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Study of Non-woven Jute Agrotextile Mulches on Soil Water, Temperature and Nutrient Status in Root Zone in Broccoli (*Brassica oleracea* L.) Cultivation

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ABSTRACT

The field studies were conducted during the middle of November to end of February for the season of 2015–2016 and 2016–2017 respectively in the red lateritic soil of Bahadurpur village of Bolpur, Birbhum, West Bengal, India which lies between 23°39'47.69" N latitude and 87°37'36.91" E longitude with an average altitude of 58.9 m above the mean sea level under sub-humid semiarid region of West Bengal, Eastern India to evaluate the performance of different types of non-woven jute agro-textile mulches (NJATM) in comparison to other mulches on soil temperature, soil moisture, soil physical properties and yield of broccoli (*Brassica oleracea* L.). The highest pooled yield (8.50 t ha^{-1}) of broccoli was recorded in 350 gsm NJATM treatment. Minimum temperature fluctuation (1–3°C) was observed in case non-woven jute agro textile mulches and it was lowest in 350 gsm NJATM treatment followed by 400 gsm NJATM. In case of soil physical properties, the maximum mean value of hydraulic conductivity (0.54 cm hr^{-1}) was observed in 400 gsm NJATM. However, the lowest pooled Bulk Density was recorded in 400 gsm NJATM treatment (1.37 g cm^{-3}) which was, however, statistically at par with 350 gsm NJATM treatment (1.38 g cm^{-3}). The soil moisture was conserved in all treatments compared to control showing highest moisture content in 400 gsm NJATM treatment. Organic carbon content of soil was increased in all mulch treated plots compared to control, and their initial value and their highest value (0.64%) was recorded in 350 gsm NJATM treatment The NJATM of 350 gsm thickness was very effective compared to other mulches as a result of the soil management practices and productivity.

KEYWORDS: Broccoli, bulk density, hydraulic conductivity, NJATM, soil temperature, yield

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1. INTRODUCTION

Mulches are known to regulate the soil temperature which is an important factor in seed germination (Dwyer et al., 1990), root growth (Kaspar and Bland, 1992), root respiration (Burton et al., 1998) and water and nutrient uptake by plants (Kaspar and Bland, 1992). It directly and indirectly affects soil physical processes like infiltration (Singh, 1992), hydraulic conductivity (Ren et al., 2014) and movement of nutrients and chemicals (solute movement) in soil profiles (Grundmann et al., 1995; Vigil and Kissel, 1995). Soil temperature influences the solute movements in soils (Merdun, 2012), controls dissolved organic carbon export (Haei et al., 2010), its residence time in soils (Euskirchen, 2006; Oquist and Laudon, 2008), rates of mineralization (Haei et al., 2013; Rustad et al., 2001), global warming, precipitation pattern (Jungqvist et al., 2014) and decomposition of soil organic matter (Davidson and Janssens, 2006; Domisch et al., 2001; Melillo et al., 2002) as well as forest productivity (Stromgren and Linder, 2002). There is direct relationship between decomposition of organic matter and soil respiration (Leiros et al., 1999). Considering its significant contribution in soil weathering process, soil temperature regime has been included as classification criteria in the Soil Taxonomy (Gislason et al., 2009; Soil Survey Staff, 1999). As the measurement of soil temperature is limited in spatio-temporal scale, air temperature has often been used to estimate soil temperature by several researchers; Zheng et al., 1993). Although soil temperature is often difficult to monitor in spatio-temporal levels as installation of soil temperature measuring equipment in soil profile not only a costly affair but also tedious. Mulches restricts weed growth (Ossom et al., 2001), conserve soil moisture, promote crop development, early harvest, and increase yields (Manna et al., 2018). The use of nonwoven agrotextiles help in extending the growing season by maintaining enough soil humidity and increasing the soil temperature, protecting seeds and plants against storm, cold spells and hail damage (Marasovic, 2019) and increase crop yield (Bhavani et al., 2017). Non-woven jute agro-textile mulch (NJATM) made of natural jute fibres having high porosity high permeability, high carbon to nitrogen (C:N) ratio, high water absorbing power (~500%) composed of 83% cellulose, 12.5% lignin, 1.1% fat and wax and 1.8% nitrogenous matter show higher efficacy compared to others (Manna et al., 2018). The extent of impact of mulch on hydro-physical properties depends on the quantity and quality of mulch, soil properties and soil environment (Lal, 1995). Rate of application of mulch has no significant effect on saturated hydraulic conductivity between soil layers of 0 to 50 cm depth (Lal, 2000). However, Kahlon et al. (2013) attributed improved saturated hydraulic conductivity, reduction in bulk density and improvement in soil moisture status to mulching. Bulk density is dependent on organic matter content, texture and porosity (Dorner et al., 2010); and this is confirmed by Majaliwa et al. (2010) who reported lower bulk density in natural forest compared to tea and eucalyptus land uses. Dec et al. (2008) opined that mulching eases water flow and retention because it ensures pore continuity which influences higher saturated hydraulic conductivity. Blanco-Canqui and Lal (2007) reported significantly lower surface soil bulk density and higher saturated hydraulic conductivity under straw mulch than under non-mulched treatment.

Comprehensive information on effect of different NJATMs on soil physico-chemical properties like soil temperature, soil moisture, hydraulic conductivity, bulk density, nutrient status and broccoli yield is not available for the light textured, acidic, nutrient poor, low productive lateritic soils of West Bengal, India. Keeping in view of above, an experiment was designed and conducted for the first time in a farmer's field with the following objectives: (1) To assess the impact of different thickness non-woven jute agro-textile mulches (NJATMs) in comparison to other mulching treatments on soil hydro-thermal and nutrient status (2) To understand the yield contributing factors and identify economically viable and environment friendly mulching options in broccoli crop in rain fed area.

2. MATERIALS AND METHODS

2.1. Study area, design and treatments of the experiment

An experiment was conducted on Broccoli in the farmer's field conducted during the middle of November to end of February for the season of 2015–2016 and 2016–2017 respectively in the red lateritic soil of Bahadurpur village of Bolpur, Birbhum, West Bengal, India which lies between 23°39'47.69'' N latitude and 87°37'36.91'' E longitude with an average altitude of 58.9 m above the mean sea level under sub humid semiarid region of West Bengal .The soil of the experimental site was a typical lateritic soil (Typicochraqualf), sandy loam in texture with acidic pH, low in organic carbon, available N, available P and available K content. The weather data pertaining to the cropping seasons of 2015–16 and 2016–17 recorded at Meteorological Observatory Office, Dept. of Meteorology, Govt. of India, Sriniketan, Birbhum, West Bengal revealed that maximum temperature during the cropping period ranged from 36.65°C to 25.30°C in 2015-16 and 36.85°C to 23.98°C in 2016–17. The average annual rainfall was 1453 mm (Table 1 and 2).

The experiment was laid in randomized block design (RBD) with six treatments viz., T_1 (control, i.e. no mulching), T_2 (300 gsm NJATM), T_3 (350 gsm NJATM), T_4 (400 gsm NJATM), T_5 (rice straw; 10 t ha^{-1}) and T_6 (black polythene mulch of 50 μm)and four replications. Twenty days old

Table 1: Meterological data from November 2015 to March 2016

Month	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Max	Min	At 8.30 AM	At 5.30 PM	
November	31.40	17.90	77.00	72.00	4.90
December	26.20	14.00	78.00	69.00	1.40
January	25.30	11.20	81.00	68.00	39.50
February	29.90	16.90	77.00	68.00	31.70
March	35.00	21.10	69.00	57.00	16.30

Table 2: Meterological data from November 2016 to March 2017

Month	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Max	Min	At 8.30 AM	At 5.30 PM	
November	30.72	16.56	74.86	71.06	0.00
December	27.36	12.51	83.19	69.87	0.00
January	26.40	10.95	76.52	62.35	2.20
February	23.98	14.23	67.75	50.21	0.00
March	33.40	18.79	64.87	48.25	10.60

healthy broccoli seedlings were transplanted in the holes on the mulches of each of the experimental plot of 3.0×6.0 m^2 with row to row and plant to plant spacing were 1.0 and 0.5 m respectively in middle of November and the crop was harvested at the end of February. Supplementary nutrients were applied at the rate of 150, 100, 100 kg ha^{-1} N, P and K respectively in the form of urea, single super phosphate (SSP), muriate of potash (MOP) respectively. The entire amount of farm yard manure (5 t ha^{-1}), full SSP and MOP and 1/4th of urea were applied as basal dose and were thoroughly mixed with the soil during final land preparation. Soils were top dressed with rest amount of urea through application in three equal instalments at 15, 30 and 45 days after planting (DAP).

2.2. *Physico-chemical analysis of mulching materials*

The chemical constituents (Table 4) like lignin, hemicellulose, fat and wax (alcohol-benzene extract) and ash of mulching materials were estimated by TAPPI Standard Method (1971), the α-cellulose content by Sarkar et al., 1948 (Table 4), the Apparent Opening Size (O_{95}) in micron (ASTM D4751-16, 2016) and the thickness of NJATM was (Table 3) measured by ASTM D5199-16, 2016.

2.3. *Irrigation*

For establishment of plants 1st irrigation was applied at 1 DAP and there after irrigation was applied at 15 days interval up to 91 DAP (i.e., total seven numbers of irrigation was applied at 1 DAP, 16 DAP, 31 DAP, 46 DAP, 61 DAP, 76 DAP and 91 DAP). Irrigation water requirement was estimated through FAO method (Anonymous, 2020). Supplementary irrigation was provided through drip irrigation system.

Table 3: Physical properties of different mulching materials

Sl. No.	Notations	Treatments	Thickness / mass area^{-1}	The apparent opening Size (O_{95}) in micron
1.	T_1	Control , i.e. no mulching	Not applicable	Not applicable
2.	T_2	300 gsm non-woven jute agrotextile mulch (NJATM)	2.72 (mm)	285
3.	T_3	350 gsm non-woven jute agrotextile mulch (NJATM	3.10 (mm)	275
4.	T_4	400 gsm non-woven jute agrotextile mulch (NJATM	3.58 (mm)	245
5.	T_5	Rice straw	(10 t ha^{-1})	Not applicable
6.	T_6	Black polythene mulch	(50 μm)	Not applicable

T_1: No mulch; T_2: 300 gsm NJATM; T_3: 350 gsm NJATM; T_4: 400 gsm NJATM; T_5: Rice straw; T_6: Black polythene; NJATM: Non-woven jute agro-textile mulch

2.4. *Observation on growth and yield of broccoli*

During the crop growth and development periodic data on plant height (cm), numbers of leaves, weight of curds (g) and curd yield of broccoli (t ha^{-1}) were recorded. Three randomly selected plants at harvest from each replication were selected for recording of growth and yield of broccoli.

2.5. *Observation on soil temperature*

Soil temperature at 10 cm depth was measured with stainless steel Fisher brand bi-metal dial thermometers at 3 DAP, 30 DAP, 60 DAP, 90 DAP in broccoli field at 8.00, 12.00 and 16.00 h for all the replications of each treatment according to Ramakrishna et al. (2006).

2.6. *Soil moisture analysis*

The moisture content of soil samples collected at 15, 30, 60 and 90 days after planting (DAP) were determined by gravimetric method.

Table 4: Chemical properties of non-woven jute agrotextile mulching (NJATM) material

Component	Mulching materials		
	Non-woven jute agro-textile mulch (NJATM)	Rice straw	Black polythene
∞- Cellulose	59.91%	36.80%	Low density polythene is a thermo plastic made from the monomer ethylene ranging density from 0.915 to 0.925 g cm^{-3}. The thickness of used black polythene was 50 µm.
Hemicellilose	23.45%	25.60%	
Lignin	12.56%	10.30%	
Fat and wax	1.10%	5.42%	
Nitrogenous matter	1.80%	1.00%	
Ash content	0.70%	7.20%	

(Manna et al., 2018)

2.7. Observation on Soil bulk density and hydraulic Conductivity

The soil bulk density (g cm^{-3}) was determined by Core Method (Dastane, 1972) and hydraulic conductivity (cm hr^{-1}) was determined by Constant head method (Mohanty et al. 1994).

2.8. Chemical analysis of soil (0–15 cm)

The initial and post harvest soil pH (1:2.5; soil: water), soil organic carbon (%), Available soil nitrogen (N) content, available phosphorus (P) content and available potassium (K) were measured by standard method (Jackson, 1973; Walkley and Black, 1934; Subbaiah and Asija, 1956; Bray and Kurtz, 1945).

2.9. Statistical analysis

The data collected from the experiment were statistically analyzed following the procedures as described by Gomez and Gomez (1983). The level of significance used in "F" and "t" test was p=0.05. Critical difference values were calculated wherever the "F" test was significant.

3. RESULTS AND DISCUSSION

All the results have been presented as pooled data during the middle of November to end of February for the season of 2015–2016 and 2016–2017 for this field studies.

3.1. Effect on growth and yield of broccoli

The effect of different mulching on the plant height of broccoli at harvest during the middle of November to end of February for the season of 2015–2016 and 2016–2017 respectively is presented in Table 5. Mulching affected the plant height significantly in winter broccoli during both the years (Table 5). The highest plant height was recorded in T_3 (350 gsm NJATM) followed by T_4 (400 gsm NJATM) during both years. NJATM of all the thicknesses showed higher plant height than rice straw, black polythene mulch and control. However, the lowest average plant height was observed in T_1 (control). Highest average number of leaves per plant of broccoli was recorded in T_3 treatment i.e., in plot treated with 350 gsm NJATM during both the years (Table 5). However, lowest average number of leaves was recorded in T_1 treatment (no mulch) which was, however, statistically at par with T_5 and T_6 treatment i.e., in plot treated with rice straw and black polythene respectively. Highest average curd weight of broccoli was recorded in T_3 treatment i.e., in plot treated with 350 gsm non-woven jute agrotextile mulch (NJATM (Table 5). However, lowest average curd weight of broccoli was recorded in T_1 treatment (no mulch). Data on curd yield of broccoli as influenced by the mulching have been presented in Table 5. Mulching significantly influenced the pooled curd yield of broccoli. The highest curd yield of 8.5 t ha^{-1} was obtained under 350 gsm NJATM treatment (T_3) which was, however, statistically equal with T_4 (400 gsm NJATM). However, all mulched treatments recorded significant higher curd yield compared to control. A perusal of pooled data of curd yield of broccoli recorded that mulching significantly influenced the curd yield of broccoli. However, all NJATM treatments were significantly superior over rice straw mulch (T_5) and black polythene mulch (T_6). The superiority of bio-degradable 350 gsm NJATM over other thickness

Table 5: Effect of different mulching materials on growth and yield of broccoli at harvest

Treatments	Plant height (cm) at harvest	Number of leaves $plant^{-1}$ at harvest	Curd weight (g) at harvest	Broccoli yield (t ha^{-1}) at harvest
T_1	12.63	10.38	144.63	3.41
T_2	15.06	12.38	289.63	7.32
T_3	18.93	15.38	353.50	8.50
T_4	17.76	13.63	320.50	8.10
T_5	13.53	11.63	229.50	6.18
T_6	13.60	12.00	254.25	6.73
SEm±	0.273	0.528	3.878	0.12
CD (p=0.05)	0.777	1.502**	11.025**	0.345**

T_1: No mulch; T_2: 300 gsm NJATM; T_3: 350 gsm NJATM; T_4: 400 gsm NJATM; T_5: Rice straw; T_6: Black polythene; NJATM: Non-woven jute agro-textile mulch; **: Indicates F value is significant at (p=0.01) level of significance

of NJATM and rice straw, polythene mulch or no mulch in the experiment might be due to the beneficial effect of increased moisture conservation, increased organic carbon and nutrient status along with high weed control efficiency (Manna et al., 2018; Sarkar et al., 2019).

3.2. Effect of different mulches on soil temperature

The non-woven jute agro-textile mulches (NJATM) and other mulch treated soil had significantly higher temperature at 10 cm soil depth during winter season (Table 6) compared to control. It was observed that black polythene mulched soil recorded highest soil temperature at 10 cm soil depth compared to bare soil and other mulched soil in 3, 30, 60 and 90 DAP. The pooled highest soil temperatures at 10 cm soil depth at 3 DAP recorded during 8.00 h, 12.00 h and 16.00 h were 22.35°C (recorded in 400 gsm NJATM), 27.65°C (recoded in black polythene mulch) and 26.16°C (recorded in again in black polythene mulch) respectively. However, the lowest pooled soil temperatures were always recorded in control or bare soil. Again, different NJATM showed little variations of soil temperatures in the range of 23.36°C to 23.83°C. The soil temperatures at 30 DAP at different day time recorded almost similar trends. At 60 DAP at 8.00h the highest soil temperature (19.59°C) was recorded in 400 gsm NJATM and lowest soil temperature (18.63°C) was recorded by bare soil. However, the black polythene mulch and rice straw mulch recorded soil temperature 19.5°C and 18.83°C at 8.00 h. The soil temperature in bare soil at 10 cm depth at 60 DAP at 16.00 h was not increased so much and it was recorded lowest (20.96°C) among all the treatment, whereas the highest pooled soil temperature (24.04°C) was recorded in black polythene mulch followed by straw mulch. At 90 DAP at 8.00 h the highest pooled soil temperature (22.20 °C) was recorded in 400 gsm NJATM followed by 350 gsm NJATM and lowest soil temperature (20.48°C) was recorded in control i.e., in bare soil. The NJATM recorded temperature in the range of 23.39–22.75°C and black polythene mulch recorded highest soil temperature (25.91°C) followed by straw mulch (24.14°C) at 16.00 h at 90DAP. Results showed the minimum variation of soil temperature in 350 gsm followed by 400 gsm NJATM. The NJATM kept the soil warm in cool season in better way in comparison to bare soil and others. Black polythene mulch recorded higher temperature at 16.00 h than control and NJATM mulch which might be because of its absorption of more solar radiation compared to others and cooling down slowly. It is observed (Table 6) that black polythene mulch increased the soil temperature both day and night period. Rice straw and NJATM also increased the soil temperature and reduced soil temperature when atmospheric temperature was high. But due to proper aeration and increased soil moisture NJATM stabilized the soil temperature more effectively. The optimum soil temperature 20-25°C (Oswal, 1993) for winter broccoli was achieved by 350 gsm NJATM followed by 400 gsm NJATM. The high soil temperatures of mulched plots (straw and polythene) observed in this investigation were in good agreement with the results of Choi and Chung (1997) recording increase in soil temperatures by 2.8–9.48°C and 0.9–7.38°C due to placement of thermostats placed at surface soil. Increased soil temperatures observed in the mulched plots compared with the unmulched plots also agreed with the findings of Park et al. (1993) recording an increase in average soil temperature by 2.48°C at 15 cm

Table 6: Effect of different mulches on soil temperature (°C) at 10 cm depth at 3 DAP, 30 DAP, 60 DAP and 90 DAP

Treatment	Soil temperature (°C) at 10 cm depth at 3 DAP			Soil temperature (°C) at 10 cm depth at 30 DAP			Soil temperature (°C) at 10 cm depth at 60 DAP			Soil temperature (°C) at 10 cm depth at 90 DAP		
	At 8.00 h	At 12.00 h	At 16.00 h	At 8.00 h	At 12.00 h	At 16.00 h	At 8.00 h	At 12.00 h	At 16.00 h	At 8.00 h	At 12.00 h	At 16.00 h
T_1	20.99	23.28	22.14	19.03	21.40	21.99	18.63	20.30	20.96	20.48	22.21	23.76
T_2	21.68	24.31	23.83	20.50	23.69	22.86	19.03	24.13	23.34	20.99	23.96	23.39
T_3	22.04	24.58	23.36	21.29	23.16	22.33	19.36	23.70	22.83	22.00	23.34	22.54
T_4	22.35	24.66	23.60	21.73	23.65	22.78	19.59	23.86	23.35	22.20	23.60	22.75
T_5	21.41	25.28	24.83	19.49	27.00	25.49	18.83	24.53	24.04	20.73	24.65	24.14
T_6	22.01	27.65	26.16	20.01	28.44	26.99	19.50	27.34	25.89	21.51	26.94	25.91
SEm±	0.10	0.12	0.06	0.07	0.07	0.07	0.06	0.07	0.09	0.08	0.09	0.06
CD (p=0.05)	0.28**	0.33**	0.16**	0.20**	0.19**	0.21	0.18**	0.20**	0.27**	0.23**	0.25**	0.18**

T_1: No mulch; T_2: 300 gsm NJATM; T_3: 350 gsm NJATM; T_4: 400 gsm NJATM; T_5: Rice straw; T_6: Black polythene; NJATM: Non-woven jute agro-textile mulch; **: Indicates F value is significant at (p=0.01) level of significance

depth under transparent film while that of 0.88°C increase in soil temperature under black film mulch. There was an increase of 2.9–3.38°C in soil temperatures with application of transparent photodegradable polythene film mulching as reported by Duhr and Dubas (1990). The lower minimum and maximum soil temperatures was observed in plot treated non-woven jute agrotextile and rice straw mulch compared to polythene mulch and it might be due to the fact that the black polythene absorbed more solar radiation compared to straw mulch (Kumar et al., 2011). Byun et al., 1991 inferred that temperature of surface soil (0–10 cm) was always higher with polythene mulches compared to straw mulch or no mulch. The results show that different mulching materials have varying effects on soil temperature.

3.3. Effect of mulches on soil moisture content

Soil moisture is an important parameter influencing nutrient dynamics and the activity of microorganisms in the rhyzosphere and growth of broccoli. Soil moisture content was lowest at T_1 (no mulch) in comparison to other NJATM and other mulch treatments at 15, 30, 60 and 90 DAP (Table 7). The bare soil of T_1 was exposed to heat and wind and lost more moisture through evapo-transpiration due to higher weed population density. Data also revealed that moisture content was lowest at 15 DAP and increased in the order 90DAP <60 DAP <30 DAP in all the treatments compared.Soil moisture content in 15, 30, 60 and 90 DAP was found to be highest in T_4 (400 gsm NJATM) treatment followed by T_3(350 gsm NJATM) >T_2 (300 gsm NJATM) >T_6 (Black Polythene) >T_5 (Rice Straw) >T_1 (No Mulch) treatment respectively in decreasing order. Higher soil moisture content was observed in mulch treated plots compared to control because of increased water retention capacity in the soil, conservation of moisture due to surface cover and reduced weed population density. Increased moisture content data in mulchedplots are in agreement with the reports of several other studies on effect of mulches on soil moisture status (Ramakrishna et al., 2006; Jordan et al., 2010; Manna et al., 2018). The moisture use efficiency of the crop, was increased significantly by 70.27% in Non-woven jute agro-textile mulch due to the treatments over control (Sarkar et al., 2018).

Table 7: Effect of different mulching materials on soil moisture content

Treatments	Moisture content (%)			
	At 15 DAP	At 30 DAP	At 60 DAP	At 90 DAP
T_1	6.59	7.32	7.02	6.97
T_2	8.94	14.53	13.83	13.50
T_3	11.11	16.21	15.76	14.77
T_4	12.71	18.73	16.93	15.25
T_5	7.41	10.21	9.54	9.30
T_6	8.38	12.02	11.25	10.24
SEm±	0.10	0.19	0.17	0.12
CD (p=0.05)	0.28**	0.55**	0.49**	0.33**

T_1: No mulch; T_2: 300 gsm NJATM; T_3: 350 gsm NJATM; T_4: 400 gsm NJATM; T_5: Rice straw; T_6: Black polythene; NJATM: Non-woven jute agro-textile mulch; **: Indicates F value is significant at (p=0.01) level of significance

3.4. Post harvest soil properties

3.4.1. Effect on pH, EC and organic carbon content of post harvest soil

Highly significant variation in soil properties after harvest of Broccoli in respect of initial value was observed after statistical analysis of the pooled data except soil pH and EC under different treatments (Table 8). After analysis of pooled data, it was observed that the percentage of organic carbon increased significantly over control and its value was highest (0.64%) in 350 gsm NJATM mulched plot (Table 8). The soil organic carbon content increased with mulching treatments in spite of reduction in weed population density in mulched treated plots compared to control. It may be attributed to higher broccoli yield and its contribution to organic C through incorporation of roots and crop residues in the soil. Moreover, nutrient immobilization and organic matter accumulation was favoured by application of NJATM with higher C:N ratio and lignin content (12.56%) leading to addition of organic material with exhausted mulch in the soil. The result was in agreement with the report of other researchers who showed mulching affected SOM content and soil moisture

Table 8: Effect of different mulches pH, EC and organic carbon of post-harvest soil

Treatments	pH	EC (mhos cm^{-1})	Organic carbon (%)
T_1	4.91	0.08	0.38
T_2	4.90	0.08	0.47
T_3	4.98	0.08	0.64
T_4	4.98	0.09	0.62
T_5	4.91	0.09	0.42
T_6	4.90	0.08	0.45
SEm±	0.036	0.002	0.006
CD (p=0.05)	NS	NS	0.017**

T_1: No mulch; T_2: 300 gsm NJATM; T_3: 350 gsm NJATM; T_4: 400 gsm NJATM; T_5: Rice straw; T_6: Black polythene; NJATM: Non-woven jute agro-textile mulch; **: Indicates F value is significant at (p=0.01) level of significance

conservation (Youkhana and Idol, 2009). Chaparro et al., 2012 opined that, organic mulches with good amount of organic matter might improve soil properties and activities of soil microbes after its incorporation in the soil.

3.4.2. Effect on hydraulic conductivity and bulk density of soil

The data pertaining to the effect of different mulches on saturated hydraulic conductivity of soil after harvest of broccoli crop are presented in Table 9. Pooled data showed that mulch had significant effect on saturated hydraulic conductivity of soil. The initial saturated hydraulic conductivity of the experimental field was 0.20 cm hr^{-1}. The mean maximum value of 0.54 cm hr^{-1} hydraulic conductivity was observed in T_4 followed by T_3 (0.46 cm hr^{-1}) and minimum of 0.20 cm hr^{-1} was noted in control. However, straw mulch and polythene mulch showed higher mean hydraulic conductivity value over control or no mulching. Mulching increases the soil porosity which in turn led to significant improvement in the saturated hydraulic conductivity. The larger the soil pores, the more water is easily transmitted through the soil. These finding are in good agreement with Dec et al. (2008).

Bulk density (BD) of experimental soil was significantly influenced by different mulching materials (Table 9). Pooled data of BD of post harvest soil revealed that the highest BD was observed in control i.e., T_1 (1.41 g cm^{-3}) which was, however, statistically at par with T_2 (300 gsm NJATM), T_5 (Rice Straw) and T_6 (Black Polythene). However, the lowest pooled BD was recorded in T_4 (1.37 g cm^{-3}) which was, however, statistically at par with T_3 (1.38 g cm^{-3}). Such decrease in BD of soil might be due to increased soil moisture, organic matter contents which in turn created favourable environment for penetration of plant roots. After decomposition of non-woven jute agro-textile mulches improve the physical, chemical and biological properties of the soil by enriching soil both with organic matter and plant nutrients increasing crop yield. And as a result of that aeration and soil microbial activities were enhanced due to lose and friable soil and resulted decrease in BD of post harvest soil. The similar result of decrease in BD as compared to control due to addition of mulches like coir pith @ 20 t ha^{-1}, press mud @ 10 t ha^{-1} was also reported by Mayalagu (1983) in heavy black soil. Efficient use of jute agro textile as soil conditioner by decreasing the bulk density and increases tomato productivity was reported by Adhikari et al., 2018. The decrease in bulk density under straw mulch (1.42 g cm^{-3}) compared to bare soil (1.50 g cm^{-3}) was noted by Lal et al. (1996). Mulching increased soil moisture, and organic matter contents leading to the decrease in bulk density.

Table 9: Effect of different mulches on hydraulic conductivity and bulk density of soil

Treatments	Hydraulic conductivity (cm hr^{-1})	Bulk density (g cm^{-3})
T_1	0.20	1.41
T_2	0.41	1.40
T_3	0.46	1.38
T_4	0.54	1.37
T_5	0.33	1.40
T_6	0.31	1.40
SEm±	0.007	0.007
CD (p=0.05)		

T_1: No mulch; T_2: 300 gsm NJATM; T_3: 350 gsm NJATM; T_4: 400 gsm NJATM; T_5: Rice straw; T_6: Black polythene; NJATM: Non-woven jute agro-textile mulch; **: Indicates F value is significant at (p=0.01) level of significance

4. CONCLUSION

Considering the impact of different mulching materials, NJATM plot recorded significantly higher productivity (8.5 t ha^{-1}) of broccoli over rice straw and black polythene. In order to achieve good mulching impact through improved hydrothermal condition, reduced soil compaction and enriched nutrient status required for optimal broccoli yield; mulching with 350 gsm NJATM is recommended to the farmers for dry red and lateritic soil of West Bengal.

5. REFERENCES

Adhikari, N., Saha, A., Bandopadhyay, P., Mukharjee, S., Tarafdar, P.K., De, S.K., 2018. Efficinet use of jute agro textile as soil conditioner to increase tomato productivity. Journal of Crop and Weed 14(1), 122–125.

Anonymous, 2020. FAO land and water development division1986.Available from. Accessed on 19th December, 2020.

Bhavani, K., Mallikarjun, Ningdalli, Sunilkumar, N.M. 2017. Agro textiles-their applications in agriculture and scope for utilizing natural fibers in agro tech sector. International Journal of Applied Home Science 4(7 & 8), 653–662.

Blanco-Canqui, H., Lal, R., 2007. Impacts of long-term wheat straw management on soil hydraulic properties under no tillage. Soil Science Society of America Journal 71, 1166–1173.

Bray, R.H., Kurtz, L.T., 1945. Determination of total organic and available forms of phosphorus in soil. Soil Science 59, 39–45.

Burton, A.J., Pregitzer, K.S., Zogg, G.P., Zak, D.R., 1988. Drought reduces root respiration in sugar maple forests. Ecological Applications 8(3), 771–778.

Byun, J.K., DoJ, H., Chang, K.H., 1991. The effects of black polyethylene film and rice straw mulches on vegetative growth and mineral element content of young jujube trees. Journal of Korean Society of Horticultural Science 32, 81–86.

Chaparro, J.M,, Sheflin, A.M., Manter, D.K., Vivanco, J.M., 2012. Manipulating the soil microbiome to increase soil health and plant fertility. Biology and Fertility of Soils 48, 489–499.

Choi, B.H., Chung, K.Y., 1997. Effect of polythene-mulching on flowering and yield of groundnut in Korea. International Arachis Newsletter 17, 49–51.

Davidson, E.A., Janssens, I.A., 2006. Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. Nature 440, 165–173.

Dec, D., Dorner, J., Beeker-fazekas, O., Horn, R., 2008. Effect of bulk density on hydraulic properties of homogenized and structural soils. Revista de la Ciencia Sueloy Nutricion Vegetal 8, 1–13.

Domisch, T., Finer L., Lehto, T., 2001. Effects of soil temperature on biomass and carbohydrate allocation in Scots pine (*Pinus sylvestris*) seedlings at the beginning of the growing season. Tree Physiology 21, 465–472.

Dorner, J., Sandoval, P., Dec, D., 2010. The role of soil Structure on the pore functionality of an ultisol**.** Journal of Soil Science and Plant Nutrition 10(4), 495–508. http://dx.doi.org/10.4067/S0718-95162010000200009

Duhr, E., Dubas, A., 1990. Effect of covering the soil with plastic film on the dynamics of plant development and yield of maize sown on different dates.Prace Komisji Nauk Rolniczych i Komisji Nauk Le-nych 69, 9–18.

Dwyer, L.M., Hayhoe, H.N., Culley, J.L.B., 1990. Prediction of soil temperature from air temperature for estimating corn emergence. Canadian Journal of Plant Science 70, 619–628.

Euskirchen, E., McGuire, A.D., Kicklighter, D.W., Zhuang, Q., Clein, J.S., Dargaville, R.J., Dye, D.G., Kimball, J.S., McDonald, K.C., Melillo, J.M., Romanovsky, V.E., Smith, N.V., 2006. Importance of recent shifts in soil thermal dynamics on growing season length, productivity, and carbon sequestration in terrestrial high latitude eco-systems. Global Change Biology 12, 731–750.

Gislason, S.R., Oelkers, E.H., Eiriksdottir, E.S., Kardjilov, M.I., Gisladottir, G., Sigfusson, B., Snorrason, A., Elefsen, S., Hardardottir, J., Torssander, P., Oskarsson, N., 2009. Direct evidence of the feedback between climate and weathering. Earth and Planetary Science Letters 277, 213–222.

Gomez, K.A., Gomez, A.A., 1983. Statistical procedures for agricultural research (2nd Edn.). New York: John Wiley and Sons.

Grundmann, G.L., Renault, P., Rosso, L., Bardin, R., 1995. Differential effects of soil water content and temperature on nitrification and aeration. Soil Science Society of America Journal 59, 1342–1349.

Haei, M., Oquist, M.G., Kreyling, J., Ilstedt, U., Laudon, H., 2013. Winter climate controls soil carbon dynamics during summer in boreal forests. Environmental Research Letters 8, 024017.

Haei, M., Oquist, M.G., Buffam, I., Agren, A., Blomkvist, P., Bishop, K., Lofvenius, M.O., Laudon, H., 2010. Cold winter soils enhance dissolved organic carbon concentrations in soil and stream water. Geophysical Research Letters, 37.

Jackson, M.L., 1973. Soil chemical analysis, 1973. New Delhi :Prentice Hall of India Pvt. Ltd ., 183–193.

Jordan, A., Zawala, L.M., Gill, J., 2010. Effects of mulching on soil physical properties and runoff under semi-arid conditions in southern Spain. Catena 81(1), 77–85. https://doi. org/10.1016/j.catena.2010.01.007.

Kaspar, T.C., Bland, W.L., 1992. Soil temperature and root growth, (USA). Soil Science 154(4), 290–297.

Kahlon, M.S., Lal, R., Ann-Varughese, M., 2013. Twenty two years of tillage and mulching impacts on soil physical characteristics and carbon sequestration in Central Ohio. Soil & Tillage Research 126, 151–158.

Kumar, S., Dey, P., 2011. Effects of different mulches and irrigation methods on root growth, nutrient uptake, water-use efficiencyand yield of strawberry. Scientia Horticulturae 127(3), 318–324.

Lal, H., Rathore, S.V.S., Kumar, P., 1996. Influence of irrigation and mixtalol spray on consumptive use of water, water use efficiency and moisture extraction pattern of coriander. Indian Journal of Soil Conservation 24, 62–67.

Lal, R., 2000. Mulching effects on soil physical quality of an alfisol in western Nigeria. Land degradation and development 11(4), 383–392. https://doi. org/10.1002/1099-145X(200007/08)11:4<383::AID-LDR393>3.0.CO;2-6

Lal, R., 1995. The role of residues management in sustainable agricultural systems. Journal of Sustainable Agriculture 5(4), 51–78. DOI: 10.1300/J064v05n04_06

Leiros, M.C., Trasar-cepeda, C., Seoane, S., Gil-Sotres, F., 1999. Dependence of mineralization of soil organic matter on temperature and moisture. Soil Biology and Biochemistry 31, 327–335.

Majaliwa, J.G.M., Twongyirwe, R., Nyenje, R., Oluka, M., Ongom, B., Sirike, J., Mfitumukiza, D., Azanga, E., Natumanya, R., Mwerera, R., Barasa, B., 2010. The

Effect of land cover change on soil properties around Kibaale National Park in South Western Uganda. Applied and Environmental Soil Science. Article ID 185689, doi:10.1155/2010/185689.

Marasovic, P., Kopitar, D., 2019. Overview and perspective of nonwoven agrotextile. Textile & Leather Review Journal 2(1), 32–45.

Manna, K., Kundu, M.C., Saha, B., Ghosh, G.K., 2018. Effect of non-woven jute agrotextile mulch on soil health and productivity of broccoli (*Brassica olaracea* L.) in lateritic soil. Environment Monitoring and Assessment 190(82), 1–10.

Mayalagu, K., 1983. Influence of different soil amendments on the physical properties of a heavy black soil and yield of groundnut TMV-7 in the Periyar Vaigai command area. Madras Agricultural Journal 70, 304–308.

Melillo, J.M., Steudler, P.A., Aber, J.D., Newkirk, K., Lux, H., Bowles, F.P., Catricala, C., Magill, A., Ahrens, T., Morrisseau, S., 2002. Soil warming and carbon-cycle feed backs to the climate system. Science 298(5601), 2173–2176.

Merdun, H., 2012. Effects of different factors on water flow and solute transport investigated by time domain reflectometry in sandy clay loam field soil. Water, Air, & Soil Pollution 223, 4905–4923. DOI 10.1007/s11270-012-1246-x.

Oquist, M., Laudon, H., 2008. Winter soil frost conditions in boreal forests control growing season soil CO_2 concentration and its atmospheric exchange. Global Change Biology 14, 2839–2847.

Ossom, E.M., Pace, P.F., Rhykerd, R.L., Rhykerd, C.L., 2001. Effect of mulch on weed infestation, soil temperature, nutrient concentration,and tuber yield in *Ipomoea batatus* (L.) Lam. In Papua New Guinea. Tropical Agriculture 78, 144–151.

Oswal, M.C., 1994. A text book of soil physics. New Delhi : Oxford and IBH Publishing Co. Pvt. Ltd.

Park, K.Y., Kim, S.D., Lee, S.H., Kim, H.S., Hong, E.H., 1993. Differences in dry matter accumulation and leaf area in summer soybeans as affected by polythene film mulching. RDA Journal of Agriculture Science 38, 173–179.

Ramakrishna, A., Tam, H.M., Wani, S.P., Long, T.D., 2006. Effect of mulch on soil temperature, moisture, weed infestation and yield of groundnut in northern Vietnam. Field Crops Research 95, 115–125.

Ren, J., Shen, Z., Yang, J., Zhao, J.,Yin, J., 2014. Effects of temperature and density on hydraulic conductivity of silty clay under infiltration of low-temperature water. Arabian Journal of Science and Engineering 39, 461-466. DOI10.1007/s13369-013-0849-x.

Rustad, L.E., Campbell, J.L., Marion, G.M., Norby, R.J., Mitchell, M.J., Hartley, A.E., Cornelissen, J.H.C., Gurevitch, J., 2001. A meta-analysis of the response of soilrespiration, net nitrogen mineralization, and above ground plant growth to experimental ecosystem warming. Oecologia 126, 543–562. doi: 10.1007/s004420000544.

Sarkar, A., Ghosh, A., Pradhan, S., Tarafdar, P.K., De, S.K., 2019. Determination of thermal use efficiency of potato and broccoli grown under different strength of jute agro textile.Crop Research 54(4), 89–93

Sarkar, A., Barui, S., Tarafdar, P.K., De, S.K., 2018. Jute agro textile as a mulching tool for improving yield of green gram. International Journal of Current Microbiology and Applied Sciences 7(05), 3604–3611. doi: https://doi.org/10.20546/ijcma 705.416

Sarkar, A., Ghosh, A., Tarafdar, P., De, S.K., 2019. Assessing the water and Thermal use efficiency of Groundnut (*Arachis hypogaea*) grown under Different Strength of Jute AgroTextile mulch in India. Current Journal of Applied Science and Technology 37(4), 1–10.

Singh, V.P., 1992. Elementary hydrology. Prentice-Hall. USA: Englewood Cliffs NJ.

Stromgren, M., Linder, S., 2002. Effects of nutrition and soil warming on stem wood production in a boreal Norway spruce stand. Global Change Biology 8, 1194–1120.

Subbaiah, B.V., Asija, G.L., 1956. A rapid procedure for the estimation of available nitrogen in soil. Current Science 25, 259–260.

Vigil, M.F., Kissel, D.E., 1995. Rate of nitrogen mineralized from incorporated crop residues as influenced by temperature. Soil Science Society of American Journal 59, 1636–1644.

Walkley, A., Black, I.A., 1934. An examination of degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science 37, 29–37.

Youkhana, A., Idol, T.W., 2009. Tree pruning mulch increases soil carbon and nitrogen in shade and full sun coffee agroecosystems in Hawaii. Soil Biology and Biochemistry 41, 2527–2534.

Zhang, Y., Chen, W., Smith, S.L., Riseborough, D.W., Cihlar, J., 2005. Soil temperature in Canada during the twentieth century: Complex responses to atmospheric climate change. Journal of Geophysical Research 110, D03112. doi:10.1029/2004JD004910.

Zheng, D., Hunt Jr, E.R., Running, S.W., 1993. A daily soil temperature model based on air temperature and precipitation for continental application. Climate Research 2, 183–191.