Vol-2, Issue-10 PP. 1497-1519 ISSN: 2394-5788

GLOBAL JOURNAL OF ADVANCED RESEARCH
(Scholarly Peer Review Publishing System)

POLYETHYLENE AND RICE STRAW AS SOIL MULCHING: REFLECTION OF SOIL MULCH TYPE ON SOIL TEMPERATURE, SOILBORNE DISEASES, PLANT GROWTH AND YIELD OF TOMATO

Fatma S. Moursy
Central Laboratory for Agricultural Climate (CLAC),
Agricultural Research Center (ARC), Giza,
Egypt.

Fatma A. Mostafa
Plant Pathology Research Institute,
Agricultural Research Center (ARC), Giza,
Egypt.

Nayera. Y. Solieman
Agricultural Economics Department,
National Research Centre, Dokki, Cairo,
Egypt

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ABSTRACT

To investigate the best type of soil mulch in saving soil temperature and reducing soil borne diseases to avoid the fungicides used, four types of mulches and its impact on these targets as well as tomato growth and productivity (super strain B) were studied during 2013/2014 and 2014/2015 seasons at the Central Laboratory for Agricultural Climate (CLAC) Dokki, ARC, Giza, Egypt. Two thickness of organic mulch (rice straw, 3 and 6 cm) and two colors of polyethylene mulch (transparent and black) were used compared with non-mulched soil as control. Data of air and soil temperatures were daily recorded in order to determine the temperature profile during the studied periods. For count the fungal colonies (cfu/g soil), soil samples were frequently collected from the rhizosphere of all treatments and cultured on potato dextrose agar (PDA). In addition, the isolated fungi colonies were identified. On the other hand, plantsgrowths parameters *i.e.* plant length, stem diameter, shoot and leaves numbers as well as fresh and dry weight per plant were measured. Finally, early and total yield were determinate as well as average fruit weight and total number of fruits.

The obtained results indicated that, soil temperature increased by all mulch types tested (organic and polyethylene) compared to control treatment. Transparent mulch, however, recorded the highest soil temperature, followed by the black one. Moreover, soil temperature in the two thicknesses of organic mulch was relatively similar and less than the other treatments. Mulch treatments were very effective in reducing total count of fungi in soil, and polyethylene mulch was the best. *Fusarim oxysporum*, *F. moniliforme*, *F. solani*, *Macrophomina phaseolina* and *Rhizoctonia solani* were identified. Furthermore, the dominate species of fungi, however, was *F. solani*. On the other hand, transparent mulch followed by 3 cm rice straw mulch recorded the highest significant values in vegetative growth parameters. However, transparent mulch followed by 6 cm rice straw mulch reflected significantly the highest early and

total yield followed by the 3 cm rice straw mulch and black polyethylene mulch. Finally, the economic evaluation reflected the same results from economic point of view.

Key words: tomato, organic soil mulch, polyethylene mulch, soil temperature, soilborne diseases, plant growth parameters and yield.

1. INTRODUCTION:

Through the history of agriculture, plastic film was used for soil mulching. Soil mulching in vegetables farms mainly used to reduce the growth of weeds, saving the soil temperature, protect soil from erosion caused by wind or water, leaching of fertilizers, especially on sandy soils, as well as protecting againstthe infection anddevelopment of soil borne diseases (Green *et al*., 2003; Scarascia-Mugnozza *et al*., 2006).On the other hand, plastic mulches directly affect the microclimate around theplants by modifying the radiation budget of the surface and decreasing the soil water loss (Liakatas *et al*., 1986). Moreover, mulching avoids the deep fluctuations intemperature in the first 20–30 cm depth in soils. Such stable condition yieldsgood root development and promoting faster crop development and earlier harvest.

In recent years, different colors of plastic mulches have been used in vegetable crops for controlling the diseases and for increasing yield and quality.Where, it's possible to create and control the microclimate around plants, depending on the color of the mulch and local climate conditions, which can be beneficial for crop growth and yield. Use of darker color mulches increases soil temperature, while lighter colors reflect more solar radiation and tend to minimize changes in soil temperature besides increasing the irradiance around the plant canopy, (Decoteau *et al*., 1990; Mahmoudpour and Stapleton, 1997) and the presence of pests or pathogen populations (Csizinszky *et al*., 1997; Greer and Dole, 2003).In addition, Toshio (1991) reported that the difference in soil temperature between mulched and bare soil in early May reached 7ºC in case of transparent film and 5ºC in case of black film.

The soil temperature under plastic mulch depends on the thermal properties (reflectivity, absorptive or transmittance) of a particular material in relation to the incoming solar radiation (Schales and Sheldrake, 1963; Tripathi and Katiyar, 1984).William and Lamont (1991) found that there are three common mulch colors were used commercially in the production of vegetable crops: black, clear, and white (or white-on-black). Black plastic is the most popular one because it retards weed growth and warms the soil in the spring. Douglas and Sanders (2001) stated that the advantages of using plastic mulches are: increasing soil temperature from 4 to 5 ºC under black mulch, 8 to 10 ºC at a 5 cm depth under clear mulch, reducing soil compaction, evaporation, weed problems, earlier crops and increasing growth. However, Djigma and Diemkouma (1986) found that the black polyethylene mulch yielded 3.3 times higher than soil without mulch in eggplant and 2.3 times in tomato, when grown during the relatively cool season, sown in September and harvested in January. In a trial carried out during the hot season, the use of plastic mulch had an adverse effect on vegetables and decreased their yields significantly. Polyethylene is one of the most commonly used plastic materials for mulching, due to the fact that it is easy to process, has excellent chemical resistance, high durability, flexibility and is odorless as compared to other polymers. It forms a relatively impermeable vapour barrier on the soil surface, changing the pattern of heat flow and evaporation (Tripathi and Katiyar, 1984). Moreover, it is non-degradable materials, not easy to removal from the field and do not break down and should never be disked or incorporated into the soil (Lamont, 1993), which implies a serious risk for the environment. However, the process of recovering and recycling them later is difficult (González *et al*., 2003). However, soil coverage with organic mulches is one of the natural methods in this concern. It can be achieved by using plant mulches and mulches from straw left after cereal grain harvest (Liebman and Davis 2000; Bàrberi 2002; Kosterna, 2014). Zagaroza (2003) show that the efficient of the mulch which depended on its thickness on the soil surface. Also, Döring *et al*. 2005 found that moderate amounts of straw (1.25, 2.5 and 5 t/ha) neither reduced nor enhanced the amount of weed significantly.

From another point of view, pathogenic infestation is limited by both the mechanical effect of an application of mulch (Hembry and Davies 1994), and by the allopathic effect of chemical compounds contained in the tissue of plant mulches (Creamer *et al.* 1996; Smeda and Weller 1996).

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The objectives of the current investigation was to assess the effects of two types of soil mulches (organic and polyethylene) on soil temperature and soil borne diseases as well as its effects on yield of tomato and economic evaluation for the tested types of soil mulching and its reflection on the yield.

2. MATERIALS AND METHODS:

2.1 Experimental site

The current investigation was conducted during seasons of 2013/2014 and 2014/2015 at research farm of Central Laboratory for Agricultural Climate (CLAC), Dokki, Giza, compare two types of soil mulching on bases of saving soil temperature, growth and productivity of tomato, soil borne diseases as well as evaluate them economically.

2.2 Plant materials and culture circumstances

Seedlings of tomato (*Solanum lycopersicum* cv. Super strain B) were transplanted in 1st of December of 2013 and 2014, at a spacing of 0.5m between plants inside the same raw. Raised beds measuring 4.0x1.0 m were prepared and recommended doses of nutrients were applied before spreading the mulches (extension bulletin no. 1294/2013). The mulches were spread manually and holes of 5 cm diameter were made over the polyethylene films for transplanting. The soil set was irrigated using drip irrigation system in which the dripping line was placed about 10 cm from the center of the seedbed.

2.3 Treatments

Two types of soil mulch were tested in this investigation as follow:

(a) Organic mulch:

Rice straw in two thicknesses, each one of the tested thicknesses was considered as separate treatments (rice straw with 6 cm thickness (T1) and rice straw with 3 cm thickness (T2).

(b) Polyethylene mulch:

Two colors of 60 micron polyethylene mulch were used. Each color was considered as a separate treatment (transparent polyethylene (T3) and black polyethylene (T4)). All treatments tested were compared to a bare soil (none mulched) as control.

2.4 Climatic conditions

In order to determine the effect of the different mulches on soil temperature under field conditions, measurements of maximum and minimum temperature at 10 cm soil depth were daily recorded in each plot and in bare soil (no mulch) by using a digital thermo/hygrometer Art.No.30.5000/30.5002 produced by TFA, Germany.

2.5 Recorded data

Data were recorded every 30 days on number of branches, number of leaves, stem diameter, plant fresh weight and plant dry weight. In addition, early and total yields as well asaverage fruit weight were determinate.

2.6 Diseases assessment under field conditions

Naturally infected tomato plants under filed conditions were assessment in all treatments as the percentages of root- rot and wilt were recorded as follows:

Disease incidence (%)=No. infected plants X 100 / total No. of plants.

2.7 Isolation of microorganisms and analysis

Soil samples were collected from rhizosphere of tomato plants in all treatments in trireplicates after 0, 30, 60, 90 and 120 days of plantation, the numbers of fungi colony were determined using the dilution plate methods and agar medium. Average number of colonies was calculated for 1g of dry soil (cfux10^2/ g). The experiment was stated with 10g of dry soil which was placed in a sterile Erlenmeyer flask with 90 ml sterile water and shacked on rotary shaker for 30 minutes. Ten ml of soil suspension were transferred to 90ml sterile water and sharked vigorously for five minutes; serially diluted 10^3 for fungi were obtained. Soil suspension, 1.0 ml was speeded with a flamed “L-shaped glass rod” and plates were incubated at 28°C. After incubation, colonies counted and isolated to obtained pure culture onto PDA medium for further investigation in laboratory.

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2.8 Isolation of the causal microorganisms

Tomato plants showing wilt and/or root-rot symptoms were thoroughly washed, cut into small pieces and surface sterilized with 0.5% sodium hypochlorite. Pieces were plated onto PDA Petri dishes. Plates were incubated at 28°C for 5 days and examined for fungal growth. The fungi were identified based on the morphological and cultural characteristics according to (Nelson *et al.*, 1983; Barnett and Hunter 1987). Identification was gently supported by the staff of Mycol. and Plant Dis. Surv., Plant Pathol. Inst., ARC, Giza, Egypt. The frequency percentages of the isolated fungi were calculated as follows:

Frequency percentage = No. of fungus x 100 /total No. of fungi

2.9 Pathogenisty test

The pathogenic effect of *F. solani*, *F. oxysporum*, *F. moniliforme*, *R. solani*, and *M. phaseolina* against Super Strain B tomato cv. Thirty-six plastic pots (30-cm-diam.) containing 6 kg of sterilized sandy loam soil (1:1) were arranged on a bench of greenhouse, according to a completely randomized designat 28 ± 2 ^{o}C. Six pots were used as replicate for each fungal isolate as well as the untreated control. Each fungal isolate was singly grown on sterilized Sorghum-Sand Medium in conical flasks (500ml) for two weeks at 28 ± 2 ^{o}C. The soil was infested with each fungus growth separately at the rate of 3kg (w/w). The infested soil was watered daily for 7 days to obtain the optimum fungal growth. Healthy-looking tomato seedlings were surface sterilized by dipping in sodium hypochlorite solution (0.1%) for 2 min. Ten seeds or three seedlings, were tested in each pot. The control pots were treated with the equal amount of uninoculated Sorghum-Sand Medium. All pots were examined to record percentages of wilt and root- rot 30 days of the planting. Percentages of disease incidence were calculated as mentioned before.

2.10 Experimental design and data analysis

The mulch treatments were arranged in randomized complete block design with four replications. Data were statistically analyzed using the analysis of variance method. L.S.D. tests at 5% level of probability were used to compare means of the treatments. Finally, economic indicators were used to provide economic evaluation for this experiment.

3. RESULTS AND DISCUSSION

3.1 Saving soil temperature

It's noted from data in Figure (1) that temperature of non-mulched (bare) soil typically has the same trend of air temperature, however, during cooler or colder months.

From data in figures (1, 2, 3 and4) it's concluded that, registered temperature in non-mulched (bare) soil was always lower than under all tested mulch treatments soil. In addition, soil temperature under the different mulches was affected by the type and the material that were used. The values of soil temperature under transparent mulch were higher than those under the other mulches tested. Registered values of maximum soil temperature under the transparent mulch were usually higher than the non-mulched soil (control) by about 5 °C (in average). In addition, applying the transparent soil mulch treatment increased value of soil minimum temperature by about 1.6 °C compared with the non-mulched soil (Fig.1).

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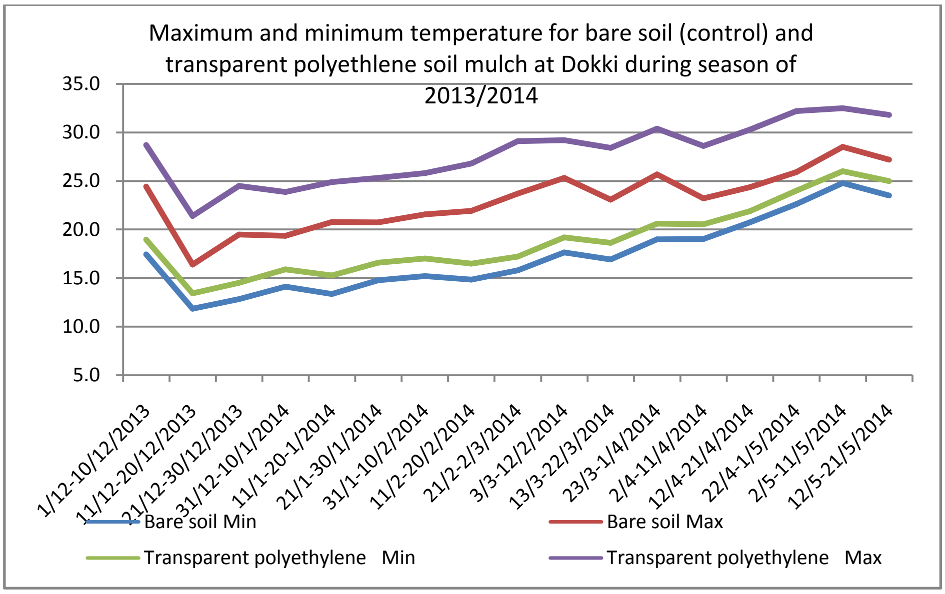

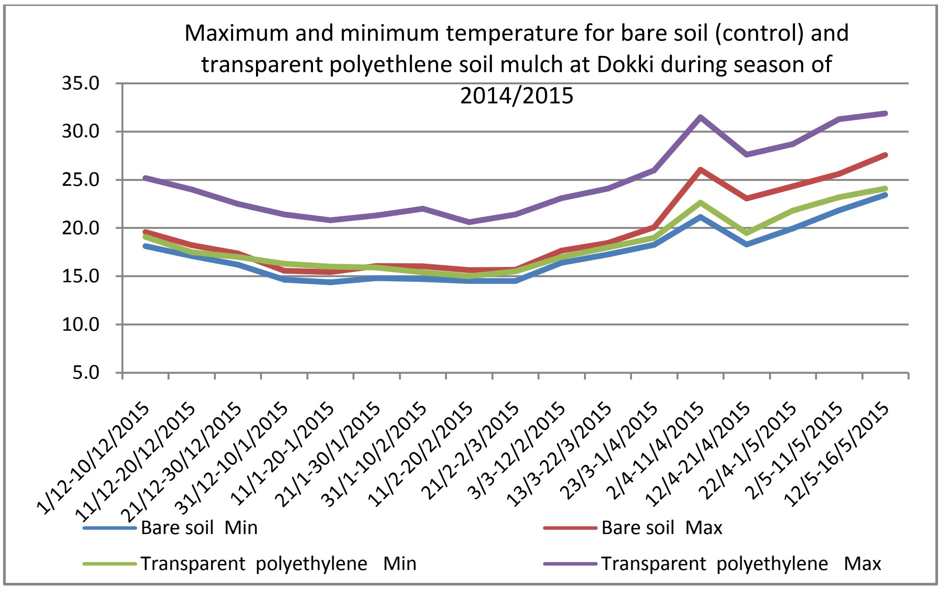

Fig. (1): Maximum and minimum temperature non-mulched soil (control) and transparent polyethylene soil mulch at Dokki during seasons of 2013/2014 and 2014/2015.

The obtained increment in soil temperature because of using the transparent soil mulching confirmed in the second season. Such results was similar to those obtained by El-Nemr (2006), who confirmed that values of soil temperature under transparent mulch were higher than those under the other mulches. These 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. Earlier on 1964, Hopen explain this results on bases of sunlight passes through transparent polyethylene and heats the soil because of the layer of water on the underside of the plastic retains the radiant heat at night through what is known as a greenhouse effect.

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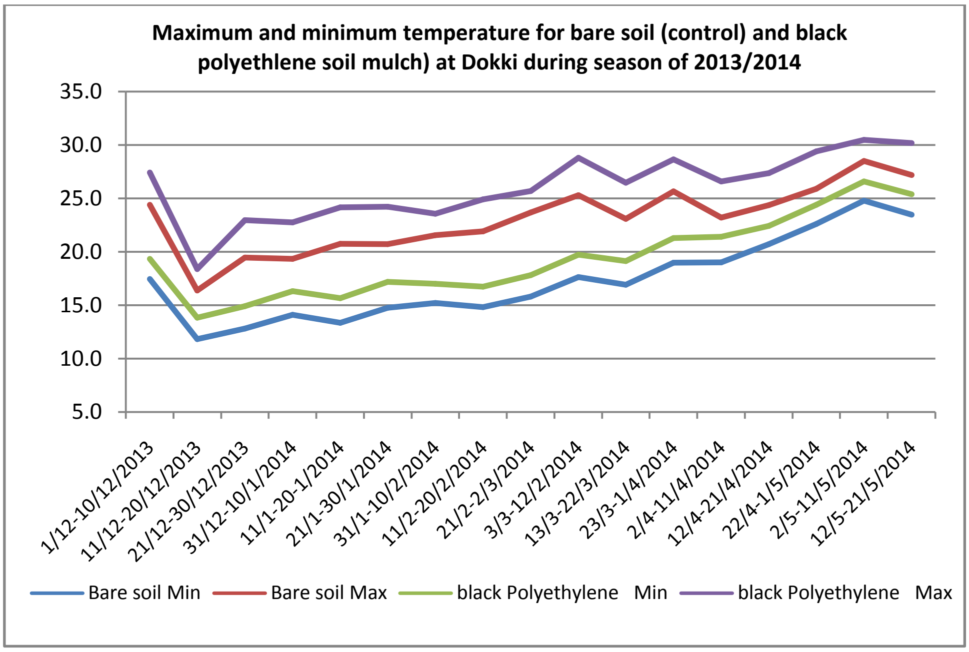

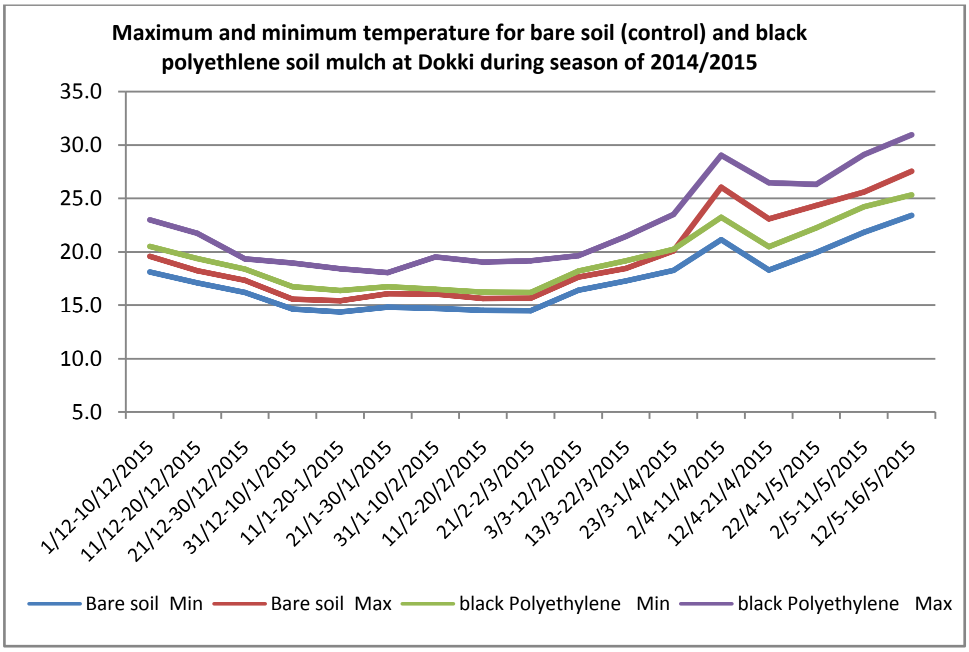

Fig. (2): Maximum and minimum temperature non-mulched soil (control) and black polyethylene soil mulch at Dokki during seasons of 2013/2014 and 2014/2015.

Concerning effect of black polyethylene soil mulch, results in Figure (3) noted that, a noted registered increment in soil temperature was obtained as a result of using the black polyethylene in soil mulching. Maximum soil temperature increased by 3°C under black polyethylene soil mulching compared to non-mulched soil, however, the minimum soil temperature under such treatments was usually higher than minimum soil temperature in bare soil by about 2°C. On 1999, Lamont reported the same results related to the thermal effect of black polyethylene. The author reports that, black polyethylene absorbs the UV, visible, and infrared wavelengths of incoming solar radiation and re-radiates absorbed

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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.

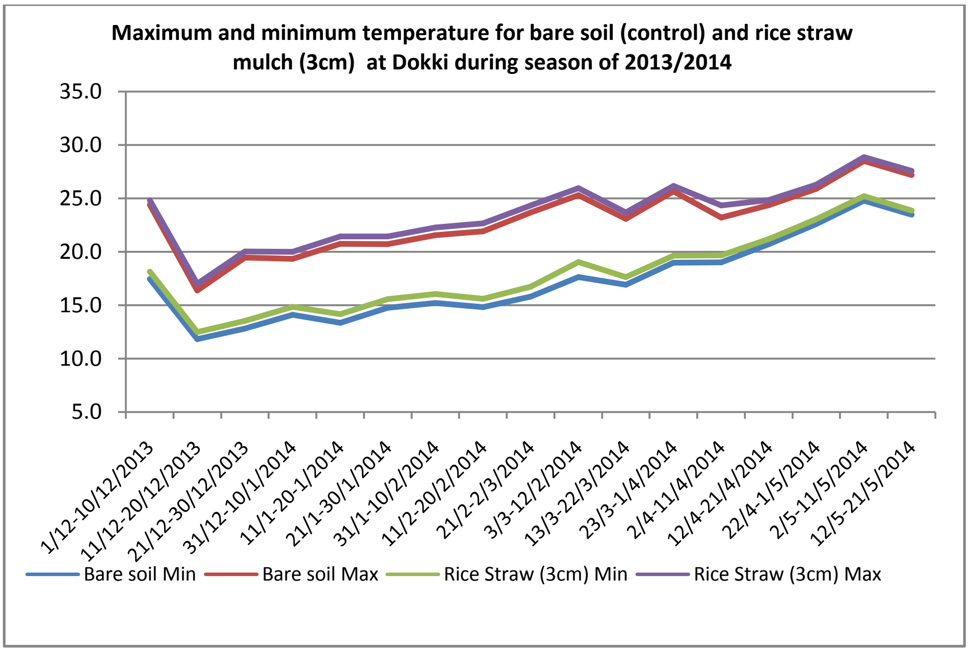
Discussing the impact of polyethylene soil mulching, many studies indicated that soil temperature increased because of applying the polyethylene mulch in relation to bare soil, these increases resulting higher in clear and dark materials than in the reflective colors such as white or silver/aluminium (Csizinszky *et al*., 1997; Rangarajan and Ingall, 2001).The results obtained in this experiment support the previous studies; thus, the soil temperature in bare soil was always lower than under mulches, and the maximum soil temperatures were always reached under the transparent polyethylene followed by black polyethylene film.

Focusing on the organic soil mulching, using rice straw as soil mulching due to a high soil temperature compared with the non-mulched soil (control), such increment in soil temperature was lower than the other tested polyethylene mulch however, the transparent or the black. 1°C and 0.6 higher in maximum soil temperature was detected when applying rice straw soil mulching with 6 and 3 cm thickness, respectively. Moreover, 1.3 and 0.7 °C increment in minimum soil temperature was recorded when using the rice straw as a soil mulching with thickness 6 and 3 cm, respectively(Figures 4 and 5).

The same change in maximum soil temperature was found by El Shaikh and Fouda (2008) when applying organic mulch (wheat straw). Moreover, Yi *et al*. (2014) demonstrated that soil temperatures under rice straw mulch were higher during the colder seasons and lower during the warmer seasons when compared with the bare soil. Because straw, that covered the soil surface, has a higher albedo and lower thermal conductivity than the bare soil, it helps to reduce the solar energy reaching the soil and, as a result, reduces temperature increases during warm conditions. Conversely, during the colder seasons, the presence of rice straw mulch on the soil surface insulates the soil from the colder air temperatures. Therefore, heat loss from the soil is somewhat lower and soil temperatures are consequently higher under rice straw mulch compared to bare soil.

Many studies reported that soil temperature under rice straw mulch has been reported to have increased (Ramakrishna *et. al*., 2006) and this can be mainly attributed to differences in climatic conditions. This effect can be explained with two basic mechanisms as observed in our field experiment. In the rice straw treatment, the mulch layer reduced soil radiation absorption during daytime, while at nighttime it reduced the outgoing heat radiation from the soil. Moreover, the mulch layer contains a significant amount of pore space. The majority of this pore space is likely to be filled with air, and air is known to be a very good insulator. The air space in the mulched layer prevents energy conduction.

Therefore, in our study the rice straw treatments had lower thermal conductivity than the non-mulch control, and acted as an insulator during the warmer period and helped to retain soil heat during the colder period, resulting in smaller fluctuations in soil temperatures (Fig. 3 and 4). (Olasantan, 1999; Chen *et al*., 2007) also observed similar results.



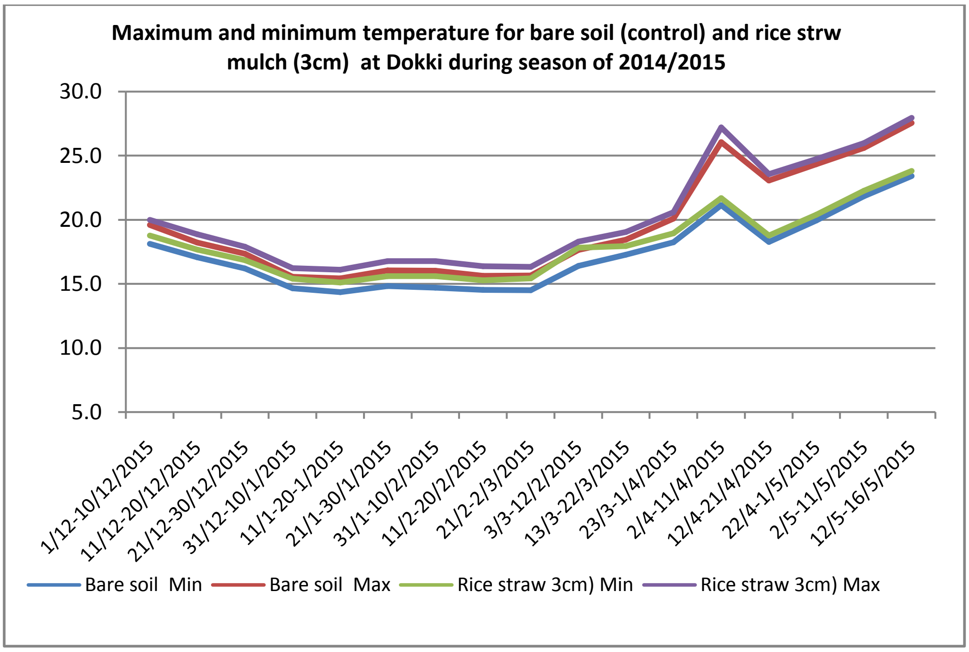


Fig. (3): Maximum and minimum temperature non-mulched soil (control) and rice straw (3cm) soil mulch at Dokki during seasons of 2013/2014 and 2014/2015.

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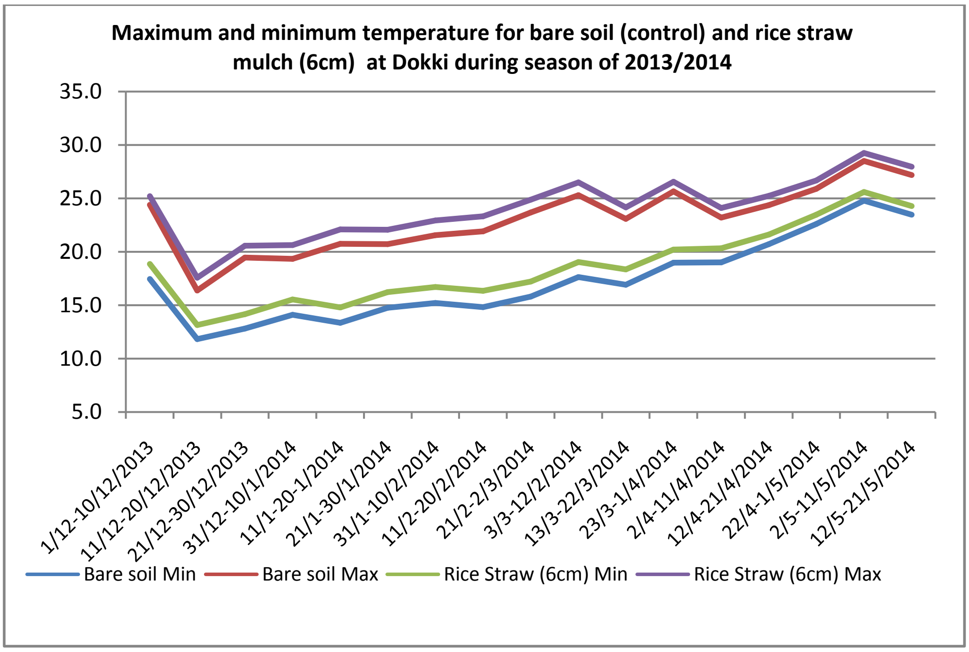

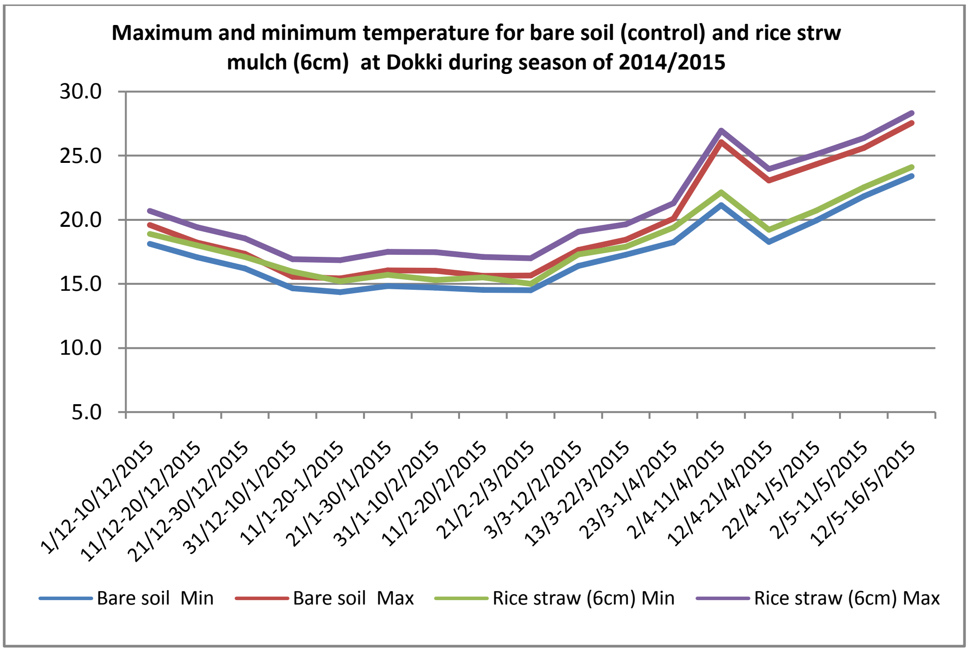

Fig. (4): Maximum and minimum temperature non-mulched soil (control) and rice straw (6cm) soil mulch at Dokki during seasons of 2013/2014 and 2014/2015.

Vegetative growth

a) Number of branches:

Both of soil mulching types (Table, 1) were affected significantly number of branches of tomato during the two seasons. Moreover, this effect of soil mulching appeared significantly after 90 and 120 days from transplanting. However, no significant effect was detected after 30 and 60 days from transplanting. The polyethylene transparent mulch

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recorded significantly the highest number of branches than the others (polyethylene or organic) during the investigated seasons. After 30 and 60 days from transplanting, the polyethylene black mulch recorded the second highest value of number of branches, whereas the rice straw was the least. After 90 days, the rice straw mulch with 6 cm thickness recorded significantly the same results of polyethylene transparent mulch. Whenever, after120 days from transplanting the rice straw mulch recorded significantly the highest significant number of branches followed by the transparent mulch.

The mentioned trend of results, however, after 30, 60, 90 or 120 days after transplanting was confirmed in both seasons.

Table (1): Effects of two types of soil mulch on number of branches of tomato after 30,60,90 and 120 days after transplanting, during seasons of 2013/2014 and 2014/2015.

Treatments	Days after transplanting:			
	30	60	90	120
First season				
Straw (6cm)	1.33	3.67	6.00	9.00
Straw (3cm)	1.33	3.00	5.00	7.67
Transparent	2.33	5.00	6.00	8.67
Black	2.00	4.00	5.33	7.33
Control	1.67	3.33	4.00	6.00
L.S.D. (0.05)	NS	NS	1.03	1.29
Second season				
Straw (6cm)	1.33	4.67	7.00	9.33
Straw (3cm)	1.33	3.33	6.00	8.67
Transparent	2.67	5.67	7.00	9.00
Black	2.33	4.49	6.33	7.67
Control	1.50	3.67	5.00	6.33
L.S.D. (0.05)	N.S.	N.S.	1.03	0.93

b) Number of leaves:

Data in Table (2) show the effect of two types of soil mulch on number of tomato leaves plants during seasons of 2013/2014 and 2014/2015. Number of leaves was affected significantly with soil mulching, however, the polyethylene or rice straw during the both studied seasons. After 30 days from transplanting, the highest significant number of leaves was found in plants mulched with transparent polyethylene followed by those mulched with black polyethylene without significant differences between them. Using rice straw as mulch (3 and 6cm), yielded significantly the lowest number of leaves compared to the other treatments. After 60 days from transplanting, the highest value of leaves number was detected in rice straw (6 cm) mulch with highest significant value, followed by transparent polyethylene mulch and without significant different between them. At this date, plants that cultivated without soil mulch (control) recorded significantly the lowest number of leaves. In addition, the same trend of results was found 90 and 120 days from transplanting.

Focusing on the performance of other treatments, its noted that, after 60, 90 and 120 days from transplanting the rice straw mulch with 3cm thickness recorded the third highest value of leaves number without significant different between the treatment and the first or second highest treatments. Concerning the performance of black mulch, it's noted that the black mulch significantly ranked the fourth in number of leaves after 30,60,90 and 120 days after transplanting. The same trend of results was found during both seasons of 2013/2014 and 2014/2015.

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Table (2): Effects of two types of soil mulch on number of tomato leaves after 30,60,90 and 120 days after transplanting, during seasons of 2013/2014 and 2014/2015.

Treatments	30	60	90	120
		First season		
Straw (6cm)	11.00	32.33	43.00	48.67
Straw (3cm)	11.33	30.00	40.00	44.67
Transparent	18.00	31.00	41.00	45.67
Black	17.00	28.00	30.00	33.33
Control	16.67	25.33	26.00	29.33
L.S.D. (0.05)	2.74	3.37	5.73	6.41
		Second season		
Straw (6cm)	11.47	32.00	45	50.33
Straw (3cm)	10.77	31.33	40	46.33
Transparent	19.04	31.33	43	49.01
Black	17.18	26.00	33	36.23
Control	15.67	26.00	27	32.94
L.S.D. (0.05)	2.41	3.62	4.31	5.98

c) Stem diameter:

Tomato stem diameter was significantly affected by the two types of soil mulching tested (Table, 3). After 30 days from transplanting, plants that mulched with transparent polyethylene recorded significantly the highest value of stem diameter, followed by those mulched with black polyethylene without significant different between the two treatments. The lowest value for stem diameter was significantly detected in plants that mulched using the rice straw (3 and 6 cm). Contrary, after 60, 90 and 120 days from transplanting, the highest significant stem diameter was found in plants that mulched using the rice straw with 6 cm thickness, followed by those mulched with transparent polyethylene. However, using rice straw as mulch with 3 cm thickness ranked the third significant highest value of stem diameter. At the same dates, control treatment ranked significantly the last by recording the lowest significant stem diameter, followed by the black polyethylene. The same trend of results was found in the second season.

Table (3): Effects of two types of soil mulch on tomato stem diameter after 30,60,90 and 120 days after transplanting, during seasons of 2013/2014 and 2014/2015.

Treatments	30	60	90	120
		First season		
Straw (6cm)	0.60	1.02	1.23	1.33
Straw (3cm)	0.61	0.97	1.17	1.24
Transparent	0.82	0.98	1.20	1.26
Black	0.79	0.96	1.14	1.23
Control	0.70	0.78	0.83	0.87
L.S.D. (0.05)	0.07	0.11	0.18	0.08
		Second season		
Straw (6cm)	0.65	1.06	1.29	1.31
Straw (3cm)	0.67	0.98	1.22	1.26
Transparent	0.86	0.98	1.29	1.28
Black	0.82	0.98	1.23	1.25
Control	0.76	0.84	0.92	0.89
L.S.D. (0.05)	0.03	0.08	0.17	0.06

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d) Plant fresh weight:

Fresh weight of plants affected significantly by soil mulching compared to non-mulched plants, such results was confirmed by the data in Table (4). After one month from transplanting, the greatest plant fresh weight was detected in plants mulched with transparent polyethylene and this result is statistically confirmed. At this time, the second significant highest fresh weight was found in plants mulched with black polyethylene. However, the lowest significant value was found when rice straw used as soil mulch with 3 or 6 cm thickness. Later on, after 60, 90 and 120 days after transplanting, the trend of the results obtained became different compared to after 30 days. During the last dates, rice straw with 6cm thickness reflected the highest significant value of plant fresh weight followed by transparent polyethylene considering the significant different between the two treatments. Regarding the order of the other treatments, rice straw (3cm), black polyethylene and control, ranked third, fourth and fifth; respectively. Such trend of results is confirmed during the second season.

Table (4): Effects of two types of soil mulch on tomato plant fresh weight after 30,60,90 and 120 days after transplanting, during seasons of 2013/2014 and 2014/2015.

Treatments	30	60	90	120
First season				
Straw (6cm)	121.42	380.33	510.67	520.77
Straw (3cm)	125.73	349.33	466.33	478.99
Transparent	194.40	370.00	470.00	500.21
Black	181.05	341.15	346.33	353.16
Control	176.37	301.19	311.10	273.07
L.S.D. (0.05)	5.24	9.83	64.95	65.42
Second season				
Straw (6cm)	117.52	390.67	516.52	522.71
Straw (3cm)	123.68	357.00	469.55	497.12
Transparent	195.53	374.00	476.67	507.59
Black	182.63	348.18	350.73	357.40
Control	177.20	307.11	295.38	215.72
L.S.D. (0.05)	3.39	11.82	67.49	70.35

e) Plant dry weight:

Tomato plant dry weight significantly affected by the two types of soil mulching tested Table (5). After 30 days from transplanting, the highest plant dry weight was significantly recorded in plants mulched with transparent polyethylene, followed by those mulched with black polyethylene. However, after 60, 90 and 120 days from transplanting, the highest significant plant dry weight was recorded in plants mulched with rice straw with 6 cm thickness. The second highest plant dry weight was detected in plants mulched with transparent polyethylene followed by rice straw with 3 cm thickness. Where is the less, lowest significant plant dry weight appeared in non-mulched plants followed by those were mulched by the black polyethylene. The mentioned results were typically during the two studied seasons.

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Table (5): Effects of two types of soil mulch on tomato plant dry weight after 30,60,90 and 120 days after transplanting, during seasons of 2013/2014 and 2014/2015.

Treatments	30	60	90	120
First season				
Straw (6cm)	15.36	45.13	57.13	65.78
Straw (3cm)	16.49	37.58	47.17	40.22
Transparent	22.55	41.03	49.59	48.95
Black	20.19	35.25	34.67	24.31
Control	19.20	33.86	30.68	23.10
L.S.D. (0.05)	2.87	3.92	6.92	8.92
Second season				
Straw (6cm)	16.46	46.39	63.82	67.70
Straw (3cm)	17.68	42.22	51.37	43.92
Transparent	23.52	43.86	51.89	50.19
Black	20.82	40.08	38.65	26.98
Control	19.54	34.72	34.27	22.33
L.S.D. (0.05)	2.27	3.32	5.49	7.11

Generally, it was noted that all measured vegetative growth parameters recorded high values comparing to those were measured in bare soil conditions. The mentioned enhancement of vegetative growth due to mulches has been reported by (Salman *et al*., 1992; Saleh *et al*., 2003) mulching has contributed positively to higher soil temperature and consequently improving growth and yield of tomato. Those results were in agreed with findings of (Farias-Larios *et al*., 1994; Siwek *et al*., 1998; Weber, 2000; Summers and Stapleton, 2002).

3.2 Early, total yield and average fruit weight

Early, total yield and average fruit weight of tomato plants are showing in Table (6). The highest significant early and total yields were obtained from plants mulched with rice straw with 6 cm thickness. Also, they were obtained from plants mulched with transparent polyethylene which was ranked the second highest significant value; the same result was confirmed in the second season. Moreover, early and total yields under rice straw with 3 cm thickness reflected the third highest significant values, followed by those grown in soil mulched with the black polyethylene. In addition, the lowest early and total yields were found in non-mulched plants, the same results were found during both seasons. Concerning the average of fruit weight, it noted that using rice straw as a soil mulch gave the highest significant fruit weight. In another words, treatments that reflected the highest significant average fruit weight were rice straw 6 cm and rice straw 3 cm thickness; respectively and with significant differences between them. However, treatments yielded the lowest average fruit weight was significantly control and black polyethylene; during both seasons.

According to Dı´az-Pe´rez and Batal (2002), the optimum soil temperature for tomato yield and fruit number is about 26 °C, while mean seasonal root-zone temperature >27 °C causes stress, resulting in plants with a lower vigour and fruit yield (Dı´az-Pe´rez *et al*., 2007). In this experiment, mean seasonal soil temperature at 5cm depth never exceeded 27 °C. During the harvest period, mean soil temperatures were always <27 °C. Thus, soil temperature probably was not harmful to the tomato plants in the different treatments. Differences in yield can be attributed to differences in soil temperature when temperature is a limiting factor (Brown *et al*., 1992). When soil temperatures are high but do not reach the maximum threshold for each crop, mulches do not influence yield (Streck *et al*., 1995; Lorenzo *et al*., 2005). The results obtained in this experiment support the previous studies, so the range of temperatures under the different mulches did not have a marked effect on the crop yield. Discussing the obtained results regarding average fruit weight and, the fact that the specific environmental conditions in each season influenced marketable yield and number of fruits but not mean weight per fruit, indicates that the differences in yield depended primarily on the number of fruits, while mean fruit weight depended on the cultivar and was little affected by the environment. Similar results were obtained by Brown *et al*. (1992).

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Table (6): Effects of two types of soil mulch on tomato early and total yield and average fruit weight, during seasons of 2013/2014 and 2014/2015.

Treatments	Total yield	Early yield	Average fruit weight
First season			
Straw (6cm)	8.27	2.32	125.00
Straw (3cm)	7.52	1.89	121.00
Transparent	7.59	2.00	116.00
Black	7.36	1.86	106.67
Control	6.02	1.58	89.33
L.S.D. (0.05)	0.469	0.131	4.14
Second season			
Straw (6cm)	8.65	2.60	127
Straw (3cm)	8.13	2.12	122
Transparent	7.98	2.25	117
Black	7.99	2.09	108
Control	6.39	1.77	90
L.S.D. (0.05)	0.454	0.147	4.13

3.3 Effect of different mulches on total fungal count

All mulches at the first season had no significantly effects on total fungal count at zero time in (Table, 7) compared with the control, after 30 days all treatments reduced the total fungal count compared with un-mulched soil**.** However, the differences effects were observed at 60, 90 and 120 days from zero time of treatments. The organic mulches significantly increased the total count by 205.8, 211.7 and 207.0(cfu×10^2 /g soil) with straw (6cm) and 200.7, 203.4 and 204.9 with (3cm) straw mulched soil compared with un-mulched soil 196.3,198 and 198.3, respectively. While, the polyethylene mulches were significantly reduced the total fungal counts at all periods. The black mulch had more effective than the transparent on total counts and reduced the total fungal counts compared with the control .The second season had the same trend of results. Stapleton and De Vay (1982) indicated that the soil mulched with polyethylene sheeting significantly reduced immediately actinomycetes and fungi counts. Thurston and Abawi (1997) reported that mulches and organic amendments have been shown to stimulate the germination of fungal propagules in soil. Also, Saremi *et al.* (2011) found that the application of soil solarization reduced population density of fungi from 1833 to 500, 266 and 100 (cfu×10^2 /g soil) after 2, 4 and 6 weeks**. (**Duff and Connelly, 1993; Nafees *et al.*, 2007) reported that *Fusarium* species, *M. phyaseolina* and *Verticillium* sp. with soil solarization were significantly controlled. Ioannou (1999) recorded those population densities of *Fusarium* spp. in soil before solarization which ranged from 2.160 to 3.700 propagules per gram of soil was reduced by 88 to 93%.

Table (7): Effect of different mulch types on fungal total count (cfu × 10^2/g soil) during seasons 2013/2014 and 2014/2015.

Treatments	First season					Second season				
	Initial	Days from transplanting				Initial	Days from transplanting			
		30	60	90	120		30	60	90	120
Straw (6cm)	200.7	193.9	203.3	211.7	214.2	197.7	195.8	200.9	206.8	207.0
Straw (3cm)	199.7	191.1	199.7	204.4	204.9	197.3	195.4	200.7	203.4	199.4
Transparent	197.7	184.0	173.1	168.2	155.7	195.6	190.3	186.2	166.9	153.8
Black	200.0	165.9	155.9	151.9	34.9	195.0	182.9	175.1	155.7	146.8
Control	205.3	197.0	196.3	198.0	198.3	197.0	196.8	192.1	198.4	192.0
L.S.D. (0.05)	N.S.	7.014	6.416	8.394	5.557	N.S.	4.446	5.590	3.947	3.384

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3.4 Effect of different mulches on disease incidence of tomato plants under field conditions

Mulching soil using organic and inorganic mulches decreased significantly on root rot and wilt diseases incidence in naturally infested soil under field conditions (Table, 8).These results indicated that the highest reductions were recorded with straw 6cm mulched soil and the lowest with black mulched soil. The results were similar to those reports by El-Mougy *et al*. (2006). Also, incidence and losses on tomato plants incited with root rot and wilt caused by several species of *Fusarium*, *R. solani* and *S. rolfsii*, which greatly reduced crop yield and quality were minimized by solirization (Widmer *et al.*, 2002; Saad, 2006; Abdel-Monaim, 2010). On the other hand, reflective and colored plastic mulches have been shown to reduce vector borne diseases on many vegetable crops, including tomato and also indicated that winter cover crops enhance yields of tomato by minimizing disease incidence (Nyochembeng *et al.*, 2014). Thurston and Abawi (1997) stated that the organic matter has been shown to generally suppress root diseases, but in some cases, organic matter mulches have increased the severity of root diseases. Mulches and organic amendments have been shown to stimulate the germination of fungal propagules of soil-borne pathogens. Soil amendments lead to competition for nutrients, particularly iron and nitrogen. The production of volatile and non-volatile toxic compounds during the decomposition of mulches and organic amendments suppresses root diseases.

Table (8): Effect of different mulch types on root rot (%), wilt (%) and reduction (%) during seasons 2013/2014 and 2014/2015.

Treatments	First season				Second season			
	Root rot	Reduction*	Wilt	Reduction*	Root rot	Reduction*	Wilt	Reduction*
Straw (6cm)	15.37	72.73	10.17	85.7	24.63	62.47	10.17	86.59
Straw (3cm)	38.47	31.75	28.23	59.4	45.80	30.21	29.57	61.02
Transparent	23.10	59.02	17.97	74.1	31.43	52.11	19.30	74.56
Black	41.10	27.01	38.47	44.4	51.77	21.11	40.47	46.65
Control	56.37	0.00	69.20	0.0	65.63	0.0	75.87	0.0
L.S.D. (0.05)	13.51	-	11.96	-	8.243	-	15.11	-

*Reduction (%) relative to the control.

3.5 Isolation and frequency of fungi from infected tomato plants

Isolation from rootsand their rhizosphere of all treatments (Table, 9) shown the highest frequency (45%) for *F. solani* followed by *R.solani* (35 %) and *F. oxysporum* (20 %). The fungi with lowest frequency were *M. phaseolina* (2%) and *F. monilliform* (3%). Fungi have been isolated from naturally infected tomato roots and rhizosphere were *F. solani*, *F. monilliform* and *R. solani*, were the most common pathogenic fungi to tomato plants (Haggag *et al.*, 2012).Also, they were found to be caused the symptoms of damping- off and root rot diseases to wide range of vegetables including tomato (Abu-Taleb *et al*., 2011).Moreover, rot diseases caused by *F. solani* and *R. solani* fungi are worldwide spread in the crop growing areas and cause significant economic losses (Abu-Taleb *et al.*, 2011; Abd El-Khair *et al.*, 2011). However, Fusarium wilt was among the most affecting diseases of tomato seedlings either in the nurseries or in the fields. It was widely spread in many parts of the world and Egypt (Moussa *et al.*, 2006 and 2007). Among the soilborne fungal diseases, damping-off and wilt caused by several species of *Fusarium, Pythium, Rhizoctonia* and *Verticillium* (Kaprashvili, 1996; Lucas *et al.*, 1997), and is widely distributed throughout the world**.** Jiskani *et al*. (2007) found that *R. solani* was isolated with highest frequency (60.0%), followed by *Fusarium oxysporum* f.sp. *lycopersici*, while the fungi with lowest frequency were *M. phaseolina*, *A. solani* and *V. albo-atrum*, respectively.

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Table (9): Frequency of fungi isolated from infected tomato plants and soil rhizosphere(combined analysis of two seasons).

Isolated fungi	Number of isolates	Frequency %
Fusarium solani	61	45
Rhizoctonia solani	47	35
Fusarium oxysporum	20	15
Fusarium moniliforme	4	3
Macrophomina phaseolina	3	2

3.6 Pathogenic effect of fungal isolates

Results of pathogenicity tests revealed that all isolates tested had the pathogenic effect against the tomato plants tested where various percentages of root rot and wilt diseases incidence were recorded (Table,10). Incidence of root rot ranged between 5.60 to 55.6 0%, while incidence of wilt was 5.60 to 50.0 % with the five isolates tested.

The incidence of root rot caused by*R. solan*, *F. solani*, *F. oxysorum*, *F. moniliforme* and *M. phaesolina* were 55.6 , 50.0, 33.8 ,5.6 and 27.8% respectively. While, incidence of wilt caused by the same pathogenic fungi were 5.6, 38.8, 50.0, 16.7 and 5.6, respectively. These results were agreement with those recorded by Haggag *et al*. (2012),whom reported that *F. solani* and *R. solani* isolates had the pathogenic effect against Ace, Brmodro, Castle Rock and Super-Marmade cvs., where percentages of damping-off and root rot incidence were recorded. In this concern, Zaghloul *et al.* (2008) found that fungi differed in their virulence against tomato plants. Howvever, *F. oxysporum* f.sp. *lycopersici* Sa-F2 strain seemed to be more aggressive which caused the highest percentages of pre- and post-emergence damping-off. The present results were somewhat similar at to those found by Abd-El-Wahab (2004), who found that *F. oxysporum* f.sp. *lycopersici*, *R. solani* and *S. rolfsii* were the most aggressive fungal isolates. Jiskani *et al*. (2007) recorded the maximum number of infected plants after 30 days of sowing as compared to15 with disease incidence of 63.63% as compared to un-infested soil (13.33%).

Table (10): Pathogenicity tests of the isolated fungi on tomato seedlings.

Treatments	Root rot(%) after days:			Wilt(%) after days:		
	15	30	% incidence	15	30	% incidence
Fusarium solani	3	6	50%	5.0	2	38.8
F. oxysporum	2	4	33.3	3.0	6	50.0
F. moniliforme	0	1	5.6	0.0	3	16.7
Rhizoctonia solani	4	6	55.6	0.0	1	5.6
Macrophomina phaesolina	2	3	27.8	0.0	1	5.6
(Untreated soil) control	1	2	16.6	0.0	1	5.6

3.7 Economic evaluation of various treatments of tomato crop productivity

This evaluation entails the study of these various treatments impact on the crop productivity through investigating the impact of each treatment on the crop productivity during the production season and on the fruit size. It also entails the comparison between the treatments and the comparison between the treatments and the control sample. The evaluation entails as well the investigation into the costs and return of production per kilogram/m^2 and the subsequent consequences whenever various treatments use is over generalized to gross crop production all over the republic.

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First: Impacts of various treatments of crop productivity and weight during the two seasons and their average:

Various treatments had positive impacts on crop productivity and fruit weight during second season (Table, 11). Crop productivity increased by almost 3.02% to 6.15%, whereas fruit size increased by 1.6% to 0.75%. Straw (6cm) has positive impact on tomato crop productivity and fruit size as the square meter gave average production by 8.40 kg/m^2. Fruit average size estimated almost 126 g during both seasons. Meanwhile, the fruit size increased estimated almost 3.57%, 8.15%, 17.59%, and 41.63% as compared to the treatment of straw (3cm), transparent, black and control successively as indicated in the table.

Table (11): The impact of different treatments on crop productivity and fruit weight.

Treatments	Production average kg / m 2			Increase* in production (%)	Fruit size average in grams			Increase* in fruit weight
	First season	Second season	Production average		First season	Second season	Average size	
Straw(6cm)	8.27	8.52	8.40	3.02	125.00	127.00	126.00	1.60
Straw(3cm)	7.52	7.78	7.65	3.46	121.00	122.00	121.50	0.83
Transparent	7.59	7.83	7.71	3.16	116.00	117.00	116.50	0.86
Black	7.36	7.71	7.54	4.76	106.67	108.00	107.34	1.25
Control	6.02	6.39	6.21	6.15	89.33	90.00	89.67	0.75

Source: Calculated from Table (6).
*Increase relative to the control.

Second: Comparison between various treatments impacts on fruits productivity:

Production average increased with various treatments by 35.27% for straw (6cm), 23.19% for straw (3cm), 24.15% for transparent and 21.42% for black. Also, fruit size increased by 40.52%, 35.5%, 29.92% and 19.71% for these treatments respectively.

Table (12): Mean of two seasons percentages of increment in weight (g) and size (cm) of fruit yields with various treatments.

Treatments	%Increase* in fruit weight (g)	%Increase* in fruits size (cm)
Straw(6cm)	35.27	40.52
Straw(3cm)	23.19	35.50
Transparent	24.15	29.92
Black	21.42	19.71

Source: - Calculated from Table (11).
*Increase relative to the control.

Third: Costand return of tomato square meter in various treatments:

The invested pounds return in each treatment entails the necessity to estimate the tomato crop cost and cubic meter return in various treatments as shown in Table (13).However, assumes that the rice straw is available for the farmer who always tends to get rid of it in a way that contributes to the environment pollution and emergence of the dark cloud resulting from burning the straw in the fields. Therefore, the rice straw costs are not calculated besides in the case of over generalizing the use of this method, the state can get rid of the straw without leading to the environment pollution. Consequently, the added value of using rice straw will increase as shown in Table (3). The square meter production cost of the crop ranged between the maximum value L.E. 7.192 pounds and the minimum value of L.E. 1.192 pounds. The crop kilogram net return realizes its highest value L.E. 1.343 pounds and L.E. 1.329 pounds when using straw (6cm) and

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straw (3cm) respectively, followed by control, black and transparent with kilogram net return valued L.E. 1.293 pounds, L.E. 1.128 pounds, L.E. 0.552 pounds, respectively. Consequently, the invested pounds will increase by L.E. 12.428 pounds, L.E. 11.852 pounds and L.E. 11.852 pounds when using straw (6cm). The invested pound return will increase as well by almost L.E. 9.978 pounds, L.E. 8.402 pounds and L.E. 8.235 pounds when using Straw (3cm) as compared to the invested pounds return of transparent, black and control successively.

Table (13): The return on the investment pounds for various mulched treatments.

Treatments	Average of productivity (m^2)	Sale price of fruit/ kg (pounds)	Total revenue (m^2)	cost of treatment m^2(pounds)	Total costs m^2/(pounds)	Net return m^2 in (pounds)	Cost of kg (pounds)	Net return of kg (pounds)	Return / Investment Pound
Straw(6cm)	8.40	1.192	12.474	-	1.192	11.282	0.142	1.343	12.98
Straw(3cm)	7.65	1.192	11.360	-	1.192	10.168	0.156	1.329	9.530
Transparent	7.71	1.192	11.449	6	7.192	4.257	0.933	0.552	0.552
Black	7.54	1.192	11.197	1.5	2.692	8.505	0.357	1.128	1.128
Control	6.21	1.192	9.222	-	1.192	8.030	0.192	1.293	1.293

Source: Calculated from Table (1), annual bulletin of Agricultural Statistics, Agricultural Economics Research Institute, Central Administration and Ministry of Agriculture Economic Bulletin (2013).

Fourth: The subsequent economic impacts of various treatments on the tomato production at the republic level:

Generalization of various treatments increased productivity (Table, 14), during the first season by 90.84%, 73.53%, 75.14%, and 69.53%. Meanwhile, the increased in the second season estimated 80.68%, 77.91% and 44.99%. The two seasons production average increased by 93.72%, 77.46%, 83.41%, 73.88% and 41.95% as for the treatments of straw (6cm), straw (3cm), transparent, black and control successively. The overgeneralization of using these treatments all over the country, the cop production will increase and hence the supply size while prices will be reduced at the consumer level besides getting rid of 11.998 million of the rice straw at the countrylevel. Consequently, pollution resulted from the dark cloud and burning rice in different fields will be eliminated.

Table (14): Average productivity of various treatments in comparison with controls.

Treatments	productivity 1st season (Tons)	% Increase productivity (Tons)	Productivity 2nd. season (Tons)	Increase productivity (Tons)	Productivity Seasonal production Tons / Fadden	% Increase in Productivity (Tons)
Straw(6cm)	34.734	90.84	35.784	96.60	35.259	93.72
Straw(3cm)	31.584	73.53	32.676	79.53	32.300	77.46
Transparent	31.878	75.14	32.886	80.68	33.382	83.41
Black	30.912	69.84	32.382	77.91	31.647	73.88
Control	00.00	00.00	00.00	00.00	00.00	00.00

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Source: Calculated from Table (11), Annual Bulletin of Agricultural Statistics, Agricultural Economics Research Institute, Central Administration and Ministry of Agriculture Economic Bulletin (2013).

4. CONCLUSION

From the allover illustrated results in this investigation it's concluded that, every type of the soil mulching as well as, all colors of polyethylene mulch save the soil temperature and enhances both of vegetative growth and crop yield, as well as, reduce the total count of soil borne diseases. But, the suitable time of applying each type or color is a vital point that should not ignored. The organic mulch such as rice straw is economically and environmentally sound as soil mulching. It's able to save soil temperature during the warm months and increase it during cool months. Hence, the organic mulch affects the plant growth in the first month but, after this time it enhances the growth and increase the yield. In addition, the organic mulch results in reducing the count of harmful fungi and at the same time increase the count of beneficial species. Also, the transparent polyethylene mulching is the highest soil mulch increasing soil temperature (maximum and minimum). So, it's recommended to use during the cool season. However, the black polyethylene will be better to use during warm season.

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