J. Hortl. Sci.
Vol. 12(2) : 106-112, 2017

Original Research Paper

Effect of plastic low tunnel and mulch type on soil temperature, growth, earliness and yield of brinjal under net-house and open field in plains of North-Western India

Ajmer Singh Dhatt, Naveen Garg*, Rajinder Singh and I. S. Aujla
Department of Vegetable Science, Punjab Agricultural University, Ludhiana 141 004, India
*E-mail: naveengargpau@gmail.com

ABSTRACT

A two-year study was conducted to compare the performance of brinjal hybrid BH-2 using paddy straw mulch @ 6 t ha^{-1}, clear plastic mulch (25 µm), black plastic mulch (25 µm), plastic low tunnel and control (bare soil) under net-house and open field at Punjab Agricultural University, Ludhiana, India. The maximum increase in morning and afternoon soil temperature over bare soil was observed using black plastic mulch followed by clear plastic mulch in both net-house and open field whereas paddy straw mulch reduced the soil temperature over bare soil in open field. Under net house, black and clear plastic mulch were better than other treatments and recorded maximum plant height (50.8 cm and 43.7 cm), number of leaves/plant (64.8 and 64.3), early yield (7.1 and 6.6 t ha^{-1}), number of fruits/plant (16.1 and 14.4) and total yield (57.4 and 55.7 t ha^{-1}), respectively. In open field, plastic low tunnel was the best treatment and recorded maximum plant height (40.4 cm), number of leaves/plant (51.2), early yield (5.9 t ha^{-1}), number of fruits/ plant (14.6) and total yield (58.5 t ha^{-1}). The study offers the scope of enhancing brinjal production in spring and early summer which may be highly profitable for farmers.

Key words: Brinjal, soil temperature, paddy straw mulch, plastic mulch, total yield, *Sclerotinia* rot

INTRODUCTION

Brinjal (*Solanum melongena* L.) crop requires a long warm season for its growth and fruit maturation and is susceptible to frost. The optimum temperature of 22-30°C is most favourable for its successful production of flowers and fruits and its growth is likely to stop at temperatures below 17°C. In plains of north-western India, where the winter is severe during December to February, the crop growth is adversely affected due to frost and low night temperature (Bhat, 2011). It results in short supply and high market price of fruits during early-February to mid-April. Although net-house cultivation has been advocated but the plant growth remain restricted during winter as the perforations (40 mesh) in the net-house do not allow the inside air temperature to rise much above the open field air temperature (Sethi *et al*, 2009).

Surface mulches promote early harvest by modifying soil and air microclimate and plastic mulch has been found beneficial in brinjal (Singh *et al*, 2005). The plastic mulch materials made of low-density polymers are mainly used due to its easy processing, excellent chemical resistance, high durability, flexibility and odourless characteristics (Espi *et al*, 2006). It has been reported that black mulch is used during spring season to warm the soil whereas aluminum and white coloured mulches are preferred in summer and autumn seasons because these mulches heat the soil less than black mulch (Diaz-Perez and Batal, 2002). In brinjal, black plastic mulch had been found to stimulate growth, induce earliness, reduce infection rate of *Verticillium* wilt and increase the yield (Mooran, 1982; Abney and Russo, 1997), whereas, organic mulch of dry guinea grass (4 t ha^{-1}) conserved soil moisture particularly in the top 4 cm layer and increased the yield (Daisley *et al*, 1988). However, the influence of mulch colour on crop growth and productivity is postulated to be highly specific and may vary with plant taxa, geographical location, climate and seasonal conditions suggesting that plants grown on coloured mulches respond to factors in addition to the light reflected by the mulch

(Mahmoudpour and Stapleton, 1997; Diaz-Perez and Batal, 2002). Besides, the use of low tunnels (covered with low density plastic sheet) in net-house over the plant rows has also been advocated to generate localized greenhouse effect for faster plant growth, earliness and higher total yield of brinjal (Sethi *et al*, 2009).

The present study was conducted to assess the effect of paddy straw mulch, plastic mulch (black and clear) and plastic low tunnel on soil temperature, plant growth parameters, earliness, total yield and incidence of insect-pests and diseases on brinjal in both net-house and open field conditions so as to enhance brinjal production during spring and early summer season in north-western plains of India.

MATERIAL AND METHODS

The present study was conducted at Vegetable Research Farm, Punjab Agricultural University, Ludhiana (247 m altitude, 30° 55' North latitude and 75° 51' East longitude). The research trial was conducted during *rabi* seasons of 2006-07 and 2007-08 to compare the performance of brinjal hybrid BH-2, (recommended for cultivation in north-western plain zone by All India Coordinated Research Project on Vegetable Crops) using paddy straw mulch (PSM) @ 6 t ha^{-1}, clear plastic mulch (CPM), black plastic mulch (BPM), plastic low tunnel (PLT) and control (bare soil) (BS) in both net-house (40-mesh size) and open field. The thickness of plastic mulch sheet was 25µm. Thirty five days old seedlings were transplanted on 90 cm wide beds in early-November in both net-house and open field. Each treatment was replicated thrice and comprised two rows of seven plants at an intra row spacing of 30 cm. The plastic low tunnel and various mulch materials were used only during winter months (early-December to end-February), when the temperature was a limiting factor in growth and development of brinjal.

The observations were recorded for soil temperature (^{0}C) (at 5 cm soil depth at 0830 hrs and 1430 hrs daily), plant height (in cm at 120 DAT and 210 DAT), number of leaves $plant^{-1}$ (at 120 DAT), plant spread (in cm at 210 DAT), days taken from transplanting to first picking, early yield (from first two pickings) (t ha^{-1}), fruit number $plant^{-1}$, total yield (t ha^{-1}), plant mortality (%) due to low temperature and frost, plant mortality (%) due to *Sclerotinia* rot, and incidence of shoot & fruit borer (%). The data were analyzed using Randomized Factorial Block Design employing standard statistical methods (Rangaswamy, 2014).

RESULTS AND DISCUSSION

Morning and afternoon soil temperature (^{0}C) at 5 cm depth

In open field conditions, use of PSM reduced the soil temperature over bare soil by 0.1-0.9^{0}C during morning and by 0.1-1.5^{0}C during afternoon hours. On the contrary, plastic mulches and low tunnel increased the soil temperature over bare soil during both morning and afternoon hours. The maximum increase was recorded in BPM closely followed by CPM. The BPM enhanced the soil temperature by 0.7-2.6^{0}C and 0.2-3.3^{0}C whereas CPM increased it by 0.2-1.7^{0}C and 0.1-2.2^{0}C during morning and afternoon time, respectively **(Tables 1 and 2).**

Under net-house, all the treatments enhanced the soil temperature over bare soil during both morning and afternoon hours. The maximum increase was recorded by BPM followed by CPM, whereas PLT and PSM did not cause any major change in soil temperature. During severe winter that prevailed from third week of January to second week of February, the cumulative effect of net-house and black plastic mulch raised soil temperature by 3.8-5.2°C during morning and by 2.4-4.6^{0}C during afternoon time. The CPM was also quite effective and it increased the soil temperature by 0.4-3.4^{0}C and 0.2-4.5^{0}C during morning and afternoon hours, respectively **(Tables 1 and 2).**

Significant increase in soil temperature using black and white plastic mulches during winter months over control in brinjal has also been reported by Awasthi *et al* (2006). This increase is higher in clear and dark colours than in the reflective ones such as white, silver or aluminum (Rangarajan and Ingall, 2001) as the degree of soil warming is correlated with reflectivity of the mulch, the black mulch having the lowest light reflectance while silver mulch having the highest (Diaz-Perez and Batal, 2002). The soil temperature lowering effect of paddy straw mulch in open field could be due to the fact that these mulches allow the cool air of atmosphere to pass through it and do not allow the sunlight to heat the soil underneath during day time.

Table 1. Effect of plastic low tunnel and mulch type on weekly morning soil temperature (°C) at 5 cm depth in net-house and open field in north-western plains of India

Week and month	Net-house					Open field				
	PSM	CPM	BPM	PLT	Bare soil	PSM	CPM	BPM	PLT	Bare soil
2nd week of Dec.	17.1	18.0	19.6	18.3	17.0	16.5	18.3	17.7	17.0	16.7
3rd week of Dec.	16.1	17.3	18.6	16.9	15.4	15.2	17.1	16.8	16.5	15.4
4th week of Dec.	16.9	17.2	18.4	16.6	16.8	15.5	17.0	17.2	16.6	15.8
1st week of Jan.	15.7	16.6	18.0	16.0	15.6	14.1	16.2	15.9	15.5	14.6
2nd week of Jan.	16.2	17.2	18.5	14.4	15.7	13.1	14.6	16.2	12.5	14.0
3rd week of Jan.	12.4	14.1	16.1	11.0	12.3	10.0	10.9	12.7	10.8	10.7
4th week of Jan.	10.2	12.4	15.6	10.0	10.4	09.4	10.8	11.2	10.4	10.0
1st week of Feb.	11.5	14.0	16.0	12.0	11.8	10.1	11.6	13.0	11.8	10.4
2nd week of Feb.	10.7	14.2	16.0	12.0	10.8	09.7	11.6	12.0	10.6	10.0
3rd week of Feb.	16.2	18.0	20.0	16.7	16.0	14.5	16.0	16.0	16.0	14.7
4th week of Feb.	17.3	19.3	20.0	18.0	17.7	15.2	16.0	16.0	16.0	15.3
1st week of March	20.1	21.0	22.0	20.0	20.0	18.9	20.0	21.0	20.0	19.0
2nd week of March	21.8	21.6	21.6	21.6	21.6	18.9	19.0	19.0	19.0	19.0
Mean	15.6	17.0	18.5	15.7	15.5	13.9	15.3	15.7	14.8	14.3

PSM= Paddy straw mulch, CPM= Clear plastic mulch, BPM= Black plastic mulch, PLT= Plastic low tunnel

Table 2. Effect of plastic low tunnel and mulch type on weekly afternoon soil temperature (°C) at 5 cm depth in net-house and open field in north-western plains of India

Week and month	Net-house					Open field				
	PSM	CPM	BPM	PLT	Bare soil	PSM	CPM	BPM	PLT	Bare soil
2nd week of Dec.	20.3	21.0	21.2	19.8	19.7	18.6	20.8	20.2	19.2	18.8
3rd week of Dec.	19.5	22.9	21.2	20.1	18.4	19.7	21.0	20.6	18.4	20.0
4th week of Dec.	19.7	23.0	21.9	20.6	19.0	20.0	21.0	21.8	19.8	20.7
1st week of Jan.	19.8	23.2	21.4	19.2	19.2	19.6	21.2	21.2	19.2	20.0
2nd week of Jan.	18.6	20.5	22.1	16.7	18.3	18.1	19.8	20.3	14.4	18.7
3rd week of Jan.	16.8	20.0	22.0	13.9	17.4	16.4	16.8	18.1	13.7	17.9
4th week of Jan.	15.7	17.0	18.0	14.0	15.6	13.8	15.0	14.8	10.4	14.0
1st week of Feb.	16.2	17.6	19.4	16.0	16.0	16.2	16.8	17.8	15.8	16.4
2nd week of Feb.	18.1	19.6	21.0	17.0	17.6	17.8	18.8	20.0	16.6	18.2
3rd week of Feb.	23.1	23.3	24.7	20.7	23.3	22.5	22.8	24.0	20.0	22.7
4th week of Feb.	24.9	24.3	26.7	22.3	24.1	20.6	22.9	24.0	21.0	20.7
1st week of March	25.2	26.2	28.0	24.0	25.0	24.8	26.8	28.0	24.0	25.0
2nd week of March	26.1	27.8	28.1	28.8	26.8	26.3	27.0	27.3	28.0	26.5
Overall mean	20.3	22.0	22.7	19.5	20.0	19.6	20.8	21.4	18.5	20.0

PSM= Paddy straw mulch, CPM= Clear plastic mulch, BPM= Black plastic mulch, PLT= Plastic low tunnel

Plant growth parameters

The comparison of plant growth parameters across two cultivation environments revealed that periodic plant height (120 DAT and 210 DAT) and number of leaves per plant of brinjal recorded 33.1%, 19.6% and 30.7% increase respectively, under net-house than open field conditions, whereas plant spread exhibited non-significant differences **(Table 3).** This depicted better growth of plants under net-house conditions which could be primarily due to high air temperature and better photosynthesis under protected cultivation environment.

The mulching and low tunnel treatments improved the growth parameters of brinjal over bare soil. The maximum improvement was noticed in plant height (120 DAT) and number of leaves (120 DAT), whereas plant height and plant spread at 210 DAT recorded values at par with bare soil except with the use of PLT. This revealed that during winter months (December to February) when the temperature is not optimum for brinjal growth, mulching and low tunnel treatments are highly beneficial in improving brinjal growth and development. However, since interaction effect was significant, the effect of these treatments varied across two cultivation environments i.e. net-house and open field. In net-house, BPM, CPM and PLT were better than PSM in improving growth attributes of brinjal, whereas PLT and BPM were better than other treatments in open field. Awasthi *et al* (2006) have also reported an increase of 146.6% & 95.7% in plant height, and 70.2% & 41.7% in plant spread using black and white plastic mulches, respectively in brinjal grown under semi-arid conditions.

Table 3. Effect of plastic low tunnel and mulch type on growth attributes of brinjal in net-house (NH) and open field (OF) in north-western plains of India (pooled data of 2 seasons)

Treatment	Plant height (cm) (120 DAT)			Plant height (cm) (210 DAT)			Plant spread (cm) (210 DAT)			Number of leaves plant^{-1} (120 DAT)		
	NH	OF	Mean	NH	OF	Mean	NH	OF	Mean	NH	OF	Mean
PSM	40.4	29.6	35.0	107.0	86.1	96.6	81.3	82.7	82.0	36.7	29.3	33.0
CPM	43.7	33.6	38.7	110.8	93.9	102.4	82.4	79.9	81.2	64.3	45.3	54.8
BPM	50.8	36.4	43.6	102.5	89.9	96.2	88.5	74.6	81.6	64.8	49.4	57.1
PLT	48.8	40.4	44.6	113.6	94.1	103.9	80.0	94.8	87.4	63.1	51.2	57.2
Bare soil	35.3	24.5	29.9	103.8	85.8	94.8	79.9	83.1	81.5	32.9	25.4	29.2
Mean	43.8	32.9	-	107.5	89.9	-	82.5	83.0	-	52.4	40.1	-
CD (P = 0.05)												
NH vs OF (A)	2.2	-	-	2.9	-	-	NS	-	-	2.8	-	-
Mulch type (B)	3.3	-	-	4.4	-	-	3.9	-	-	4.0	-	-
Interaction (A x B)	4.7	-	-	6.2	-	-	5.6	-	-	5.7	-	-

Earliness and yield attributes

The mean values shows that brinjal crop raised in net-house took 9.8 days less to first picking along with 74.7%, 140% and 87.7% increase in number of fruits, early yield and total yield, respectively **(Table 4).** This could be due to a little higher temperature in net-house than in open field. The previous studies conducted on tomato (Cheema *et al*, 2004), bell pepper (Singh *et al*, 2004) and brinjal (Sidhu and Dhatt, 2007) showed considerable increase in early, total and marketable fruit yield in net-house than in open field.

The minimum number of days to first picking was taken by CPM and PLT in net-house and open field, respectively. In net-house, the use of different mulches resulted in improvement in early yield (55-255%), number of fruits per plant (28%-80.9%) and total yield (23.9- 63%) over bare soil. However, in open field, these treatments caused increase or decrease in early yield (0 to 742.8%), number of fruits per plant (-28% to 156%) and total yield (-36% to 219.7%) over control.

Table 4. Effect of plastic low tunnel and mulch type on earliness and yield attributes of brinjal in net-house (NH) and open field (OF) in north-western plains of India (pooled data of 2 seasons)

Treatment	Days to first picking			Early yield (t.ha^{-1})			No. of fruits plant^{-1}			Total yield (t.ha^{-1})		
	NH	OF	Mean	NH	OF	Mean	NH	OF	Mean	NH	OF	Mean
PSM	133.7	149.7	141.7	3.1	0.7	1.9	11.4	4.1	7.8	43.6	11.7	27.7
CPM	124.7	139.7	132.2	6.6	1.1	3.9	14.4	7.0	10.7	55.7	21.2	38.5
BPM	129.0	136.0	132.5	7.1	1.4	4.3	16.1	6.1	11.1	57.4	20.4	38.9
PLT	128.3	128.5	128.4	5.0	5.9	5.5	14.6	14.6	14.6	52.0	58.5	55.3
Bare soil	139.5	150.2	144.9	2.0	0.7	1.4	8.9	5.7	7.3	35.2	18.3	26.8
Mean	131.0	140.8		4.8	2.0		13.1	7.5		48.8	26.0	
CD (P = 0.05)												
NH vs OF (A)	1.5			0.2			1.1			2.6		
Mulch type (B)	2.2			0.4			0.8			3.8		
Interaction (A x B)	3.2			0.5			1.2			5.4		

Apparently, BPM, CPM and PLT were better than PSM in increasing early and total yield of brinjal in net-house, whereas PLT was the best among all treatments in open field. This improvement in plant growth, earliness, and yield parameters of brinjal may be attributed to less weed population, conservation of soil moisture, increase in CO_2 levels in soil, increase in root-zone temperature which ultimately enhances uptake of water and mineral nutrients by the plants (Abney and Russo, 1997; Diaz-Perez and Batal, 2002; Lamont, 2005). In the open field, low tunnel was better than mulches as it protects tender plants from cold winds and frost and provides warmer growing temperatures inside the tunnel. Awasthi *et al* (2006) have also reported an increase of 560% & 380% in fruit number, 516.3% & 341.5% in fruit yield over control with black and white plastic mulches, respectively, in brinjal grown under semi-arid irrigated conditions.

Incidence of shoot and fruit borer (%)

The incidence of shoot and fruit borer was nil in net-house, whereas it varied from 8.4% (PLT) to 35.1% (bare soil) in open field conditions **(Fig. 1).** Reduced incidence of fruit borer under net-house than in open has also been reported earlier in brinjal (Sidhu and Dhatt, 2007), tomato (Cheema *et al*, 2004) and bell pepper (Singh *et al*, 2004). This may be due to the reason that

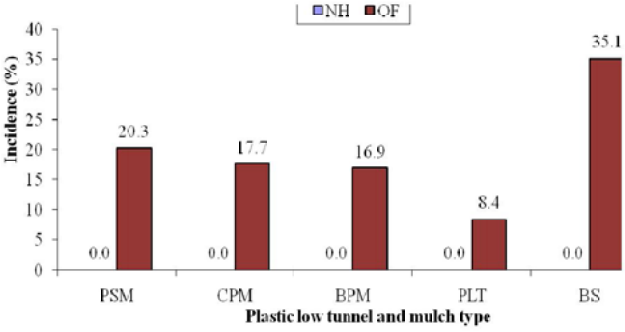

Fig. 1. Effect of plastic low tunnel and mulch type on incidence of shoot and fruit borer (%) in brinjal under net-house (NH) and open field (OF) in north-western plains of India

net-house acts as a barrier between adults and larvae of shoot and fruit borer and inside grown plants. The reduced attack of shoot and fruit borer under PLT in open field may be due to protection cover of plastic tunnel from insect-pest infestation during initial plant growth.

Plant mortality (%) due to frost and *Sclerotinia* rot

In net-house, plant mortality due to frost was not observed in any of the treatments, whereas in open field, all the treatments except PLT showed plant mortality, the maximum was observed in PSM (36.5%) followed by control (34.7%), CPM (21.2%) and BPM (14.2%) **(Fig.2)**. The probable reason for this is that

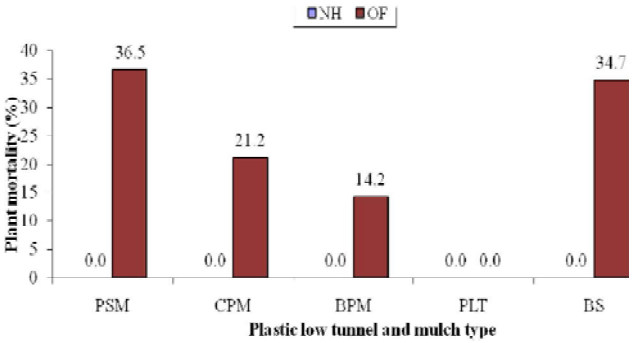

Fig. 2. Effect of plastic low tunnel and mulch type on plant mortality (%) due to low temperature and frost in brinjal under net-house (NH) and open field (OF) in north-western plains of India (pooled data of 2 seasons)

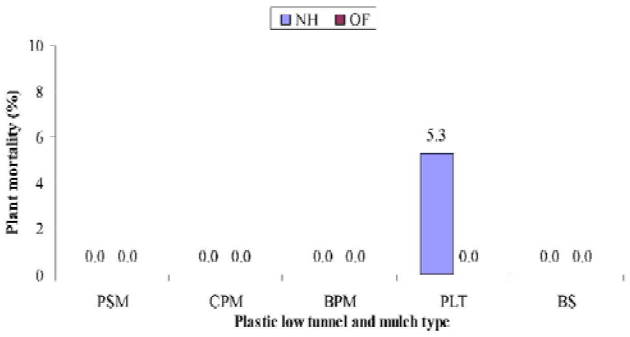

Fig. 3. Effect of plastic low tunnel and mulch type on plant mortality (%) due to *Sclerotinia* rot in brinjal under net-house (NH) and open field (OF) in north-western plains of India (pooled data of 2 seasons)

clear plastic tunnels allow sunlight to pass through during the day and slow heat loss from the surface at night. The downward radiation from the sky at night is enhanced by covering the plants. The condensation, which forms underneath the polyethylene, releases latent heat, warms the plastic and provides even more protection. In addition, under advection frost conditions, the PLT covers also block the wind and provide protection. On the other hand, PSM caused higher plant mortality (36.5%) than did bare soil (34.7%). This could be due to the fact that organic mulches reduce the transfer of heat from ground to surface soil and hence make crops more prone to frost.

The incidence of mortality due to *Sclerotinia* rot was not observed in all growing conditions except PLT in net-house where 5.3% mortality of plants was recorded **(Fig. 3).** This could be attributed to high relative humidity build-up in low tunnel which along with low temperature (15.5-21.0°C) and light is considered conducive for sclerotia germination and infection.

CONCLUSION

In net-house, BPM, CPM and PLT were better than PSM in improving growth attributes, early and total yield, however, BPM and CPM are recommended for commercial utilization due to incidence (5.3%) of *Sclerotinia* rot under PLT. In open field, PLT is recommended as it was better than other treatments in improving growth attributes, increasing early and total yield, protecting plants from frost injury, and decreasing the incidence of shoot and fruit borer.

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(MS Received 26 June 2016, Revised 02 November 2017, Accepted 20 December 2017