Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2021; 10(1): 1126-1130
Received: 22-11-2020
Accepted: 24-12-2020

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Effect of mulching and irrigation levels on growth and productivity of barley (*Hordeum vulgare* L.)

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Abstract
A field experiment was conducted during *rabi* 2019-20 at Research Farm, Guru Kashi University, Talwandi Sabo, Bathinda (Punjab) to find out the suitable mulching and irrigation levels for higher productivity of barley. The experiment was laid out in split plot design comprising three mulching levels (0, 5 and 10 t/ha) in main plots and three irrigation levels *viz.*, one irrigation at tillering, two irrigations at tillering + earing and three irrigations at tillering + earing + dough in sub plots. Paddy straw mulching @ 5 t/ha has profound effect on yield and yield contributing characters of barley and straw mulch seemed to be helpful for better yields. The highest grain yield (41.1 q/ha) was recorded from straw mulch @ 5 t/ha in barley which was significantly higher than control (36.6 q/ha), but it was statistically at par with straw mulch @ 10 t/ha (40.8 q/ha). Application of three irrigations (Tillering +earing+ dough stage) significantly increased growth parameters *viz.*, plant height, dry matter accumulation, number of tillers/m^2 and yield attributes *viz.*, number of effective tillers/m^2, number of grains/spike and test weight than one irrigation and two irrigations treatments. The highest grain yield (45.4 q/ha) was obtained with application of three irrigations (I_3) which was significantly higher than one irrigation (I_1) and two irrigations (I_2). The lowest grain yield (33.6 q/ha) was produced with application of one irrigation (I_1). Application of three irrigations resulted in the 35.1 and 14.9% more grain yield as compared to one and two irrigations, respectively.

Keywords: Barley, dry matter, grain yield, mulching, plant height and irrigation

Introduction
Barley (*Hordeum vulgare* L.) is an ancient cereal grain, which upon domestication has evolved largely a food grain to a feed and malting grain. It is frequently being described as the most cosmopolitan of the crops and also considered, as poor man's crop because of the low input requirement and better adaptability to drought, salinity, alkalinity and marginal lands. It is fourth important cereal crop in the world after maize, wheat and rice with a share of 7% global cereal production.
Water is the most crucial input in agriculture as major share of water resources is used in agriculture and food requirements are increasing while water resources are shrinking. The global water crisis has drawn worldwide attention to the urgency of achieving a more efficient use of water resources particularly, to increase crop production and national food security. Since agriculture uses infiltrated water that forms soil moisture in the root-zone of the crops and subsequently loss through evaporation and transpiration (ET), water conservation is the most important for sustaining food and livelihood security of people practicing agriculture. In this context mulching is one of the important agronomic practices in conserving the soil moisture and modifying the soil physical environment.
Mulching is a common practice to cover soil surface and it not only conserves moisture but also moderates temperature besides effectively controlling the weeds. It creates congenial conditions for the growth and ameliorates various environmental stresses (Macilwain, 2004) [5]. It exerts decisive effects on earliness, yield and quality of the crop. Straw mulching has a major effect on soil water and thermal regimes. The mulch probably acts as an insulator, resulting in smaller fluctuations in soil temperature in mulched treatments as compared to without mulch. Mulches can be more effective under extreme weather conditions as compared to normal conditions. Mulching is a common practice recommended for tropical small farming holder, due to its ability to conserve soil and moisture and also suppress weeds (Shah 2015) [7]. Mulching increased soil moisture content, improved the soil structure and decreased the weed growth, and thereby enhanced yield in crops (Govindappa 2014) [3]. The yield and water productivity gains were due to greater root proliferation which was the result of moderation of soil temperature and water conservation with straw mulching (Arora *et al.* 2011) [1]. Straw mulch results in maintaining soil moisture in root zone resulting enhanced rate of seed germination and final count of seedling emergence (Singh and Jolly 2008) [9].

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. Irrigation plays an important role in improving the productivity of barley. The irrigation requirement may be changed due to use of different type of mulching material. Mulching increases the infiltration of water in to the soil through run off control and increasing opportunity time to infiltration, reduces the evaporation loss and controls weed infestation. Straw mulching has been reported to retain greater availability of soil water by controlling evaporation loss from the soil surface and improving water infiltration (Chen *et al.*, 2007) [2]. Although, efforts have been made to quantify rates of mulches to conserve moisture and control weeds in many crops, but literature is both scare and limited in respect to its integration with irrigation, especially in barley. Therefore, it is justifiable to quantify the amount of straw mulch in barley with different levels of irrigation.

Material and Methods

The present study entitled **"**Effect of mulching and irrigation levels on growth and productivity of barley (*Hordeum vulgare* L.)" was carried out during the *Rabi* season 2019-20 at agricultural research farm of Guru Kashi University, Talwandi Sabo, Bathinda. Talwandi Sabo is located at 29 57'N latitude and 75 7'E longitude and altitude of 213 meters above the sea level. This tract is characterized by semi arid climate, where both winters and summers are extreme. The meteorological data recorded at the meteorological observatory of the Punjab Agricultural University, regional station, Bathinda during the crop growing season (November to April). Five plants per plot were selected randomly to measure the height from ground level to the tip of longest leaf at 30 days after sowing (DAS), up to the base of top most fully opened leaf at 60 DAS, up to the base of flag leaf at 90 DAS and up to the base of the ear at harvest. Above ground plant samples from 50 cm row length were taken periodically at 30, 60, 90 DAS and at harvest. The samples were first sun dried and thereafter, they were kept in an oven at a temperature of 60ºC to achieve constant weight. The dry weight thus obtained was recorded and expressed as q ha^{-1}. Total number of tillers per metre row length was recorded at 30, 60, 90 DAS and at harvest from two sites in each plot.

Effective tillers per metre row length from two spots in each plot were counted at harvest. Five spikes were selected at random from each plot and their length excluding awns was measured and then averaged values were calculated. The average length was expressed in cm. Randomly selected five spikes were taken from each plot and threshed manually. The number of grains were counted and averaged for number of grains $spike^{-1}$. One thousand grains from produce of each plot were taken and their weight was recorded. The thousand grain weight was expressed in grams.

The total produce was weighed in bundles after harvesting and threshed thereafter. The weight of grains was recorded. The straw weight was obtained after deducting the weight of grains from total bundle weight. Grain and straw yield were computed and expressed as quintal ha^{-1}. HI was calculated by dividing economic (grain) yield by the total biological (grain + straw) yield and expressed as percentage.

$$\text{HI (\%)} = \frac{\text{Economic yield}}{\text{Biological yield (Grain + Straw)}} \times 100$$

Results and Discussion

Growth parameters of barley

Plant height is an important index of the plant development. The perusal of data on plant height indicates plant height was significantly influenced by different mulching levels. The highest plant height was attained from straw mulch @ 5 t/ha in barley, which was significantly higher than control and it was statistically at par with straw mulch @ 10 t/ha. Control (no mulch) produced the lowest plant height. This might be due to soil moisture content and temperature differences among the mulching treatments. Straw mulch conserved more soil moisture than control. The result is partially similar to that reported by Mishra (1996), who found that soil mulching increased the availability of conserved moisture in the soil profile and significantly enhanced plant water use efficiency and plant height. Plant height was significantly influenced by irrigation scheduling. The highest plant height was recorded when three irrigations were applied (I_3), which was significantly higher than one irrigation (I_1) and two irrigations (I_2). The lowest plant height was observed with one irrigation. Increased plant growth under more irrigations *i.e.* up to three may be attributed to the fact that the loamy sand soil had limited water holding capacity and increased moisture content in the soil might have resulted in better nutrient use efficiency thereby leading to profuse plant growth. Similar results have been reported by Rahman *et al*. (2000), Saren and Jana (2001) and Singh *et al*. (2004). The interaction effect between mulching and irrigation levels on plant height of barley was found to be a non- significant.

Table 1: Effect of mulching and irrigation levels on growth parameters of barley

Treatments	Plant height (cm)	No. of tillers/m²	Dry matter accumulation (q/ha)
Mulching (t/ha)			
Control	94.0	208	73.6
5	97.8	250	78.8
10	97.1	241	77.5
LSD (P=0.05)	1.5	12	1.4
Time of irrigation			
I_1 (1 irrigation)	93.1	216	68.8
I_2 (2 irrigations)	95.9	237	77.3
I_3(3 irrigations)	99.9	246	83.7
LSD (P=0.05)	1.2	5.0	2.2

The data pertaining to effect of different treatments on the number of tillers/m^2 have been shown in Table.1 Number of tillers/m^2 was significant affected by mulching levels. The highest number of tillers/m^2 was obtained from mulch @ 5 t/ha which was significantly higher than control and it was statistically at par with straw mulch @ 10 t/ha. Lowest number of tillers/m^2 was found in control. Mulching might have reduced the fluctuation of soil temperature and increased the soil moisture and resulted in more rapid crop growth and produced more number of tillers. The result was partially similar to the findings of Mishra (1996) who stated that soil mulching significantly enhanced the number of tillers per plant. There was significant effect of irrigation scheduling on number of tillers/m^2 at 120 DAS. The highest number of tillers/m^2 was recorded when three irrigations were applied (I_3), which was significantly higher than one irrigation (I_1) and two irrigations (I_2). The lowest plant height was observed under one irrigation plots. Increased plant growth under more irrigations *i.e.* up to three may be attributed to the fact that the loamy sand soil had limited water holding capacity and increased moisture content in the soil might have resulted in better nutrient use efficiency thereby leading to profuse plant growth. Similar results have been reported by Rahman *et al*. (2000), Saren and Jana (2001) and Singh *et al*. (2004). The interaction effect between mulching and irrigation levels on number of tillers/m^2 of barley was found to be a non-significant.

The data regarding dry matter accumulation have been presented in Table 1 indicates that the effect of mulching levels on the dry matter accumulation was significant. The highest dry matter accumulation was obtained from straw mulch @ 5 t/ha which was significantly higher than control, but being at par with mulch @ 10 t/ha. Control produced the lowest dry matter accumulation. The result is partially in agreement to the findings of Wang *et al.* (1998) who reported that mulching accelerated greening, and increased the dry matter accumulation. Further data revealed that application of three irrigations (I_3) resulted in the highest and significantly more dry matter accumulation as compared to one (I_1) and two irrigations (I_2). Increased plant growth under more irrigations *i.e.* up to three may be attributed to the fact that the loamy sand soil had limited water holding capacity and increased moisture content in the soil might have resulted in better nutrient use efficiency thereby leading to profuse plant growth. Similar results have been reported by Rahman *et al*. (2000), Saren and Jana (2001) and Singh *et al*. (2004). The interaction effect between mulching and irrigation levels on dry matter accumulation of barley was found to be a non-significant.

Table 2: Effect of mulching and irrigation levels on yield parameters of barley

Treatments	Number of effective tillers/m^2	Number of grains/spike	Test weight (g)
Mulching (t/ha)			
Control	204	32.8	46.2
5	248	36.9	48.7
10	239	37.0	48.1
LSD (P=0.05)	12	2.3	0.8
Time of irrigation			
I_1 (1 irrigation)	212	32.1	45.6
I_2 (2 irrigations)	234	34.7	47.6
I_3 (3 irrigations)	244	40.0	49.8
LSD (P=0.05)	NS	3.5	1.1

Yield attributes of barley

Number of effective tillers/m^2 was found significant by mulching treatments. The highest number of effective tillers/m^2 was obtained from mulch @ 5 t/ha which was significantly higher than control and it was statistically at par with straw mulch @ 10 t/ha. Lowest number of effective tillers/m^2 was found in control. Mulching might have reduced the fluctuation of soil temperature and increased the soil moisture and resulted in more rapid crop growth and produced more number of tillers. The result was partially similar to the findings of Mishra (1996) who stated that soil mulching significantly enhanced the number of effective tillers per plant. The effect of irrigation levels on number of effective tillers/m^2 was significant. The highest number of effective tillers/m^2 was obtained with application of three irrigations (I_3) which was significantly higher than one irrigation (I_1) and two irrigation (I_2). The lowest number of effective tillers/m^2 was observed with application of one irrigation. Application of three irrigations resulted in the highest and significantly more number of effective tillers/m^2 as compared to one and two irrigations. Increased effective tillers under more irrigations *i.e.* up to three may be attributed to the fact that the loamy sand soil had limited water holding capacity and increased moisture content in the soil might have resulted in better nutrient use efficiency thereby leading to profuse plant growth. Similar results have been reported by Rahman *et al*. (2000), Saren and Jana (2001) and Singh *et al*. (2004). The interaction effect between mulching and irrigation levels on number of effective tillers/m^2 of late sown wheat was found to be a non- significant.

The data on number of grains/spike have been presented in Table 2. The effect of mulching on the number of grains/spike was significant. Higher number of grains/spike was recorded from straw mulch @ 5 t/ha, which was significantly higher than control and was at par with straw mulch @ 10 t/ha. The lowest number of grains/spike was obtained from control. Similar results were also reported by Ha *et al.* (1985). The effect of irrigation levels on number of grains/spike of barley was significant. The highest number of grains/spike was obtained with application of three irrigations (I_3) which was significantly higher than one irrigation (I_1) and two irrigations (I_2). The lowest number of grains/spike was produced with application of one irrigation (I_1). Application of three irrigations resulted in the highest and significantly more values of number of grains per spike as compared to one and two irrigations. The reason is obvious that adequate supply of water might have kept all the nutrient ions in proper available form. Similar results have been reported by Jana *et al*. (2001), Guler (2003) and Sharma (2004). Interaction effect of mulching and irrigation levels on number of grains per spike was found to be non-significant.

The data on 1000-grain weight have been presented in Table 2. Mulching play significant role on 1000-grains weight in barley. The highest 1000-grain weight was obtained from mulch @ 5 t/ha, which was significantly higher than control, but it was at par with straw mulch @ 10 t/ha. The 1000-grain weight was recorded from control. The effect of irrigation levels on 1000-grain weight of barley was significant. The highest 1000-grain weight was obtained with application of three irrigations (I_3) which was significantly higher than one irrigation (I_1) and two irrigations (I_2). The lowest 1000-grain weight was produced with application of one irrigation (I_1). Application of three irrigations resulted in the highest and significantly more values of 1000-grain weight as compared to one and two irrigations. The reason is obvious that adequate supply of water might have kept all the nutrient ions in proper available form. Similar results have been reported by Jana *et al*. (2001), Guler (2003) and Sharma (2004). Interaction effect of mulching and irrigation levels on 1000-grain weight was found to be non-significant.

Table 3: Effect of mulching and irrigation levels on growth and productivity of barley

Treatments	Grain yield (q/ha)	Straw yield (q/ha)	Harvest index (%)
Mulching (t/ha)			
Control	36.6	57.5	38.8
5	41.1	62.8	39.5
10	40.8	65.7	38.3
LSD (P=0.05)	1.1	3.2	NS
Time of irrigation			
I_1 (1 irrigation)	33.6	53.7	38.5
I_2 (2 irrigations)	39.5	62.2	38.8
I_3 (3 irrigations)	45.7	70.2	39.3
LSD (P=0.05)	1.7	3.4	NS

Productivity of barley

The variation in grain yield was significant due to mulching levels. The highest grain yield (41.1 q/ha) was recorded from straw mulch @ 5 t/ha in barley which was significantly higher than control (36.6 q/ha), but it was statistically at par with straw mulch @ 10 t/ha (40.8 q/ha). No mulch treatment produced the lowest and statistically inferior grain yield of barley. Similar results were observed by Sachan (1976), De *et al*. (1983), Chen (1996) and Upadhyay and Tiwari (1996). Authors observed that mulching with rice straw significantly increased the yields of wheat. Plant absorbed soil moisture as vaporized forms but there was no enough facilities to vaporize the soil moisture in control treatment (no mulch) whereas, mulching treatments suppressed the weed growth and conserved available soil moisture and vaporized the moisture for absorption by the plants. It might have enhanced all the growth stages which directly or indirectly increased the yield of wheat. The effect of irrigation levels on grain yield of barley was significant. The highest grain yield (45.4 q/ha) was obtained with application of three irrigations (I_3) which was significantly higher than one irrigation (I_1) and two irrigations (I_2). The lowest grain yield (33.6 q/ha) was produced with application of one irrigation (I_1). Application of three irrigations resulted in the highest and significantly more values of yield attributes *i.e.* effective tillers, number of grains per spike as compared to one and two irrigations. The reason is obvious that adequate supply of water might have kept all the nutrient ions in proper available form. Similar results have been reported by Jana *et al*. (2001), Guler (2003) and Sharma (2004). Had the atmospheric temperature not risen abruptly in the month of February or had there been winter rains during the season perhaps there would not have been much difference between the growth due to three and two irrigations. Since crop yield is a cumulative effect of factors related to plant growth and development, the improvement in yield was, therefore, obvious.

The influence of mulching on straw yield was significant. Straw mulch @ 10 t/ha gave the highest straw yield, being at par with straw mulch @ 5 t/ha and was significantly higher than no mulch treatment. Control produced the lowest and inferior straw yield. The result was partially similar to the findings of Sharma *et al.* (1998). They found that application of increased moisture extraction, water use efficiency and grain and straw yields of wheat. The effect of irrigation levels on straw yield of barley was significant. The highest straw yield was recorded with application of three irrigations (I_3) which was significantly higher than one irrigation (I_1) and two irrigations (I_2). The lowest straw yield was produced with application of one irrigation (I_1). Application of three irrigations resulted in the highest and significantly more straw yield as compared to one and two irrigations. Application of three irrigations resulted in the highest and significantly more values of yield attributes *i.e.* effective tillers, number of grains per spike as compared to one and two irrigations. The reason is obvious that adequate supply of water might have kept all the nutrient ions in proper available form. Similar results have been reported by Jana *et al*. (2001), Guler (2003) and Sharma (2004).

Harvest index is an important parameter indicating the efficiency of partitioning of dry matter to the economic parts of the crop. Higher value of harvest index indicates that plant is more efficient in producing economic yield. Mulching and irrigation levels had non-significant effect on harvest index of barley. Interaction effect of mulching and irrigation levels on harvest index was found to be non-significant.

Conclusion

Paddy straw mulching @ 5 t/ha has profound effect on yield and yield contributing characters of barley and straw mulch seemed to be helpful for better yields. Application of paddy straw mulching @ 5 t/ha significantly increased growth parameters *viz.*, plant height, dry matter accumulation, number of tillers/m^2 and yield attributes *viz.*, number of effective tillers/m^2, number of grains/spike and test weight than control. The highest grain yield (41.1 q/ha) was recorded from straw mulch @ 5 t/ha in barley which was significantly higher than control (36.6 q/ha), but it was statistically at par with straw mulch @ 10 t/ha (40.8 q/ha). Application of three irrigations (Tillering +earing+ dough stage) significantly increased growth parameters *viz.*, plant height, dry matter accumulation, number of tillers/m^2 and yield attributes *viz.*, number of effective tillers/m^2, number of grains/spike and test weight than one irrigation and two irrigations treatments. The highest grain yield (45.4 q/ha) was obtained with application of three irrigations (I_3) which was significantly higher than one irrigation (I_1) and two irrigations (I_2). The lowest grain yield (33.6 q/ha) was produced with application of one irrigation (I_1). Application of three irrigations resulted in the 35.1 and 14.9% more grain yield as compared to one and two irrigations, respectively.

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