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SOIL SOLAR-WARMING WITH DIFFERENT TYPES OF MULCH

[58]

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ABSTRACT

The effectiveness of the cladding and four mulch types on raising soil temperature was studied during two successive seasons of 2002 and 2003 at Kaha experimental station, Agricultural Research Center, Cairo, Egypt (Latitude, longitude, and altitude are 30.8, 31.15, and 16.9 m respectively). Cucumber seedlings (*Cucumis sativus* L. F1 local hybrid Sinai 1) were grown in clay soil under unheated two plastic houses. One of them was covered with one year old cladding material (PE 200µm) while the other was covered with new cladding. Soil surface was covered with different plastic mulch colors, i.e., black, silver, and transparent, in addition to a new suggested mulch that was craft-paper saturated with paraffin wax. Soil temperatures were measured at 5 cm depth. Global solar radiation and air temperature were measured inside and outside the greenhouses. The vegetative growth , i.e., plant height, leaf number, leaf fresh and dry weight, early and total yield were recorded. The results showed that new cladding cover promoted plant growth and yield. Craft-paper saturated with paraffin wax gave the highest soil temperature during the sunny days in comparison with other mulches and best results concerning vegetative growth and yield were obtained by both black mulch and craft-paper saturated with paraffin.

Key words: Solar heating; Plastic mulch; Paraffin mulch; Cladding; Cucumber; Soil temperature; Yield

INTRODUCTION

In the course of studying the responses of soil temperature to plastic mulch**, Lippert and Witing. (1964)** found that the influence of the type of polyethylene mulch on soil temperature and crop response was dependant upon film color. **Hopen (1964)** found that black polyethylene exchanged large quantities of energy with the atmosphere and caused relatively small changes in soil temperature while transparent polyethylene film transmitted radiation to the soil surface, which was absorbed and converted to sensible heat. The main

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effect of transparent mulch on plant growth apparently was due to the raising of soil temperature. **Richard (1976)** reported that the use of plastic mulch would affect soil temperatures in four main ways: it would reduce connective heat loss, outgoing radiation and evaporation, thus increasing soil temperatures. **Ballif and Dutil (1981)** showed the very clear advantage of transparent films, which produced a considerable build up of heat in the soil during the day because of a better transmissivity of short wave infrared radiation, thus providing the maximum of heat. **Manutention (1984)** reported that with black plastic film, the heat was dispatched by conduction, half going into the soil and half into the air space, the soil was therefore heated up quite slowly. While with transparent film, the film transmitted practically the whole of the solar radiation that became absorbed by the soil, the soil was therefore heated up more quickly.

The previous investigators have shown that the plastic films (transparent and black) created favorable conditions for increasing temperature in soil**.** **Salman & Gorski (1985) and Bonanno & Lamomt (1987)** showed that the soil temperature was 4.9°C higher under clear plastic mulch. **Haddadin, (1982)** found that in tomato field the average soil temperature was highest under clear plastic mulch followed by the black plastic much and bare soil treatments. But the differences in soil temperature became narrow as mulches were partially shaded by the plant **(Hill *et al* 1982). Hanada, (1991)** reported that mulching with appropriate materials has a number of effects: it increases the soil temperature, conserves soil moisture, texture and fertility; and controls weeds, pests and diseases. More recently, **Kwabiah, (2004)** investigated the optimum soil temperature required for sweet corn (*Zea mays* L.). It was found that the plastic mulch treatment decreased days from planting to emergence by 3–5 days and correspondingly decreased silk appearing by 8–17 days and maturity by 7–13 days. It was also found that the plastic mulch increased total and marketable yields.

Plastic mulching modifies the caloric balance. **Ballif and Dutil (1981)** showed that the plastic mulch allowed an additional take up of solar energy representing up to 4% increasing of energy absorption. Thus if the soil warmed up slowly, heating of the same soil covered with transparent polyethylene film was earlier, more rapid and more intense. this resulted, therefore, in a greater storage of heat during daylight, a limitation of cooling during the night-time and consequently produing an important gain of heat during the initial period of growth.

It is frequently reported in the literature that plastic mulch (both clear and colored) enhanced plant growth and increased vegetable production and

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earliness (**Chen & Katan, 1980 and Wien & Minotti, 1987).**

The effects of plastic mulch on weed control were reported by **Emmert (1956), Richard (1976) and Manutantion (1984)**. They reported that the absence of light with black plastic mulch didn't allow photosynthesis under the film and therefore weed growth was depressed. On the contrary with transparent film, the presence of light with the improved condition for growth (heat, moisture, good soil structure, etc.) encouraged weed growth.

Zhang *et al* (1996) studied the effect of different greenhouse covering materials**.** They found that the measured average PAR (photosynthetical active radiation) transmission depended mainly on the transmissivity of the used cladding. The increasing of transmission of cladding has an effect on the plants as described by **Kobayashi and Gyokusen (2004)** who concluded that nitrogen content of leaf per unit area increased with increasing light and nitrogen supply.

The objective of these experiments is to study the effect of different mulch color and types (black, silver, transparent, and craft-paper saturated with paraffin wax) on the growth and yield of cucumber grown under unheated plastic house. In addition, the effect of transmittance of the new and old cladding on solar radiation inside the greenhouse was studied.

MATERIAL AND METHODS

The experiments was performed during the two successive seasons of 2002 and 2003 at Kaha experimental station, Agricultural Research Center, Cairo, Egypt (latitude, longitude, and altitude are 30.8, 31.15, and 16.9 m, respectively). Cucumber transplants (*Cucumis sativus* L. F1 local hybrid Synai 1) were set up in the field in the last week of September 2002 and 2003, uder unheated plastic house of 50 meters long, 9 meters wide, and three meter height. The greenhouse has five raised beds, each 100cm wide. Double rows have been planted on each bed at a distance of 50cm between rows. Plants were trained to one stem. Cultural operations other than the experimental treatments were carried out normally according to the recommendations of Ministry of Agriculture, Egypt. The effect of plastic mulch and transmittance of the new and old plastic house cover (Polyethylene material 200 µm) were studied in a split plot experimental design with 4 replicates, considering the 2 cover types (new and old) as the main plots and 4 plastic much types as the sub-plots. The sub-plots were: covering the soil by transparent polyethylene (60µm), black polyethylene (60µm), silver color polyethylene (60µm) and craft-paper saturated with paraffin wax. Data of the experiments were subjected to statistical analysis of variance **(Snedecor and Cochran, 1980)**.

The following data were collected

1- Solar radiation intensity inside and outside the greenhouse.
2- Soil temperature at surface and 5 cm depth.
3- Vegetative growth ,i.e., plant height and leaf number (at 30 and 60 days)
4- Fresh and dry weight of the plant leaves
5- Total chlorophyll content measured using Minolta Chlorophyll Meter Spade-501.

6- Total nitrogen was determined using microkjeldahl apparatus as described by **Black (1965)**.
7- Early yield (first four picking)
8- Total yield.

RESULTS AND DISCUSSION

1. Effect of cladding materials on light intensity

The solar energy fluxes that represented in Figs. (1) are the intensity of the internal solar radiation for both greenhouses. Concerning the intensity, for clear day, the internal solar radiation flux inside the new cladding greenhouse was approximately 67% of the global solar radiation. However, it was about 26% for the old cladding greenhouse. The transmittance of the used cladding was from 0.65 to 0.75 due to the color added to the plastic material used for hot areas. As for cloudy day, the internal solar radiation inside the new cladding greenhouse was approximately 72% of the global solar radiation. However, it was about 26% for the old cladding greenhouse. The values mentioned above reveal that the transmittance of the plastic cover decreased to approximately 26% due to the degradation happened through the one year old. The trned of the solar energy flux inside the new cladding greenhouse was similar to the trned of the global solar radiation. However, the trned of the solar energy flux inside the old cladding greenhouse is not similar to that of the global. This is as both the global solar radiation and the solar energy flux inside the new cladding greenhouse are consisting of the direct and the diffuse components of the solar radiation.

2. Effect of cladding materials mulch on soil and surface temperature

Figures (2) show that the values of soil temperatures with mulching are much higher than those of soil without mulching. This may be owing to mulching prevents cooling of the soil surface due to evaporation. The values of soil temperature under transparent mulch were higher than those under the other mulches. This clear plastic mulch may permit warming of 3 to 8°C to a depth of 5 cm, whereas black plastics permit warming of 2 or 3.5°C. The results of the new cladding showed that that values of soil temperature under the craft paper is less than those under the clear mulch and greater than those under the black plastic mulch. The results of the old cladding showed that the value of the soil temperature under the craft paper is close to that under silver plastic mulch.

Sunlight passes through the clear plastic and heats the soil. A layer of water on the underside of the plastic retains the radiant heat at night through what is known as a greenhouse effect. Black plastic mulch absorbs most of the sunlight and becomes greatly warmed, and little energy passes through to warm the soil **(Hopen, 1964).**

Using mulch types (polyethylene and paraffin mulch) enhanced soil temperature. Clear plastic mulch increased soil temperature more than black and silver plastic mulch especially during the first weeks after transplanting where plants did not have enough canopies to shade the soil.

Concerning the Surface temperature, Plastic mulches directly affect the microclimate around the plant by modifying the radiation budget (absorbitivity vs. reflectivity) of the surface and decreasing the soil water loss. The color of mulch largely determines its energy-radiating behavior and its influence on the microclimate around a vegetable plant.

Color affects the surface temperature of the mulch and the underlying soil temperature. This can be noticed from Figs. (3) that illustrate the values of the mulch surface-temperature. Black plastic mulch is an opaque blackbody absorber and radiator. Black mulch absorbs most UV, visible, and infrared wavelengths of incoming solar radiation and re-radiates absorbed energy in the form of thermal radiation or long-wavelength infrared radiation. Much of the solar energy absorbed by black plastic mulch is lost to the atmosphere through radiation and forced convection **(Lamont, 1999).** The degree on contact between the mulch and soil, often quantified as a thermal contact resistance, can affect greatly the

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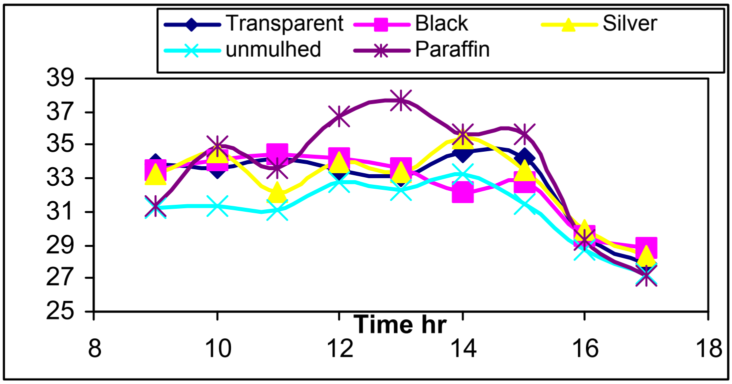
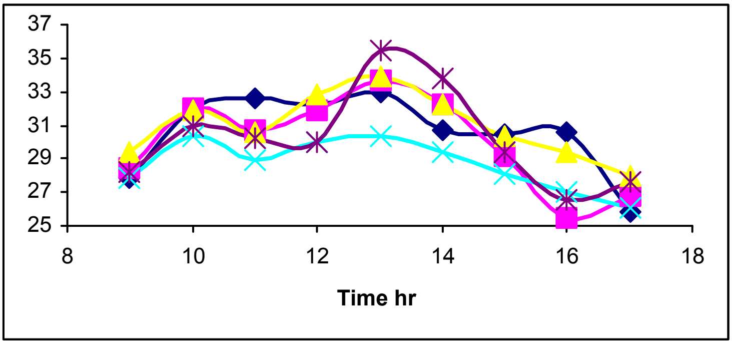


New cladding



Old cladding

Fig 3. Soil surface temperatureof each mulch type in plastic houses covered with ew and old claings.

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performance of mulch. If an air space is created between the plastic mulch and the soil by a rough soil surface, soil warming can be less effective than would be expected from particular mulch. Surface temperature of the craft paper saturated with paraffin wax was the highest compared to those of the other mulches especially with new cladding cover in sunny day. This was clear when cucumber plant was in the first stage of growth when plant canopy did not cover the soil yet. This may be due to the releasing of latent heat of the melting wax.

3. Growth and yield

3.1. Effect of cladding material

A significant effect on the growth and yield of cucumber due to using new cover was observed (Table 1a). Vegetative growth of plants i.e., leaf number, fresh and dry weight was promoted with new cover except for the plant heights which recorded higher values with old cover in comparison with new one.

New plastic cover resulted in the higher chlorophyll and nitrogen content of cucumber leaves while, old cover gave the lowest value. The same result was found by **Kobayashi and Gyokusen (2004)** who found that **t**he new cover resulted in significant increase in early and total yield of cucumber. This may be a reflection of increasing the chlorpyl, nitrogen and the growth of plants.

3.2. Effect of mulch type

Generally, Paraffin mulch gave the best vegetative growth i.e., plant height, number of leaves, fresh and dry weight in comparison with black, Silver and clear polyethylene mulch (Table 1b).

The lowest plant height, leaf number, fresh and dry weight were recorded with un-mulched soil. The enhancement of vegetative growth due to mulches has been reported by **Vicaria (1952), Emmert, (1956) and Manutention, (1984).**

Mulching has contributed positively to higher soil temperature and consequently improving gowth and yield of cucumber. Those results were in agreed with findings of **Hopen, (1964).**

Concerning chlorophyll and nitrogen contents, there were no significant differences between mulch treatments**.**

The greatest yield was recorded with black polyethylene mulch followed by paraffin, silver and then by clear polyethylene mulch.

Increased yield could be largely attributed to the increase in soil temperature due to application of mulch, which resulted in enhancement of soil environment around roots of cucumber plants, which led to increasing plant growth, and hence increasing nutrient absorption and uptake. Hence, the increasing in early and total yield was found. These results were in line with

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those obtained by **Clarkson & Frezier (957) and Salman *et al* (1990).**

Although, clear plastic mulch may result in an increase in soil temperature, the presence of light led to the disadvantage of weed growth. While, the absence of light with black plastic and paraffin mulch did not allow photosynthesis of weeds under the film and therefore weed growth was suppressed. This result was in agreement with that found by **Vicaria, (1952)**. Using paraffin mulch had the advantage of clear mulch in rising soil

temperature and at the same time the advantages of black plastic much on weed control.

3.3. Effect of the interaction between cladding cover and mulch types

The application of paraffin mulch and new plastic cover treatment gave the highest leaf number per plant, fresh and dry weight followed by black, silver and clear mulches. While the lowest values were recorded with un-mulched and old cover treatment as shown in (Table, 2).

Concerning the effect of interaction between greenhouse cover and mulch type on chlorophyll and nitrogen content in cucumber leaves, no significant differences were observed among the investgated treatments (Table, 2).

Concerning the early and total yields, it was obvious that application of new cover led to a progressive increase in the yield. The highest yield was obtained from the new cover treatment with black plastic mulch followed by paraffin mulch with the new cover and the lowest combined yield was recorded with un-mulched soil with old cover.

Using mulches with cucumber under unheated plastic house resulted in an increase in vegetative growth i.e. plant height, leaf number, leaf area, fresh weight, dry weight, and yield of plants. These results are in agreement with those reported by **Hopen & Oebkcer (1976) and Chen & Katan (1980).**

CONCLUSION

Under the experimental conditions, it is strongly recommended to use new cladding because of its capability in transmitting solar radiation in comparison with old cladding. Further more, using paraffin mulch had the advantage of clear plastic mulch in rising soil temperature and at the same time the advantages of black plastic much on weed control. The application method of paraffin mulch needs further research concerning the application method to increase its use efficiency.

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التسخين الشمسي للتربة باستخدام أنواع مختلفة من أغطية التربة

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سميرة بيومي سالم[1] - سامي عبد الجواد عبد رفعت أحمد يوسف[2] - عبد الطيف الباز[3]

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2- قسم بحوث الخضر – مركز البحوث الزراعية – الجيزة – مصر

3- قسم الطاقة الشمسية – المركز القومي للبحوث – الدقي – القاهرة – مصر

أجريت هذه الدراسة خلال الموسمين الزراعيين 2002/2003 و 2003/2004 ... على بعد 5 سم من سطح التربة وقيس درجات الحرارة داخل وخارج ... بمحطة بحوث الخضر ... والتابعة لمركز البحوث الزراعية بمصر (خط طول 31.15 – خط عرض 30.8) ... وقد استخدمت النباتات ... (م 16.9) ... درجة حرارة التربة.

وقد تمت زراعة ... (1) ... درجة حرارة التربة ... (الكنترول).

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