*Journal of Agrometeorology 16 (2) : 172-177 (December 2014)*

# Microclimatic alteration through protective cultivation and its effect on tomato yield

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## ABSTRACT

Microclimatic alteration produced by mulching with different coloured plastic sheets, inside and outside the polyhouse and its effect on yield of tomato was studied during 2012-13 at Birsa Agricultural University, Ranchi. The mean weekly minimum and maximum air temperature during last week of December to 1st week of March were found to be higher by 2 to 9 $^0$C inside the polyhouse than open field. Relative humidity was always higher in the open field during January to February by 2 to 7 % but it was higher inside the polyhouse in the months of March to May by 4 % at 7.00 AM. Almost a similar trend at 2.00 PM was also observed but during March to April relative humidity was higher by 10 % in polyhouse condition. The maximum available light intensity inside the polyhouse was about 30 to 40 % lower than that of the open field irrespective of growth stages. Average soil temperature was found to be higher by 2 to 5 $^0$C under open field condition than inside the polyhouse. Leaf temperature of tomato grown under polyhouse was always lower than the open field condition. These microclimatic conditions inside the polyhouse favoured the performance of tomato and fruit yield obtain from the polyhouse was 65 t ha$^{-1}$ against 33 t ha$^{-1}$ from the open field

***Key words :*** Microclimate, Polyhouse, Plastic mulch, Tomato

Protective cultivation is a unique and specified form of agriculture which modify the natural environment by practices or structures to achieve optimal productivity of crop by enhancing yield, improving quality, extending the effective harvesting period and expanding production areas (Wittwer & Castilla,1995).The overall intend of microclimatic alteration is the most effective use of natural as well as climatic resources by creating a favourable environment for the sustained growth of plant so as to realize its maximum potential even in adverse climatic conditions. Protected cultivation of vegetables not only overcome the biotic and abiotic stresses but also open the gates for off-season and year round supply of vegetables with remunerative prices to the growers. Location specific growing system is essential for quality product along with to meet the market demand throughout the year. Poly-greenhouse structures and use of different plastic mulches have provided a new scope for commercial application of high value crops. Partial control of microclimatic conditions, which have major influence on plant growth characteristics, can be achieved in poly greenhouses (Ganeshan, 1999). Greenhouses protect the crop from varied climatic conditions like wind, rainfall, excess solar radiation, extreme temperature conditions and also incidence of pests and diseases

Plastic mulches are used in many horticultural crops to suppress weed growth, conserve soil moisture and to alter temperature in the rhizosphere (Kamal & Singh, 2011). One of the main benefits associated with plastic mulching is the modification of the microclimate around the plant by altering the radiation budget (absorbitivity vs. reflectivity) of the surface and decreasing the soil water loss (Liaktas et al., 1986). Mulching is effective means of microclimatic modifications, both under protected as well as open conditions. However, feasibility of this technology and its effect on tomato are not well known under the agroclimatic condition of Jharkhand. Jharkhand comes under the agro-climatic region of Eastern plateau and Hills having humid to sub-humid tropical monsoon type of climate. The region as a whole is food deficit in terms of cereals, pulses and oilseeds; average productivity is lower than national averages. Though, the region is surplus in vegetables which fetch substantial cash through market it locally and export to major cities. However, potential is not fully utilized. Protection agriculture, by manipulating microclimate, is more relevant in this region than in other parts of the country. In Jharkhand, tomato is extensively cultivated in the vegetable belts covering districts like Ranchi, Lohardaga, Hazaribagh and Godda district and covers approximately 13.9 % of the area under vegetable cultivation. Therefore, the present investigation was carried out to study the influence of growing conditions through microclimatic alterations and their interactions on yield of tomato.

## MATERIALS AND METHODS

The experiment was conducted in a covered poly-greenhouse, facing east to west with ultra-violet stabilized high-density polyethylene film (200 micron thickness) on bamboo frame along with an open field with different plastic mulches aside the field of the Department of Agriculture Engineering, Birsa Agricultural University, Ranchi during the period from December 2012 to May 2013. To reduce high temperature during summer months, polyethylene film was replaced into shade net of green colour on 6th of March 2013, for the free air flow.

The experiment comprised of two factors; (A) Two microclimatic treatments viz. polyhouse climate and natural climate (*i.e.* open field), and (B) three different plastic mulches viz. Black, Silver black, Transparent and a Control plot ( without mulch) following a Completely Randomized Design (CRD) with four replications. Size of a unit plot was 3m x 1m. Two adjacent unit plots and blocks were separated by 0.5 and 0.75 m, respectively. One month old seedlings of tomato (cv. Allrounder) were planted. Regular irrigation by drip method, fertilization, stacking and crop protection measures was adopted as per recommended package of practices.

Daily relative humidity, temperature and solar radiation were recorded inside the polyhouse and in an open field at 7.00 AM and 2.00 PM. Lux meter recorded light intensity. Daily soil temperature was also recorded inside the polyhouse and in an open environment at 7.00 AM and 2.00 PM at 5 cm depth by soil thermometer. These were averaged over the weeks for which data were collected for both conditions. Leaf temperature was recorded inside and outside the polyhouse at 15 days interval by using the Infra red thermometer.

## RESULTS AND DISCUSSION

### *Air Temperature*

The temporal variation in air temperature both within and outside the polyhouse showed (Fig. 1 a & b) that it was less for polyhouse as compared to open field. Air temperature inside the polyhouse was distinctly higher than that at outside during 52 (24 -31st Dec) to 10th (5-11th March) meteorological week. The mean weekly temperatures were found to be higher by 2 to 9 °C inside the polyhouse than in the open field. However, the temperature differences between polyhouse and open field were small at 7.00 AM which increased gradually with the advancement of time and amounted to a difference of about 10 °C at 2.00 PM irrespective of the growing stages of the crops. During this period the average weekly air temperature at 2.00 PM under polyhouse and open field varied from 25.2 to 32.2 °C and 18.1 to 28.5 °C, respectively. Nimje and Shyam (1993) also obtained similar results. Polyhouse permits restricted entrance of lower amount of incident solar radiation of short-wave radiation due to the greater inference of the roof of polyhouse against the incoming solar beam but it traps the outgoing long-wave radiation. As a result the air temperature inside the polyhouse gradually increased due to the greenhouse effect. Thus, inner of the polyhouse became warm to warmer and temperature remained at optimum level (about 28 °C) for the growth and development of tomato plants during the cooler months (December to February).

Enhanced temperature accelerates plant growth and allows sustaining plant growth even when outside ambient temperatures are unfavourably low. However, during summers, inside temperatures rise higher than the optimum levels and therefore cooling/ventilation provision are necessary. Atmospheric temperature gradually increased from 11th week and tomato crops outside the polyhouse were exposed to higher minimum and maximum temperature as compared to polyhouse condition by altering the microclimate through replacing the UV stabilized polyhouse roof by shade net (50 %) material of green colour. Average weekly temperature inside the polyhouse at 7.00 AM and 2.00 PM varied for 13 to 23.6 °C and 30.5 to 38.1 °C which was about 1.0 to 3.7 °C lower than open condition with the temperature varying from15.9 to 25.6 °C and 33.1 to 41.0 °C, respectively. It is evident, from temperature data mentioned above, that temperature within polyhouse could desirably be maintained at higher level than ambient temperature (outside) till 11th March (10th SMW) by utilising the green house effect of the polyhouse. While for the later stages of crop the temperature within the polyhouse could successfully be maintained at lower levels when the outside temperature rose. Temperature, so maintained within the poly house provided very congenial condition for growing tomato crop which has reflected at the performance of the crop.

***Relative Humidity***

Humidity affects leaf area development and stomatal conductance thereby interfering with the photosynthesis and dry matter production (Jolliet, 1994). Relative humidity recorded at 7.00 AM and 2.00 PM showed more or less reverse trend with respect to temperature under both environmental conditions *i.e.* lower RH was found at 2.00 PM and higher RH was found at 7.00 AM, both within and outside the polyhouse. Average weekly relative humidity inside the polyhouse was always 2-7 % lower than that of the outside environment during winter season (January – February) but it was always found higher (upto 4%) inside the greenhouse during summer (Mid Feb-May) at 7.00 AM (Fig. 1c & d). Contrary to temperature pattern, the relative humidity had maintained opposite patterns with that of air temperature *i.e.* it was lower inside the polyhouse as compared to open field in initial condition and higher or almost similar during later stages. Almost a similar trend at 2.00 PM was also observed but differences in RH were higher (2-6.5 %) between open and greenhouse condition. Relative humidity was higher by 10 % in the months of March and April inside the polyhouse. Optimum relative humidity of air for most of the plants (vegetables and fruits) is 60 – 85 %. Relative humidity inside polyhouse as well as open condition ranged between 71 to 80 % and 73 to 78 %, respectively and maintained at optimum range throughout the growing season of tomato. High levels of humidity can lead to yield loss especially for tomato crop (Holder and Cockskull, 1990). Higher humidity also leads to occurrence of fungal disease and majority of other diseases inside the greenhouse.

***Light intensity***

Light intensity affects the colour of the leaves, fruit set and fruit colour. Light intensity inside the polyhouse was reduced by about 30 to 40 % compared to the outside (*i.e.* open field). The lower amount of incident solar radiation under polyhouse as compared to the open field was due to the greater inference of the roof of polyhouse against the incoming solar beam.

On an average, the weekly measured solar radiation at 7.00 AM varied from 2.1 to 7.4 Klux and 4 to 11 Klux inside the polyhouse and open environment, respectively (Fig. 1 e & f). Similarly, at 2.00 PM it varied between 18 to 44.7 Klux and 25 to 49 klux under polyhouse and open condition, respectively. It suggests that the plants inside the polyhouse received less energy in the form of net solar radiation than outside the polyhouse. The type of roof material used caused the reduction of the total solar radiation in the polyhouse. The reduction of solar energy received by the plants also results in the reduced evapo-transpiration.

***Soil Temperature***

Soil temperature extremes influence the germination of seeds, functional activity of root system and development of crop. As evident from the Fig. 2 (a & b) the effect of mulches on soil temperature were found more pronounced upto $10^{th}$ week (5 to $11^{th}$ March) under polyhouse as well as open condition. In general, this effect was more pronounced during the early crop season when tomato plants shaded less soil surface (Kamal & Singh, 2011). Temporal variation in soil temperature both within and outside the polyhouse showed that it was less for poly house as compared to open field.

The highest soil temperature occurred under transparent mulch followed by silver black, black and no mulch plot during 52 to $10^{th}$ week (December to mid March) at 7.00 AM and 2.00 PM. It was found to be higher by about 1 to 10 $^{o}$C as compared to no mulch plot inside and outside the polyhouse. After $10^{th}$ week, soil temperature was found 2 to 4 $^{o}$C higher under no mulch plot as compared to transparent mulch under polyhouse. But there was no definite pattern observed under mulched or no mulched condition, either at 7.00 AM or 2.00 PM in open field condition. Black mulch always maintained an optimum soil temperature ranged from 10 to 26 $^{0}$C and 19 to 32 $^{0}$C at 7.00 AM and 2.00 PM respectively inside polyhouse and in open field it ranged from 10.5 to 28 $^{0}$C and 18 to 36 $^{0}$C at 7.00 AM and 2.00 PM, respectively. Among the treatments soil temperature under black mulch recorded lowest average temperature during the growing period of tomato inside and outside the polyhouse (20 and 23.2 $^{0}$C). Much of the solar energy absorbed by black plastic mulch is lost to the atmosphere through radiation and forced convection.

***Leaf temperature***

The leaf temperature can well characterise the water supply status of plants. Crops with temperatures above the ambient air temperature are usually stressed. Under same amount and duration of irrigation by drip method, leaf temperature at fortnightly interval was always found lower (1-4 $^{0}$C) inside the polyhouse. Stress degree days i.e. difference between leaf temperature (Tl) and air temperature (Ta) showing negative values indicate no sign of water stress inside the polyhouse under mulch treatments at fortnightly intervals (Table 1). This might be due to reduction

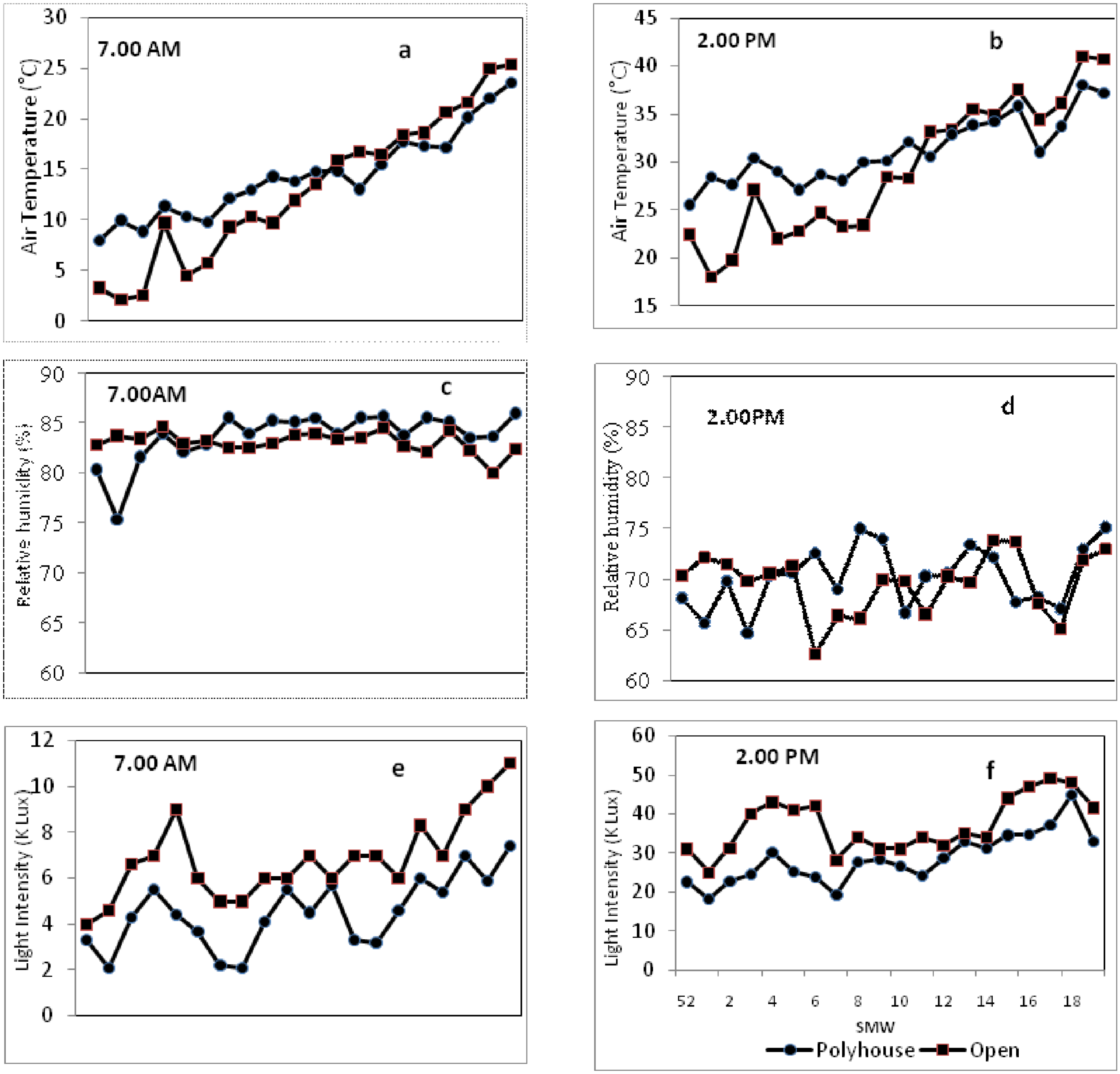


**Fig. 1:** Weekly average of air temperature, light intensity, relative humidity inside and outside of polyhouse

in evapo-transpiration inside the polyhouse which resulted into unstressed condition throughout the growing season. Positive values have been observed during the initial condition of growth period (15-45 DAT) in open condition which might be due to reflective properties of different mulches.

***Yield contributing characters and yield***

The number of fruits/plot, individual fruit weight and fruit yield of tomato crop grown under polyhouse were found significantly higher than the crop grown in the open field (Table 2).

The average weight of fruit was significantly higher (62.9 g/fruit) in polyhouse as compared to open condition (55.5 g/fruit). Significantly higher number of fruits per plot (316.0) was obtained under polyhouse as compared to open condition (181.0). Among the mulching significantly higher number of fruits per plot (285) was recorded under black mulch inside and outside the polyhouse. The minimum (205) number of fruits was recorded in under no mulch condition. The tomato plants grown within polyhouse climate produced

**Table 1 :** Stress degree days inside and outside the polyhouse.

| Treatments/ | 15 DAT | | 30 DAT | | 45 DAT | | 60 DAT | | 75 DAT | |
|---|---|---|---|---|---|---|---|---|---|---|
| Stages | P | O | P | O | P | O | P | O | P | O |
| Black | -2.2 | 5.6 | -6.6 | 1.5 | -2.5 | 1.1 | -5.9 | -0.4 | -11.0 | -5.3 |
| Silver Black | -3.2 | 2.3 | -5.5 | 0.9 | -2.9 | 1.2 | -5.1 | -2.7 | -11.1 | -4.8 |
| Transparent | -3.4 | 3.3 | -6.4 | 0.7 | -5.1 | 0.9 | -5.7 | -3.1 | -11.3 | -6.1 |
| Control | -5.3 | 0.9 | -6.6 | 0.3 | -6.5 | -3.7 | -6.3 | -5.4 | -10.8 | -5.1 |

P = Polyhouse, O = Open field, DAT – Days after transplanting

**Table 2:** Yield contributing characters and yield of tomato inside & outside the polyhouse

| Treatments/stages | No. of fruits/plot | Fruit wt.(g/fruit) | Fruit yield t $ha^{-1}$ |
|---|---|---|---|
| **Growing conditions** | | | |
| Polyhouse | 316 | 62.9 | 65.2 |
| Open field | 181 | 55.5 | 33.2 |
| S. Em. ± | 9.03 | 1.75 | 1.85 |
| C D at 5% | S | S | S |
| **Mulch** | | | |
| Black | 285 | 58.7 | 55.6 |
| Silver Black | 256 | 58.6 | 50.4 |
| Transparent | 250 | 57.2 | 47.7 |
| No mulch | 205 | 62.3 | 43.16 |
| S. Em. ± | 12.78 | 2.48 | 2.62 |
| C D at 5% | S | NS | S |
| Interaction (Growing condition X Mulch) | | | |
| S. Em. ± | 18.07 | 3.51 | 3.71 |
| C D at 5% | S | S | NS |

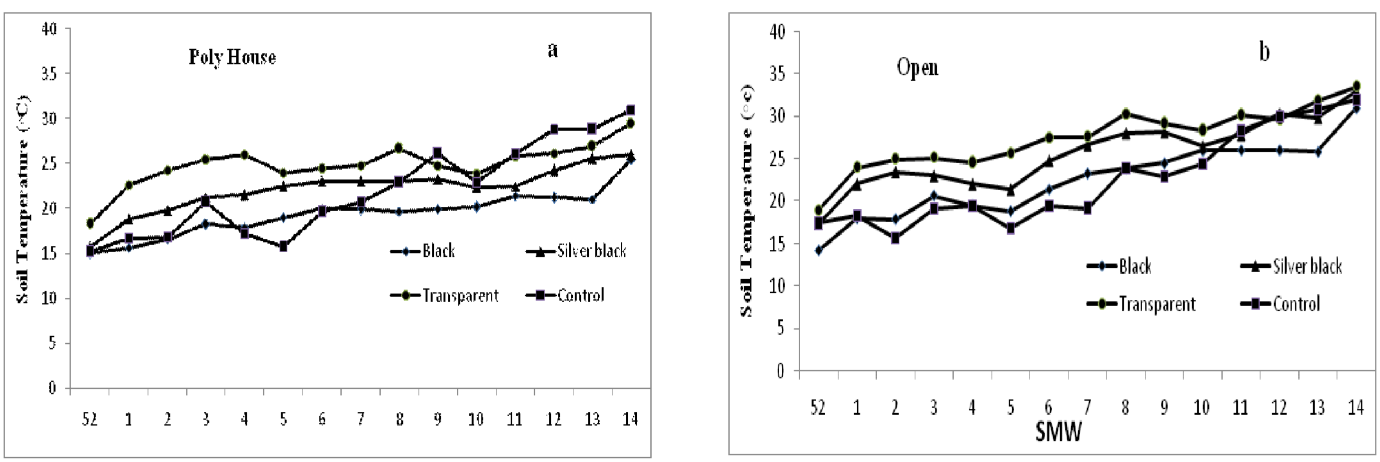


**Fig. 2:** Weekly average of soil temperature with mulches inside (a) and (b) outside of the polyhouse

75% higher number of fruit than the tomato plant grown outside the polyhouse. Similar result has been reported by Parvej *et al.* (2010).This seems to be mainly due to the more number of flowers under polyhouse because of vigorous and healthy plants.

The growing conditions had a significant influence on fruit yield per hectare. The plants grown in polyhouse recorded significantly higher (65.2 t $ha^{-1}$), almost double, mean yield as compared to open field (33.2 t $ha^{-1}$). This may be taken as overall impact of polyhouse, a partially controlled and modified microclimatic condition.

Considering the performances of tomato under different mulches,it is evident that significantly superior and higher fruit yield obtained under black mulch (55.6 t $ha^{-1}$) followed by silver black mulch (50.4 t $ha^{-1}$) and transparent mulch and lower (43.1 t $ha^{-1}$) fruit yield was recorded under no mulch plot inside and outside the polyhouse.

Under the open condition, maximum fruit yield (37.3 t $ha^{-1}$) was obtained in black mulch which was significantly superior over the no mulch condition (28.6 t $ha^{-1}$). The silver black and transparent mulch were at par with each other under open field condition. Black plastic mulch significantly and positively affected the tomato yield. Yield increased with black plastic mulch was 28 to 30 % as compared to no mulch soil under both conditions. One of the main benefits associated with plastic mulching is the higher total yield due to a positive influence on the microclimate around the plants (Lamont, 2005). Evidence from the table 3 showed that the mean minimum and maximum soil temperature during vegetative and reproductive stage were negatively associated with the total yield but it was significantly higher during the reproductive stage.

## CONCLUSION

Low cost polyhouse with locally available materials may be quite suitable for the regions like Jharkhand where the temperature falls during winter and sudden rise in temperature during summer season is very common. The growth and development of tomato plant becomes restricted during the cold winter months of December to February because of its season bound nature. Polyhouse has been found to be a good alternative to have minor alterations under microclimatic conditions for achieving almost double yield as well as better quality of tomato compared to open field. The optimum temperature accompanied by low relative humidity at initial stage and low temperature and high humidity at later stage with low solar intensity inside polyhouse provide the most suitable growing environment, so growers are benefited by being able to produce higher and off-season tomato which fetched premium prices in the market. Among different mulches, black and silver black mulches have been found to bring about the desired conditions both within the polyhouse as well as open conditions. When farmers are not able to grow tomato under polyhouse conditions application of these two mulches would be advantageous even under open conditions.

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*Received : March 2014 ; Accepted : September 2014*