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Influence of different organic mulches on soil hydrothermal and plant growth parameters in potato crop (*Solanum tuberosum* L.)

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ABSTRACT

Present study was conducted to investigate the effect of different mulching materials on soil hydrothermal environment and plant growth parameters for potato crop at field experimental station of National Institute of Technology, Hamirpur in the humid sub-tropical agro climate of Western Himalayas. The field experiments were conducted in a randomized complete block design with four mulching treatments; wheat straw mulch, pine needle mulch, rice straw mulch and no mulch in three replications. An increase in soil moisture retention ranging from 5.14% to 42% was observed depending upon the mulch material and depth of the soil layer in root zone. Mulching also reduced the daily maximum soil temperature up to 3.5ºC with an average temperature reduction of 1-2ºC during the period of tuber formation. Mulching produced beneficial effects on root depth, plant height, leaf area index and tuber yield. Mulching helped to bring about a yield surplus of 1.7-4.4 tonnes ha^{-1} over unmulched conditions and an increase in water use efficiency which varied from 13.5% in rice straw mulch to 34.9 % inwheat straw mulch.

Key words : Mulching, soil moisture, soil temperature, tuber yield, water use efficiency

Potato ranks fourth in production after rice, wheat and maize in the world and hence has a very important place in world agriculture. World produced 388 million tonnes potato from 19.3 million ha planted area with an average yield of 20.11 tonnes ha^{-1} in 2017. India ranks 2nd in potato production with an average yield of 22.3 tonnes ha^{-1} (FAO2019). Potato being a shallow rooted crop, it often requires small frequent irrigations in order to obtain a successful crop. Magnitude and quality of produce largely depends on a proper balance between soil, air and soil moisture available in the plant root zone throughout the crop growth period (Singh *et al.,* 2012). Mulching is an approach to enhance efficiency of irrigation besides improving potato tuber yield (Banerjee *et al.,* 2016). Mulch has a favourable effect on soil physical and chemical properties by retaining soil moisture and maintaining soil temperature, preventing soil compaction and positively affecting pH, organic carbon, water holding capacity and bulk density of the soil (Singh *et al.,* 2005).Though several organic mulch materials have been used in potato crop (Panging *et al*., 2019) the precise inputs on the comparative effectiveness of the mulching materials on soil hydrothermal properties and growth parameters of potato is lacking. In present study an effort has been made to evaluate various organic mulch materials i.e. wheat straw mulch (WM), rice straw mulch (RM) and pine needle mulch (PM)with the objective to study the effect of different mulching materials on selected soil hydrothermal properties,plant parameters and translate the effect produced on tuber yield in terms of water use efficiency (WUE).

MATERIALS AND METHODS

The investigations were conducted at field experimental station of National Institute of Technology, Hamirpur, Himachal Pradesh, located at 31°42'40" N latitude; 76°31'33"E longitude; with an elevation of 900 m above mean sea level. The region belongs to sub-humid mid hills of western Himalayas with an average annual rainfall of 1572 mm, 80 percent of which falls during June to September due to South West monsoons. The rainfall received during the period of investigation (24th January 2018 to 21st May, 2018) was 180 mm. The soil of the area was sandy loam with sand, silt and clay content of 77.32%, 14.44% and 8.24%, respectively and a bulk density of 1.59 gcm^{-3}.The popular variety of potato "KufriJyoti" was used as test crop. The experiments comprised of four treatments viz. Wheat strawnulch, Rice straw mulch, Pine middle mulch and No mulchreplicated three times according to randomized complete block design (RCBD). The sowing of potato tubers was done on 24th January, 2018 in ridge and furrow pattern having ridge to ridge spacing of 450 mm and plant to plant

Table 1: Average soil moisture in various mulch treatments

Treatment	Mean soil moisture (%)			Average soil moisture (%)
	100 mm	200 mm	300 mm	
Wheat mulch (WM)	20.12	15.79	13.30	16.40
Pine mulch (PM)	19.54	18.18	23.36	20.36
Rice mulch (RM)	18.84	17.36	18.79	18.33
No mulch (NM)	14.15	15.02	18.66	15.94

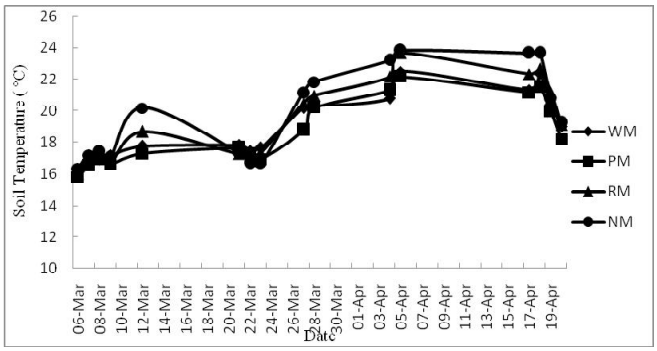

Fig. 1: Effect of different mulch treatments on daily mean soil temperature

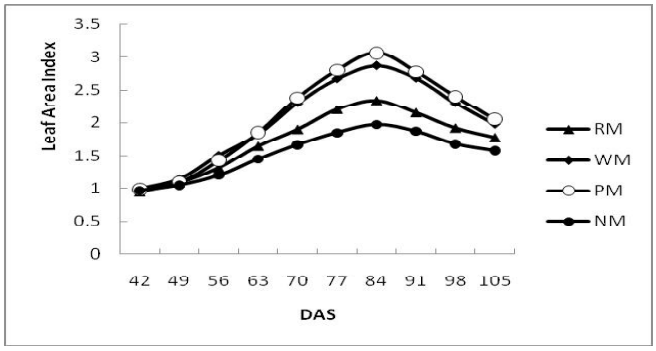

Fig.2: Effect of different mulch treatments on Leaf Area Index

spacing of 150 mm. The mulches were spread on the ridges @ 10 tonnes ha^{-1} at first earthing up after 30 days of sowing (DAS). All the plots were irrigated uniformly to a depth of 30 mm as per crop requirement and total eleven irrigations were applied during the crop period. The crop was harvested on 21st May 2018 with a crop period of 118 days.

Analysis of soil hydrothermal properties

Selected soil properties viz. soil moisture, soil temperature, bulk density and porosity were determined. As the potato crop is shallow rooted, investigations on the soil characteristics was confined to 300 mm soil depth. The soil moisture content was determined by using soil moisture probe - Diviner 2000 (Sentek Pty Ltd.,Stepney, South Australia). PVC pipes of 50 mm diameter were inserted into the field to a depth of 500 mm in the middle of each plot and soil moisture data at depths of 100mm, 200mm and 300mm were recorded. The temperatureof the soil was recorded at 100 mm depth using dial gauge soil thermometer by inserting the sensor needle below the soil surface thrice a dayat 9:00hrs, 14:00hrs and 17:00 hrs. For determination of the bulk density and porosity of the soil; undisturbed soil samples were collected from the crop root zone after harvesting of the crop using core cutter sampler.

Crop parameters

Investigationson plantgrowth characteristics e.g. plant height, root depth, leaf area index (LAI) and tuber yield were carried out. The plant emergence occurred at 30 DAS. The root depth, plant height and LAI were measured after six weeks of sowing and continued till maturity with seven days interval. Yield from each treatment was recorded at the harvest of the crop, to investigate the effect of the soil properties on crop development and growth.WUE was worked out using the procedure described by Meshram*et al*. (2018):

$$\text{WUE (Kg ha}^{-1}\text{mm}^{-1}) = \frac{\text{Tuber yield (kg ha}^{-1})}{\text{Water applied through irrigation (mm)}}$$

RESULTS AND DISCUSSION

Soil hydrothermal properties

The daily soil moisture data recorded at 100mm, 200 mm and 300 mm soil depths and average soil moisture data combined for all depthsare presented in Table 1, respectively. At 100 mm soil depth the soil moisture was significantly high in all the mulch treatments as compared to No mulch (NM) treatment, being maximum for Wheat mulch (WM) followed by Pine mulch (PM) and Rice mulch (RM). The increase in soil moisture in mulched plots with reference to plots without any mulch at 100 mm soil depth was 42 %, 38 % and 32 % in WM, PM and RM plots, respectively. At 200 mm soil depth, the order of soil moisture content in various treatments was PM>RM>WM>NM. At this depth, per cent increase in soil moisture over NM reduced to 5.12 %, 21.02 % and 15.58 % for WM, PM and RM, respectively. At 300 mm soil

Table 2: Effect of different mulch treatments on bulk density and porosity

S.No.	Type of Mulch	Bulk density (gcm^{-3})	Porosity (%)
1	Wheat mulch (WM)	1.54	41.88
2	Rice mulch (RM)	1.56	41.13
3	Pine mulch (PM)	1.57	40.75
4	No mulch (NM)	1.59	40

Table 3: Effect of different mulch treatments on tuber yield and water use efficiency

S.No.	Type of Mulch	Tuber yield (tonnes ha^{-1})	WUE($kg\ ha^{-1}mm^{-1}$)
1	Wheat mulch (WM)	17.0	51.52
2	Rice mulch (RM)	16.6	47.27
3	Pine mulch (PM)	14.3	43.33
4	No mulch (NM)	12.6	38.18

depth, the soil moisture was least in WM, at par in RM and NM and highest in PM.

The results of present investigations indicated that at the small applied levels of uniform irrigation, wheat straw absorbed maximum water and checked water from percolating to lower soil layers. This resulted in maximum soil moisture at 100 mm depth and least at 300 mm depth in WM which is particularly suitable for shallow rooted crops like potato. In PM and RM the distribution of moisture was consistent at all the three depths with average soil moisture being maximum for PM.

Overall, the mulches helped to keep the daily mean soil temperature low as depicted in Fig.1. There was negligible difference in temperature among the mulching materials used. Temperature reducing effect of mulches can be explained in terms of the fact that mulch materials have a poor conducting surface, due to which lesser solar radiation is able to penetrate the soil and as a result, soil temperature remains low in mulched plots. Bodlaender (1963) reported a range of 15°C to 24°C to be the optimum soil temperature for tuber formation and development. This cooling effect obtained by mulching was particularly desirable for potato crop in the month of March and April, because this is the period of crop growth when tuber formation takes place. In present study it was observed that when the soil temperature increased to 26.5°C, the mulches reduced the soil temperature to 23.5°C, a factor favourable for increased tuber production. The temperature reducing effect of organic mulches in potato has been observed by Panging *et al.* (2019).

The bulk density of soil in NM was 1.59 gcm^{-3}. Mulching caused slight decrease in bulk density, which was observed to be 1.54 gcm^{-3}, 1.57 gcm^{-3} and 1.56 gcm^{-3} in WM, PM and RM, respectively. This resulted in a corresponding increase in soil porosity (Table 2). Such findings have been observed by Pervaiz*et al.*(2009) who reported that straw mulch decreased bulk density and increased porosity.

Plant growth parameters

The observed LAI for entire crop period is shown in Fig. 2. The maximum LAI values were attained at 84 days after sowing; which were 3.06, 2.87, 2.34 and 1.97 for PM, WM, RM and NM, respectively. The average increase in LAI observed was 38.79% in PM, 37.70% in WM and 13.79% in RM over NM. More LAI recorded in case of PM and WM is correlated to the consistent high moisture and root proliferation up to 300mm soil layer in PM and highest moisture retention in top most soil layer in WM, the region from which maximum root water uptake takes place. This resulted in better plant growth and LAI.

A significant difference in the tuber yields of mulched and unmulched plots was observed (Table 3). The tuber yield obtained from WM, PM, RM and NM plots were 17.0, 16.6, 14.3 and12.6 tonnes ha^{-1}, respectively. This indicated that use of mulch could bring about a yield surplus of 1.7-4.4 tonnes ha^{-1} over unmulched conditions. An increase in tuber yield of 3-4 tonnes ha^{-1} has also been reported by Saha *et al*. (1997) and Panging *et al*. (2019). Positive effects of mulching in increasing tuber yield have also been reported by Banerjee *et al.* (2016) and Dash *et al*. (2018). Mulching significantly led to an increase in the WUE for potato under all treatments of mulches as given in Table 3. The increase recorded in WUE as a result of mulching varied from 13.5% in RM to 34.9% in WM as compared to NM. The results are in conformity with the studies of Kar and Kumar (2007), Banerjee *et al*. (2016)and Dash *et al.*(2018) who reported

significantly higher WUE in the mulched plots as compared to the unmulched plots.

CONCLUSION

Mulching exerts a significant effect on soil hydrothermal properties and plant growth parameters, specifically tuber yield, in potato crop. Mulches have significant influence on soil moisture retention in root zone with wheat mulch showing maximum retention in top soil layer. Mulching also reduced maximum soil temperature by 3.5°C during tuber bulking with an average soil moisture reduction of 1-2°C during entire crop season for the crop under study. The effective soil moisture retention and significant reduction in soil temperature in root zone, influenced various plant growth parameters such as root depth, plant height, LAI, tuber growth, which resulted in better crop yield and increased WUE. Improved soil hydrothermal characteristics due to mulching i.e. maximum soil moisture retention in the top soil layer and favorable temperature in root zone, are best utilized by shallow rooted crop like potato. Performance of WM is found to be best followed by PM and RM in improving the soil hydrothermal characteristics.

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