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Organic Mulching Effects on Water Productivity, Soil Temperature, Growth and Yield of Lentil Varieties

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ABSTRACT

The experiment was conducted at College of Post Graduate Studies in Agricultural Sciences, Umiam, Meghalaya during the *rabi* season (November–April, 2022) to study the effect of organic mulching on growth, yield and water productivity of lentil varieties in mid-hills of Meghalaya. The experiment was carried out in split plot design with four mulch treatment under main plot (M_0: Un-mulch/control, M_1: Paddy straw mulch, M_2: Maize stover mulch, M_3: Weed mulch) and four varietal treatments under sub plot (V_1: HUL-57, V_2: PL-4, V_3: PDL-1 and V_4: PSL-9) which were replicated thrice. Results indicated that, plant height, number of branches plant^{-1}, water productivity were highest under paddy straw mulch. Paddy straw mulch (43.57) which was on par with weed mulch (41.29) has reported significantly highest number of pods plant^{-1} over maize stover mulch (38.18) and un-mulch (36.21) treatments. Different mulches have reported economic yield advantage of 21.01% to 10.55% over the control. Water productivity has found significantly higher under paddy straw mulch (3.25 kg ha^{-1} mm^{-1}) over the control treatment (2.57 kg ha^{-1} mm^{-1}). Mulches also modified soil thermal regimes and effected plant growth and development. Soil temperature has shown increasing trend towards the end of crop season, since, air temperatures are increasing towards the end of growing season. Paddy straw mulch, weed mulch and maize stover mulch increased 2.31°C, 1.88°C, 0.27°C temperature, respectively, over the control during morning hours.

KEYWORDS: Lentil varieties, organic mulches, soil temperature, water productivity

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1. INTRODUCTION

The hill and mountain regions of the Indian Himalayas are environmentally vulnerable and less economically developed than the plains (Ghosh et al., 2016). Due to restricted availability of resources (water, land, and labour), this ecosystem has poor land-use efficiency and cropping intensity (Das et al., 2017). Agriculture constitutes the primary livelihood in the hilly region, relies majorly on subsistence-based practices (Yadav et al., 2019), and is hindered by complex and varied climatic, physiographic, technical, and socioeconomic restrictions (Das et al., 2020). The main causes of deterioration of different natural resources including soil, water, and vegetation are cultivation along steep slopes, heavy rainfall, removal and/or burning of plant biomass, and conventional tillage (Das et al., 2018; Das et al., 2019). Under the rainfed circumstances of Himalayan ecology, farmers often practice mono-cropping of rice (*Oryza sativa* L.) or maize (*Zea mays* L.) in both upland and valley land ecosystems (Layek et al., 2014). South Asia covers 40% of the world's harvested rice area, of which 22.3 mha of rice-fallow regions were found in India which is 88%, whereas, Bangladesh has 8.7% and Nepal has 1.4% (Choudhary et al., 2023). Every year, approximately 15 mha of cultivated land in South Asia, with 11.65 mha specifically in the India, remains unused after the harvest of rice (*Oryza sativa*) (Subbarao et al., 2001; Gumma et al., 2016; Yadav et al., 2017). During post-rainy season after monsoon rice, these substantial fallow lands can be used to grow short-duration, low-water-use legumes, pulses, and oilseed crops (Gumma et al., 2016). Major obstacles for increasing cropping intensity and productivity in rainfed rice fallow regions include a lack of suitable crops and cultivars, irregular or no rainfall, especially during the post-rainy season (winter) (Layek et al., 2014, Gumma et al., 2016). Growing pulse crops in these fallow areas of rice monocropping system during the post rainy season can be a suitable option (Hazra et al., 2018).

Lentil is a short duration legume crop well suited for cultivation during winter season in North Eastern Regions (NER) of India (Nath et al., 2019). Lentil being a legume crop, its introduction in rice monocropping system could improve fertility with biological nitrogen fixation. Lentil is grown in winter season on residual soil moisture because of limited or poor irrigation opportunities in these regions. Though NER receives a plenty of rainfall (>2,000 mm year^{-1}), confined mainly to monsoon seasons. Hence, crops grown in the *rabi* season often suffer due to moisture stress during maturity stage, often leads to crop failure (Ghosh et al., 2016). Therefore, prominent options for growing crop in these regions could be crop residue management (Ghosh et al., 2016). Providing the irrigation at critical stages of crop is suitable strategy in the rice fallow lands for improving the productivity of winter grown crop and suitable crop intensification (Das et al., 2019).

Mulching is a protective cover made of organic or inorganic material spread on the surface of the soil to reduce evaporation losses, preventing weed growth, reduces soil compaction due to heavy rains. Covering the soil with crop residues improves water holding capacity and also prevents soil evaporation losses. Water productivity is an important index for scheduling of irrigation in terms of water management (Ali and Talukder, 2018). The evaporation from the soil has been reduced by 35–50% due to the presence of crop residue on the surface (Sauer et al., 1996). Straw mulch is an easily accessible material by the local farmers and it is economically feasible. The objective of the study is to estimate growth, yield and water productivity of lentil varieties under different organic mulching as discussed below.

2. MATERIALS AND METHODS

2.1. Experimental site

The experiment was conducted at College of Post Graduate Studies in Agricultural Sciences, Umiam, Meghalaya during the *rabi* season (November-April 2022). The climate of Ri-Bhoi is classified as subtropical humid type with high rainfall and cold winters. The Monsoon rainfall is normally sets in at the first fortnight of June and extends up to end of September. Withdrawal of monsoon takes place in October first week with a deceasing rainfall trend from September. The experimental site experiences an average annual rainfall of 2617.10 mm with some pre-monsoon showers during March to May (Ray et al., 2012). The experimental site also experiences high relative humidity and low sunshine hours as compared to other parts of the country. The maximum temperature rises up to 30°C in the months of July–August and minimum falls down to 5 to 6°C during the first week of January. During the experimentation period, total rainfall of 9.3 cm was received, of which maximum weekly rainfall of 3.8 cm was received during 13th standard meteorological week. Soil samples were collected randomly from the top 0–30 cm, for physical and chemical analysis from the experimental site and mixed thoroughly to make composite sample. The physical and chemical analyses were carried out to determine the physico-chemical properties of the soil. Soil of the experimental site was classified as sandy clay loam soils, with acidic pH (4.76) containing high organic carbon (1.13%), low, medium, moderate available N (222.5 kg ha^{-1}), P_2O_5 (15.24 kg ha^{-1}), K_2O (241.24 kg ha^{-1}), respectively.

2.2. Treatments and experimental design

The experiment was conducted at the experimental field of College of Post Graduate Studies in Agricultural Sciences, Umiam, Ri-Bhoi district, Meghalaya. The experimental site is situated at 91°18' to 92°18' East longitude and 25° 40' to 26° 20' North latitude and at an altitude of 950 m above the mean sea level (MSL). The study was carried out under split plot design with four main-plot treatments (mulches), viz., i) un-mulch, ii) paddy straw mulch, iii) maize stover mulch, iv) weed mulch were applied @ 5 t ha^{-1} and four sub-plot treatments (varieties), viz., i) HUL-57, ii) PL-4, iii) PDL-1 and iv) PSL-9 and the experiment was replicated three times. The spacing followed in the experiment was 30×5 cm^2. Mulching was done on the next day of sowing in the respective experimental plots @ 5 t ha^{-1}. The field experiment was started in November 2019 and harvested in April, 2020. The major nutrients nitrogen (N), phosphorous (P) and potash (K) were supplied through the chemical fertilizer Urea, Single super phosphate (SSP) and Murate of potash (MOP), respectively. At the time of sowing, full doses of P, K and 50% of N dose was applied as basal (recommended doses of N, P and K=20:40:40 kg ha^{-1}). Rest 50% of N fertilizer was applied at pre-flowering stage through top dressing. Standard agronomic practices were followed during crop growing period and crop was harvested at maturity. Seed treatment was done before the sowing with Captan @ 2 g kg^{-1} seed.

2.3. Irrigation method and quantification

Irrigation was provided by surface method of irrigation. Irrigation was started when the soil moisture availability was 50% depleted. Amount of irrigation water applied was quantified on discharge rate basis using a 0.5 HP (Horse Power) electric pump. The discharge rate of the pump was determined volumetrically as shown in Equation 1 and the average discharge rate of pump was recorded as 1.8 L s^{-1}. Irrigation scheduling was done on the basis of critical stages of irrigation of the crop.

Discharge rate (L s^{-1}) =Amount of water collected in the bucket/(Time require to fill the bucket … (1)

2.4. Water productivity

Water productivity was defined as the crop produced per unit of water involved in crop production. Water productivity was calculated by the formula as shown in Equation 2. Water Productivity was expressed as kg ha^{-1} mm^{-1}.

Crop water productivity=Economic yield/Total amount of water applied ….(2)

2.5. Soil temperature

Soil temperature was measured at 15 cm and 30 cm depth with soil thermometers. The temperature values were measured with two different sized thermometers which were installed in the field to take observations. Observations were recorded daily two times, i.e., morning (8.00 am) and evening (4.00 pm). The weekly average trend of soil temperature were depicted in Figure 1, 2, 3 and 4.

2.6. Rainfall and irrigation

The irrigation to the crop was provided based on the moisture sensitive stages of the crop. Each time irrigation provided was 32.4 mm which was same during all the four irrigations, *viz.*, (1) Before gap filling, 2) Vegetative stage of crop 3) Flower initiation stage 4) Pod formation stage. The gross plot size of the experiment was 200 m^2. The discharge rate of the pump used was 1.8 L s^{-1}, where it was always irrigated for 1 h for whole experimental plot. Therefore, the total irrigation of 32.4 mm ha^{-1} was provided each time. The total amount of rainfall received during the total crop growing period was 93 mm. The total water use (rainfall+irrigation) was 222.6 mm. The irrigation provided was by surface method.

The statistical analysis was done by using the technique of analysis of variance (ANOVA) for split plot design over the computer. The difference between the treatment means was tested as for their statistical significance with appropriate critical difference (CD) value at 5% level of significance (CD (p=0.05)) as explained by Gomez and Gomez (1984).

3. RESULTS AND DISCUSSION

3.1. Soil temperature

Effect of organic mulches and un mulch treatments on soil temperature were depicted in Figure 1, 2, 3 and 4. Mulches modified soil thermal regimes and effected plant growth and development (Likatas et al., 1986). Mulches also modifies hydrothermal regimes of soil by conserving soil moisture and promotes soil productivity (Singh et al., 2011). Mulches altered the soil temperature during the crop season. It reduced the soil temperature during day time and increased during night time compared to un mulch. The temperature variation was more prominent among the observations recorded at 15 cm (Figure 2, 4) than 30 cm (Figure 3) depth when compared to un mulch treatment. Paddy straw mulch reported higher temperature during the morning hours (8.00 am) compared to un mulch treatment. However, control reported higher temperature for the observations recorded during the evening hours (4.00 pm) compared to paddy straw mulch. These findings were

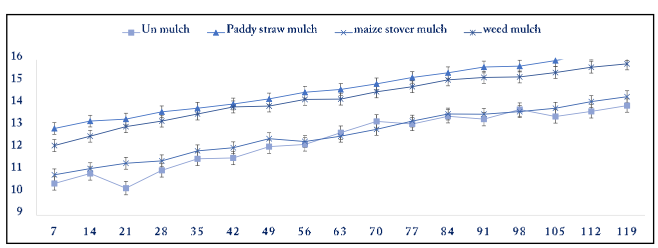

Figure 1: Soil temperature change at 15 cm depth during morning hours (8.00 am)

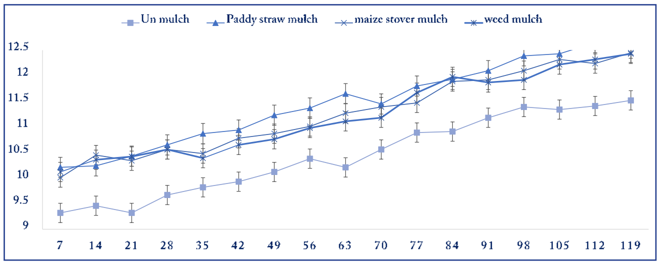

Figure 2: Soil temperature change at 30 cm depth during morning hours (8.00 am)

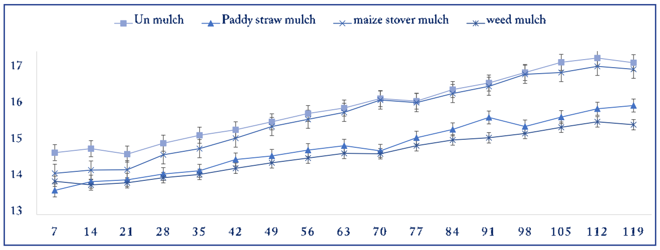

Figure 3: Soil temperature change at 15 cm depth during evening hours (4.00 pm)

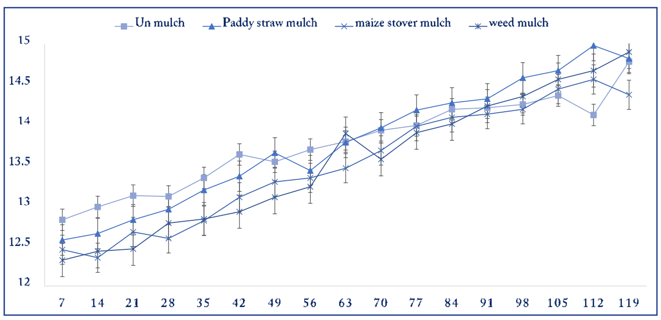

Figure 4: Soil temperature change at 30 cm depth during evening hours (4.00 pm)

supported by Chen et al. (2007) who reported that mulch reduced soil temperature by reducing radiation absorption and at night time mulch reduced outgoing radiation from the soil. It was observed that soil temperature has shown increasing trend towards the end of crop season, since, air temperatures were increasing towards the end of growing season. Paddy straw mulch, weed mulch and maize stover mulch increased 2.31°C, 1.88°C, 0.27°C temperature, respectively, over the control during morning hours at 15 cm depth. Organic mulch reduces the loss of heat to colder atmosphere due to thermal insulation and albedo of mulched soil (reflectance) was higher than the un mulched soil. Therefore, temperature extremes were less in mulched conditions than un mulched condition (Pramanik et al., 2015). The reduction in temperature caused by weed mulch, paddy straw mulch, and maize stover mulch, respectively, during the evening hours (4:00 pm) was 1.28, 1.08, and 0.23°C Teasdale and Mohler (1993) reported that organic mulches decrease maximum temperatures but increase minimum temperatures.

3.2. Growth, yield and yield attributing parameters

Data on plant height, branches plant^{-1}, pods plant^{-1}, seeds per pod, Test Weight, Biological yield, Economic yield, Harvest Index, Water Productivity and BCR were presented in Table 1. The Significantly highest plant height (28.28 cm) and number of branches plant^{-1} (4.86) were reported under paddy straw mulch compared to control. The plant height was recorded significantly higher under paddy straw mulch (28.18 cm) during the entire crop season compared to control (24.19 cm). The reason might be due to better soil moisture availability and better regulation of soil temperature under mulching compared to un-mulch or control. Mathukia et al. (2015 reported significantly highest plant height of pigeon pea (202 cm) and number of branches plant^{-1} (19.3) under wheat straw mulch over the control. This might be due to conserving more soil moisture by wheat straw, reducing the evaporation, maintaining optimum soil temperature, improving the soil physical conditions and availability of more plant nutrients and increase in microorganism activity. These findings were in agreement with those of Gajera and Ahlawat (2002). Yadav and Bhati (2013) observed maximum plant height (116.95 cm) under polythene mulch than organic mulch (112.14 cm) and without mulch (104.12 cm) in fennel mainly dure more availability of soil moisture. The variety PL-4 has shown highest plant height (27.03 cm) and number of branches plant^{-1} (4.82) than other varieties during the entire crop season. The reason may be due to genetical traits of a variety and the location in which it grows. These findings were agreed by Das et al. (2014), Yadav et al. (2015) and Prakash and Ram (2014).

The data on yield parameters and benefit cost ratio (BCR) were presented in Table 2. Yield was directly corelated with number of pods plant^{-1}. It was regarded as major yield attributing parameter. Paddy straw mulch (43.57) which was on par with weed mulch (41.29) has reported significantly highest number of pods plant^{-1} over maize stover mulch (38.18) and un-mulch (36.21) treatments. Mathukia et al. (2015) reported that mulching with wheat straw (WS) registered significantly the higher number of pods plant^{-1} (142) over no mulch, however, it was statistically at par with groundnut shell mulch (GS). The enhanced yield attributes with mulching can be attributed to optimum soil temperature, increased microbial activity, reduced evaporation, conserving more soil moisture and uptake of more nutrients that in turn resulted in better plant growth, photosynthetic activity and partitioning of assimilates. These results were agreed by the research findings of Gajera and Ahlawat (2002). The results were also found significant among the cultivars, where the cultivars PDL-1 (41.92), PSL-9 (37.18) recorded highest and lowest number of pods plant^{-1} respectively. The reason might be that, there

Table 1: Effect of mulching on growth, yield attributing characters including yield and BCR of lentil varieties

Treatments	Plant height	Branches plant^{-1}	Pods plant^{-1}	Seeds pod^{-1}	Biological yield (kg ha^{-1})	Economic yield (kg ha^{-1})	Harvest index (%)	Water productivity (kg ha^{-1} mm^{-1})	BCR
Main-plot									
Un-mulch	24.19	4.12	36.21	1.64	1525.3	571.3	37.5	2.57	1.41
Paddy straw mulch	28.18	4.86	43.57	1.67	1888.8	723.3	38.7	3.25	1.81
Maize stover mulch	25.57	4.25	38.18	1.59	1654.8	638.7	38.6	2.87	1.56
Weed mulch	26.04	4.40	41.29	1.63	1793.8	676.2	38.3	3.04	1.73
SEm±	0.56	0.14	0.94	0.02	70.0	27.3	1.6	0.12	0.07
CD(p=0.05)	1.94	0.50	3.24	NS	242.0	94.6	NS	0.42	0.23
Sub-plot									
HUL-57	25.09	4.27	40.37	1.65	1628.7	604.0	37.2	2.71	1.52
PL-4	27.03	4.82	39.78	1.63	1874.0	717.5	39.1	3.22	1.79
PDL-1	26.76	4.33	41.92	1.66	1698.3	643.6	38.0	2.89	1.59
PSL-9	25.11	4.21	37.18	1.59	1661.7	644.4	39.0	2.89	1.60
SEm±	0.58	0.13	0.88	0.03	60.1	21.5	1.3	0.10	0.05
CD (p=0.05)	1.70	0.39	2.57	NS	175.4	62.7	NS	0.28	0.16

Table 2: Nutrient status of the soil after crop harvest under different organic mulching and varietal treatments

Treatments	Soil nutrient status				
Main plot (level of mulching=04)	Soil pH	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Un-mulch (M_0)	4.79	1.13	277.50	14.47	255.76
Paddy straw mulch (M_1)	4.76	1.10	266.75	14.24	242.84
Maize stover mulch (M_2)	4.86	1.19	272.75	13.93	238.91
Weed mulch (M_3)	4.67	1.06	260.50	14.44	251.54
SEm±	0.11	0.04	6.19	0.27	5.57
CD (p=0.05)	NS	NS	NS	NS	NS
Sub-plot (Level of cultivar=04)					
HUL-57 (V_1)	4.78	1.15	278.67	15.04	262.09
PL-4 (V_2)	4.81	1.10	255.67	12.86	226.00
PDL-1 (V_3)	4.74	1.02	273.58	14.36	245.85
PSL-9 (V_4)	4.73	1.20	269.58	14.83	255.11
SEm±	0.08	0.04	9.18	0.55	7.77
CD (p=0.05)	NS	0.12	NS	1.62	22.68

was a correlation between number of branches plant^{-1} and pods plant^{-1}, where the cultivar PL-4 recorded the highest branches plant^{-1} which was on par with PDL-1. However, the cultivar PSL-9 reported the least branches number and pods plant^{-1}. Significant results among different cultivars of crop for number of pods plant^{-1} was also reported by Gupta et al. (2006) and Mondal et al. (2011). The number of seeds per pod has shown no significant difference among the mulches and varietal treatments. The average number of seeds pod^{-1} in Lentil crop was two, therefore, there was no significant difference has been reported both under mulches and varietal treatments. However, the higher number of seeds pod^{-1} has been reported under paddy straw mulch. Teame et al. (2017) reported, higher number seed per capsule in sesame under mulching with sorghum straw because of better moisture conservation, which facilitate source-sink assimilate translocation, whereas, it was statistically at par with sesamum straw mulch.

The biological yield was affected significantly by mulches and varietal treatments. The significantly higher biological yield was reported under paddy straw mulch (1888.8 kg ha^{-1}), which was statistically at par with weed mulch (1793.8 kg ha^{-1}) and maize stover mulch (1654.8 kg ha^{-1}). The reason might be due better availability of moisture under mulched condition leads to better nutrient uptake by crop, better growth and development. Significantly highest biological yield was reported under the variety PL-4 (1874.0 kg ha^{-1}) over PSL-9 (1661.7 kg ha^{-1}), HUL-57 (1628.7 kg ha^{-1}), however, PL-4 was statistically at par with PDL-1 (1698.3 kg ha^{-1}). Bhardhwaj and Bhardhwaj (2022) reported that, WH 1142 (9852 kg ha^{-1}) of wheat variety has shown highest straw yield, although the lowest yield of straw was shown under WH 1105 (5084 kg ha^{-1}). This may be due to the fact that, the straw yield in variety follows a similar pattern of dry matter accumulation (Kumari, 2015). The significant results were reported among mulch treatments for economic yield. Paddy straw mulch reported significantly highest economic yield of 723.3 kg ha^{-1} over other treatments. These results may be due to adequate soil moisture availability which promote better uptake of nutrients form soil and helps in better growth and yield of the crop. These results were supported by the findings of Karunakaran and Behera (2013). Sanbagavalli et al. (2017) reported significantly highest yield (1219 kg ha^{-1}) with mulch application of bajra straw mulch @ 5 t ha^{-1} as compared to no mulch (1006 kg ha^{-1}) in soybean crop. This might be due to availability of moisture will increases cell expansion because of turgor pressure and increases of photosynthesis rate, which in turn, increases assimilate production and transportation from source to sink thereby increasing yield components. Among the varietal treatments, significantly highest economic yield was reported by PL-4 (717.5 kg ha^{-1}) over the other varieties. The significant results for economic yield among the varietal treatments of rajma crop was reported by Marwein and Ray (2019). Parida et al., 2023a reported that maximum green pod yield and green seed yield of garden pea were recorded in Paddy straw mulch (89.33 q ha^{-1}) followed by weed mulch (39.96 q ha^{-1}) and no mulch. Under different varietal treatments, VM 12 of garden pea, reported highest green pod yield (89.78 q ha^{-1}) and green seed yield (41.66 q ha^{-1}) under different organic mulching. The non-significant results were reported for harvest index among the both mulch and cultivar treatment. The reason might be due to cumulative accumulation of economic and biological yield did not affect Harvest Index among both mulches and varietal treatments. Bochliya et al. (2020) has also reported that mulching and varietal treatments did not affect the Harvest Index significantly.

3.3. *Cost benefit analysis*

Paddy straw mulch has reported significantly highest BCR (1.81), which was at par with weed mulch (1.73). Un-mulch (1.41) treatment reported significantly lowest BCR. Sanbagavalli et al. (2017) reported that mulching with bajra straw mulch reported highest BCR (1.45) compared to control. This might be improvement in growth and yield attributes and ultimate increase in seed yield could be the reason for enhanced economic returns in the above treatments. Among the varieties, PL-4 variety has recorded significantly highest BCR over the other varieties. This might be attributed due to higher grain, biological yield and harvest index performance of this variety. Similar findings were also observed by Parida et al., 2023b.

3.4. *Effect of organic mulching on Water productivity*

The water productivity was significantly influenced by organic mulches and varietal treatments of lentil. Mulching mainly conserves soil moisture by reducing surface evaporation and controlling the soil erosion (Qin et al., 2015). Mulch regulates soil temperature, therefore, decreases irrigation demand of the crop (Kader et al., 2017) during off periods. Significantly highest water productivity was reported under paddy straw mulch (3.25 kg ha^{-1} mm^{-1}) compared to un mulched treatment (2.57 kg ha^{-1} mm^{-1}). Among lentil cultivars, significantly highest water productivity was reported by PL-4 (3.22 kg $ha^{-1}mm^{-1}$) compared to the variety HUL-57 (2.71 kg ha^{-1} mm^{-1}). The reason for the highest water productivity under paddy straw mulch may be the result of increased water use for the crop growth than that of for the evapotranspiration (Shylla et al., 2016). The amount of water saved by mulching was still unknown fact which was critical due to interaction of plant microclimate, soil environment and crop performance (Steinmetz et al., 2016).

3.5. *Soil chemical analysis*

The result for soil pH was found non-significant for both main plot and sub-plot treatments. It indicates that, soil pH was not influenced by mulching. The results for soil organic carbon (SOC) were found non-significant under organic mulches. Chatterjee et al., 2018 reported that, in comparison to no mulch treatment, the application of crop residue mulch decreased the labile pools of SOC but increased the very labile, less labile, and non-labile pools of SOC at both the soil depths of 0–5 and 5–15 cm. The greatest rise in carbon labile pools was observed in VL pools. However, the highest value of soil organic carbon was found in maize stover mulch. The results for available nitrogen, available phosphorous and available potassium was also found non-significant. The highest values of available soil nitrogen (277.5 kg ha^{-1}), available soil phosphorous (14.47 kg ha^{-1}) and available soil potassium (255.76 kg ha^{-1}) in un-mulch treated plot after harvest of the crop was reported, may be because crop cannot uptake nutrients from the soil due to lack of soil moisture. Therefore, nutrients remain intact in soil in control plot, So, un-mulch treated plot reported highest values of soil nutrients. This indicates that mulching increased the nutrient uptake from the soil and resulted in better growth and development of the crop compared to un-mulched condition. The soil nutrient status after the crop harvest has shown in Table 2.

4. CONCLUSION

Paddy straw mulch had significant effect on growth, yield and water productivity of crop compared to un-mulch. The yield advantage in paddy straw mulch was of 21.01% over un-mulch, 11.69% over maize stover mulch and 6.51% over weed mulch. Organic mulching significantly enhanced growth, yield and water productivity of the lentil variety PL-4 over other varieties. This could be attributed to improved soil moisture conservation, temperature regulation, and nutrient uptake facilitated by the mulching practice during winter season of Meghalaya.

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