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# Effect of straw mulching and irrigation on physiological activities, yield of maize (*Zea mays* L.) and soil physical properties under available soil moisture depletion conditions in Mollisols

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## ABSTRACT

*A field experiment was conducted during winter season of 2016-17 and 2017-18 to evaluate the effect of residue mulch and irrigation on the physiological response and yield of maize and soil physical properties at G. B. Pant University of Agriculture and Technology, Pantnagar. The experiment was laid-out in split-plot design which includes three irrigation scheduling in main plots and four residue mulch practices in sub plots. Soil temperature at 15 cm enhanced by 0.6-9.8 $^{0}$C under mulch and by 0.7-1.2 $^{0}$C with irrigation at 20% DASM over other irrigation levels. Mulch significantly decreased bulk density by 1.43-3.59% while increased saturated hydraulic conductivity by 3.8-41.0% and mean weight diameter by 6.0-20.0%. Irrigation at less depletion of available soil moisture favoured soil physical properties. Mulch and increase in irrigation frequency tended to increase in relative water content and transpiration rate while decreased leaf diffusive resistance. No noticeable differences in leaf temperature were observed under mulch and irrigation. Green gram straw mulch and irrigation given at 20% DASM produced 2.6-14.2 % and 1.3-9.2% higher grain yield, respectively. Combined application of green gram straw mulch @ 5 t ha$^{-1}$ along with irrigation at 20% DASM was found most beneficial for maintaining favourable soil environment and can be recommended for obtaining higher maize yield in Mollisols.*

**Keywords:** Straw mulch, irrigation, transpiration rate, saturated hydraulic conductivity, yield, maize

## INTRODUCTION

Maize (*Zea mays* L.) assumes its cultivation under much diverse agro climatic zones extending from tropical to cooler temperate region**.** In fact the suitability of maize to diverse environments is unmatched by any other crop. Despite of several advantages of winter maize viz., low incidence of diseases and insect attack, slow growth of weeds, high productivity etc., maize crop growth period is exposed to low moisture and temperature stresses. In the *tarai* region of north-western plain, maize is mainly grown during June-September (wet season), which is accompanied by high temperature and precipitation but during winter there is low precipitation (<50 mm) and temperature occasionally touches 0 $^{0}$C. Frost is also expected from late December to middle of February. Hence, crop usually requires irrigation water to manage existing stresses which may adversely affect the crop production. Temperature is a major environmental factor that limits the distribution, productivity, and survivability of plants. Responses to temperature differ among crop species throughout their life cycle and are primarily the phenological responses, i.e., stages of plant development (Hatfield and Prueger, 2015). Plants exposure to low temperature and freeze injury during winter often exhibit serious physiological and morphological responses, including damage to various cellular structures and decreased chlorophyll content, photosynthetic rate, stomatal conductance and transpiration rate (Schreiber *et al.,* 2013; Zhang *et al.,* 2020).When the full crop water requirements are not met, water deficit in the plant can develop to a point where many of the physiological activities of plants are impaired. The limited supply of water during growth period affect maize crop due to its relative high water requirements. Thus, detection of water status is important for monitoring the physiological status of plants. Deficit irrigation is a technique in which irrigation is done during drought sensitive growth stages of a crop and aims at stabilizing yields and at obtaining maximum crop water productivity rather than maximum yields.Straw mulch is practiced successfully in many advanced countries like America and Australia

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and has been widely used as an important management tool in many parts of world (Zhang *et al.,* 2015). Mulch when applied to the soil surface known to increase the crop yields by providing surface cover to soil, retaining soil moisture, increase soil temperature and regulate diurnal/seasonal fluctuations in soil temperature (Li *et al.,* 2013), and improves, to a certain extent, soil structure and quality. Effect of mulching on improving soil physical properties and increasing productivity of crops had been reported in many crops (Shiva Kumar *et al.,* 2018; Biswas *et al.,* 2022). Scanty information is available on the comparative effect of various straw mulch and irrigation on winter maize in *tarai* region of mollisols. Keeping the view of the declining ground water level, severe cold stress during vegetative growth, less rain water availability and high yield potential during winter season, the present study was carried out to determine the effect of irrigation and straw mulch levels on physiological characteristics, root behaviour and yield of maize and soil physical properties in sub tropical mollisols.

## MATERIALS AND METHODS

A field experiment was conducted during 2016-17 and 2017-18 at N. E. Crop Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (Uttarakhand) on *tarai* region which lies in a narrow belt to the south from the foothills of *Shivalik* range of Himalaya having an altitude of 243.84 m and $29^0$ 1' N latitude and$79^0$ 30' E longitude under humid sub-tropical climate. The experiment comprises irrigation at depletion of available soil moisture (DASM) and straw mulch levels on maize hybrid during winter season. The experimental soil is derived from calcareous alluvium and classified as fine mixed hyperthermic Aquic Hapludoll. The area experiences the total annual mean rainfall from 1200 to 1650 mm, of which more than 85% is received during wet season (June-September). Frost is also expected from late December to February. The maximum temperature may go up to the 43 $^0$C in May and minimum below 2 $^0$C in January. Mean monthly pan evaporation and sun shine hours were observed almost similar in both the years. Mean minimum and maximum air temperature was recorded slightly cooler in January and warmer in April in both seasons and most of the weeks arrested maximum temperature from 0-7.4 $^0$C and minimum temperature from 0.1-7.3 $^0$C higher during 2016-17 compared to 2017-18. Total rainfall in the second year (55.8 mm) was higher and well distributed than the first year (18.0 mm). The experimental set up was a split plot design with three replications. Three irrigation given at 20 ($I_1$), 30 ($I_2$) and 40 ($I_3$) per cent depletion of available soil moisture (DASM) from field capacity were taken as a main plot and four levels of straw mulch viz., no mulch ($M_0$), green gram ($M_G$), maize ($M_M$) and lantana ($M_L$) as sub plot. The experimental soil was sandy loam in texture, pH 7.1, EC 0.05 dSm$^{-1}$, organic carbon 7.80 g kg$^{-1}$, bulk density 1.47 Mg m$^{-3}$, hydraulic conductivity 11.0 cm hr$^{-1}$, maximum water holding capacity 39.15%, available N 200.7 kg ha$^{-1}$, available P 20.16 kg ha$^{-1}$ and available K 194.88 kg ha$^{-1}$. All plots received the one third of N (40 kg ha$^{-1}$), entire amount of P (60 kg P ha$^{-1}$) and K (40 kg K ha$^{-1}$) as basal and remaining 80 kg N ha$^{-1}$ was applied in two equal splits as top dressing through urea at knee high (25-35 DAS) and tassel emergence (100-130 DAS) stages with minimum disturbance to mulching. Maize (cv. P-3396) was sown manually in the second week of November at 20 cm distance in 60 cm spaced row. Straw mulches were applied @ 5 t ha$^{-1}$ after the germination of seeds (7-12 DAS) in between the rows, allowing plants to grow normally. A depth of 6 cm irrigation water was applied in each plot when available soil moisture had depleted to 20, 30 and 40 % from field capacity level. The details of total water received through irrigation and rainfall are given in Table 1. Photosynthetic characteristics readings were taken using a steady state porometer (model no. LI-1600) after solar noon time (1400 hr). For measuring infield hydration status quantitatively, fresh mid leaf samples of plant are first weighed then placed in distilled water overnight and re-weighed. Then dried at 65 ± 5 $^0$C in an oven till constant weight and weighed and relative leaf water content was calculated (Chakraborty *et al.,* 2008). Grain yield of each plot was recorded at 15% moisture content on a dry weight basis. Samples were analyzed for bulk density measured by core method, infiltration rate by double ring infiltrometer, maximum water holding capacity (WHC) by Hilgard apparatus, saturated hydraulic conductivity ($K_{sat}$) by constant head permeameter and mean weight diameter (MWD) by modified Yoder's wet sieving method. Soil temperature at 15 and 30 cm depths was recorded using mercury thermometers at three points in each plot once in a day at 1400 hr. The data were analyzed following the techniques of analysis of variance (ANOVA) prescribed for split plot design on standard computer programs developed by department of Mathematics, Statistics and Computer Science, college of basic sciences and humanities, G. B. Pant University of Agriculture and Technology, Pantnagar. The least significant difference values were tested at 5% level of probability.

Table 1: Water availability to the crop during experimental period

| Irrigation and mulch treatment | | Total irrigation water applied (mm) | | Water received through rainfall (mm) | | Total water received (mm) | |
|---|---|---|---|---|---|---|---|
| | | 2016-17 | 2017-18 | 2016-17 | 2017-18 | 2016-17 | 2017-18 |
| $M_0$ | $I_1$ | 840 | 480 | 18.0 | 58.6 | 858.0 | 538.6 |
| | $I_2$ | 540 | 300 | 18.0 | 58.6 | 558.0 | 358.6 |
| | $I_3$ | 420 | 180 | 18.0 | 58.6 | 438.0 | 238.6 |
| $M_G$ | $I_1$ | 600 | 360 | 18.0 | 58.6 | 618.0 | 418.6 |
| | $I_2$ | 540 | 240 | 18.0 | 58.6 | 558.0 | 298.6 |
| | $I_3$ | 300 | 180 | 18.0 | 58.6 | 318.0 | 238.6 |
| $M_M$ | $I_1$ | 600 | 360 | 18.0 | 58.6 | 618.0 | 418.6 |
| | $I_2$ | 480 | 240 | 18.0 | 58.6 | 498.0 | 298.6 |
| | $I_3$ | 300 | 180 | 18.0 | 58.6 | 318.0 | 238.6 |
| $M_L$ | $I_1$ | 600 | 360 | 18.0 | 58.6 | 618.0 | 418.6 |
| | $I_2$ | 480 | 240 | 18.0 | 58.6 | 498.0 | 298.6 |
| | $I_3$ | 300 | 180 | 18.0 | 58.6 | 318.0 | 238.6 |

## RESULTS AND DISCUSSION

### Soil Temperature

In both the years soil temperature at 0-15 cm depth was higher (0.6–9.8 $^0$C) under mulch than non mulched practices. The temperature recorded during crop season at 20 days interval, in general, decreased from sowing to 40 days after sowing in first season and to 60 days after sowing in the second season and increased thereafter till harvest. Surface soil maintained higher temperature than sub surface and ranged from 0.2 to 8.9 $^0$C and 0.1 to 4.9 $^0$C in the first and second season, respectively. Soil temperature at 0- 15 cm ranged from 13.5 to 32.7, 12.8 to 31.5 and 13.2 to 31.5 and at 15- 30 cm from 12.8 to 29.7, 11.1 to 29.2 and 10.1 to 28.9 $^0$C under 20, 30 and 40 % available DASM, respectively, during both seasons. Maize stover mulch applied plots maintained higher soil temperature in the first season; however, green gram mulch applied plots in the second season over other mulch treatments.

### Soil physical properties

The mulch significantly affected the soil bulk density, $K_{sat}$, infiltration rate, WHC and MWD during both years of study. Bulk density was found maximum under no mulch compared with mulch (Table 2). Javeed *et al.* (2013) also noted the same results. Maize and lantana straw mulched plots showed non significant effect on bulk density. A little difference in bulk density was noted among mulched plots and in relation to control lowered by 2.14-2.86% in the first season and by 1.44-3.60% in the second season. Application of green gram as a mulch had more reduction in soil bulk density. Saturated hydraulic conductivity ($K_{sat}$) under the mulch treatments was significantly enhanced and observed 0.04-0.23 and 0.27-0.41 times greater over control in first and second year, respectively. Furthermore, it enhanced in mulched plots but reduced in control plot in the second year. Blanco-Canqui and Lal (2007) also reported that the larger $K_{sat}$ in straw mulched treatments than in the unmulched treatment for the 0–30 cm depth after 10 consecutive years of straw management. Mulch application resulted significantly higher infiltration rate from 0.24-

0.41cm $hr^{-1}$ and 0.43-0.60 cm $hr^{-1}$ during first and second season of crop, respectively, over non mulch. Infiltration rate was noted non-significantly lower in lantana mulch than maize mulch during both years. Increase in infiltration rate was found in the order of $M_G > M_M > M_L > M_0$ in both season. Compared to first season, infiltration rate increased in the second season under mulched plots but decreased in non mulch plot. The readily decomposition of green gram mulch accelerated the more inclusion of organic material in to the soil resulted in lower bulk density and consequently enhanced water infiltration into the soil. The improvement in water infiltration with straw mulching is in agreement with the findings of Enyioko *et al.* (2017). Mulched plots recorded higher values of MWD than control however maize and lantana mulch had non significant effect on MWD. Green gram mulch applied plot enhanced 0.05-0.11 mm and 0.08-0.14mm MWD during first and second season, respectively over other treatments. Irrigation given at different available water depletion conditions also significantly affected soil physical properties. Plot irrigated at 20% DASM had significantly higher bulk density over other irrigation levels however observed at par between in 30 and 40% DASM in both the years. $K_{sat}$ increased significantly with irrigation given at 10% increment in DASM. In the second year $K_{sat}$ increased by 0.05-0.31 cm $hr^{-1}$ among all irrigation levels over first year. Plots irrigated with increased available soil moisture depletion in general led to significant increase in infiltration rate with maximum under 40% DASM and minimum under 20% DASM. This might be due to more vacant pores availability in the soil. This is supported by the findings reported by Yaseen *et al.* (2014). More frequently irrigated plot (20% DASM) arrested 1.94-3.38% and 1.71-2.94% higher WHC during first and second year, respectively, over other irrigation levels. This could be because of more moisturized condition due to frequent irrigation. Extension in irrigation interval resulted to drop MWD values. This may probably due to low macro aggregate stability with decrease in macro-porosity and production of finer particles and micro aggregates (Malgwi and Abu, 2011).

Table 2: Soil physical properties under various straw mulch and irrigation level

| Treatment | Bulk density ($Mg\ m^{-3}$) | | Saturated hydraulic conductivity ($K_{sat}$) ($cm\ hr^{-1}$) | | Infiltration rate ($cm\ hr^{-1}$) | | Maximum water holding capacity (%) | | Mean weight diameter (mm) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2016-17 | 2017-18 | 2016-17 | 2017-18 | 2016-17 | 2017-18 | 2016-17 | 2017-18 | 2016-17 | 2017-18 |
| Straw mulch practices | | | | | | | | | | |
| $M_0$ | 1.40 | 1.39 | 2.33 | 2.17 | 1.14 | 1.11 | 32.90 | 37.32 | 0.67 | 0.70 |
| $M_G$ | 1.36 | 1.34 | 2.88 | 3.06 | 1.55 | 1.71 | 36.93 | 40.62 | 0.78 | 0.84 |
| $M_M$ | 1.37 | 1.36 | 2.56 | 2.81 | 1.43 | 1.59 | 35.28 | 39.14 | 0.73 | 0.76 |
| $M_L$ | 1.37 | 1.37 | 2.43 | 2.75 | 1.38 | 1.54 | 34.84 | 38.79 | 0.71 | 0.75 |
| SEm± | 0.007 | 0.008 | 0.04 | 0.04 | 0.02 | 0.02 | 0.40 | 0.45 | 0.01 | 0.01 |
| CD (P=0.05) | 0.02 | 0.02 | 0.12 | 0.12 | 0.06 | 0.06 | 1.17 | 1.35 | 0.02 | 0.02 |
| Irrigation at available soil moisture depletion | | | | | | | | | | |
| $I_1$ | 1.40 | 1.40 | 2.41 | 2.46 | 1.29 | 1.39 | 36.76 | 40.52 | 0.77 | 0.86 |
| $I_2$ | 1.36 | 1.36 | 2.55 | 2.63 | 1.35 | 1.49 | 34.82 | 38.81 | 0.72 | 0.75 |
| $I_3$ | 1.37 | 1.34 | 2.69 | 3.00 | 1.49 | 1.58 | 33.38 | 37.58 | 0.67 | 0.68 |
| SEm± | 0.003 | 0.008 | 0.05 | 0.02 | 0.03 | 0.01 | 0.22 | 0.43 | 0.01 | 0.01 |
| CD (P=0.05) | 0.01 | 0.03 | 0.20 | 0.09 | 0.10 | 0.04 | 0.85 | 1.70 | 0.04 | 0.04 |
| Interaction | NS | NS | 0.27 | 0.20 | 0.13 | 0.09 | NS | NS | NS | NS |

**Physiological activity**

Relative leaf water content (RWC) measured at knee high and tasseling stage significantly influenced with mulch practices (Table 3). Green gram mulch maintained significantly higher leaf water status at knee high but was at par with maize and lantana mulch at tasseling. No mulch showed the significantly lowest RWC at both the stages during both seasons.

Table 3: Effect of straw mulch and irrigation levels on relative water content and temperature of leaves of maize

| Treatment | Relative leaf water content (%) | | | | Leaf temperature ( $^0$C) | | | |
|---|---|---|---|---|---|---|---|---|
| | At knee high stage | | At tasseling stage | | At knee high stage | | At tasseling stage | |
| | 2016-17 | 2017-18 | 2016-17 | 2017-18 | 2016-17 | 2017-18 | 2016-17 | 2017-18 |
| Mulch practices | | | | | | | | |
| $M_0$ | 81.73 | 82.52 | 87.81 | 76.07 | 21.9 | 26.4 | 31.9 | 32.9 |
| $M_G$ | 86.46 | 86.27 | 91.21 | 82.71 | 22.1 | 26.5 | 31.9 | 33.6 |
| $M_M$ | 85.14 | 83.94 | 90.64 | 81.98 | 22.1 | 26.4 | 31.7 | 33.3 |
| $M_L$ | 84.56 | 83.79 | 90.29 | 81.77 | 22.1 | 26.5 | 31.9 | 33.4 |
| SEm± | 0.37 | 0.28 | 0.69 | 0.64 | 0.15 | 0.09 | 0.28 | 0.21 |
| CD (P=0.05) | 1.10 | 0.84 | 2.06 | 1.90 | NS | NS | NS | NS |
| Irrigation at available soil moisture depletion | | | | | | | | |
| $I_1$ | 86.73 | 85.50 | 92.99 | 83.38 | 22.4 | 26.8 | 32.2 | 33.5 |
| $I_2$ | 84.56 | 84.32 | 89.00 | 80.41 | 22.4 | 26.4 | 31.8 | 33.3 |
| $I_3$ | 82.13 | 82.57 | 87.98 | 78.09 | 21.3 | 26.1 | 31.6 | 33.1 |
| SEm± | 0.31 | 0.39 | 0.74 | 0.64 | 0.22 | 0.18 | 0.26 | 0.37 |
| CD (P=0.05) | 1.23 | 1.52 | 2.90 | 2.49 | NS | NS | NS | NS |
| Interaction | 2.04 | 1.95 | 4.20 | 3.75 | 0.79 | NS | NS | NS |

Leaf temperature (LT) influenced non significantly within mulch practices at knee high and tasseling stages however, crop residue mulch had higher LT compared to no mulch (Chakraborty *et al.* 2008). At both growth stages, transpiration rate (TR) by crop under mulch applied plots showed significantly higher values over no mulch (Table 4). However, the highest rate of transpiration was observed under green gram mulch applied plants which gave 0.07-0.33, 0.07- 0.20 µg $cm^{-2}$ $s^{-1}$ at knee high and 0.16 - 0.28 and 0.11-0.23 µg $cm^{-2}$ $s^{-1}$ at tasseling higher TR during first and second season, respectively. Zhang *et al.* (2015) also observed that mulched maize plants could maintain a higher TR than unmulched plants. Despite the fact that the mulch could increase the soil moisture content, it could also increase the soil temperature which attributed to higher TR. Un mulched plants had higher values of leaf diffusive resistance (LDR) than mulched plants which might be due to reduction in water under water stress condition. With the advancement of growth to tassel emergence there was 4-6 fold increase in the LDR during both years. The diffusion resistance of each individual leaf may be uniquely related to its own water potential as modified by age and stress conditioning. Maize plants responded significantly in relative leaf water content to water deficit due to irrigation frequency at knee high and tasseling stages during both seasons. Plants irrigated when soil attained 20% DASM (adequately irrigated) maintained significantly higher RWC which reduced with lowering of irrigation frequency. These results are in the agreement with the findings of Surender *et al.* (2013) who found significant decrease in RWC with progression in soil moisture depletion; this might be due to decrease in internal water content of protoplasm and loss of chlorophyll a:b ratio. There was significant variation in RWC among irrigation levels at knee high stage but was at par between $I_2$ and $I_3$ at tasseling stage. Leaf temperature, irrespective of irrigation at DASM did not respond significantly. However, plants in more frequently irrigated plots showed slightly higher LT. With increasing the irrigation application time i.e. from $I_1$ to $I_3$, transpiration rate in general declined significantly. Similarly with the advancement in growth, TR decreased from 0.97-1.09 and 0.71-0.89 µg $cm^{-2}$ $s^{-1}$ during first and second season, respectively. However, the highest rate of transpiration at both stages of growth was observed when irrigated at 20% DASM. The decline in transpiration rate with the reduction in irrigation frequency (from $I_1$ to $I_3$) could be attributed to the higher soil drying rate which resulted from higher stomatal conductance. Eiasu *et al.* (2012) and Hou *et al.* (2019) also observed lower TR for lower irrigation frequency. Irrigation frequency influenced LDR behaviour significantly at both growth stages. Less often irrigated plants ($I_3$) had higher LDR which indicated that long term water stress induced changes in LDR. Findings agree with results reported by Eiasu *et al.* (2012).

Table 4: Effect of straw mulch and irrigation levels on transpiration rate and diffusive resistance of leaves of maize

| Treatment | Transpiration rate (µg $cm^{-2}$ $s^{-1}$) | | | | Leaf diffusive resistance (cm $s^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | At knee high stage | | At tasseling stage | | At knee high stage | | At tasseling stage | |
| | 2016-17 | 2017-18 | 2016-17 | 2017-18 | 2016-17 | 2017-18 | 2016-17 | 2017-18 |
| Mulch practices | | | | | | | | |
| $M_0$ | 1.95 | 1.64 | 1.00 | 0.83 | 4.09 | 5.32 | 22.88 | 22.34 |
| $M_G$ | 2.28 | 1.84 | 1.28 | 1.06 | 3.26 | 4.30 | 18.48 | 18.78 |
| $M_M$ | 2.11 | 1.71 | 1.10 | 0.88 | 3.92 | 4.92 | 19.98 | 19.99 |
| $M_L$ | 2.21 | 1.77 | 1.12 | 0.95 | 3.62 | 4.60 | 19.31 | 19.35 |
| CD (P=0.05) | 0.07 | 0.03 | 0.05 | 0.04 | 0.09 | 0.13 | 0.72 | 0.56 |
| Irrigation at available soil moisture depletion | | | | | | | | |
| $I_1$ | 2.26 | 1.83 | 1.29 | 1.12 | 3.30 | 3.97 | 16.79 | 16.63 |
| $I_2$ | 2.21 | 1.69 | 1.12 | 0.87 | 3.64 | 4.83 | 20.86 | 20.89 |
| $I_3$ | 1.94 | 1.70 | 0.97 | 0.81 | 4.23 | 5.57 | 22.84 | 22.82 |
| CD (P=0.05) | 0.06 | 0.03 | 0.04 | 0.03 | 0.08 | 0.11 | 0.62 | 0.48 |
| Interaction | NS | 0.06 | 0.08 | 0.06 | 0.16 | 0.22 | 1.24 | NS |

**Grain yield**

Organic mulch treated crop yielded significantly higher than no mulch in both the years (Table 5). Zhang *et al.* (2015) indicated that straw mulching applied @ 6 t $ha^{-1}$ could significantly improve 1000 kernel weight and yield of maize by 5.7% and 6.2%, respectively, when compared with the no mulching treatment. Green gram straw mulch ($M_G$) plot produced higher grain yield from 2.6-12.2% (first year) and 3.6-14.4% (second year) over other mulch practices indicating green gram straw mulch could maintain better moisture in soil and thereby extraction of water and nutrient to the maximum possible extent by the roots for prolong period. However, maize stover mulch ($M_M$) treated plot yielded similar to lantana leaves mulch ($M_L$) plot. In case of irrigation treatments, grain yield was affected significantly and maximum yield was obtained in irrigation at 20% DASM ($I_1$) and minimum in least irrigated plots ($I_3$) in both the years. These findings are in the agreement with the results of Kara and Biber (2008). When compared with first season, 25.0-45.5% less total water availability in the second season reduced the grain yield from 364-472 kg $ha^{-1}$ and 368-512 kg $ha^{-1}$ under mulch and irrigation practices, respectively, however reduction was less in $M_G$ and $I_2$. Interaction between irrigation and mulching was observed significant.

Table 5: Grain yield of maize under various levels of straw mulch and irrigation

| Treatment | Grain yield (kg $ha^{-1}$) | |
|---|---|---|
| | 2016-17 | 2017-18 |
| Mulch practices | | |
| $M_0$ | 7557.0 | 7090.0 |
| $M_G$ | 8476.0 | 8112.0 |
| $M_M$ | 8176.0 | 7704.0 |
| $M_L$ | 8261.0 | 7827.0 |
| SEm± | 84.2 | 68.3 |
| CD (P=0.05) | 251.4 | 203.4 |
| Irrigation at available soil moisture depletion | | |
| $I_1$ | 8358.0 | 7941.0 |
| $I_2$ | 8209.0 | 7841.0 |
| $I_3$ | 7786.0 | 7274.0 |
| SEm± | 66.3 | 32.5 |
| CD (P=0.05) | 259.6 | 126.7 |
| Interaction | 430.2 | 325.7 |

It may be concluded from the results that straw mulch and high irrigation frequency enabled the plants to maintain higher soil temperature in the active root zone as well as higher relative water content, leaf temperature and transpiration rate however declined leaf diffusive resistance. Green gram mulch and higher irrigation frequency improved the soil physical properties. Green gram straw mulch and irrigation applied at 20% depletion of soil moisture produced the higher grain yield of maize 82.94 and 81.50 q $ha^{-1}$, respectively. Straw mulch saved irrigation water up to 28.6% compared to no mulch. Overall application of green gram straw mulch @ 5 t $ha^{-1}$ along with irrigation at 20% DASM proved beneficial for maintaining favourable soil environment and higher maize yield during winter in mollisols of *tarai* area.

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