheat straw mulch, white plastic mulch and finally the bare soil (Table 4). The highest efficiency in the use of irrigation water (EUIW) for the variable of total yield was for the two treatments with plastic mulch. This meant that although the total yield was higher with white plastic mulch (Table 3), a greater amount of water was also required to produce it. On average, 288.2 kg $ha^{-1}$ of complete plant biomass was produced per each mm of irrigation sheet applied.

**Table 4. Efficiency in the use of water in the cultivation of cabbage due to the effect of different types of mulches.**

| Treatment | Irrigation sheet | EUIW total yield | EUIW cabbage | EUIW leaves |
|---|---|---|---|---|
| | (mm) | | (kg $ha^{-1}$ $mm^{-1}$) | |
| Black plastic | 234 | 298.9 (±62.5)a[†] | 195.7 (±15.3)a | 103.1 (±24.1)a |
| White plastic | 276 | 277.5 (±59.6)a | 185.6 (±16.4)ab | 92 (±19.2)a |
| Wheat straw | 271 | 241.6 (±48.3 b | 164.5 (±21.7)b | 77 (±21.9)ab |
| Control | 337 | 199.6 (±41.4)c | 134.2 (±18.1)c | 65.3 (±18.4)b |
| Significance | | < 0.0001 | < 0.0001 | < 0.0001 |

[†]= different letters within the same column mean significant differences according to the Tukey test ($p$< 0.05); EUIW = efficiency in the use of irrigation water.

In the case of the EUIW for the production of cabbage (head) biomass and fresh leaf biomass, mulching or not the soil produced great differences. In the soil with black plastic mulch, 195.7 kg $ha^{-1}$ of cabbage per each mm of irrigation water sheet was produced, while in the bare soil only 134.2 kg $ha^{-1}$ was produced. This means an increase of 45.8% in the EUIW. On the other hand, in the case of leaves, the results showed that mulching the soil with plastic (black or white) produced an average of 97.5 kg $ha^{-1}$ of leaves of the cabbage plant per each mm of water applied, while for bare soil, only 65.3 kg $ha^{-1}$ were obtained. A 49% increase in the UEAR.

Unlike other cruciferous crops, the organ of interest in cabbage is composed of leaves (head). The leaves are the main organ by which the transpiration and fixation of $CO_2$ happens, studies indicate that up to 400 transpired water molecules are required per each fixed molecule of $CO_2$ (Blum, 2005). In this sense, the use of mulch in the production of cabbage reduces water requirements and increases the EUIW, which greatly benefits this crop. As an example of this, Biswas *et al*. (2022) evaluated mulching a soil with rice straw and not mulching it and found an increase in the EUIW of 30%.

## Conclusions

The efficiency in the use of water was higher in the treatments with plastic mulch regardless of the color used, while it was lower in the bare soil. Likewise, generally the soil with black plastic mulch resulted in the highest concentration of $NO_3$ in the cell extract. Finally, the highest commercial yield was obtained by the soil with white plastic mulch and the lowest was with the soil mulched with wheat straw. The weight of cabbage (head) was greater in the treatment with white plastic mulch. Considering the efficiency in the use of irrigation water and commercial yield, the use of white plastic mulch is recommended.

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