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Enhancing the Growth and Yield of Barley through Mulch and Irrigation Levels –A Review

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A B S T R A C T

Barley (*Hordeum vulgare* L.) is the most important fourth largest cereal crop of world after maize, wheat and rice in the world with a share of 7% of the global cereal production. The crop is considered as poor man's crop and better adaptable to problematic soils and marginal lands. Among the various production inputs, water is the most crucial in agriculture especially under limited water availability. Further, the growing demand of water for industries, house hold consumption and other uses is likely to create water crisis in agriculture. Therefore, water conservation is the most important for sustaining food and livelihood security of ever increasing food demand in India. In this context mulching is one of the important agronomic practices in conserving the soil moisture and modifying the soil physical environment. Mulching not only conserve the soil moisture by preventing evaporation but also control weed, moderate soil temperature, reduce runoff and increase infiltration. Soil evaporation is an important component of the water balance in agriculture.

Introduction

Mulching and irrigation levels on crop growth and plant height

Mohler *et al.,* (1992) studied that plant height increased significantly by increasing mulch levels and maximum plant height was observed in wheat mulch (186.88 cm), followed by berseem mulch (171.97 cm) and minimum in no-mulch (164.63 cm). Crop height increased with higher crop density and mulching practices. The increase in plant height under mulching treatment has been attributed to better availability of conserved moisture in soil profile (Sandhu *et al.,* 1980; Mishra, 1996; Brahma *et al.,* 2006). Rahman *et al.,* (2006) recorded highest plant height (82.58 cm) when mulching was done with water hyacinth followed by mulching with rice straw (873.2 cm) and no mulch treatment (80.0 cm). Khurshid *et al.,* (2006) reported

maximum plant height in maize (217.67 cm) when mulch was applied @ 12 Mg ha^{-1} followed by 217.35 and 205.71 cm in 8 and 4 Mg ha^{-1} whereas minimum plant height (185.63 cm) was obtained in control treatment. These results are in agreement with those of (Diaz-Zorita *et al.,* 2000). Ahmed *et al.,* (2007) reported that mulch @ 4 t ha^{-1} produced tallest plants in wheat than all other treatments. Shortest plants were recorded in control plots. The plant height was increased by the application of different rates of mulches compared with control. Pervaiz *et al.,* (2009) reported that maximum plant height in maize was obtained in Mulch @ 14 Mg ha^{-1} (2.53 m), followed by Mulch @ 7 Mg ha^{-1} (2.45 m) and minimum in no mulch treatment (2.40 m). Similar trend in plant height was observed at harvest. Wicks *et al.,* (1994); Khurshid *et al.,* (2006) pointed out that maize grew taller under greater mulch levels, because of availability of more soil moisture contents for plant growth. Pervez (2009); Vetsch and Randall (2002) conducted an experiment and recorded that plant height was significantly maximum in conventional tillage + wheat straw mulch treatment followed by conventional tillage + saw dust mulch (203.11 cm) and sub soiler tillage+ wheat straw (181.89 cm) treatments. The mean minimum plant height value (146.11 cm) was observed in zero tillage + wheat straw treatment. Significant difference was observed in plant height when wheat straw mulch was applied with different tillage implements as compared with controlled treatments. Taller plants in the conventional tillage and wheat straw mulch might be due to good soil physical conditions and more water conservation under the wheat straw mulch. Ahamd *et al.,* (2010) reported that maximum plant height (99.95 cm) was recorded in treatment T_2 weed free (no mulch) with respect to treatments T_6 (polythene sheet mulch), T_5 (maize stover @ 5 t/ha) and T_3 (wheat straw mulch @ 5 t/ha). Respectively controlled (no mulch) treatment recorded minimum plant height in aerobic rice. Yi *et al.,* (2011) conducted two-year field experiment at the Changwu agro-ecosystem research and recorded significantly higher maximum plant height in maize and leaf and stem biomass with treatment supplementary irrigation (SI) treatment than film mulching (FM), and a rain-fed (RF) control. Zamir *et al.,* (2012) studied that plant height was significantly maximum (202.89 cm) in T_2 (conventional tillage + wheat straw mulch) followed by 203.11 cm and 181.89 in case of T_3 (conventional tillage + saw dust mulch) and T_{11} (sub soiler tillage+ wheat straw), respectively. Minimum plant height value (146.11 cm) was observed in T_5 (zero tillage + wheat straw). Taller plants in the conventional tillage and wheat straw mulch might be due to good soil physical conditions and more water conservation under the wheat straw mulch. Similar results were also observed by those of Pervez *et al.,* (2009); and Vetsch and Randall *et al.,* (2002). Sarwar *et al.,* (2013) recorded maximum plant height in wheat (105.00 cm) in rice straw mulch @ 4 t ha^{-1} followed by wheat straw mulch @ 4 t ha^{-1} attaining plant height (103.18 cm). Maize straw mulch @ 4 t ha^{-1} was statistically non-significant with animal manure mulch @ 4 t ha^{-1} giving plant height (101.36 cm); (101.17 cm) respectively, compared to minimum plant height (97.58 cm) from those plots where no mulch was applied. Yaseen *et al.,* (2014) studied significant effect irrigation regime on plant height and recorded that maximum plant height in maize (229.38 cm) was observed in with Irrigation depth at 711.2 mm and minimum (222.92 cm) was in case of treatment Irrigation depth 558.8 mm. The mulch also had significant effect on plant height and the mean maximum value of plant height (235.20 cm) was found in treatment M_{15} where straw was applied @ 15 Mg ha^{-1} and minimum (217.90 cm) was in M_0 (control). Gao *et al.,* (2013) compared the effect of varying rates of mulch with the control. Statistically highest plant height in

wheat (35.94 cm) was recorded in treatment where wheat straw mulch was applied at the rate of 14750 kg/ha which increased the plant height by 27.5% over the treatment where no wheat straw mulch was applied. Kushwah *et al.,* (2013) concluded that significant maximum plant height in wheat (59.12 cm) was recorded in mulching with leaves of palas, which was significantly superior over other materials. Mulching with paddy straw secured second place followed by polyethylene and dry grass. Minimum plant height (39.12 cm) was recorded in case of no mulch. These findings are in line with those of Singh *et al.,* (2005) in tomato. Rajput *et al.,* (2014) recorded highest plant height in maize under guava with paddy mulch at 40, 60 and at harvest, 124.29 cm, 231.81 cm and 235.49 cm, respectively. Paddy mulch and legume mulch remained at par with 40 DAS over rest of the treatments. Minimum plant height was noticed in control. Brahma *et al.,* (2007) observed significantly higher plant height in durum wheat (96.70 cm) in the treatment receiving five irrigations over one irrigation at crown root initiation and Two irrigations at CRI + Flowering stage, but it was at par with four irrigations at CRI + Tillering + Late jointing + Milk stage. Khonok *et al.,* (2012) studied the effect of irrigation and straw mulch on barley and recorded significantly maximum plant height (57.7 cm) with 3 cm mulch compared to no mulch irrespective of irrigation treatments.

Mulching and irrigation levels on number of tillers

Ahmed *et al.,* (2007) reported that application of mulch significantly increased the number of tillers in wheat as compared to control. The mulch application @ 1, 2, 3 and 4 t ha^{-1} produced statistically same number of tillers m^{-2} but different from control. Guo *et al.,* (2012) concluded that the application of mulch significantly increased the number of tillers as compared to the weedy plots (the control) in wheat. Kushwah *et al.,* (2013) concluded that significant number of tillers/hills in wheat (6.58) were highest with application of palas leaves mulch followed by paddy straw, polyethylene and dry grass. Minimum number of tillers/hill (3.48) was recorded under control treatment. Sarwar *et al.,* (2013) reported that rice straw mulch @ 4 t ha^{-1} produced significantly higher spike bearing tillers in wheat (385.66) followed by wheat straw mulch @ 4 t ha^{-1} (367.00) as compared to minimum number of spike bearing tillers (311.66) that was recorded in no mulch treatment. Brahma *et al.,* (2006) reported that number of effective tillers per meter row length at harvest was significantly higher (147.33) in Five irrigations at CRI + Tillering + Late jointing + Flowering + Milk stage irrigation schedule over rest of the irrigation schedules, but was at par with I_4 = Four irrigations at CRI + Tillering + Late jointing + Milk stage (153.56). The lowest number of effective tillers was observed in I_1 = one irrigation CRI (99.22) in durum wheat.

Mulching and irrigation levels on leaf area index

Bhallacharya *et al.,* (1996) observed that leaf mulches of acacia gave significantly highest mean maximum LAI value (2.3) followed by glyricidia (1.3), chan (1.3) and no-mulch (1.1) in black gram. Hassan *et al.,* (2003) recorded highest mean LAI (1.35) in clay soil with mulching as compared to non-mulched treatment (1.12). Kar *et al.,* (2007) recorded maximum LAI in potato (6.4) in the mulched plot with the four irrigations. Study revealed that maximum LAI was 21–35% greater in the mulched plots than in the non-mulched plots under different irrigation levels and hence straw mulch had an impact on LAI depending on the irrigation treatments. Qin *et al.,* (2010) reported significantly highest leaf area with straw mulch treatment in rice grown in non-

flooded plots as compared to no mulch treatment. Gao *et al.,* (2013) reported that Leaf area of soybean increased with the increase in quantity of wheat straw mulch. Minimum leaf area (14.86 cm^2) was recorded in the control treatment and highest (20.20 cm^2) was noted in treatment where wheat straw mulch was applied at the rate of 7500 kg/ha. Ram *et al.,* (2013) reported that LAI in wheat was significantly larger with the increase in irrigation level and the highest LAI was recorded in the I_5 (five irrigations) treatment, which was 11.3, 13.4 and 6.8% higher than the I_2 (two irrigations) treatment in three years.

Mulching and irrigation levels on dry matter production

Ramakrishna *et al.,* (2006) studied that significantly maximum total dry matter production t/ha was in polythene mulch (6.88 t/ha) as compared to straw mulch (6.40 t/ha), chemical mulch (6.14 t/ha) and minimum dry matter production was in unmulched (5.84 t/ha) treatment in groundnut. Malecka *et al.,* (2008) concluded that significant maximum total dry matter in barley (7.64 t ha^{-1}) was found in treatment oat+ pea mixture than white mustard (6.93) and minimum total dry matter (5.96 t ha^{-1}) with no mulch treatment. Iqbal *et al.,* (2010) recorded maximum plant dry biomass in maize (27.18 Mg ha^{-1}) in treatment where mulch was applied @ 12 Mg ha^{-1} followed by 27.10 Mg ha^{-1} in treatment where mulch was applied @ 4 Mg ha^{-1} and 26.55 Mg ha^{-1} in treatment where mulch was applied @ 8 Mg ha^{-1} and minimum value 20.54 Mg ha^{-1} was observed in control. There was 31.95%, 32.34% and 29.26% increase in plant biomass respectively than control. These results are also in agreement with those of (Bonari *et al.,* 1994). Rajput *et al.,* (2014) concluded that the highest total dry matter accumulation was recorded in maize under guava with the application of paddy mulch in all growth stages and the lowest dry matter was recorded in control treatment. At harvest stage only legume mulch was at par with paddy mulch. Similar results have also been observed by Mishra (1996) and Samaila (2011) in wheat and tomato crops, respectively.

Mulching and irrigation levels on crop yield and yield attributes

Mulching and irrigation levels on crop yield attributes

Mulching and irrigation levels on number of ear heads

Janawade *et al.,* (2007) determine the effect of effective tillers per meter row length at harvest were significantly highest (147.33) with five irrigation over rest of the treatments. The present findings are in accordance with Rathore and Patil (1991); Pal *et al.,* (1996); Jana *et al.,* (2001) and Saren *et al.,* (2004). Brahma *et al.,* (2007) concluded that in wheat number of effective tillers per meter row length at harvest was significantly higher (147.33) in (I_5 = Five irrigations at CRI + Tillering + Late jointing + Flowering + Milk stage) irrigation schedule over rest of the irrigation schedules, but was at par with (153.56) (I_4 = Four irrigations at CRI + Tillering + Late jointing + Milk stage, I_4) The present findings are in accordance with Rathore and Patil (1991); Pal *et al.,* (1996); Jana *et al.,* (2001) and Saren *et al.,* (2004).

Malecka *et al.,* (2008) evaluated the effect of mulching on crop performance in barley and reported that significantly maximum ears m^{-2} (618) with mixture of Oats + pea treatments, White mustard straw (553) than other treatment and minimum ears m^{-2} (504) no mulch treatment. Khurshid *et al.,* (2009) concluded that maximum mean number of cobs $plant^{-1}$ (1.06) in maize in treatment, where mulch was applied @ 12 Mg ha^{-1}

followed by 1.05 in treatment where mulch was applied @ 4 Mg ha^{-1} and 1.02 in treatments where mulch was applied @ 8 Mg ha^{-1} with minimum mean value 1.00 was observed in control. Similar results were shown by (Albuquerque *et al.,* 2001). Khurshid *et al.,* (2009) observed maximum value of number of cobs per plant in maize T_5 (zero tillage + wheat straw) which was statistically at par with those of T_9 (bar harrow tillage + saw dust mulch) (1.46) and T_{12} (sub soiler tillage + saw dust mulch) (1.46), respectively. Minimum value of number of cob was observed in T_2 (conventional tillage + wheat straw mulch), followed by those of T_1 (conventional tillage) (1.13).

Javeed *et al.,* (2012) reported that significantly maximum number of cobs per plant 1.46 was observed in T_5 (zero tillage + wheat straw) and minimum number of cob 1.07 was observed in T_2 (conventional tillage + wheat straw mulch), followed by those treatment T_1 (conventional tillage). Ram *et al.,* (2013) conducted an experiment in wheat with different levels of mulch and reported significantly highest effective tillers with highest in M_6 treatment (6 t ha^{-1} mulch) which was significantly higher than no mulch but statistically at par with M_4 (4 t ha^{-1}) and M_2 (2 t ha^{-1}) mulching levels.

The M_6 treatment produced 6.6–20.7% more tillers than other mulching and no mulch treatments which were significantly higher than that of other mulching levels in wheat. The increase in tiller density due to mulching could be due to the better soil hydro-thermal regime compared to no mulch treatment. Ram *et al.,* (2013) reported that I_5 (five irrigations) treatment produced significantly higher number of effective tiller compared with the I_2 (two irrigations) and I_3 (three irrigations) treatments while it was similar to the I_4 (four irrigation) treatment in wheat. Sarwar *et al.,* (2013) concluded that rice straw mulch @ 4 t ha^{-1} resulted in maximum number of spikelets (18.62) per spike followed by maize straw @ 4 t ha^{-1} and wheat straw mulch @ 4 t ha^{-1} producing(18.11; 18.00) spikelets per spike respectively.

Yaseen *et al.,* (2014) revealed that the mulch had significant effect on the number of rows per cob in maize. In case of irrigation, the mean maximum value (15.38) of number of rows per cob was observed in treatment (I_2=Irrigation depth 711.2 mm) and minimum (14.98) was in case of treatment. (I_1= Irrigation depth 558.8 mm). As regards mulch, the mean maximum value of 16.00 numbers of rows per cob was observed in M_{15} where straw was applied @ 15 Mg ha^{-1} treatment and minimum of 14.36 rows per cob was in case of M_0 (control).

Mulching and irrigation levels on ear length

Ram *et al.,* (2013) concluded that mulching treatment of M_6 (6 t ha^{-1} mulch) significantly increased the spike length in wheat as compared to no mulch, M_2 (2 t ha^{-1} mulch) and the M_4 (4 t ha^{-1} mulch) treatment where it was statistically at par with the M_4 treatment. On an average the M_6 treatment produced 9.1–11.6% lengthy ears than no mulch treatment. Mishra (1996) reported an increase in spike length of wheat with straw mulching. Yaseen *et al.,* (2014) as regards the irrigation levels, mean maximum values of 14.8 cm cob length was measured in maize treatment (I_2=Irrigation depth 711.2 mm) followed by (I_1= Irrigation depth 558.8 mm) which showed 14.4 cm cob length in maize.

The mean values show that there is no significant effect on cob length under different irrigation levels. As regards the mulch, the mean maximum value of 14.7 cm cob length was observed in case of treatment M_{15} straw was applied @ 15 Mg ha^{-1} and minimum of 14.5 cm cob length was noted in case of control treatment (M_0).

Mulching and irrigation levels on number of grains ear head^{-1}

Sparling *et al.,* (1992) concluded that maximum number of grains per cob was (532.66) in T_5 (zero tillage + wheat straw) which was statistically at par with those of (521.66) in T_{12} (sub soiler tillage + saw dust) respectively treatments. Similarly, these results were observed already by (Albuquerque *et al.,* 2001). Ramirez and Kelly *et al.,* (1998) maximum number of seed (6/pod) was found in with treatment in (3 cm of mulch). Minimum number of seed (4.3/pod) in no mulch treatment. Under relatively wet soil condition, greater translocation of photosynthesis gave higher seed yield. Khurshid *et al.,* (2006) conducted an experiment to study the effect of mulch on maize maximum number of grains cob^{-1} (610.55) were observed in treatment where mulch was applied @12 Mg ha^{-1} followed by (609.55) in control treatment, (608.55) in treatment, where mulch was applied @ 4 Mg ha^{-1} and minimum mean value (603.11) in treatment where mulch was applied @ 8 Mg ha^{-1}.Brahma *et al.,* (2007) reported significantly higher number of grains in wheat per ear (49.76) in I_5 = Five irrigations at CRI + tillering + Late jointing + Flowering + Milk stage) over (I_1) one irrigation at crown root initiation (CRI) and (I_2) Two irrigations at CRI + Flowering stage (45.09 and 44.91 respectively), but was at par with (I_3) Three irrigations at CRI + Late jointing + Milk stage and I_4 = Four irrigations at CRI + tillering + Late jointing + Milk stage (48.23 and 48.58, respectively). The results are in agreement with the findings of Rathod and Patil (1991); Patil *et al.,* (1996).Uwah *et al.,* (2011) concluded that weight of grains per cob in maize obtained at 6 and 8 t/ha mulch rates across the seasons were statistically at par but higher than other mulch rates. The least weight of grains/cob reported in the control in both seasons. The total grain yield produced at 2 and 4 t/ha mulch rates were statistically similar but lower than those obtained at 6 and 8 t/ha rates which however, had similar grain yield, but all the mulched plots had higher grain yields than the control in both seasons. These agree with the findings of (Khurshid *et al.,* 2006). Sarwar *et al.,* (2013) concluded that highest number of grains per spike in wheat (53.20) were recorded in rice straw mulch @ 4 t ha^{-1} followed by wheat straw mulch @ 4 t ha^{-1} having (52.05) grains per spike. However, maize straw mulch @ 4 t ha $^{-1}$ and animal manure mulch @ 4 t ha^{-1} were statistically at par with each other, while lowest number of grains per spike (46.67) was produced by no mulch (control). Din *et al.(*2013) concluded that significant maximum grains cob^{-1} in maize (319.33) were exhibited by wheat mulch which also progressively decreased to the minimum (264.50) in those treatments having no-mulch applied under non-irrigated condition. These results are in agreement with Liu *et al.,* (2000). Khonok *et al.,* (2013) concluded that significant effect of straw mulch and irrigation management on seed number/pod 5.735 higher in bean that other treatments. Achakzai *et al.,* also recommended mulching for the achievement of better crop growth and yield and also for minimizing the loss of water from the soil surface. Rajput *et al.,* (2014) studied that paddy straw mulch showed maximum number of grain cob^{-1} in maize under guava (419.81) followed by legume mulch (418.57) and other treatments are statistically differing from paddy straw mulch.

Mulching and irrigation levels on test weight

Brahma *et al.,* (2006) recorded that thousand seed weight in wheat was significantly higher in (I_5) Five irrigations at CRI + Tillering + Late jointing + Flowering + Milk stage treatment (41.04 g) over (I_1) one irrigation at crown root initiation (CRI), (I_2) two irrigations at CRI + Flowering stage and (I_3) three irrigations at CRI + Late jointing + Milk stage,

irrigation schedules (32.27, 35.63 and 37.13 g), respectively but was at par with (I_4) four irrigations at CRI + Tillering + Late jointing + Milk stage (39.79 g). Khurshid *et al.,* (2006) concluded that significant maximum value of 1000 grain weight in case of maize (398.68 g) was observed in treatment where mulch was applied @ 12 Mg ha^{-1} followed by (390.76 g) in treatment where mulch was applied @ 8 Mg ha^{-1} and (386.16 g) in treatment, where mulch was applied @ 4 Mg ha^{-1} while mean minimum value (360.63 g) was observed in case of control.

Malecka *et al.,* (2008) recorded significantly maximum 1000 grain weight (g) in barley in treatment with oat-pea mixture, phacelia (46.3) no mulch (45.7), than White mustard straw (45.6) and minimum test weight in straw mulch (45.2) treatments. Zamir *et al.,* (2012) reported significantly maximum value of 1000 grain weight in maize (341.67 g) was observed in T_5 (zero tillage + wheat straw), followed by (332 g, 326.67 g) in T_3 (conventional tillage + saw dust mulch) and T_2 (conventional tillage + wheat straw mulch), respectively. Minimum value (288 g) was observed in T_{11} (sub soiler tillage + wheat straw mulch). These findings are supported by those of (Shirani *et al.,* 2002).Zamir *et al.,* (2012) significantly recorded maximum number of grains per cob in maize was (532.66) in T_5 (zero tillage + wheat straw) which was statistically at par with those of 521.66 in T_{12} (sub soiler tillage + saw dust). Minimum value 453.44 was observed in T_8 (bar harrow tillage + wheat straw) which was statistically at par with those of T_6 (zero tillage + saw dust) (460.44) and T_4 (zero tillage), respectively. Similarly, these results were observed already by (Albuquerque *et al.,* 2001). Ali *et al.,* (2013) recorded maximum 1000 kernel weight (g) in aerobic rice in treatment T_6 (polythene sheet mulch) in comparison with treatments T_2 weed free (no mulch) T_5 (maize stover @ 5 t/ha) and T_3 (wheat straw mulch @ 5 t/ha). Respectively treatments at panicle length cm (21.52) in T_1 weed controlled (no mulch) in aerobic rice. Sarwar *et al.,* (2013) mulched with rice straw @ 4 t ha^{-1} fashioned the maximum 1000-grain weight in wheat (52.20 g). It was trailed by wheat straw mulch @ 4 t ha^{-1} that was statistically at par with maize straw mulch @ 4 t ha^{-1} by producing (50.71 g; 50.63 g) respectively, while minimum 1000-grain weight was found in no mulch with (45.45 g) weight. Maximum 1000-grain weight in rice straw mulch @ 4 t ha^{-1} may be attributed to the fact that plants involve in successive uptake of moisture and nutrients due to better soil moisture and nutrient conservation as compared to other treatments. Din *et al., (*2013) concluded that significant maximum thousand grain weights in maize (137.50 g) was recorded in wheat mulch and minimum test weight (124.86 g) was recorded in treatments having no-mulch (control). Shafi *et al.,* (2014) as regards irrigation, the mean maximum value, i.e. 307.0 g 1000-grain weight in maize was observed in treatment (I_2) Irrigation depth 711.2 mm and minimum of 271.50 g was in treatment (I_1) Irrigation depth 558.8 mm. In case of mulch, the maximum value, *i.e*. 306.50 g 1000-grain weight was observed in treatment (M_{15}) mulch applied @ 15 Mg ha^{-1} and minimum of 272.0 g was observed in M_0 control (no mulch) treatment. Due to the application of mulch the 1000-grain weight was increased and in case of M_{15}, 1000-grain weight increased 9.6 %over control. Shafi *et al.,* (2014) revealed that the mulch had significantly affected the number of grains per rows in maize. The maximum number of grains 38 per row was observed in treatment (I_2= Irrigation depth 711.2 mm) and minimum, i.e. 36 was noted in I_1=Irrigation depth 558.8 mm) treatment. In case of mulch, the maximum 39 grains per row was observed in (M_{15}= mulch applied @ 15 Mg ha^{-1}) treatment and minimum of 35 grains per row was observed in case of treatment (M_0) control

Mulching and irrigation levels on crop yield

Mulching and irrigation levels on grain yield

Tolk *et al.,* (1999) observed that mulches applied on soil increased grain yield in maize significantly as compare with bare soil. Mulch significantly increased grain yield in maize. Maximum grain yield was observed in M_2 (Mulch @ 14 Mg ha^{-1}) (10.5 Mg ha^{-1}), followed by M_1 (Mulch @ 7 Mg ha^{-1}) (9.4 Mg ha^{-1}) and minimum in M_0 (Mulch @ 0 Mg ha^{-1}) (8.6 Mg ha-1). Tolk *et al.,* (1999) and *Liu et al.,* (2002) concluded that mulch increases soil moisture and nutrients availability to plant roots, in turn, leading to higher grain yield. Reported significantly maximum grain yield in maize 5.77 Mg ha^{-1} was observed in treatment where mulch was applied @ 8 Mg ha^{-1} followed by 5.70 Mg ha^{-1} in treatment where mulch was applied @ 12 Mg ha $^{-1}$ and 5.38 Mg ha^{-1} in treatment, where mulch was applied @ 4 Mg ha^{-1} with mean minimum value 4.92 Mg ha^{-1} was observed in case of control. There was significant difference in grain yield when mulch was applied @ 12, 8 and 4 Mg ha^{-1} as compared with control (Khurshid *et al.,* 2006). Ramakrishna *et al.,* (2006) concluded that polythene mulched plots produced the highest yields in groundnut, 94.5% higher than the unmulched plots, 46.8% higher than the chemically mulched plots and 25.5% higher than the plots mulched with rice straw. Brahma *et al.,* (2006) concluded that grain yield in wheat was significantly higher (2545 kg ha^{-1}) with Five irrigations at CRI + Tillering + Late jointing + Flowering + Milk stage irrigation schedule over one irrigation at crown root initiation (1754 kg ha^{-1}), Two irrigations at CRI + Flowering stage (1923 kg ha^{-1}) and Three irrigations at CRI + Late jointing + Milk stage, (2020 kg ha^{-1}) but was at par with Four irrigations at CRI + Tillering + Late jointing + Milk stage (2400 kg ha^{-1}). Likewise, three irrigation (2020 kg ha^{-1}) recorded significantly higher grain yield over one irrigation (1754 kg ha^{-1}) but was at par with two irrigation (1923 kg ha^{-1}) irrigation schedule. Rahman *et al.,* (2006) concluded that highest yield in tomato (73.75 t/ha) was obtained from rice straw mulch, which was significantly different from other treatments. The lowest yield (50.21 t/ha) was found from control (no mulch) treatment. Kar *et al.,* (2007) reported significantly highest tuber yield in potato of 14.9 t ha^{-1} (pooled data of 2 years) in mulched plots and of 11.2 t ha^{-1} in non-mulched plots were achieved with four irrigations. Rice straw mulch application increased the potato tuber production with 24–42% in the different irrigation treatments (pooled data of 2 years). Behara *et al.,* (2007) reported that maize stover mulch at 5 t/ha gave statistically higher grain yield of pigeon pea as compared to control. Banik *et al.,* (2008) conducted an experiment at Agricultural Experimental Farm, Indian Statistical Institute, Giridih, Jharkhand and reported that treatment (M_1) mulching with 10 tones/ha rice straw significantly increased the grain or seed yield (4.18 t/ha) of winter crops compared to no mulching (M_0) (3.87 t/ha). Mulching also gave maximum rice equivalent yields of different rice-based systems in both the years. Pervaiz *et al.,* (2009) concluded that mulch significantly increased grain yield in maize. Maximum grain yield was observed in M_2 = Mulch @ 14 Mg ha^{-1} (10.5 Mg ha^{-1}), followed by M_1 = Mulch @ 7 Mg ha^{-1} (9.4 Mg ha^{-1}) and minimum in M_0 = control (8.6 Mg ha^{-1}). Masanta *et al.,* (2009) concluded that white polythene mulch found to be better in grain yield as compared to black polythene, paddy straw and forest leaf mulch. Hence, grain yield of wheat under white polythene mulch was significantly higher in both the years (avg. 4017 kg ha^{-1}) which were 123% higher than the control plot. Similar findings were also observed by Khera and Singh *et al.,*

(1998) in case of maize yield in Punjab. Masanta *et al.,* (2009) conducted experiment at farmer's field at Purulia district of West Bengal under the National Agricultural Technology Project (RRPS-17), BCKV centre. He revealed that the highest grain yield of wheat was obtained with four irrigations (scheduled at 8-10 cm depth) each at crown root initiation (CRI) maximum tillering, flowering and grain filling stage, which was 498%, higher than the control plot. Similar findings were also reported by Zaman *et al.,* (2006). Rashidi *et al.,* (2010) reported that yield components of tomato were significantly influenced by mulch levels. Between two mulch levels plastic mulch plots recorded significantly higher yield (11.4 t ha^{-1}) compared to no mulching plots (7.36 t ha^{-1}). Malekmohammadi *et al.,* (2012) concluded that highly significant variation in garlic yield ha^{-1} was due to the effect of different mulches. Black plastic mulch (25.12 t ha^{-1}) and cow dung mulch (22.9 t ha^{-1}) gave the maximum yield followed by control (20.43 t ha^{-1}) and the lowest yield (17.43 t ha^{-1}) was observed with wheat straw mulch. Khonok *et al.,* (2013) concluded that different levels of irrigation management and mulch had a significant effect on yield in bean. A yield at different levels in nearly surface mulch and more mulch is free conditions Singh *et al.,* in the same study found that use of irrigation and mulch in fruits and vegetables that are high yield product. Din *et al.*(2013) reported that highest grain yield of 2258.7 kg ha^{-1} was resulted in wheat straw mulch while no mulch treatments showed lower grain yield of 2014.3 kg ha^{-1} in non-irrigated condition under maize. three water management regimes high dry high flooding (T_3) treatment, high dry low flooding (T_2) treatment, and shallow and frequent irrigation (T_1) treatment in all mulching and weedy plots, where T_1 is the traditional water management regime. Towa *et al.,* (2013) mulching treatment had significant effect on grain yield in rice the results show that the mean maximum and minimum grain yields were (5042.4 kg ha^{-1}) at T_2 = high dry low flooding (4033.4 kg ha^{-1}) at T_1= shallow and frequent irrigation respectively, in mulching showing 20% reduction while grain yield recorded in weedy plots was (1273.6 kg ha^{-1}) at T_2 and (903 kg ha^{-1}) at T_3= high dry high flooding respectively, with 30.8% reduction. Amini *et al.,* (2013) concluded that in lentil significant maximum grain yield recorded at treatment (I_1) 40 mm irrigation (110.1 g/m^2), 70 mm irrigation (I_2) (105.7),100 mm irrigation (I_3) and minimum grain yield in 160 mm irrigation (I_4) (46.1). But in case of mulch treatment significantly (2 t/ha mulch) grain yield was recorded with 89.4 g/m^2 and minimum grain yield in (no mulch) 80.1g/m^2. Sarwar *et al.,* (2013) observed maximum grain yield in wheat (5.16 t ha^{-1}) was in treatment rice straw mulch @ 4 t ha^{-1} but different from wheat and maize straw mulch @ 4 t ha^{-1} which were statistically at par with each other whereas minimum grain yield (4.17 t ha^{-1}) was recorded from no mulch treatment. Similar findings were also been described by Bhatt and Khera *et al.,* (2005). Birru *et al.,* (2013) recorded that 6 ton ha^{-1} farmyard manure gave the highest grain yield in wheat (4195 kg ha^{-1}) whereas the 6 ton ha^{-1} straw mulching resulted in the lowest grain (2942 kg ha^{-1}) and biomass (10.7 ton ha^{-1}) yields. This is might be due to below optimum soil temperature that influences crop growth. Chen *et al.,* (2007) reported reduction in grain yield of winter wheat by 7% with 6 ton ha^{-1} straw mulching as compared to the control. Ram *et al.,* (2013) conducted an experiment at Punjab Agricultural University, Ludhiana India. He reported that significant highest grain yield in wheat was recorded in the I_5 (five irrigations) treatment which was 23.1–23.5% and 8.1–11.5% and significantly higher than I_2 (two irrigations) and I_3 (three irrigations) treatments in wheat respectively. Taparauskiene *et al.,* (2013) recorded

maximum yield of two years in the field which were mulched with black polyethylene layer, at 1,805 g/plant; the field mulched with straw produced the minimum yield of 1,036 g/plant; yield in the strawberry field without mulches was 1,115 g/plant. Ram *et al.,* (2013) conducted an experiment to studies the different mulch treatments on wheat at Punjab Agricultural University, Ludhiana India and reported that significant increase in grain yield due to mulching was significant up to the M_4 (4 tha^{-1}) treatment only, which increased the yield by 20.2 and 25.9% over the M_0 no mulch treatments within three years in wheat. Ghalandarzadeh *et al.,* (2013) concluded that interaction of cultivar × irrigation × mulch was significant on grain and biological yield. The mean data showed that the highest grain yield (3135.2 kg/ha) and biological yield (8087.6 kg/ha) were obtained in well-watered (I_1) treatment and application of 2 tons/ha mulch. Increasing of grain yield under well-watered treatment was mainly due to availability of adequate water for beans. Rajput *et al.,* (2014) reported that the application of paddy straw mulch and legume mulch in maize crop under guava based agri-horti system were gave higher grain yield (53.34 q ha^{-1} and 52.88 q ha^{-1}), respectively over the rest treatments. Significantly lower grain yield (36.57 q ha^{-1}) was recorded in control to other treatments. Similar result was concluded by Liu *et al.,* (2000) and Mishra (1996). Nalayini *et al.,* (2014) concluded that polyethylene mulching recorded the highest seed cotton yield of 5641 kg/ha and was at par with bio-degradable polyethylene mulching (5234 kg/ha) at the same moisture level and polyethylene mulching under conventional irrigation and biodegradable polyethylene mulching under conventional irrigation. Yaseen *et al.,* (2014) shows that irrigation and mulch rates had significant effect on grain yield of maize crop. Regarding the irrigation effect on grain yield, the mean maximum value (3.81 Mg ha^{-1}) of grain yield was recorded in case of treatment I_2 and minimum (2.77 Mg ha^{-1}) was found in treatment I_1. In case of mulch rates, the mean maximum value (4.00 Mg ha^{-1}) of grain yield was observed in treatment M_{15} and minimum (2.59 Mg ha^{-1}) was found in case of treatment M_0. Mehmood *et al.,* (2014) recorded that mulch had significant effect on the grain yield in sorghum, poultry manure produced maximum grain yield (2.51 t ha^{-1}) that was statistically similar to wheat straw (2.50 t ha^{-1}). Minimum grain yield (2.38 t ha^{-1}) was recorded for control. Wie *et al.,* (2015) recorded significantly highest grain yields with treatments H (incorporation of straw at a high rate of 9000 kg h m^{-2} wheat straw), M (incorporation of straw at a medium rate of 6000 kg h m^{-2} wheat straw) and L (incorporation of straw at a low rate of 3000 kg h m^{-2} wheat straw) were higher than that with CK (no straw incorporation), *i.e*., 19.31%, 18.02%, and 6.84% higher in 2008; 26.60%, 22.40% and 6.58% higher in 2009; 28.43%, 24.31% and 7.94% higher in 2010; and 34.09%, 21.34% and 7.32% higher in 2011, respectively. The grain yields agreed with the precipitation levels in each growing season.

Mulching and irrigation levels on straw yield

Uwah *et al.,* (2011) reported that dry stover yield in maize increased significantly with each increment in mulch rate up to the 6 t/ha but not further in the two seasons. Mean maximum dry stover yield (24.29 t/ha) was obtained at 8 t/ha mulch rate, followed by 21.62 t/ha obtained at 6 t/ha mulch rate. The 4 and 2 t/ha mulch rates however, produced 17.82 t/ha and 15.82 t/ha dry stover yield respectively. Increasing the mulch rates from zero to 2, 4, 6 and 8 t/ha resulted in corresponding increases in dry stover yield by 19.0, 34.3, 63.4 and 83.5% respectively. These agree with the findings of (Khurshid *et*

al., 2006). Sarwar *et al.,* (2013) concluded that mulches also showed significant difference in case of straw yield as maximum straw yield in wheat (8.58 t ha $^{-1}$) was obtained where rice straw mulch @ 4 t ha^{-1} was used followed by wheat straw mulch @ 4 t ha^{-1} treatment with straw yield of 8.36 t ha^{-1}. However maize straw mulch @4 t ha^{-1} was statistically similar with animal manure mulch @ 4 t ha^{-1} and with burning rice straw mulch treatments. While minimum straw yield (7.27 t ha^{-1}) was recorded in no mulch. Towa *et al.*, (2013) concluded that significant maximum and minimum straw yields in rice were (6722.2 kg ha^{-1}) at T_2 = high dry low flooding and (5531.9 kg ha^{-1}) at T_1 = shallow and frequent irrigation in mulching, respectively, with 17.9 % reduction and in weedy plot it was 2223.4 kg ha^{-1} at T_1 and 1819 kg ha^{-1} at T_3 = high dry high flooding respectively, with 18% reduction. Comparing mulching and weedy plots the reduction was 67%. Agarwal and Rajat have also shown that straw application increased the production in barley. It is concluded that mulching is one of the important agronomic practices in conserving the soil moisture and modifying the soil physical environment. Mulching not only conserving the soil by preventing evaporation but also control weed, moderate soil temperature, reduce runoff and increase infiltration. Soil evaporation is essential to increase the water use efficiency. The practices of mulching have been widely used as a moisture conservation tool in agriculture and save of environment.

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