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Effect of Mulching on Microclimatic Manipulation, Weed Suppression, and Growth and Yield of Pea (*Pisum sativum* L.)

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Authors' contributions

This work was carried out in collaboration between all authors. Author MAA designed the study, wrote the protocol and wrote the first draft of the manuscript. Author PCD managed the literature searches. Author MSS managed the experimental process and performed data analyses. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Aim: An experiment was conducted in the Bangladesh Agricultural University to study the effect of various mulches on microclimatic manipulation, weed suppression, and growth and yield of pea (*Pisum sativum* L.).
Study Design: Treatments were comprised of transparent polyethylene, black polyethylene and rice straw mulches and a no mulch treatment (control). Treatments were laid-out following a randomized complete block design with three replicates.
Place and Duration of Study: The study was conducted in the Field Laboratory of the Department of Crop Botany, Bangladesh Agricultural University, Mymensingh, during the cropping season extended from November 2009 to February 2010.
Methodology: Measurements included soil and air temperatures, soil water, weed and crop dry weights, plant height, primary branch number per plant, yield components, and grain yield.

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Results: The transparent and black polyethylene covers increased soil temperature whereas rice straw decreased it as compared to that at no mulched soil. However, all mulch covers retained significantly higher amount of soil water in the order of black polyethylene>transparent polyethylene>rice straw>no mulch. Weed growth was suppressed by black polyethylene mulch whereas it was promoted under transparent film followed by the no mulched soil. Plant height, number of primary branches per plant, leaf area index, dry matter accumulation, seed yield and yield contributing attributes like number of pod per plant and seed per pod, seed weight per plant and individual seed weight were influenced by different mulches. High yield attributes occurred from the crops grown with black or transparent polyethylene mulches whereas lowest yields occurred from the crops grown with rice straw mulch or control. The highest seed yield was obtained from the crops grown with black (5.66 t/ha) or transparent polyethylene covers (5.54 t/ha), and the lowest occurred with rice straw (4.38 t/ha) or with no mulch (4.26 t/ha).

Conclusion: Black or transparent polyethylene sheet can be used as an effective mulching material for the better yield of pea crop under the existing agro-climatic conditions of Bangladesh.

Keywords: Black and transparent polyethylene; microclimate; pea; temperature; weed suppression.

1. INTRODUCTION

Pea (*Pisum sativum* L.) is an important legume, which is globally cultivated in 7.06 million hectares of land with a production of 13 million metric tons in 2008 [1]. The top five green pea producing countries are China, India, USA, France, and Egypt [2]. Pea seeds contain about 21-25% protein. Seeds also contain high level of carbohydrate with low fibre, thereby making it an excellent livestock feed. The edible part of pea is the green immature pod, which is used as vegetable like country bean (*Phaseolus vulgaris* L.) [3]. Moreover young pea plants can be used as fodder or green manure [4]. Pea vine is also used for making silage or hay, which contains on an average 6.9% digestible nutrient on dry weight basis [5]. Being a legume, growing pea crops add substantial amount of nitrogen (N) in soil by biological N_2 fixation through rhizobium bacteria in root nodules.

Pea grows best in moist and cool regions. However, it grows in many tropical and sub tropical countries. Peas do best in a climate where there are two months of cool growing weather (http://veggieharvest.com/vegetables/peas.html; accessed on February 27, 2016). Following late fall, the winter climate of Bangladesh extends from middle of December to middle of February, is quite ideal for pea production.

Pea requires a temperate climate for its proper development. The ideal temperature is between 10℃ and 30℃ with an optimum of 20°C (http://agrifarming.in/green-peas-farming; accessed on February 27, 2016). For emergence, vegetative and reproductive stages of pea a threshold or base temperature of 3℃, an optimum tempearure of 28℃ and a maximum temperature of 38℃ are appropriate as cardinal temperatures [6]. Close linear relationships were found between number of nodes and sum of air temperature (i.e. thermal time or degree-days that is expressed as ℃d) which is accumulated from sowing or emergence of vining peas (*Pisum sativum* L.). Therefore, the number of nodes is a reliable indicator to assess the status of this crop for experiencing the actual air temperature's sum from seed sowing [7]. Rhizobium growth for fixing atmospheric nitrogen is affected by temperature and is inhibited by low soil temperature as compared to optimum one [8].

Plant growth and development depend on the microclimatic conditions along with management practices. Soil microclimate can be altered through the application of different mulching materials [9]. Mulches manipulate the soil heat flux and thereby affect soil temperature. Mulch cover reduces evaporation from the land surface therefore soil water contain is retained [10,11]. Additionally, mulch cover suppresses weed infestation in the crop field [12]. Therefore, various types of mulching material are used to alter the microclimate along with the improvement of crop yield [13-17]. However the application of mulches on the production of pea crop has not been conducted. Therefore, the experiment was carried out to assess the alteration of microclimatic parameters (like soil temperature and soil water) and weed suppression due to the application of different mulching materials and their effects on the growth and yield of pea crop.

2. MATERIALS AND METHODS

2.1 Crop Husbandry and Experimental Design

An experiment was conducted in the Crop Botany Field Laboratory during the cropping season from November 2009 to February 2010. The treatments were mulching with transparent polyethylene, black polyethylene, and rice straw along with no mulch or control. The experiment was a randomized complete block design with 3 replicates. The rice straw, transparent polyethylene and black polyethylene were placed on the respective plots as per layout of the experiment. Before sowing the seeds, polyethylene sheets were placed on the plots tightly and held with sticks. Holes were prepared with a knife on the sheets maintaining the proper spacing. Then the seeds were sown in the centre of holes. Straw mulch was uniformly placed soon after seed sowing.

Seeds of pea (*Pisum sativum* L.) cv. Aisura were sown on 13 November 2009 maintaining row to row and plant to plant distances in a row as 50 and 20 cm, respectively. In each point, 3 or 4 seeds were sown at a depth of approximately 5 cm. After sowing, the seeds were covered with loose soil. Following emergence only one healthy seedling was maintained by removing the others. No irrigation was given to the plots during the entire cultivation period. Weeding was done at 30 days after sowing (DAS) to keep the plots reasonably weed free throughout the growing period with minimum disturbances to the mulches. An area of 1 m^2 in each plot remained unweeded until the collection of weed growth data.

2.2 Data Collection

2.2.1 Microclimatic parameters

2.2.1.1 Soil temperature

Data on soil temperature were recorded on two sunny days, 21 December 2009 and 10 January 2010 with transparent glass thermometers covered with a metal case. Temperatures were measured at 5, 10, 15, and 20 cm depths in soil with hourly intervals starting from 6 AM to 6 PM. The soil thermometers were placed in between the rows. Before setting a thermometer, a hole of same diameter of metal case was made at appropriate depth with a rod for easy penetration of thermometer. Air temperature of respective hours at 2-m height from the ground for the both days was also measured by a thermometer.

2.2.1.2 Soil water

Soil samples were collected by an auger from the depth of 0-5 cm. The auger was placed between the rows of plants. Soon after augered, each soil sample was encased with a polyethylene packet to avoid evaporation loss and then brought to the laboratory for recording its weights. Soil water content was calculated by the following formula:

$$\%\ \text{Soil water content} = \left\{ (W_1 - W_2) / W_1 \right\} \times 100$$

here, W_1 = weight of soil before drying, weight properly maintained with air-tight polyethylene packets, W_2 = weight of soil after oven dried until constant weight at 80±2℃.

2.2.2 Weed biomass

All weeds of a previously selected 1 m^2 (1 m × 1 m) area from each plot were uprooted on 23 December 2009 (i.e. 41 DAS). Proper care was taken to ensure maximum volume of roots therein. The harvested weeds were cleaned and dried at 80±2℃ until constant weight and weighed with an electronic balance.

2.2.3 Crop growth parameters

Five plants from each plot were uprooted carefully keeping maximum volume of roots and then brought to the laboratory for recording data on plant height, number of primary branches per plant (branches originated directly from the main stem), leaf area, and total dry matter accumulation. Sampling was done at 10-day interval starting from 30 day after sowing (DAS) until maturity on 80 DAS. Leaf area was recorded with an electronic leaf area meter (LI-3000, LiCor, USA). Then the leaf area index (LAI; ratio of leaf area to its ground area) was calculated by using the formula [18]:

$$\text{i.e. LAI} = \text{LA} / \text{GA}$$

where, 'LA' and 'GA' indicate leaf area and ground area, respectively. Ground area is calculated from the spacing of the plant.

The harvested plants were oven dried at 80±2℃ until constant weight and weighed with an electronic balance to record data on total dry matter accumulation.

2.2.4 Yield and yield components

The plants of entire plots were harvested at physiological maturity to record data on yield and yield attributes when the pods were turned brown in colour and slightly dried. The pods were dried under normal sunshine, and seeds were collected by splitting the dried pods. The seeds were weighed and preserved in polyethylene bags after drying and cleaning. The yield components like number of pods per plant and seeds per pod, weight of seeds per plant, 100-seed weight, and yield were recorded. Seed weight per plant as well as seed yield and biological yield were recorded as sun-dry and oven-dry basis. Harvest index (HI) was calculated from the yield data by the following formula as proposed by Donald and Humblin [19].

$$HI = \frac{\text{Economic yield (i.e. seed yield)}}{\text{Biological yield (i.e. total dry matter)}} \times 100\%$$

The collected data on different parameters were analyzed statistically to obtain the level of significance using the MSTAT-C Package Programme developed by Russel [20]. Least Significant Difference (LSD) was computed for easy comparing between the pair of means. The differences between means were compared by Duncan's Multiple Range Test, DMRT [21].

3. RESULTS AND DISCUSSION

3.1 Microclimatic Parameters

3.1.1 Soil temperature

Fig. 1 shows the seasonal time-course of daily record of soil temperature at different soil depths (5 to 50 cm) along with respective air temperature beginning from sowing of seed on 13 November 2009 to crop maturity. Soil and air temperatures slowly decreased with progress of season until the end of December 2009. Thereafter, the temperature remained static or slightly increased at the end of January 2010. The soil temperature decreased with soil depths. Air temperature was always lower than the soil temperature for most of the season. The daytime course of soil temperature at hourly intervals under different mulches at different depths from 5 to 20 cm was measured on two clear sunny days and the data are presented in Figs. 2 and 3.

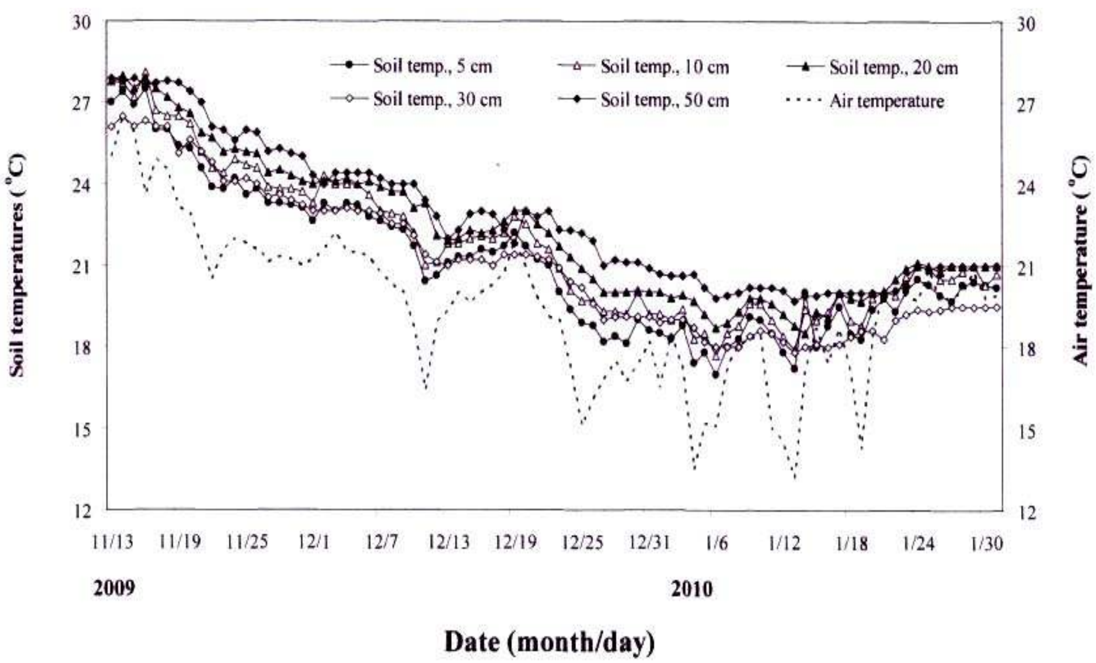

Fig. 1. Daily record of soil temperatures at different depths from 5 to 50 cm during the experimental period. Data on daily average air temperature are also shown

A remarkable variation of soil temperature was observed at hourly intervals of the day for the different mulching practices (Fig. 2). Transparent or black polyethylene film cover increased soil temperature whereas straw cover decreased it as compared to control. Results showed that the initial minimum soil temperature in the early morning gradually increased with the advancement of the day and it reached to a maximum at 14:00-15:00 hours in all the treatments. There were significant differences in soil temperatures for the mulching practices. The inter-treatment soil temperature variation was decreased with soil depths or progress of season (Figs. 2 and 3).

Awal and Ikeda [15-17] reported that soil temperature increased with transparent or black polyethylene mulches and decreased with straw mulch compared to no mulch, results that are full agreement with our findings. Fig. 4 shows the day-time average (from 06:00 to 18:00 hrs) of soil temperatures over the solar hours. The soil temperature under different treatments was in the order of transparent polyethylene>black polyethylene>control>straw, or 5 cm>10 cm>15 cm>20 cm. The soil temperature also decreased as the season progressed due to the effect from shading offered from canopy. Similar finding were also reported [13].

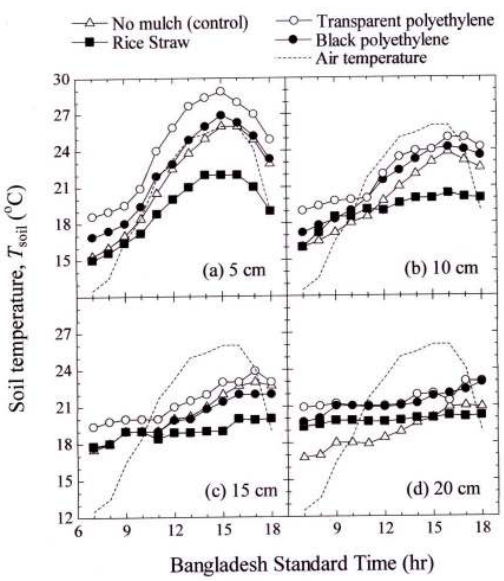

Fig. 2. Diurnal course of soil temperature at 5 cm (a), 10 cm (b), 15 cm (c), and 20 cm (d) depths under different mulches at 39 DAS (21 December 2009). Data on corresponding air temperature above the canopy are also shown

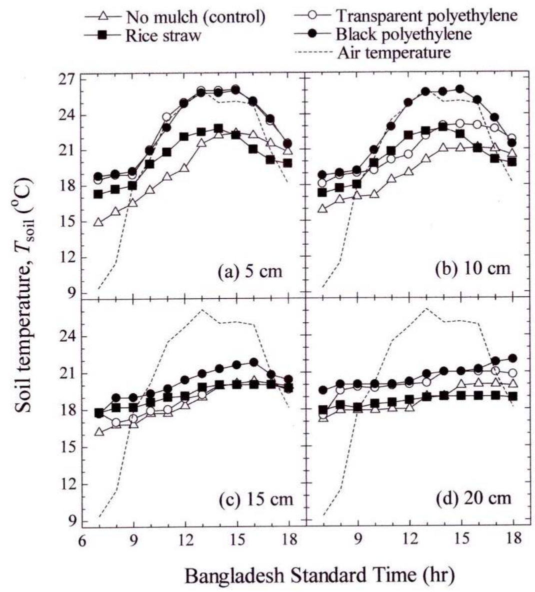

Fig. 3. Diurnal course of soil temperature at 5 cm (a), 10 cm (b), 15 cm (c), and 20 cm (d) depths under different mulches at 59 DAS (10 January 2010). Data on corresponding air temperature above the canopy are also shown

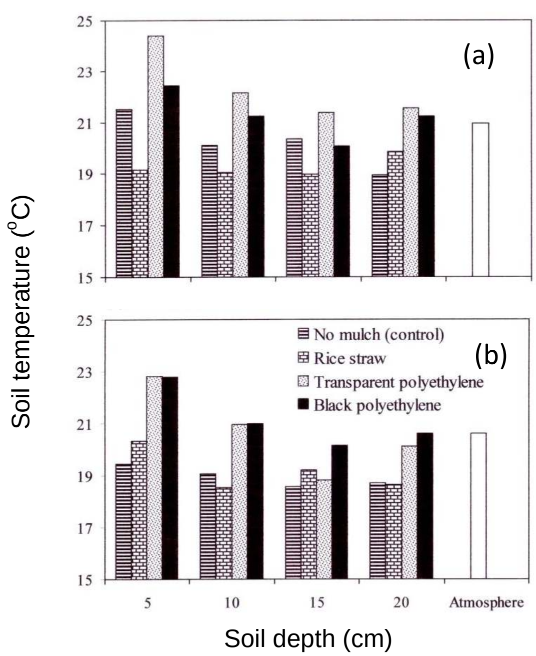

Fig. 4. Daytime average (from 6 to 18 hour) soil temperatures at varying depths under different mulches at 39 DAS (21 December 2009) and 59 DAS (10 January 2010). Data on corresponding air temperature above the canopy are also shown

3.1.2 Soil water content

The soil water content was affected significantly by the various mulches (Fig. 5). The highest soil water content was in the plots mulched with black polyethylene or transparent polyethylene, and the lowest soil water was recorded in control plot. In general, mulches conserve soil water [13,22] by creation of barrier against the direct evaporation of water from soil. Straw mulch also improves soil water retention [23-25]. These findings support our results.

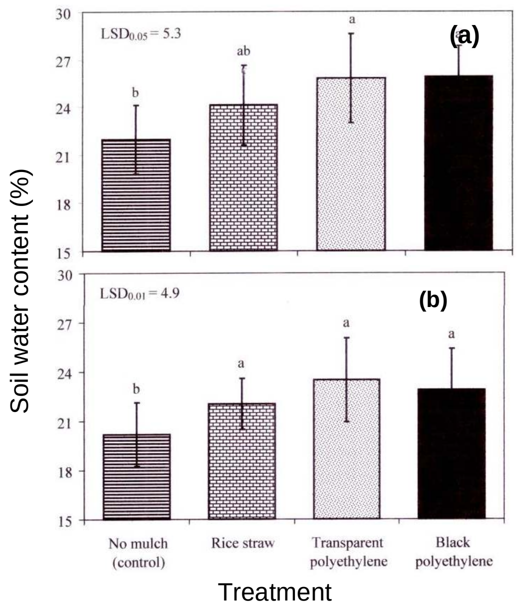

Fig. 5. Gravimetric water content in soil on 21 December 2009 i.e. 39 DAS (a) and 10 January 2010 i.e. 59 DAS (b) subjected to different mulches. vertical bar represents the standard deviation (±) of mean (*n* = 3). Dissimilar smaller letters above the treatments indicate the significant difference. $LSD_{0.01}$ and $LSD_{0.05}$ indicate least significant difference at 1 and 5% level of probabilities, respectively

3.2 Weed Suppression

Total biomass of weed population under different mulches was harvested on 23 December 2009 i.e. 41 DAS, and the data are presented in Fig. 6. Weed biomass varied significantly for the different mulching treatments. Highest weed biomass was recorded in the plots mulched with transparent polyethylene. In contrast, the lowest weed biomass was in the black polyethylene mulched plot. Rice straw mulch is also acted as a weed suppressor. The suppression of weed growth by the black polyethylene film or rice straw mulch is a common phenomenon and the finding is supported well by the Tanaka and Tsuno [26] in black gram (*Vigna mungo* L.). Prihar et al. [27] observed that wheat straw mulch limits the weed population. The efficacy of organic mulches as suppressants of weed growth and development are well documented as rye mulching significantly restricted the emergence and survival of weed in maize field [28]. The weed biomass also decreases in maize (*Zea mays* L.) crop by polythene mulch [29]. All of these previous results support our finding. Weed infestation lowers the crop yield including those of pea [30]; therefore, use of black polyethylene can be considered.

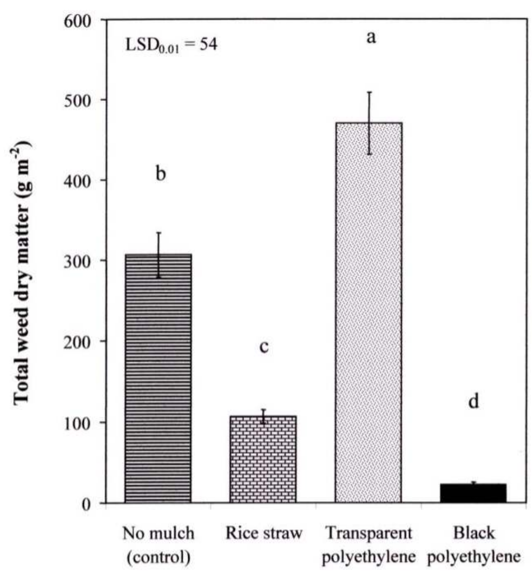

Fig. 6. Total biomass of weed population grown naturally under different mulches (harvested on 23 December 2009 i.e. 41 DAS). Vertical bar represents the standard deviation (±) of mean (*n* = 3). Dissimilar smaller letters above the treatments indicate that the treatment differences are significant at 1% level of probability ($LSD_{0.01}$)

3.3 Plant Height and Number of Primary Branches per Plant

The plant height increased with the advancement of season (Fig. 7). The plant height was different among mulch treatments and time. The tallest plant was recorded in crop mulched with black or transparent polyethylene and the shortest plant was found in control plot. Straw mulched plants ranked intermediate. Similar findings were

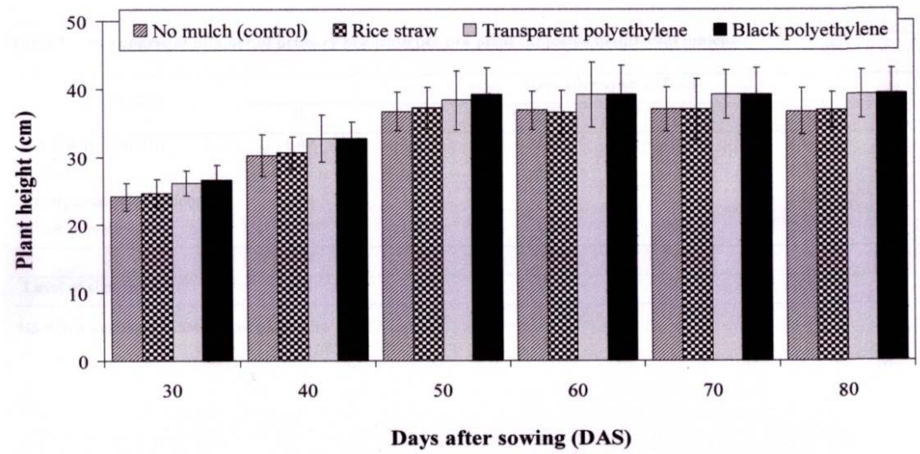

Fig. 7. Seasonal time-course of plant height of pea crops grown with different mulches. Vertical bar represents the standard deviation (±) of mean (n = 3)

reported for mulching in onion (*Allium cepa* L.) [31] and soybean (*Glycine max* (L.) Merr.) [32]. Mulches change the soil temperature and soil moisture content, which might favour vigorous growth and resulted taller plants than the plants grown with no mulch. The black and transparent polyethylene mulched plant maintained slightly higher number of primary branches, and the lowest number was with no mulched plants whereas the straw mulched plants remarked being in between. However, the variation between the treatments was found insignificant (data not shown).

3.4 Leaf Area Index (LAI)

Leaf area index increased gradually after 30 DAS and reached to a maximum at 60 DAS followed by a decline toward maturity (Fig. 8). The effect of different mulches on the leaf area indices was significant from 50 to 70 DAS according to the Least Significant Difference (LSD). Mulched plants maintained higher leaf area index (LAI) compared to no mulched ones. The black and transparent polyethylene mulched plants maintained the maximum leaf area index, and plants with no mulch maintained minimum LAI during the middle stage of growth. The variation in LAI occurs due to the variation with the branches per plant and with the expansion of leaves. The highest LAI from black or transparent polyethylene mulched plants could be attributed for higher soil temperature and availability of adequate soil water that might enhance leaf growth [33]. The results obtained from this study are also consistent with the results of Awal and Ikeda [16,17] in peanut (*Arachis hypogaea* L.) crop.

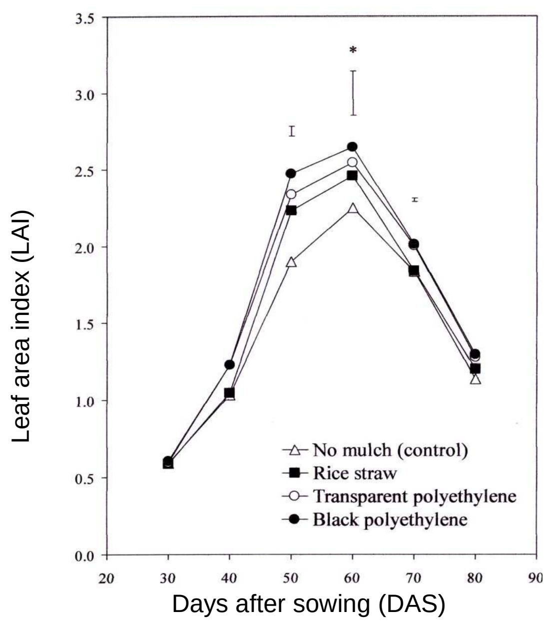

Fig. 8. Time-course of leaf area index (LAI) of pea crops grown with different mulches. Vertical bars represent the Least Significant Difference (LSD) at P<0.01 ($^*P$<0.05) while the plots without bar were not significant

3.5 Total Crop Dry Matter Accumulation

There was little dry matter accumulation following seedling emergence and a slow increase until about 50 DAS (Fig. 9). Thereafter, dry matter accumulation increased until maturity. The highest biomass was obtained from the plants grown with black or transparent polyethylene mulch, and the lowest in the plants from the plots with no mulch. Dry matter accumulation for a crop has a direct relation with leaf area index [34]. Plants grown in mulched plots had higher leaf area index than control plants in unmulched plots. This increase in LAI might contribute to accumulate higher amount of dry matter in plants grown with mulches. Application of mulches encourage dry matter accumulation in crops, and the phenomenon is supported by many workers such as Awal and Khan [13] with maize crop; Awal and Ikeda [16,17] and Awal et al. [35] with peanut (*Arachis hypogaea* L.) crop.

3.6 Pod Dry Matter Accumulation

Mulching had significant influence on the pod dry mater accumulation (Fig. 10). Following the initiation of pods, the pod dry matter from 50 DAS rapidly increased until physiological maturity of the crop. The highest pod dry matter was obtained from the plants grown with black or transparent polyethylene mulch whereas the lowest amount of dry matter was produced from plants grown with rice straw mulch or without mulch. As pod length and breadth were slightly larger from the plants grown with black or transparent polyethylene mulch (Table 1) the pod dry weight was obviously highest from the plants grown with black or transparent polyethylene cover. Awal and Khan [13] found the higher ear dry matter from the maize plants mulched with straw and other organic debris. Increase in weight of garlic (*Allium sativum* L.) bulbs with transparent polyethylene and straw mulches than that of no mulched plants was also reported [36].

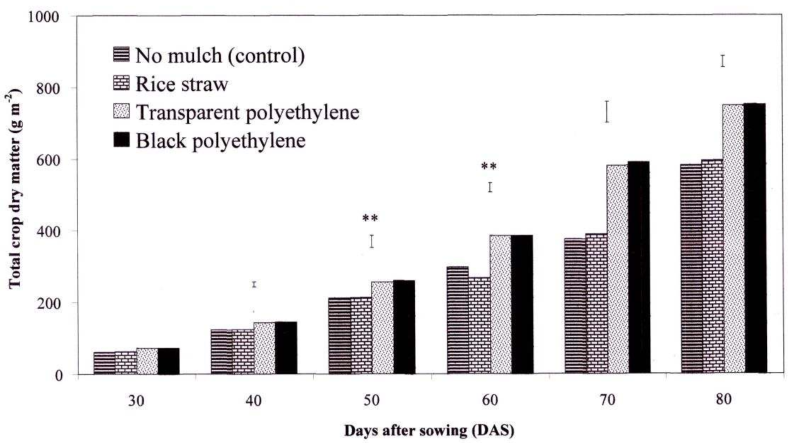

Fig. 9. Time-course of total dry matter (TDM) accumulation of pea crops grown with different mulches. Vertical bars represent the Least Significant Difference (LSD) at *P* = 0.05 (*P* = 0.01) while the data in a date without bar are not significant**

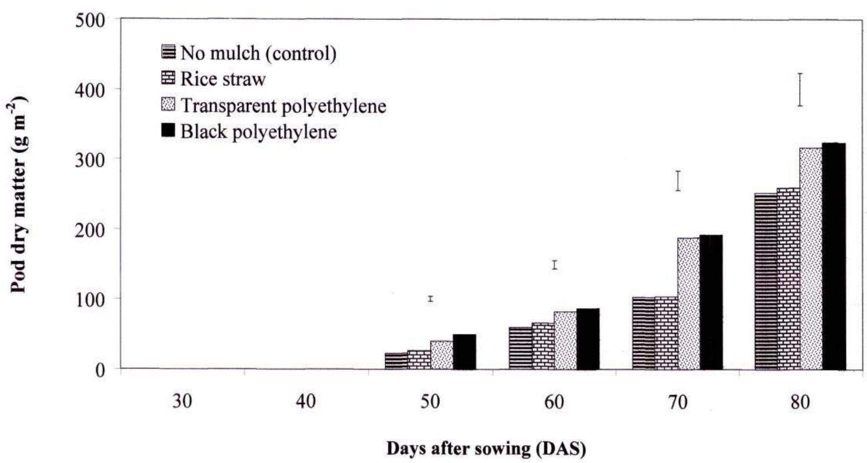

Fig. 10. Seasonal time-course of dry matter accumulation in pods of pea crops grown with different mulches. Vertical bars represent the Least Significant Difference (LSD) at *P* = 0.01)

3.7 Yield Contributing Characters

Some important yield attributes of pea such as number of pod per plant and seed per pod, seed weight per plant, and 100-seed weight showed significant differences for different mulches used (Table 1). Black or transparent polyethylene mulched plants exhibited the highest values of those traits whereas unmulched ones produced the lowest. Availability of soil water significantly improved the various yield attributes in pea [37]. Black and transparent polyethylene mulches retained higher amount of soil water with efficient use of nutrients, which might have enhanced plant growth consequently maximizing the yield attributes. The finding is in full agreement with the previous findings [17,32,35,38-40].

The higher values of pod length and breadth were obtained from the plants grown with black or transparent polyethylene mulch compared to the plants grown with rice straw mulched or no mulch condition (Table 1). However, the variation among the treatments was non-significant. A similar result was also reported by Savithri et al. [41] in soybean crop.

3.8 Grain or Seed Yield and Biological Yield

There was a remarkable variation in seed yield and biological yield due to the application of different mulch materials to the pea crop (Table 1). The highest seed yield and biological yield were observed from the crops grown with black or transparent polyethylene mulch, lowest yields were noticed in no mulched plot, and straw mulched crop ranked intermediate.

Seed yield in legumes is correlated positively with number pods per plant, 100-seed weight, and number of nodes in main stems [42]. Mulch covers increased soil water storage as well as number of pods and branches per plant and 100-seed weight, and these should contribute higher seed yields. This finding is supported well by the results of Sluyters et al. [32] and De et al. [37].

The higher biological yield from polyethylene mulched plants could be attributed due to the higher conservation of soil water along with higher soil temperature resulting in higher number of branches and pods per plant and higher leaf area index (LAI). This higher biological yield should contribute to higher seed yield. Higher biological yield harvested from crops due to the mulching was reported by Awal and Khan [13] with maize, Awal and Ikeda [16,17] with peanut, Suh et al. [31] with onion, and Rekoweska [43] and Baten et al. [44] with garlic. These findings support the present results.

3.9 Harvest Index (HI)

Harvest index is an important parameter that indicates the performance of a crop for partitioning it's assimilate to economic parts i.e., seed or grain. Overall 40% of assimilate was partitioned towards the seed of pea crops, and the mulching effect was almost nil (Table 1). Higher harvest index generally corresponds to higher grain yield provided that there is higher biological yield. Higher yield in plants is determined by physiological processes leading to a high net accumulation of photosynthetic products and their partitioning into seeds [45]. In this study, mulched plants accumulated a greater amount of biomass, i.e., biological yield, which was the reason for higher seed yield of pea as the HI remained unchanged due to the mulches applied.

Table 1. Yield components, yield, and harvest index of pea crops at physiological maturity subjected to different mulches

Treatment	Number of pod size (cm)				Seed weight/ plant (g)	100-seed weight (g)	Seed yield (t/ha)	Biological yield (t/ha)[1]	Harvest index (HI)[1] %
	Pod/ plant	Seed/ pod	Length	Breadth					
No mulch	16.27 b	3.86 b	6.56	1.43	4.26 b	42.50 b	4.26 b	5.82 b	40.0
Rice straw	16.54 b	4.22 b	6.70	1.53	4.38 b	43.60 b	4.38 b	5.95 b	40.2
Transparent polyethylene	18.38 a	4.84 a	7.33	1.56	5.54 a	54.75 a	5.54 a	7.39 a	40.2
Black polyethylene	19.17 a	5.05 a	7.63	1.58	5.66 a	56.25 a	5.66 a	7.50 a	40.4

In a column figures with same letter or without letter do not differ significantly whereas figures with dissimilar letters differ significantly at P = 0.01 (**), [1]Calculated as oven dry basis

4. CONCLUSION

Mulch covers had significant effects to alter soil microclimate. Transparent polyethylene film effectively elevated soil temperature followed by black film whereas rice straw cover reduced the soil temperature compared to unmulched soil. The soil water content was greater in all the mulched plots compared to the no mulched one. The transparent or black polyethylene mulched plots retained more soil water than the straw mulch or unmulched soil. Black polyethylene cover suppressed weed growth whereas transparent polyethylene enhanced it. Plant height, leaf area index, number of pods per plant and seeds per pod, seed size, biological yield, and seed yield were maximum in plants mulched with both black or transparent polyethylene and minimum in the plants grown with straw mulch or no mulch. Since black polyethylene cover suppressed weed growth and ensured higher yield, it would be the best mulch. Therefore, black polyethylene is recommended as an effective mulching material for the better yield of pea under the existing agro-climatic conditions of Bangladesh.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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