International Research Journal of Pure & Applied Chemistry

21(17): 40-48, 2020; Article no.IRJPAC.61387
ISSN: 2231-3443, NLM ID: 101647669

Soil Hydrothermal Regimes, Biological Activity and Nutrient Availability under Various Mulches and Weed Management Practices in Tomato

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IRJPAC/2020/v21i1730264
Editor(s):
(1) Dr. Wolfgang Linert, Vienna University of Technology Getreidemarkt, Austria.
Reviewers:
(1) Valéria Priscila de Barros, University of Sergipe (UFS), Brasil.
(2) Sadeq H. Lafta, University of Technology, Iraq.
Complete Peer review History: http://www.sdiarticle4.com/review-history/61387

Original Research Article

Received 19 July 2020
Accepted 23 September 2020
Published 07 October 2020

ABSTRACT

The impact of different mulching materials and weed management practices on soil properties were evaluated by a field study conducted at College of Horticulture, Rajendranagar during 2015 with tomato as test crop**.** The experiment was laid out in randomized block design with seven treatments consisting of control (unweeded check), pendimethalin (PE) @1.0 kg *a.i.* ha^{-1} + hand weeding at 30 DAT, black polythene mulch, reflective polythene mulch, paddy straw mulch, paddy husk mulch, hand weeding two times (20 DAT & 40 DAT) and replicated thrice. The mean temperature was higher by 1.7°C under black polythene mulch compared to control (bare soil) and it was less by 1.8 °C under paddy straw mulch. Soil moisture content under black polythene mulch was significantly higher by 31.21%, 36.07% and 24.19% respectively at 20, 40 DAT and at harvest. In the initial stages i.e., at 20 DAT, reflective polythene mulch (28.81%) and paddy husk mulch (24.52%) were also equally effective in maintaining soil moisture on par to that of black polythene mulch. Significantly highest dehydrogenase activity (8.62 and 6.17 µg of TPF released $g^{-1}day^{-1}$ respectively), acid phosphatase activity (121.81 and 92.15 µg of PNP released $g^{-1}hr^{-1}$ respectively) and alkaline phosphatase activity (135.19 and 106.10 µg of PNP released $g^{-1}hr^{-1}$ respectively) were recorded under paddy straw mulch at 40 days after transplanting and after harvest. Similarly,

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significantly highest bacterial count (7.49 log_{10} CFU g $soil^{-1}$ and 7.34 log_{10} CFU g $soil^{-1}$), fungal count (4.53 log_{10} CFU g $soil^{-1}$ and 4.36 log_{10} CFU g $soil^{-1}$) and actinomycetes count (5.42 log_{10} CFU g $soil^{-1}$ and 5.26 log_{10} CFU g $soil^{-1}$) at 40 DAT and after harvest respectively were high under paddy straw mulch. Availability of nitrogen and phosphorus was high under reflective polythene mulch while that of potassium under straw mulch. Weed management either through pre-emergence application of pendimethalin @1.0 kg a.i. ha^{-1} + hand weeding at 30 DAT or by hand weeding two times (20 DAT & 40 DAT) did not influence the soil properties significantly.

Keywords: Tomato; mulching; soil temperature; moisture; enzyme activity; microbial population; nutrient availability.

1. INTRODUCTION

Tomato is the most-sought-after vegetable in the cuisine of Telangana as well as in India and is being cultivated across the country. Successful tomato cultivation largely depends on the cultural practices and efficient use of available resources. Soil moisture is very important in tomato production however, soil moisture is lost by transpiration from the plant leaves and evaporation from the soil. Conservation of soil moisture may help to prevent the loss of water through evaporation permitting maximum utilization of moisture by plants. Extensive research in the past indicates that mulches modify soil hydrothermal regimes in crop root zone, conserve soil moisture, keep down weeds and promote soil productivity. However, the magnitude of the desired effects depends on the quality, quantity, durability of mulch material, soil type and climatic conditions [1]. Soil temperature is agriculturally more significant than aerial temperature with respect to crop growth [2]. Favorable soil temperature for the growth of nitrogen fixing bacteria generally ranges from 20 to 25°C. Different types of mulch can be used to modify soil thermal regimes which lead to better crop production. Soil temperature is one of the most important factors that affect the soil heat storage, soil heat flux, soil water flux, seed emergence, nutrient transformation, transport, uptake and plant growth. In the climate change era (with increased frequency of heavy rainfall and high terminal heat), mulching materials should be extensively used especially under rainfed conditions for soil and moisture/water conservation, temperature moderation, soil health maintenance and increased productivity.

2. MATERIALS AND METHODS

A field experiment was laid out with seven treatments and three replications in randomized block design with Arka Vikas variety of tomato *(Solanum lycopersicon L.)* as test crop at research farm of College of Horticulture, Rajendranagar, Hyderabad. The treatments include control or unweeded check (T_1), pre-emergence application of pendimethalin @1.0 kg a.i. ha^{-1} + hand weeding at 30 DAT (T_2), black polythene mulch (T_3), reflective polythene mulch (T_4), paddy straw mulch (T_5), paddy husk mulch (T_6), hand weeding two times at 20 DAT & 40 DAT (T_7). Black polythene and reflective polythene mulch of 30 microns thickness were spread over on raised plots of T_3 and T_4 treatments respectively. For the purpose of transplanting the seedlings holes of 4–5 cm diameter were made in the film at the recommended spacing and 3–5 cm of moist soil was put at the base of stem of transplanted seedling to conserve moisture and temperature. Paddy straw mulch of 10 cm thickness was created manually by spreading straw as carpet on raised plots of T_5 treatment after 5 days of planting. Paddy husk mulch of 5 cm thickness was also created similarly on raised plots of T_6 treatment. Mulch material was kept in the respective plots until the final harvest of tomato. Hand weeding was done at 20 and 40 days after transplanting for controlling weeds in treatment T_7. Application of herbicide, pendimethalin (PE) @ 1.0 kg a.i.ha^{-1} + hand weeding at 30 DAT was done for controlling weeds in treatment T_2. The crop was transplanted on 2nd January, 2015 and final picking/harvest was done on 7th May, 2015.

The experimental soil was sandy clay loam in texture, neutral in reaction (pH-6.14), non saline with electrical conductivity of 0.14 dSm^{-1}, medium in organic carbon (0.53%) and available phosphorus (36.1 kg ha^{-1}). The status of available nitrogen (232.0 kg ha^{-1}) and available potassium (120.3 kg ha^{-1}) were low. The analytical methods outlined by Piper [3] were adopted for soil analysis. Soil temperature at 5 cm depth was measured with stainless steel Fisher brand bi-metal dial thermometers having a stem length of 20.3 cm, gauge diameter of 4.5 cm, and accuracy of 1.0% of dial range at any point of dial. Observations were recorded during the crop growth period at 8:00 am and 2:00 PM in both mulched and unmulched plots. Moisture content of soil was determined at 20 DAT, 40 DAT and at harvest. Percent soil moisture content was determined gravimetrically by oven drying the soil samples at 105°C until constant weight and by using the following equation:

$$Moisture\ Content(\%) = \frac{FW-ODW}{ODW} \times 100$$

Where:

FW = Fresh weight of soil in grams
ODW = Oven dry weight of the soil in grams

Soil enzyme activity before planting, at 40 DAT and after harvest was measured both in terms of activity of soil enzymes viz., Dehydrogenase, Alkaline phosphatase, acid posphatase and also the microbial population. Dehydrogenase activity was determined as per Thalmann [4] method, modified by Alef and Nannipieri [5] by incubating the soil with 2, 3, 5 triphenyl-tetrazolium chloride (TTC) and measured the triphenyl formazan (TPF) produced at 485 nm. Alkaline and acid phosphatases were determined according to Tabatabai and Bremner method [6] by incubating soil with p-nitrophenyl phosphate disodium and measuring the p-nitrophenol (PNF) released at 400 nm.

The serial dilution plate technique [7] was employed to enumerate the rhizosphere soil bacteria (CFU X 10^6 g soil^{-1}), fungi (CFU X 10^3 g soil^{-1}) and actinomycetes (CFU X 10^4 g soil^{-1}). Nutrient agar, potato dextrose agar and actinomycetes isolation agar media were used for isolation of soil bacteria, fungi and actinomycetes respectively. The inoculated petri plates were incubated at 30±1°C for 24 hours, 25±1°C for 5 days and 30±1°C for one week for bacteria, fungi and actinomycetes respectively. After the incubation period, the colony forming units were counted using a colony counter and expressed as CFU g^{-1} of soil on a moisture free basis.

Available nitrogen was estimated by alkaline permanganate method [8] and expressed in kg ha^{-1}. While Available phosphorus content of the soil was extracted with sodium bicarbonate as outlined by Olsen et al., [9] and expressed in kg ha^{-1} and available potassium was estimated by neutral normal ammonium acetate method [10] using flame photometry and expressed in kg ha^{-1}.

3. RESULTS AND DISCUSSION

Soil temperature and moisture are the important hydrothermal properties that showed distinct variation with agronomic crop management practices.

3.1 Soil Temperature

Soil temperature during the crop growth period i.e., from January to May (at 8 AM and 2 PM) was significantly influenced by mulching practices (Table 1). The mean soil temperature from January to May at 8 AM was ranging from 19.0°C to 22.6°C. Plastic mulches maintained higher soil temperature compared to organic mulches throughout the crop growth. The mean temperature was higher by 1.7°C under black polythene mulch compared to control (bare soil) and it was less by 1.8°C under paddy straw mulch. A mean temperature difference of 3.6°C was recorded in between black polythene mulch (T_3) and paddy straw mulch (T_5). At 2 PM, mean soil temperature in different treatments was ranging from 27°C to 30.7°C. The trend of temperature differences was similar to that at 8 AM. On an average temperature difference of 3.7°C was noticed between black polythene mulch (T_3) and paddy straw mulch (T_5). The highest soil temperature was recorded under black polyethylene mulch and it was 1.6 to 1.7°C more than the unweeded control.

In general, this effect was more evident during the early crop season when tomato plants shaded less soil surface. Black plastic mulches are more effective in increasing soil temperature due to a greater net radiation under the mulch compared to bare soil. This observation is in consonance with the properties of black bodies as good heat emitters as well as good heat absorbers. The heat radiated from the sun during the day is absorbed by the black plastic mulch and emitted to the soil surface which was transmitted through the soil in proportion to the heat received. The effect of mulching material on soil temperature obtained in this study is in agreement with those reported by Haynes [11] and Streak et al. [12]. Black plastic mulches raise soil temperatures quickly so that plants can increase growth resulting in earlier and higher yields compared to bare ground production [13]. Soil temperature under black plastic mulch was 2.2 to 3.4°C more than bare soil [14].

The soil temperature under reflective polyethylene mulch was lower compared to black

Table 1. Soil temperature during crop growth period of tomato under different mulching and weed management practices

Treatment	Soil temperature (°C) at 8 AM					Mean	Soil temperature (°C) at 2 PM					Mean
	Jan	Feb	Mar	Apr	May	(8 AM)	Jan	Feb	Mar	Apr	May	(2 PM)
T_1	16.9	18.1	21	22.8	26	20.9	24.9	26.7	28.8	30.5	34.5	29.1
T_2	16.3	17.5	20.6	22.1	25.8	20.4	24.1	26.4	28.4	30.2	34.2	28.7
T_3	18.4	20.6	22.5	24.2	27.6	22.6	26.3	28.2	30.6	32.1	36.2	30.7
T4	15.8	16.8	19.6	21.7	25.3	19.8	23.1	25.5	27.5	29.2	33.5	27.8
T_5	14.8	16.1	18.8	21	24.7	19.0	22.1	24.6	26.7	28.6	32.8	27.0
T_6	15.1	16.5	19.2	21.4	25	19.4	22.5	25.1	27.1	28.9	33.2	27.4
T_7	16.6	17.8	20.2	22.4	25.6	20.5	24.3	26.1	28.2	29.9	33.9	28.5
SE (m)±	0.11	0.18	0.25	0.32	0.35		0.27	0.22	0.22	0.29	0.45	
CD*(P=.05)*	0.34	0.57	0.78	1.02	1.10		0.84	0.70	0.69	0.93	1.42	

T_1 – Control; T_2 - Pendimethalin (PE) @1.0 kg a.i. ha^{-1} + hand weeding at 30 DAT; T_3 - Black polythene mulch; T_4 -Reflective polythene mulch; T_5 - Paddy straw mulch; T_6 - Paddy husk mulch; T_7 - Hand weeding two times (20 DAT & 40 DAT); SE (m)±- Standard error of mean; CD-Critical difference

polyethylene mulch as it reflects most of the light. For this reason, the reflective mulches are recommended to establish a crop when soil temperatures are high and any reduction in soil temperature is beneficial. In the present study also soil temperature under reflective mulch is less than black polythene mulch. The low soil temperature recorded by the paddy straw mulch and paddy husk mulch may be due to prevention of direct contact of solar radiation with the soil by the organic mulches. Straw mulches at 20 cm depth curtailed soil temperature by l.1-5.6°C [15]. This result is in agreement with those reported by Nkansah et al. [16] and Norman et al. [17] who indicated that organic mulches were more effective in reducing soil temperature compared to the control. Pre-emergence application of pendimethalin @1.0 kg a.i. ha^{-1} + hand weeding at 30 DAT treatment recorded 0.2 to 0.6°C lower temperatures at 8 AM and and 0.3 to 0.8 °C at 2 than control. Similarly, hand weeding two times at 20 DAT & 40 DAT registered 0.3 to 0.8 °C lower temperatures at 8 AM and 0.6 °C at 2 PM than control but the variation was nonsignificant.

3.2 Soil Moisture

Different mulching practices significantly influenced the moisture content of soil at 20 DAT, 40 DAT and at harvest (Table 2). Soil moisture content under black polythene mulch (T_3) was significantly higher at 20, 40 DAT and at harvest with 31.21%, 36.07% and 24.19% respectively. At 20 DAT, reflective polythene mulch (28.81%) and paddy husk mulch (24.52%) were also equally effective in maintaining soil moisture on par to that of black polythene mulch. Lowest moisture content of 18.76%, 20.27% and 14.33% was recorded in unweeded control (T_1) at 20, 40 DAT and at harvest respectively. Gravimetric soil moisture did not vary with weed management either through chemical or hand weeding.

Table 2. Soil moisture content (%) under different mulching and weed management practices in tomato

Treatment	Soil moisture content (%)		
	20 DAT	40 DAT	At harvest
T_1 - Control (Unweeded check)	18.76	20.27	14.33
T_2 - Pendimethalin (PE) @1.0 kg a.i. ha^{-1} + hand weeding at 30 DAT.	19.63	22.41	15.31
T_3 - Black polythene mulch	31.21	36.07	24.19
T_4 -Reflective polythene mulch	28.81	32.40	22.23
T_5 - Paddy straw mulch	22.37	25.27	20.52
T_6 - Paddy husk mulch	24.52	26.31	19.48
T_7 - Hand weeding two times (20 DAT & 40 DAT)	20.21	21.37	16.33
SE (m)±	2.19	2.95	1.68
CD*(P=.05)*	6.82	9.20	5.26

The increased moisture content in black polythene and other mulches might be attributed to adequate soil cover provided by the mulches. This prevented contact between the soil and dry air, which reduced water loss into the atmosphere through evaporation. Also, mulches reduce impact of raindrops and splash, thereby preventing soil compaction, reducing surface run-off and increasing water infiltration. All these combined to increase the soil moisture content and reduce moisture depletion. Higher soil moisture content increases root proliferation and thus enhances availability of nutrients to crop roots. The moisture content in straw mulch is higher compared to control but lower compared to black polythene mulch. The ability of organic mulch to conserve soil moisture was appreciably lower than that of the polyethylene mulch [18]. Better soil moisture conservation with straw mulches has also been reported by Singh et al. [19] and Dalorima et al. [20].

3.3 Soil Enzyme Activity

Different mulching practices significantly influenced the soil enzyme activity (dehydrogenase, acid and alkaline phosphatase) at 40 DAT and after harvest (Table 3). Enzyme activity increased from initial status to 40 DAT and decreased again by harvest.

3.3.1 Dehydrogenase activity

Dehydrogenase activity is thought to reflect the total scope of activity of soil microflora and is consequently a good indicator of microbial activity [21]. Initially the soil had a dehydrogenase activity of 6.14 µg of TPF $g^{-1}day^{-1}$. The results revealed that the dehydrogenase activity (DHA) in all the treatments was high at 40 DAT and decreased by the time of harvest. Among the treatments paddy straw mulch recorded significantly highest dehydrogenase activity at 40 DAT (8.62 µg of TPF $g^{-1}day^{-1}$) and at harvest (6.17 µg of TPF $g^{-1}day^{-1}$) which was on par with paddy husk mulch (7.89 µg of TPF released $g^{-1}day^{-1}$ at 40 DAT and after harvest 5.42 µg of TPF $g^{-1}day^{-1}$). Lowest dehydrogenase activity was observed under black polythene mulch (3.38 and 1.71 µg of TPF $g^{-1}day^{-1}$ at 40 DAT and after harvest respectively) and was on par with DHA under reflective polythene mulch (4.25 and 2.57 µg of TPF $g^{-1}day^{-1}$ at 40 DAT and after harvest respectively).

3.3.2 Acid phosphatase activity

Phosphatase enzymes are believed to be involved in mineralizing organic phosphorus to inorganic phosphorus. The activity of acid phosphotase in the initial soil was 106.79 µg of PNP released $g^{-1}hr^{-1}$ and was significantly highest under paddy straw mulch with 121.81 and 92.15 µg of PNP released $g^{-1}hr^{-1}$ at 40 DAT and harvest respectively. Black polythene mulch (T_3) treatment recorded lowest acid phosphatases activity of 63.92 and 36.68 µg of PNP released $g^{-1}hr^{-1}$ at 40 DAT and at harvest.

3.3.3 Alkaline phosphatase activity

The initial soil sample registered an acid phosphatase activity of 90.63 µg of PNP released $g^{-1}hr^{-1}$. The results on alkaline phosphatase activity revealed that paddy straw mulch has recorded significantly highest alkaline phosphatase activity at 40 DAT (135.19 µg of PNP released $g^{-1}hr^{-1}$) and also at harvest (106.10 µg of PNP released $g^{-1}hr^{-1}$). However, black polythene mulch (T_3) has recorded lowest alkaline phosphatases activity of 66.22 and 44.83 µg of PNP released $g^{-1}hr^{-1}$ at 40 DAT and after harvest respectively.

The increased soil enzyme activity in paddy straw mulch might be attributed reason that addition of organic matter through straw mulch acted as a substrate for soil enzymes resulting in increased activity levels of various soil enzymes. Soil enzyme activities were found to be significantly and positively correlated with organic carbon content which supports a more general theory of enzyme activity increasing with organic inputs, regardless of the source [22&23]. Results had also shown that residue incorporation in the soil can increase the activity levels of various soil enzymes [24,25]. Zhao et al. [26] found that alkaline phosphatase in the topsoil (0–15 cm) was higher with straw compared with the control. Martens et al. [27] stated that straw incorporation provided organic matter that was used as a substrate for soil enzymes. Dick et al. [28] stated that the increase in alkaline phosphatase was due to higher levels of endoenzymes in the viable microbial populations and increased levels of accumulated soil enzymes in the soil matrix by application of paddy straw mulch. The results are in agreement with findings of Siczek and Lipiec [29] and Buck et al. [30].

Table 3. Soil dehydrogenase activity, acid phosphatase activity and alkaline phosphatase activity at 40 DAT and after harvest of tomato under different mulching and weed management practices

Treatment	Dehydrogenase (µg of TPF $g^{-1}day^{-1}$)		Acid phosphatase (µg of PNP $g^{-1}hr^{-1}$)		Alkaline phosphatase (µg of PNP $g^{-1}hr^{-1}$)	
	40 DAT	At harvest	40 DAT	At harvest	40 DAT	At harvest
T_1	4.92	3.30	72.71	44.55	79.69	58.17
T_2	4.75	3.12	73.12	46.97	82.52	60.52
T_3	3.38	1.71	63.92	36.68	66.22	44.83
T_4	4.25	2.57	69.30	42.83	75.61	53.37
T_5	8.62	6.17	121.81	92.15	135.19	106.10
T_6	7.89	5.42	107.72	80.74	111.21	88.31
T_7	5.04	3.58	73.39	43.45	78.13	59.73
SE (m)±	0.29	0.28	2.33	3.63	2.89	2.95
CD*(P=.05)*	0.90	0.88	7.27	11.31	9.01	9.22

3.4 Microbial Population in the Soil

Population of soil microbes' viz., bacteria, fungi and actenomycetes varied under different treatments (Table 4).

3.4.1 Bacteria

Lowest bacterial count of 7.27 CFU g $soil^{-1}$ and 7.10 CFU g $soil^{-1}$ was recorded at 40 DAT and after harvest respectively under black polythene mulching. Bacterial count under reflective polythene mulch (7.30 CFU g $soil^{-1}$ and 7.13 CFU g $soil^{-1}$), hand weeding two times (7.34 CFU g $soil^{-1}$ and 7.20 CFU g $soil^{-1}$), pendimethalin (PE) @ 1.0 kg a.i ha^{-1} + hand weeding at 30 DAT (7.34 CFU g $soil^{-1}$ and 7.19 CFU g $soil^{-1}$) and unweeded control (7.32 CFU g $soil^{-1}$ and 7.18 CFU g $soil^{-1}$) was on par at 40 DAT and after harvest. However population was highest under paddy straw mulch (7.49 and 7.34 CFU g $soil^{-1}$) at 4 DAT and harvest.

3.4.2 Fungi

Mulching with paddy straw also registered significantly highest fungal count of 4.53 CFU g $soil^{-1}$ and 4.36 CFU g $soil^{-1}$ at 40 DAT and after harvest. At harvest, the fungal population under paddy husk mulching (4.33 CFU g $soil^{-1}$) was on par to that of paddy straw mulch. However, black polythene mulching resulted in lowest fungal count at 40 DAT (4.34 CFU g $soil^{-1}$) and after harvest (4.19 CFU g $soil^{-1}$). Similarly, reflective polythene mulch (4.38 CFU g $soil^{-1}$ at 40 DAT and 4.23 CFU g $soil^{-1}$ after harvest) and pendimethalin (PE) @ 1.0 kg a.i ha^{-1} + hand weeding at 30 DAT (4.26 CFU g $soil^{-1}$ after harvest) recorded low and on par fungal population as that of black polythene mulching.

3.4.3 Actinomycetes

Similar to bacterial and fungal population, actinomycetes count was significantly highest under paddy straw mulch both at 40 DAT (5.42 CFU g $soil^{-1}$) and after harvest (5.26 CFU g $soil^{-1}$). An on par actinomycetes count was registered with paddy husk mulch (5.39 CFU g $soil^{-1}$ at 40 DAT and 5.24 CFU g $soil^{-1}$ after harvest). However, black polythene mulch has recorded lowest actinomycetes count of 5.24 CFU g $soil^{-1}$ and 5.09 CFU g $soil^{-1}$ at 40 DAT and after harvest. The other treatments, reflective polythene mulch (5.27 CFU g $soil^{-1}$ and 5.13 CFU g $soil^{-1}$), unweeded control (5.28 CFU g $soil^{-1}$ and 5.15 CFU g $soil^{-1}$), pendimethalin (PE) @ 1.0 kg a.i ha^{-1} + hand weeding at 30 DAT (5.29 CFU g $soil^{-1}$ and 5.18 CFU g $soil^{-1}$) and hand weeding two times (5.30 CFU g $soil^{-1}$ and 5.16 CFU g $soil^{-1}$) recorded low and on par at 40 DAT and after harvest.

The highest microbial population in paddy straw mulch might be attributed to addition of organic carbon by paddy straw mulch which is required for growth and multiplication of microorganisms. Straw mulching stimulates soil microorganisms owing to loose, well aerated soil conditions, uniform moisture and temperatures. Gong et al. [31] stated that crop residue provided abundant organic matter, which supported the growth of microorganisms. Martens et al. [32] stated that the microbial population was increased by straw incorporation, due to provision of organic matter as a substrate. Rose [33] reported that straw have high carbon to nitrogen ratio. The findings are in close conformity with findings of Duppong et al. [34] and Shashidhar et al. [35].

Table 4. Soil microbial population at 40 DAT and after harvesting of tomato under different mulching and weed management practices

Treatment	Bacteria (CFU X 10^6 g^{-1} of soil)		Fungi (CFU X 10^3 g^{-1} of soil		Actinomycetes (CFU X 10^4 g^{-1} of soil)	
	40 DAT	**At harvest**	**40 DAT**	**At harvest**	**40 DAT**	**At harvest**
T_1	7.32	7.18	4.44	4.29	5.28	5.15
T_2	7.34	7.19	4.42	4.26	5.29	5.18
T_3	7.27	7.10	4.34	4.19	5.24	5.09
T_4	7.30	7.13	4.38	4.23	5.27	5.13
T_5	7.49	7.34	4.53	4.36	5.42	5.26
T_6	7.44	7.28	4.49	4.33	5.39	5.24
T_7	7.34	7.20	4.44	4.29	5.30	5.16
SE (m)±	0.03	0.04	0.02	0.02	0.02	0.09
CD(*P=.05*)	0.11	0.11	0.05	0.06	0.07	0.03

3.5 Nutrient Availability (N, P and K) at Harvest

Variations in soil physic-chemical properties (pH and electrical conductivity) though were non-significant; the available nutrient status (N, P and K) of soil was significantly influenced by different mulching practices (Table 5).

Available nitrogen content in soil at harvest was significantly higher in all mulching treatments than control. Reflective polythene mulch (T_4) has recorded significantly highest available nitrogen (235.73 kg ha^{-1}). However, the treatments viz., hand weeding two times (234.8 kg ha^{-1}), pendimethalin (PE) @ 1.0 kg a.i ha^{-1} + hand weeding at 30 DAT (229.7 kg ha^{-1}), paddy husk mulch (227.7 kg ha^{-1}), black polythene mulch (224.1 kg ha^{-1}) and paddy straw mulch (223.24 kg ha^{-1}) also had nitrogen content on par to that of reflective polythene mulch. Significantly lowest available nitrogen was recorded in unweeded control (188.45 kg ha^{-1}). Similarly, available phosphorus at harvest under reflective polythene mulch (T_4) was significantly highest (36.74 kg ha^{-1}). The treatments viz., hand weeding two times (36.02 kg ha^{-1}), paddy husk mulch (35.30 kg ha^{-1}), paddy straw mulch (34.92 kg ha^{-1}), black polythene mulch (34.42 kg ha^{-1}) and pendimethalin (PE) @ 1.0 kg a.i ha^{-1} + hand weeding at 30 DAT (32.23 kg ha^{-1}) also recorded on par available phosphorus content. Unweeded control (T_1) recorded significantly lowest available phosphorus (26.03 kg ha^{-1}) than all other treatments. The increased availability of available nitrogen and phosphorus in reflective polythene mulched plot might be attributed to the optimum soil temperature, optimum soil moisture levels, reduction in nutrients leaching and lower uptake of nutrients by weeds. Higher availability of nutrients may be attributed to the conductive temperature availability.

Available potassium status under paddy straw mulch (253.52 kg ha^{-1}) was significantly highest and was on par with paddy husk mulch (250.23 kg ha^{-1}) and black polythene mulch (247.87 kg ha^{-1}). However, lowest available potassium was recorded in unweeded control (182.29 kg ha^{-}). The treatments, pendimethalin

Table 5. Soil p^H, EC, bulk density and available N, P and K at harvesting of tomato under different mulching and weed management practices

Treatment	p^H	Electrical conductivity (dSm^{-1})	Nutrient availability (kg ha^{-1})		
			Nitrogen	**Phosphorus**	**Potassium**
T_1	7.86	0.35	188.45	26.03	182.29
T_2	8.11	0.22	229.70	32.23	187.50
T_3	7.99	0.25	224.07	34.42	247.87
T_4	7.89	0.27	235.73	36.74	214.87
T_5	8.09	0.27	223.24	34.92	253.52
T_6	8.21	0.20	227.65	35.30	250.23
T_7	8.02	0.41	234.82	36.02	199.33
SE (m)±	N.S	N.S	6.37	1.57	6.20
CD at 5%	N.S	N.S	19.87	4.89	19.33

(PE) @ 1.0 kg a.i ha-1 + hand weeding at 30 DAT (187.50 kg ha^{-1}) and hand weeding two times (199.33 kg ha^{-1}) also recorded lower potassium content and on par with control. The increased availability of available potassium in paddy straw mulched plot might be attributed to addition of potassium to the soil which is present in the straw. Tan et al. [36] reported that the level of potassium in the straw comprised approximately 80% of that in the whole plant, most of which was returned to the soil, thereby increasing the K content. Broschat [37] found that plots mulched with organic materials had significantly higher soil potassium concentrations than no mulched plots.

4. CONCLUSIONS

Study revealed that during the cold seasons/ months polythene mulches help in increasing the soil temperature but organic mulches like paddy straw or paddy husk have beneficial effect on soil biological properties, nutrient transformations and availability.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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