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Effects of Mulching Materials on Soil Temperature under Polyhouse Condition

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Abstract
In order to generate information and suggest solution experiment was conducted to study the effect of mulch (black and white plastic mulch as well as grass mulch) on soil temperature under polyhouse condition. The treatments were arranged in Randomized Complete Block Design with three replications during main rainy season of 2012 and 2013. Soil temperature during each individual years and combined over years was significantly improved with both plastic mulches over no mulch and grass mulch. The highest soil temperature was recorded under white plastic mulch followed by black plastic mulch. On the other hand lowest soil temperature was recorded under grass mulch treatment. White plastic mulch scored higher temperature by 1.17, 2.48 and 3.78 °C compared to black plastic mulch, no mulch and grass mulch, respectively. In general, all mulched and no mulched treatments soil temperatures were under optimal range for most warm season vegetable crops for water and mineral uptake from the soil. Both plastic mulches are recommended for users to produce most warm season vegetable crops by enhancing soil temperature during cool season and grass mulch to reduce soil temperature during hot season under polyhouse growing conditions.
Keywords: Mulch, Temperature polyhouse and vegetable

1. INTRODUCTION

Climate is the predominant factor that determines crop production. Growers modify their climate have a competitive advantage over growers in the same region that do not manipulate climate. Manipulation of the growing season can be achieved through a variety of cultural practices. Among the cultural practices mulching is the one that involves placing organic or synthetic materials on the soil around plants to provide a more favorable environment for growth and production [1].

Plastic mulches are commonly used to modify soil temperature, weed control, conserve water, protect fruits from contact with soil moisture and pathogens, repel certain insects, and control erosion [2]. Soil temperatures under black plastic during the day time can be as much as 5 ºF higher at 2 inch depth and 3 ºF higher at a 4 inch depth than bare soil at the same depths. Soil temperatures during the day time under clear plastic can reach 8-14 ºF higher at 2 inch depth and 6-14 ºF higher at 4 inch depth than bare soil at the same depths due to a greater (85 to 95 %) solar radiation transmittance [3].

White plastic mulches can be used to establish crops in the summer, when a reduced soil temperature might be beneficial. Coextruded white on black plastic mulch helps cool the soil while black controlling weeds. There were significant differences among the mulches in soil warming characteristic at which the weekly average air temperature dramatically rose 11 ^{o}F. The soil temperature was found higher in infra red than red and in black than silver plastic mulch. Red and black mulch were provided an equal amount of soil temperature [4].

Melek and Atilla [5] reported that, soil temperature in white and black mulch applications were higher 5-8 ^{o}C and 1-4 ^{o}C than that of the control, respectively. According to Decoteau *et al.,* [6], the surface color of the mulch affected root zone temperatures. Soil temperature under black mulch was found higher than white mulch by 1 ^{o}C. The same result was reported by Henry and Barbara [4], that daily maximum soil temperature found between 4 to 5 pm. As expected, white mulch resulted in plus 13 ^{o}F compared with black mulch. White plastic mulch produced greater than 90 ^{o}F soil temperature which effect has shown detrimental to continued tomato growth and fruit development.

According to Toshio [7], polyethylene mulch raises the soil temperature. This effect derives mostly from the suppression of latent heat loss through evaporation. The extent of the increase in soil temperature depends on the color of the film and the intensity of solar radiation. The penetration of sunlight and the increase in soil temperature was most marked when transparent film was used while black film was not as effective in raising soil temperatures. The difference in soil temperature between mulched and bare soil reached 7 °C with transparent film and 5 °C with black film. However, this increase in soil temperature diminished later, as the canopy of carrot leaves began to cover the mulch.

According to Jakhdhar [8], highest soil temperature was obtained under the black plastic mulch during the early growth season due to less shade on the surface. The difference in temperature between mulched and

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bare soil was 2.2 to 3.4 °C. Black plastic mulch significantly affects the tomato yield. The yield increased with black plastic mulch from 20.7 to 29.8% as compared to bare soil**.** Garry *et al.* [9] concluded that, soil temperatures were 5 to 7 °C lower than air temperatures. The dark colors, black, blue, and red, resulted in higher soil temperatures than silver or white colored mulches. Warmer air and soil temperatures did not always correlate to greater yield.

According to Moreno *et al*. [10], the temperatures registered in bare soil were always lower than under mulch treatments and the soil temperature under the different mulches was affected by the type of material employed. In the selected measuring dates during the crop cycle, soil temperatures were significantly higher ($P<0.05$) in black polyethylene. The lowest values were obtained under the black biodegradable film, although without significant differences with respect to the aluminized photodegradable mulch.

Mulching significantly ($P< 0.05$) influenced soil moisture, temperature and weed weight and population density. Soil moisture was lower on bare soil compared to mulched plots, with plastic mulches being superior over the wheat straw. Significantly lower soil temperatures were recorded on wheat straw and the un-mulched, while higher temperatures were recorded on the plastic mulched plots with the black mulch giving the highest temperature [11].

Plastic mulches absorbed incident radiation that can be readily transmitted to the soil surface and the air is relatively immobile near the soil surface with a low thermal conductivity which increases soil temperature consistently [12]. This increase in soil temperature consistently improves root development in vegetables grown under mulches. On the other hand Taber and Gansemar [13] observed that organic mulches keep the soil cold and relatively retarding plant growth due to slower cell division and cell maturation.

With the established irrigation schemes year-round production practice is a key to avoid seasonal price fluctuation and maintain reasonable year round profit. However, supply of crops like tomato and onion overwhelm the marketing during few months in the dry season, and as a result, the price of the crop drastically decreases in western Amhara in particular and in Ethiopia in general. On the other hand, the same crops disappear from the market in the wet season. Disease prevailing during rainy season attributed to the shift of production. If this situation is to continue, forthcoming medium scale irrigation projects may not justify investment on processing plants that may need year round availability of certain commodities such as tomato [14].

These problems can be overcome by introducing new production techniques that involve integrated disease management methods and modification of the environment through protected cultivation that can include use of plastic shelters and mulch. This will enable producers get year round income, with reliable market and higher prices. Therefore, the present study was conducted to compare the effect of different mulching materials to create favorable soil temperature for vegetable production under polyhouse condition.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The experiment was conducted at Woramit Horticultural Crops Trial Site of Adet Agricultural Research Center, during the rainy season of 2012 and 2013. Woramit is located in the North-western part of Bahir Dar town on the shore of Lake Tana. The site has an altitude of 1800 m.a.s.l. It has warm and humid microclimate with distinct dry and wet seasons. The soil is deep with red-brown color (Nitosol). The mean daily maximum temperature is 29.5 ^{0}C in April. The mean daily minimum temperature is 6.2 ^{0}C in January. The area receives a mean annual rainfall of 800-1250 mm. Generally the agro-ecology is regarded as Woina Dega.

2.2. Experimental Materials

Black and white colored plastic sheets (PE) with 20 micro (0.02 mm) thickness and dried grass at the rate of 4 tons ha^{-1} were used as mulch. Transparent polyethylene sheet with 150 micron (0.15 mm) thickness was used as a covering material for the ploy house. The treatments were applied in polyhouse which had size of 12 m wide and 33 m length with 3 m height at the center. Two-third of the four sides of the plastic house was covered with UV film sheet from the ground and the remaining 1/3 upper portion of the walls was covered with insect proof net for ventilation. Polyhouse was made up of bamboo frame and covered with 150 micron (0.15 mm) clear polyethylene sheet which have greater than 80 % light transmission capacity fastened by cut used car tires string.

2.3. Treatments and Experimental Design

The experiment consists of three types of mulch namely; Black Plastic Mulch (BPM), White Plastic Mulch (WPM) and Grass Mulch (GM) including no mulch as a control which was arranged in a Randomized Complete Block Design (RCBD) with three replications.

2.4. Data Collection

Soil temperature was measured using digital thermometer under each mulched treatment. Digital thermometer

was inserted at 10 cm depths under the mulch. Daily soil temperature was recorded at 5: 00 pm after mulch treatments accumulated heat throughout the day time.

2.5. Statistical Analysis

Analysis of variance (ANOVA) was computed using SAS (9.00 version) software. Duncan multiple range tests at 5% probability level was carried out for mean separation.

3. RESULT AND DISCUSSION

The combined analysis of variance revealed that, there was a significant ($P<0.01$) difference among treatments for soil temperature. Season of the year was also significant ($P<0.01$) for soil temperature. Mulch by season of the year interaction was non-significant for soil temperature (Table 1). Non significant mulch by season of the year interaction effect indicates that application of mulching materials respond similarly to variation of season of the years.

Soil temperature during each individual years and combined over years was significantly improved with both plastic mulches over no mulch and grass mulch (Table 2, 3, and 4). The combined result over years indicates that in July the highest soil temperature was recorded under white plastic mulch (28.62 ^{o}C) followed by black plastic mulch (27.45 ^{O}C). White plastic mulch brought higher soil temperature by 1.17, 2.48 and 3.78 °C as compared to black plastic mulch, bare soil and grass mulch, respectively. The result agreed with Toshio (1991) [7] that soil temperature under transparent and black film higher by 7 °C and 5 °C as compared to bare soil. Singh and Kamal [15] also reported that the highest soil temperature occurred under black polyethylene mulch which was 2.2 to 3.4 °C higher than the bare soil. During August highest soil temperature (25.93 ^{o}C) was recorded under white plastic mulch and the second highest with black plastic mulch (25.59 ^{o}C) but diminished as compared to July. According to Singh and Kamal [15] this increase in soil temperature diminished later, as the canopy of leaves began to cover the mulch. In contrast to the present finding, Decoteau *et al*. [6] reported that soil temperature under the black mulch averagely higher by 1^{o}C than soil temperature under white mulch.

During September highest soil temperature was also recorded under white plastic mulch (26.62 ^{o}C) and the second highest under black plastic mulch (25.99 ^{o}C) in comparison with no mulch and grass mulch treatments. It agreed with Incalcaterra *et al*. [16] finding transparent polyethylene mulch increased soil temperatures in comparison to the bare soil. A slit reduction of soil temperature was exhibited at each mulch treatment in August and September as compared to July. As Streck *et al*. [17] suggested that mulch effect on root zone temperature was more evident during the early crop season when plants shaded less the soil surface under greenhouse condition.

In the present study average values of mean soil temperature followed the same trend as the June, August and September. Lowest mean soil temperature was recorded under grass mulch followed by no mulch treatments. It is agreed with Rioba [11] that significantly lower soil temperatures were recorded on wheat straw and no mulched plots under green house condition as compared to plastic mulches. Awodoyin *et al*. [18] also reported that the soil temperatures were lowest under the grass mulched treatment and highest under the plastic mulched both at 5 cm and 15 cm depths. Reduced soil temperature recorded under grass mulch in the current study was agreed with Schonbeck and Evanylo [19] result that hay mulch reduced soil temperature than plastic and paper mulches soil temperature

In the present study, white plastic mulch was scored higher mean soil temperature approximately by 1.0, 1.5 and 3.00 °C in comparison to black plastic mulch, no mulch and grass mulch, respectively. The result supported by Jakhdhar [8] who reported that soil temperatures during the day time under clear plastic can reach higher than under bare soil due to a greater solar radiation transmittance and suppression of latent heat loss through evaporation. According to Toshio [7] the penetration of sunlight and the increase in soil temperature was mostly marked when transparent polyethylene film was used as mulch while black film was not as effective in rising soil temperatures. In the current study, the average soil temperature for all mulch treatments as well as no mulch treatments was within the biological acceptable range for most warm season vegetable crops growth and production. The optimum root zone temperature was observed by Jones [20] to be between 20 °C to 30 °C, and at soil temperatures less than 20 °C plant growth will be significantly reduced.

Mulch treatments significantly influenced both maximum and minimum soil temperature (Table 2, 3 and 4). Grass mulch system had highly reduced soil minimum and maximum temperatures relative to the plastic mulch systems. The result agreed with Teasdale and Abdul-Baki [21] who reported maximum soil temperature under black polyethylene mulch was found greater by 5.7 and 3.4 ^{o}C than those under hairy vetch at 5 and 15 cm deep, respectively. Both plastic mulch systems did not recorded significant difference in soil minimum temperature. Maximum soil temperature was 33.66 °C that was recorded for white plastic mulch treatment in 2013. On the other hand, minimum soil temperature 21.47°C was recorded under grass mulch treatments in 2012 under polyhouse condition.

Table 1. Mean squares from combined analysis of variance (ANOVA) for soil temperature

Source of variation	df	Mean Squares July	August	September	mean	minimum	maximum
mulch	3	32.12**	6.32**	10.48**	14.25**	5.144**	61.12**
rep	2	1.57ns	3.46ns	19.71**	5.94ns	0.56ns	6.75ns
year	1	15.15**	80.46**	72.75**	50.84**	22.55**	61.20**
Mulch*year	3	0.49ns	0.11ns	2.46ns	0.30ns	0.12ns	2.54ns
Error	38	0.44	0.62	1.01	0.50	0.58	1.64ns

*, ** & ns- significant (P<0.05), highly significant (P<0.01) and non significant, respectively.
BPM= black plastic mulch, WPM= white plastic mulch and GM= grass mulch.
Means in columns with the same letter are non-significant each other at ≤ 0.05

Table 2 Effect of mulching material on soil temperature (°C) at 10cm depth in 2012

Treatment	July(°C)	August(°C)	September(°C)	Mean(°C)	Minimum(°C)	Maximum(°C)
BPM	27.22^{b}	24.31^{ab}	24.40^{ab}	25.28^{a}	22.68^{ab}	30.18^{b}
WPM	28.17^{a}	24.57^{a}	25.10^{a}	25.92^{a}	22.88^{a}	31.92^{a}
GM	24.25^{d}	23.11^{c}	23.86^{b}	23.74^{c}	21.47^{c}	26.35^{d}
No mulch	25.39^{c}	23.70^{bc}	24.53^{ab}	24.54^{b}	22.05^{bc}	27.70^{c}
Significance	**	**	*	**	**	**
CV%	2.44	2.37	2.87	2.30	2.89	3.05

* and ** significant at P≤0.05 and P≤0.01
BPM= black plastic mulch, WPM= white plastic mulch and GM= grass mulch.
Means in columns with the same letter are non-significant each other at ≤ 0.05

Table 3. Effect of mulching material on soil temperature (°C) at 10cm depth in 2013

Treatment	July(°C)	August(°C)	September(°C)	Mean(°C)	Minimum(°C)	Maximum(°C)
BPM	27.75b	26.89a	27.60a	27.41ab	23.86a	31.68b
WPM	29.17a	27.31a	28.13a	28.20a	24.31a	33.66a
GM	25.46d	25.43b	25.01b	25.30c	22.70b	28.56c
No mulch	26.92c	26.37ab	26.92a	26.74b	23.68ab	31.26b
Significance	**	*	**	**	*	**
CV%	2.43	3.46	4.28	3.02	3.80	4.95

* and ** significant at P≤0.05 and P≤0.01
BPM= black plastic mulch, WPM= white plastic mulch and GM= grass mulch.
Means in columns with the same letter are non-significant each other at ≤ 0.05

Table 4. Effect of mulching material on soil temperature (°C) at 10cm depth combined over years

Treatment	July(°C)	August(°C)	September(°C)	Mean(°C)	Minimum(°C)	Maximum(°C)
BPM	27.45b	25.59ab	25.99a	26.34b	23.27ab	30.93b
WPM	28.62a	25.93a	26.62a	27.06a	23.60a	32.79a
GM	24.84d	24.27c	24.40b	24.50d	22.08c	27.45d
No mulch	26.14c	25.02b	25.73a	25.63c	22.86b	29.48c
Significance	**	**	**	**	**	**
CV%	2.50	3.03	4.11	2.70	3.23	4.33

* and ** significant at P≤0.05 and P≤0.01
BPM= black plastic mulch, WPM= white plastic mulch and GM= grass mulch.
Means in columns with the same letter are non-significant each other at ≤ 0.05

4. CONCLUSION AND RECOMMENDATIONS

Application of mulch significantly influenced soil temperature. In the current study, soil temperatures under the mulches were constantly higher than bare soil except grass mulch during the whole experimentation periods. In general, under all mulched and no mulched treatments soil temperatures were found under optimal range for most warm season vegetable crops root for water and mineral uptake. Therefore, both plastic mulches are recommended to produce for most warm season vegetable crops during cool season and grass mulch during hot season under polyhouse growing conditions.

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