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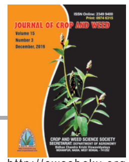

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Performance of wheat under different tillage methods and potassium levels under irrigated and rainfed conditions of Northern-India

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ABSTRACT

The impact of two tillage methods [conventional and conservation tillage], two irrigation levels [no irrigation and two irrigations of 2.5 cm each at tillering and flowering stages only] and three potassium levels [100 per cent, 125 per cent, and 150 per cent recommended dose of potassium] were evaluated for soil moisture content, yield, nutrient uptake by wheat crop and soil properties at the experimental farm of Department of Soil Science, CSK HPKV, Palampur, during rabi, 2016-17. The results indicated that plots under conservation tillage exhibited early emergence, higher soil moisture content, plant height (77.2 cm), relative leaf water content, better yield attributes (spike length, number of grains per spike, number of effective tillers and 1000-grain weight) and grain (26.6 q ha^{-1}) and straw yield (39.5q ha^{-1}) in comparison to the conventional tillage. Among the irrigation levels, higher plant height (76.0 cm), relative water content, better yield attributes and grain (28.4 q ha^{-1}), and straw yield (41.1q ha^{-1}) were recorded when the crop was irrigated twice as compared to no irrigation. The treatment comprising two irrigations coupled with the application of 150 per cent recommended dose of potassium under conservation tillage recorded higher gross returns (Rs. 97106 ha^{-1}), net return (Rs. 62860 ha^{-1}) and B: C ratio (2.84).

Keywords: Irrigation, net returns,potassium, tillage, yield

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops; belongs to the grass family Poaceae and is widely cultivated for its seed, a cereal grain. In India, only 1/3rd irrigated wheat receives desired irrigations. The remaining 2/3rd of the wheat acreage has resorted to limited irrigation only. In Himachal Pradesh too, about 80% of the area is rain-fed and during *rabi* season wheat is the major crop among cereals occupying an area of about 381 thousand hectares. The average productivity of wheat in India, as well as Himachal Pradesh, is quite low *i.e.* 31.8 and 15.9 q ha^{-1}, respectively. The main reason for such low productivity is the moisture deficit. The availability of water together with other nutrients is a key factor in plant growth. It is well recognized that only with ample water supply, crop plants can effectively exploit soil and fertilizer applied nutrients. Even mild water stress can be detrimental to proper crop growth. Any water deficit significantly disturbs plant function, which negatively impacts plant life processes, both at the molecular and whole-plant levels. Drought stress induces stomatal closure, reducing evapo-transpiration and the mass flow of soil solution to the root surface. As a consequence, the rate of mineral-element delivery decreases, which limits plant nutrition and growth (Gonzalez-Dugo *et al.,*2010).Therefore, we have to look for management strategies that can help in minimizing the losses from the soil as well to alleviate the adverse effects of moisture stress. Potassium participates in maintaining the permeability of cell membranes and in keeping cell protoplasm in the proper degree of hydration. Potassium also increases the tolerance of plants against moisture stress, heat, frost, and diseases (Singh, 2000). There is evidence that plants suffering from environmental stresses like drought have a larger internal requirement for K. The enhanced need for K by plants suffering from environmental stresses appears to be related to the role of K for maintenance of photosynthetic CO_2 fixation as drought stress is associated with stomatal closure and thereby with decreased CO_2 fixation. Therefore, an adequate supply of potassium in wheat grown under rain-fed/limited water supply would help in alleviating the adverse effects of moisture stress (Grzebisz *et al.,* 2013**)**. Another way to cope up with the limited water availability in wheat may be the adoption of such a tillage system which conserves the residual moisture as well as check the evaporation losses during the crop growth. Conventional tillage disturbs soil structure and affects soil temperature, mechanical properties, continuity of macro-pores and available water capacity of the soil as well as growth and distribution of roots (Verhulst*et al.,* 2011).Nonetheless, the development of agricultural research has revealed that tillage operations are not necessary practices to produce crops. Seedbed preparation practices are tending to a single operation (no-tillage), owing to lower soil disturbance during

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planting practices (Choudhary and Baker, 1993). No-tillage provides an opportunity to revive traditional agriculture with a new concept of conservation agriculture (Ehsanullah *et al.,* 2013).The no-tillage system has some advantages when compared to the conventional tillage, for instance, reduction of machinery passes over the field, fuel consumption, reduction in field preparation time and tillage and soil loss due to better aggregate stability, as well as the protective effect of crop residues left over the soil. Furthermore, no-tillage systems enhance soil physical properties e.g. available water, and some bio pores that may facilitate root growth (Martinez *et al.*2008). Entirely, it could be enounced that the aims of these systems by plant residue management are control of water and wind erosion, reduction of consumed energy, and conservation of soil and water (Unger and McCalla, 1980; Wang *et al.*, 2012). However, the impact of a particular tillage system on soil properties depends on the site (*i.e*. soil, climate) and the number of years since the tillage system has been implemented (Rhoton, 2000). Among tillage manipulations, conservation tillage, a method of soil cultivation that leaves about 30 percent of the previous year's crop residue on fields before and after planting the next crop, is very promising in conserving moisture for utilization of next crop.Various studies conducted at different parts of India and the world has revealed the importance of conservation tillage in wheat in conserving the soil moisture and reducing the soil erosion and runoff. Sustainable soil management can be achieved through conservation tillage, high crop residue return, and crop rotation (Hobbs *et al.,* 2008). Studies conducted under a wide range of climatic conditions, soil types, and crop rotation systems showed that soils under no-tillage and reduced tillage have significantly higher soil organic carbon(SOC) contents compared with conventionally tilled soils (Alvarez, 2005). No-tillage (NT) has been shown to improve soil properties, thereby enhancing water transmission, water retention, and crop yield in many parts of the world (He *et al.,* 2009).The studies on the effect of conservation tillage coupled with the use of enhanced potassium application on the performance of wheat grown under rain-fed and limited water conditions are, however, very limited particularly, under wet temperate conditions. Therefore, this investigation was planned to investigate the effect of conservation tillage along with different potassium levels under rain-fed and limited water conditions on wheat productivity and soil properties.

MATERIALS AND METHODS

The field experiment was conducted at the experimental farm of Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur (32^{o} 6' N latitude, 76^{o} 3' E longitude and 1290 m altitude) during *rabi,* 2016-17. The climate of the study area is characterized as wet temperate, with mild summers (March to June) and cool winters. The average annual rainfall of the area ranges from 2500-3000 mm. In general, a major portion of the rainfall (about 75 per cent) is received during the monsoon period from June to September. The soil of the experimental site was acidic in reaction and silty clay loam in texture, low in available nitrogen, high in available phosphorus and medium in available potassium. The organic carbon content at the initiation of the experiment was medium. The field experiment was laid out in split-plot design with twelve treatment combinations of two tillage methods, three potassium levels and two irrigation levels each replicated thrice in a gross plot size of 1.8 × 5m (9 m^2).The main plot consists of two Tillage Methods (C_1: Conventional tillage and C_2: Conservation tillage) and two Irrigation Levels (I_1: No irrigation and I_2: Two irrigations of 2.5 cm each at tillering and flowering stages only). Subplot consists of three Potassium levels (% of the Recommended dose of 40kg K_2O ha^{-1}) *i.e.*K1:100%, K_2:125%, and K_3: 150%. The wheat crop (variety HPW 236) was sown on 26th December, 2016 and harvested on 7th May, 2017. In conservation tillage, only furrows were opened to sow wheat seeds without disturbing the remaining plot area. Crop residues from the previous crop were utilized to cover the plots under conservation tillage. Seeds of wheat were soaked in water for 24 hours before sowing. The changes in soil water content during the season at 0-15 and 15-30 cm depths were determined by the thermo gravimetric method at 15 days interval till maturity of the crop. The emergence count was recorded on alternate days from 1m area (marked for sampling) from the date of the first emergence of seedling until it was constant. The number of days taken to emergence was worked out from the date of sowing. The number of wheat seedlings emerging from one-meter row length at three different sites in each plot was counted daily from sowing till it became constant in all the treatments and the data were converted into per meter square. The produce from each net plot was harvested and threshed after sun drying. The grains were cleaned and weighed after threshing. The weight of grains per net plot was converted into kilograms per hectare (kg ha^{-1}).Total biological yield (grain + straw) from each net plot was recorded by weighing the dried harvested produce from each plot. The straw yield was worked out by subtracting the grain yield from biological yield and expressed in kilogram per hectare (kg ha^{-1}). The relative leaf water content (RLWC) was determined at maximum tillering and flowering stages at 7:00 am and 12:00 noon. It was computed from the fresh weight, turgid weight, and oven-dry weight according to the method given by Weatherly (1950). The processed surface soil samples (0-0.15 m and 0.15-0.30 m) after harvest were analyzed for soil pH, organic carbon, available nitrogen, phosphorus, and potassium and initial samples were also analyzed for physical separates. The data generated from field and laboratory analyses were subjected to statistical analysis using the technique of analysis of variance for a split-plot design for the interpretation of results as described by Gomez and Gomez (1984). The economic analysis was carried out using the cost of cultivation and the gross returns obtained from the total produce under different treatments as under:

Net return (Rs. ha^{-1}) = Gross income (Rs. ha^{-1}) – Cost of cultivation (Rs. ha^{-1})

Benefit-costs ratio

$$(B: C) = \frac{\text{Gross returns (Rs. ha}^{-1})}{\text{Cost of cultivation (Rs. ha}^{-1})}$$

RESULTS AND DISCUSSION

Soil moisture content

The soil moisture content determined at 15 days intervals throughout the growth period have been embodied in Table 1. The soil moisture content was significantly higher in conservation tillage as compared to conventional tillage except at 15 DAS, 75 DAS, and 105 DAS. The differences in soil moisture content values were non-significant under different irrigation levels except at 60 DAS and 90 DAS. Significantly higher soil moisture content was recorded when there was the application of two irrigations of 2.5 cm each at maximum tillering and flowering stages in wheat as compared to no irrigation.

Growth parameters

The data pertaining to the effect of tillage, irrigation and potassium levels in wheat on days to complete emergence have been presented in Table 2.The emergence was earlier in conservation tillage as compared to the conventional tillage. The fast emergence in conservation tillage might be due to the minimum soil manipulation that economized the soil water loss through less evaporation (Licht and Kawasi, 2005) and the softened seedbed might have helped in fast emergence by early softening of the seed coat. The mean plant height recorded under conservation tillage was significantly higher (77.2 cm) as compared to conventional tillage (68.9cm). Similar results were reported by Kausar *et al.* (1993), Ayoub *et al.* (1994) and Maqsood *et al.* (1999).

Yield attributes

The data about the effect of tillage, irrigation and potassium levels in wheat on yield attributes have been presented in Table 3.Conservation tillage resulted in significantly more number of effective tillers per square meter (268.3 m^{-2}) as compared to conventional tillage (244.4 m^{-2}). The positive effect of conservation tillage may be attributed to improved physical, chemical, and biological properties of soil (Kumar *et al.,* 2015)**.**When there was limited irrigation there were significantly more effective tillers per meter square (267.8 m^{-2}) as compared to no irrigation treatment (244.9 m^{-2}). Similar results have been reported by Ram *et al.* (2013) and Patil *et al.* (2014). Only the highest level of potassium (150% of recommended K) recorded a significantly higher number of effective tillers (265.9 m^{-2}) over 100 per cent recommended level of K (244.6 m^{-2}) but remained statistically at par with the 125 per cent recommended level of K (258.6 m^{-2}). Almost similar results were obtained by Maurya *et al.* (2014) and Khaskheli *et al.* (2017)**.** The mean spike length recorded under conservation tillage (10.4 cm) was significantly higher as compared to conventional tillage (9.4 cm). Similar results were reported by Jabran and Aulakh (2015). The higher value of spike length under conservation tillage might be due to its favorable impact on different soil physicochemical properties (Akhtar, 2006) and the continuous availability of essential plant nutrients due to the favorable hydro-thermal regime (Akhtar, 2006). Application of two irrigations of 2.5 cm each at maximum tillering and flowering stages recorded mean spike length significantly higher (10.2 cm) than that recorded under no irrigation (9.6 cm). Similar results were reported by Waraich *et al.* (2007) and Mahamed *et al.* (2011) who also reported an increase in spike length with the increased amount of irrigation water. The spike length increased significantly with the application of a 150 per cent recommended dose of potassium in comparison to the application of 100 percent recommended dose of potassium but it remained at par with that recorded in 125 per cent recommended dose of potassium. Application of 125 per cent recommended dose of potassium, however, was at par with 100 per cent of recommended K. Potassium in addition to its role as nutrient also maintained higher relative water content besides lowering osmotic potential, thereby resulting in the improved ability of plants to tolerate drought stress and improve yield contributing characters. Similar results were reported by Brhane *et al.* (2017) and Khaskheli *et al.* (2017). The grains per spike recorded under conservation tillage were significantly higher (38.9) as compared to conventional tillage (33.7). Grains per spike in conservation tillage might be due to improved physical,

Table 1: Effect of tillage methods, irrigation and potassium levels on soil moisture content by weight (%)

Treatment	15 DAS Soil Depth (m)		30 DAS Soil Depth (m)		45 DAS Soil Depth (m)		60 DAS Soil Depth (m)		75 DAS Soil Depth (m)		90 DAS Soil Depth (m)		105 DAS Soil Depth (m)		120 DAS Soil Depth (m)	
	0-0.15	0.15-0.30	0-0.15	0.15-0.30	0-0.15	0.15-0.30	0-0.15	0.15-0.30	0-0.15	0.15-0.30	0-0.15	0.15-0.30	0-0.15	0.15-0.30	0-0.15	0.15-0.30
Tillage methods																
C_1 (Conventional)	26.4	28.1	22.8	23.7	25.8	26.7	26.8	27.1	27.3	28.4	25.5	26.7	23.5	25.8	21.5	24.1
C_2 (Conservation)	27.3	28.7	24.5	24.7	27.6	28.3	28.5	28.9	28.0	29.6	28.0	28.8	24.2	26.8	25.2	25.5
LSD (0.05)	**NS**	**NS**	**0.8**	**0.9**	**0.6**	**0.8**	**1.4**	**1.5**	**NS**	**NS**	**1.4**	**1.7**	**NS**	**NS**	**1.1**	**1.3**
S. E (±)	**0.39**	**0.48**	**0.31**	**0.39**	**0.26**	**0.80**	**0.58**	**0.62**	**0.55**	**0.72**	**0.55**	**0.70**	**0.48**	**0.39**	**0.46**	**0.52**
Irrigation levels																
I_1 (No irrigation)	26.4	28.2	23.3	24.2	26.6	27.4	26.8	27.1	27.3	28.7	25.2	25.9	23.6	25.9	23.1	24.7
I_2 (Limited irrigation)	27.4	28.6	24.0	24.3	26.8	27.7	28.4	28.9	28.0	29.3	28.3	29.6	24.1	26.7	23.6	24.9
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**1.4**	**1.5**	**NS**	**NS**	**1.4**	**1.7**	**NS**	**NS**	**NS**	**NS**
S. E (±)	**0.39**	**0.48**	**0.31**	**0.39**	**0.26**	**0.80**	**0.58**	**0.62**	**0.55**	**0.72**	**0.55**	**0.70**	**0.48**	**0.39**	**0.46**	**0.52**
Potassium levels (% of recommended K)																
K_1 (100)	26.7	28.2	23.4	23.8	26.3	27.3	27.2	27.4	27.6	29.4	26.7	28.2	23.7	26.2	23.3	24.5
K_2 (125)	26.7	28.4	23.7	23.8	26.9	27.4	28.2	28.8	28.1	28.4	27.2	27.2	23.9	26.2	23.4	24.9
K_3 (150)	27.1	28.5	23.7	25.1	26.9	27.8	27.4	27.8	27.1	29.1	26.2	27.7	24.0	26.5	23.4	25.0
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
S. E (±)	**0.79**	**0.56**	**0.69**	**0.57**	**0.46**	**0.53**	**0.72**	**0.77**	**0.84**	**0.66**	**0.84**	**0.75**	**0.56**	**0.79**	**0.56**	**0.60**

Note- None of the interaction was found significant

***DAS- days after sowing**

Table 2: Effect of tillage methods, irrigation and potassium levels on days to complete emergence, emergence count and plant height

Treatment	Days to complete emergence (no.)	Emergence count (no. m^{-2})	Plant height at harvest (cm)
Tillage methods			
C_1 (Conventional)	10.4	178.3	68.9
C_2 (Conservation)	9.7	182.5	77.2
LSD (0.05)	**0.6**	**NS**	**5.6**
S. E (±)	**0.23**	**1.96**	**2.27**
Irrigation levels			
I_1 (No irrigation)	10.0	179.5	70.1
I_2 (Limited irrigation)	10.0	181.3	76.0
LSD (0.05)	**NS**	**NS**	**5.6**
S. E (±)	**0.23**	**1.96**	**2.27**
Potassium levels (% of recommended K)			
K_1 (100)	9.8	177.1	69.0
K_2 (125)	10.1	181.8	73.4
K_3 (150)	10.0	182.2	76.6
LSD (0.05)	**NS**	**NS**	**2.2**
S. E (±)	**0.54**	**4.30**	**1.05**

Note- None of the interaction was found significant

chemical and biological properties of soil vis-a-vis proper moisture conditions and temperature moderation due to residues cover on the surface as compared to conventional tillage. Similar results were reported by Kumar *et al.* (2015) and Alamouti and Mohammadi (2015). Application of two irrigations of 2.5 cm each at maximum tillering and flowering stages recorded significantly higher grains per spike (37.0) than that recorded under no irrigation (35.5). Lesser grains per spike in no irrigation was probably because moisture stress might have hastened the development of primordia which consequently resulted in poor or incomplete pollination, fertilization, and seed set (Machando *et al.,* 1993; Simane *et al.,* 1993 and Hamam, 2008). A higher number of grains per spike was recorded with the application of 150 per cent of the recommended dose of potassium (37.8) which was at par with 125 per cent of the recommended dose of potassium (36.5) followed by the application of 100 per cent of the recommended dose of potassium (34.5). An increase in grains per spike with increased potash levels can be attributed to greater spike length. Similar results were also reported by Abbas *et al*. (2013) and Tahir *et al.* (2008).The 1000- grain weight was significantly higher under conservation tillage (40.3 g) as compared to conventional tillage (36.7 g). Similar effects of conservation tillage on test weight of wheat grains were also reported by Kumar *et al.* (2015) and Alamouti and Mohammadi (2015). Higher grain weight under the conservation tillage may be attributed to better plant growth and utilization of nutrients and translocation of photosynthates for the formation of grains due to comparatively higher moisture status vis-a-vis better physical, chemical, and biological properties of soil. Application of two irrigations of 2.5 cm each at maximum tillering and flowering stages recorded significantly higher (40.0g) 1000- grain weight than that recorded under no irrigation (37.0 g) which might be due to better uptake of various nutrients and their translocation and utilization within the plants owing to higher moisture contents at crucial stages and better translocation of photosynthates towards grains. A higher value of 1000- grain weight was recorded with the application of 150 percent of the recommended dose of potassium (41.0g) which was at par with 125 per cent of the recommended dose of potassium (38.4 g) followed by the application of 100 per cent of the recommended dose of potassium (36.2 g). Potassium performs an important role in increasing the cell division, cell growth, photosynthesis process, and transport of photosynthates into seeds for proper grain filling and helps to increase the dimensions of seed and consequently, seed weight increases (Movahedi, 2012). Similar findings were reported by Hossain *et al.*

Table 3: Effect of tillage methods, irrigation and potassium levels on spike length (cm), and no. of tillers (no. m^{-2}), grains per spike and 1000- grain weight (g)

Treatment	No. of effective tillers (no. m^{-2})	Spike length (cm)	Grains $spike^{-1}$	1000- grain weight(g)
Tillage methods				
C_1 (Conventional)	244.4	9.4	33.7	36.7
C_2 (Conservation)	268.3	10.4	38.9	40.3
LSD (0.05)	**13.6**	**0.6**	**0.8**	**2.9**
S. E (±)	**5.56**	**0.25**	**0.33**	**1.19**
Irrigation levels				
I_1 (No irrigation)	244.9	9.6	35.5	37.0
I_2 (Limited irrigation)	267.8	10.2	37.0	40.0
LSD (0.05)	**13.6**	**0.6**	**0.8**	**2.9**
S. E (±)	**5.56**	**0.25**	**0.33**	**1.19**
Potassium levels (% of recommended K)				
K_1 (100)	244.6	9.0	34.5	36.2
K_2 (125)	258.6	10.0	36.5	38.4
K_3 (150)	265.9	10.7	37.8	41.0
LSD (0.05)	**16.1**	**1.1**	**2.2**	**3.7**
S. E (±)	**7.61**	**0.47**	**1.06**	**1.75**

Note- None of the interaction was found significant

(2013), Mohammadi *et al.* (2013), and Abbas *et al.* (2013).

Relative leaf water content

The relative leaf water content (RLWC) values at maximum tillering (Fig. 1) and flowering (Fig. 2) were recorded at 7.00 AM (0700h) and afternoon at 2.00 PM (1400h).The relative leaf water content (RLWC) values at maximum tillering and flowering were significantly higher under conservation tillage as compared to the conventional tillage which was due to greater availability in conservation tillage because in conservation plots, surface covering with residues increased retention of moisture in soil due to checking of water loss through evaporation. The RLWC values at maximum tillering and flowering stages were significantly higher when there was the application of two irrigations of 2.5 cm each at maximum tillering and flowering stages as compared to no irrigation. Reduced soil water availability under no irrigation resulted in the low relative water content of plants. Similar results were observed by Kumar *et al.* (2017) where an increase in several irrigations tended to increase the relative leaf water content. The RLWC values at maximum tillering and flowering increased consistently with an increase in potassium levels except at 1400 hours at maximum tillering. Potassium is known for maintaining higher relative water content and the lower osmotic potential resulting in the improved ability of plants to tolerate drought stress (Kant and Kafkafi, 2002). Potassium regulates the opening and closing of the stomata for keeping the plants turgid. It is directly involved as an osmotic constituent and also regulates the synthesis of osmotically active organic solutes thereby having an impact on turgor potential (Beringer, 1978).

Yield of wheat

The data on the effect of tillage methods, irrigation, and potassium levels on grain, straw, and biological yield of wheat are presented in Table 4. The conservation tillage gave significantly higher grain yield (26.6 q ha^{-1}), straw yield (39.5 q ha^{-1}) and total biological yield (66.1q ha^{-1}) as compared to conventional tillage. Higher grain yield under conservation tillage may be attributed to significantly higher moisture contents in soil for most of the crop duration that might have helped in proper utilization of native and applied nutrients from the soil solution leading to improvement in different yield attributing characters. Secondly, residues on the soil surface moderate the adverse effects of rapid alterations in soil temperature leading to enhanced activities of microbes and release of nutrients from organic sources for crop utilization. Yield advantages in wheat following conservation tillage have also been reported by Brennan *et al.* (2014), Kumar *et al.* (2015), and Bazaya *et al.,*

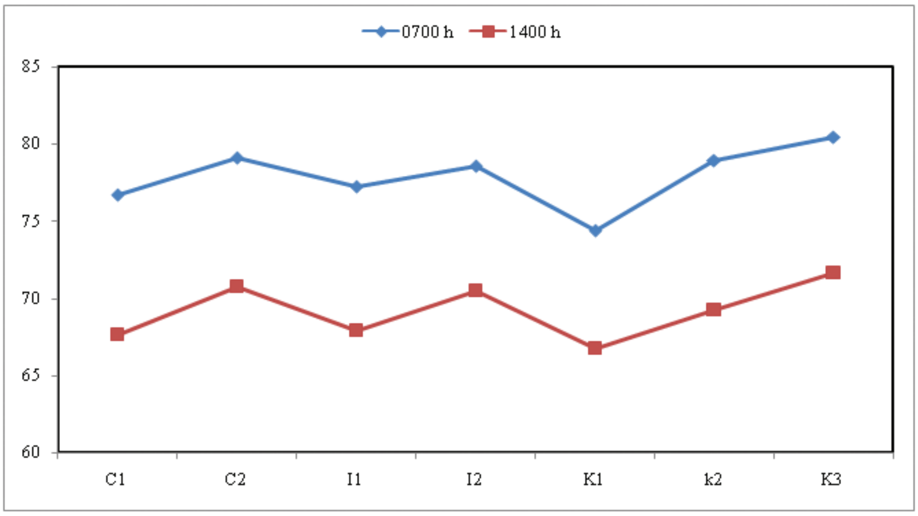

Fig. 1: Effect of tillage, irrigation and potassium levels on relative leaf water content (%) of wheat at maximum tillering

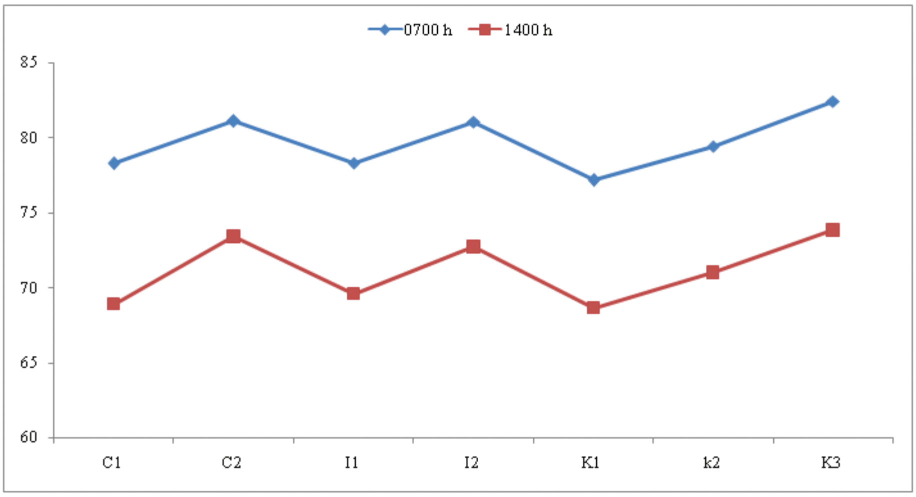

Fig.2: Effect of tillage, irrigation and potassium levels on relative leaf water content (%) of wheat at flowering

(2016). Low yield levels realized in the present study are mainly due to delayed sowing of wheat for want of proper moisture conditions in the soil. The sowing of wheat could be done in the last week of December after the rains. The grain (28.4 q ha^{-1}), straw (41.1 q ha^{-1}) and total biological yield (69.5 q ha^{-1}) were significantly higher when there was limited irrigation as compared to no irrigation treatment. The grain, straw, and total biological yield increased consistently with an increase in potassium levels. Similar results were also reported by Bhattacharyya *et al.*(2008), Akbari *et al.* (2011), and Han *et al.* (2017). Application of 150 per cent of the recommended dose of potassium resulted in higher grain (28.4 q ha^{-1}), straw (41.8 q ha^{-1}), and total biological yield (70.2 q ha^{-1}) than the application of 100 and125 per cent of the recommended dose of potassium. Application of two irrigations of 2.5 cm each at maximum tillering and flowering stages under conservational tillage was the best combination and produced the maximum grain (29.5 q ha^{-1}), straw (43.2 q ha^{-1}), and total biological yield (72.7 q ha^{-1}). Potassium nutrition has been reported to be associated with maintaining the permeability of the cell membrane and keeping the cell protoplasm in a proper degree of hydration under moisture stress conditions. It is known for imparting tolerance in plants against moisture stress, heat, frost, and diseases (Singh, 2000; Alderfasi and Refay, 2010). Although K is a co-factor for several enzymes, yet its effect on starch synthesis is well established. Therefore, enhanced availability of potassium can have a profound effect on grain development. The positive effect of increased potassium

Table 4: Effect of tillage methods, irrigation and potassium levels on grain, straw and total biological yield (q ha^{-1})

Treatment	Grain yield	Straw yield	Biological yield
Tillage methods			
C_1 (Conventional)	22.2	32.4	54.5
C_2 (Conservation)	26.6	39.5	66.1
LSD (0.05)	**1.9**	**2.8**	**4.59**
S. E (±)	**0.76**	**1.12**	**1.88**
Irrigation levels			
I_1 (No irrigation)	20.4	30.8	51.1
I_2 (Limited irrigation)	28.4	41.1	69.5
LSD (0.05)	**1.9**	**2.8**	**4.6**
S. E (±)	**0.76**	**1.12**	**1.88**
Potassium levels (% of recommended K)			
K_1 (100)	19.4	29.6	49.0
K_2 (125)	25.3	36.3	61.6
K_3 (150)	28.4	41.8	70.2
LSD (0.05)	**2.2**	**3.4**	**5.5**
S. E (±)	**1.03**	**1.58**	**2.59**

Table 5: Interaction between tillage methods and irrigation levels on grain, straw and biological yield (q ha^{-1})

Tillage Methods	Irrigation Levels		
	I_1 (No irrigation)		**I_2 (Limited irrigation)**
Grain Yield			
C_1 (Conventional)	17.1		27.3
C_2 (Conservation)	23.6		29.5
LSD (0.05)		**2.6**	
S. E (±)		**1.08**	
Straw Yield			
C_1 (Conventional)	25.7		38.1
C_2 (Conservation)	35.8		43.2
LSD (0.05)		**3.9**	
S. E (±)		**1.59**	
Biological Yield			
C_1 (Conventional)	42.8		66.2
C_2 (Conservation)	59.4		72.7
LSD (0.05)		**6.5**	
S. E (±)		**2.65**	

levels on grain yield under moisture stress conditions in the present study is, therefore, justifiable in the light of above explanations. Similar results on the effect of potassium application on grain yield of wheat under various situations have also been reported by many workers (Dwivedi, 2001; Khan *et al.,* 2007; Tahir *et al.,* 2008; Abbas *et al.,* 2013 and Maurya *et al*., 2014).

Among various interactions, only the interaction between different tillage methods and irrigation levels was found significant and the data about this interaction have been given in table 5. It is clear from the data that

Table 6: **Treatment combinations wise cost of cultivation, gross returns, net returns and B: C ratio**

Treatment	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C
$C_1I_1K_1$	33523	40453	6930	1.21
$C_1I_1K_2$	33792	48693	14901	1.44
$C_1I_1K_3$	34078	59773	25696	1.75
$C_1I_2K_1$	34279	61593	27314	1.80
$C_1I_2K_2$	34548	81533	46985	2.36
$C_1I_2K_3$	34834	90610	55776	2.60
$C_2I_1K_1$	32935	56420	23485	1.71
$C_2I_1K_2$	33204	69527	36323	2.09
$C_2I_1K_3$	33385	80100	46715	2.40
$C_2I_2K_1$	33691	67846	34154	2.01
$C_2I_2K_2$	33960	89805	55845	2.64
$C_2I_2K_3$	34246	97106	62861	2.84

the lowest yield was recorded in the treatment combination where wheat was grown under conventional tillage without any irrigation (C_1I_1) and the highest yield was recorded when wheat was grown under conservation tillage with limited irrigation (C_2I_2).

Economics

The data on treatment combinations wise cost of cultivation, gross returns, net returns and B: C ratio are presented in Table 6. The highest gross returns (Rs. 97106 ha^{-1}), net returns (Rs. 62860 ha^{-1}) and B: C (2.84) were recorded when wheat was grown following conservation tillage along with two irrigations of 2.5 cm each at maximum tillering and flowering stages and application of 150% of recommended dose of potassium. Minimum gross returns (Rs. 40453 ha^{-1}), net returns (Rs. 6929 ha^{-1}) and B: C (1.21) were observed in 100 per cent recommended dose of potassium coupled with no irrigation under conventional tillage.

CONCLUSION

Conservation tillage exhibited early emergence, higher soil moisture content, plant height (77.2 cm), relative leaf water content, better yield attributes (spike length, number of grains per spike, number of effective tillers and 1000-grain weight) and grain (26.6 q ha^{-1}) and straw yield (39.5q ha^{-1}) in comparison to the conventional tillage. Among the irrigation levels, higher plant height (76.0 cm), relative water content, better yield attributes and grain (28.4 q ha^{-1}), and straw yield (41.1q ha^{-1}) were recorded when the crop was irrigated twice as compared to no irrigation. The treatment comprising two irrigations coupled with the application of 150 per cent recommended dose of potassium under conservation tillage recorded higher gross returns (Rs. 97106 ha^{-1}), net return (Rs. 62860 ha^{-1}) and B: C ratio (2.84).

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