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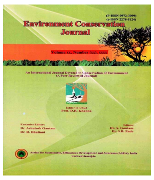

Growth and yield of wheat as affected by tillage practices, seed priming and nutrient management under rain fed conditions

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ABSTRACT

The present study was conducted on wheat for two years from 2020-2022 to evaluate the effect of seed priming, tillage practices and nutrient management on growth and yield studies of crop under rainfed conditions at CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The experiment was laid out in factorial randomized block design with three factors. Factor I (Tillage practices) consisted of Conventional tillage (CT), Conventional tillage+ mulch (CT+M) and Zero tillage+ mulch (ZT+M); Factor II (Seed priming) consisted of Hydropriming and micronutrient (Zn, Mn) priming; Factor III (Nutrient management practices) consisted of recommended dose of fertilizers (RDF) and Integrated nutrient management. An additional treatment of control was also kept for general comparison of results. Tillage practices and nutrient management significantly effected growth and yield studies of wheat. However, seed priming had no significant effect on various parameters. Growth and yield of wheat were found to be significantly superior under conventional tillage+mulch (CT+M) as compared to other tillage practices. Maximum height (108.4 cm), dry matter accumulation (896.7 g/m^2), leaf area index (2.43) and yield (9.19 t/ha) of wheat was obtained with CT+M. Zero tillage+mulch being the second best treatment proved to be better than conventional tillage. The growth and yield of wheat was significantly enhanced with integrated nutrient management as compared to recommended dose of fertilizers. Among different treatment combinations, T_6 (CT+M, Hydro, Int) was found to be best in terms of both growth and yield studies in wheat under rainfed conditions.

Introduction

Wheat (*Triticum aestivum* L.), being a major cereal crop, accounts for 26 per cent of world cereal production (Rahman *et al.,* 2021); and plays an important role in nutritional and food security. It is most extensively grown cereal in the world from temperate dry to irrigated and high rainfall area; and from dry cold to warm humid environment. In Himachal Pradesh, wheat is mainly grown under rainfed areas. Rainfed agriculture plays a significant part in ensuring global food security. In India, rainfed agriculture covers 86 mha which is 60 percent of net cultivated area and it produces 40 per cent of food grains (Rao *et al.,* 2015). Due to erratic and uncertain rainfalls, rainfed crop production depends on moisture stored in soil (Borgomeo *et al.,* 2020). The conventional intensive tillage practices results in reduction of soil organic carbon and increased runoff; thus reducing soil moisture.

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Several improved management practices under conservation agriculture has been reported such as zero or minimum tillage in wheat and residue management that improved resource use efficiency and crop productivity (Timalsina *et al.,* 2021). Conservation tillage along with residue retention is recognized as cost effective method to enhance soil moisture conservation and maintain productivity of crops (Mukherjee 2015). According to reports, one of the main challenges in better crop growth and yield is lack of synchronized crop establishment; which is caused by unfavourable weather conditions (Singh *et al.,* 2017a). Seed priming is easy and cost effective solution under such conditions. It reduces the time gap between sowing and emergence, and enhances synchronization in plants (Sarlach *et al.,* 2013). Excessive supply of chemical fertilizers has degraded soil structure and decreased organic matter, thus reducing microbial activity in soil (Dhaliwal *et al.,* 2021). Moreover, declined use of organic manures and crop residues have resulted in micronutrient deficiencies in north-western India (Bharti and Sharma 2017). Integrated nutrient management is a feasible approach for improving soil health as well as agricultural productivity. The use of well decomposed manure is known to improve crop yield, soil organic matter, encourage microbial population and increases amount of macro and micronutrients in soil. The challenge of improving productivity and resource conservation in rainfed areas can be addressed by proper crop establishment method along with efficient utilization of nutrients. Work done on tillage and nutrient management in wheat is region specific. Hence, investigation was carried out to study the effect of seed priming, tillage and nutrient management practices on growth and yield of wheat under rainfed conditions.

Material and Methods

The present study was undertaken at the Water Management Research Farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The experimental site was at 32°6' N latitude, 76°32 E longitude, and 1290 m altitude. Site is located in Himachal Pradesh's sub-temperate mid-hill region. The test site's soil had a silty clay loam texture, was acidic in reaction, rich in organic carbon and phosphorus, and had a medium level of available nitrogen and potassium. . Recommended dose of fertilizers were applied as 80:40:40 kg/ha N: P_2O_5: K_2O for wheat. In case of integrated nutrient management, 50% nitrogen was provided by FYM and 50% of nitrogen, rest of phosphorus and potassium was given through chemical fertilizers. All other recommended package of practices of region were followed for variety 'HPW 236'. Five randomly selected plants in each plot were tagged for height measurement. Plant height was measured from the base of plant to the top. The average height of the five plants was calculated and expressed as plant height (cm). For recording dry matter accumulation, plant samples were taken from the sampling rows from each plot at 30 days interval up to harvest. The plants were cut close to the ground and after sun drying; they were kept in oven for 3 hours at 70 ˚C. Weight was noted when samples attained constant weight.Leaf area index was recorded using manual method. For this, leaf area was calculated as the product of the total length and breadth at the broadest point of the longest leaf on the plant i.e. Leaf Area = lamina length x maximum width x k (coefficient). Leaf area so obtained was divided by ground area to get leaf area index. Crop growth rate was calculated using the formula:

$$\mathbf{CGR} = \frac{(w2-w1)}{t2-t1}.$$

Relative growth rate was calculated as following:

$$\mathbf{RGR} = \frac{(loge\ w2-loge\ w1)}{t2-t1}$$

where, w_1 and w_2 are dry weight per unit area at t_1 and t_2 time, respectively.

The crop from each net plot was harvested and dried thoroughly for 5 days. When most of the straw in a handful bundle broke up on folding, then total produce was weighed and recorded as biological yield (grain + straw).

Results and Discussion

Plant height

Data on plant height of wheat has been depicted in table 1. Significantly higher plant height of wheat was found in conventional tillage+mulch (108.4cm), which was followed by zero tillage+ mulch (101.8 cm) during both years of study.

The lowest plant height (95.5 cm) was observed in conventional tillage without mulch. The reason may be good soil physical conditions and more water conservation under conventional tillage and mulch treatments. The results are in close conformity with Qamar *et al.,* 2015. Higher plant height in the zero tillage than conventional tillage was observed due to the high moisture availability and higher nutrient content in zero tillage at the upper soil surface compared to conventional tillage (Hemmat and Eskandari (2006) and Lupwayi *et al.,* (2006).

Seed priming methods had no significant effect on plant height of wheat at different intervals during both years of experiment. Plant height was significantly effected by nutrient management practices in wheat at all intervals except at 60 DAS, where the effect was found to be non significant. Significantly higher plant height (104.2 cm) of wheat was obtained with Integrated nutrient management (50% N through FYM +50% N and rest of P and K through inorganic sources) as compared to RDF(recommended dose of fertilizers) during both years. This can be possibly explained by the fact that the balanced supply of nutrients from organic manures plays an important role for rapid growth and development of a crop, which results in increased plant height.

Moreover direct and rapid supply of nutrients through chemical fertilizer; and slow release and mineralization of nutrients through organic manures during the growing period of the crop might have increased plant height under this treatment. The results are in line with Kavinder *et al.,* 2019 who observed significantly higher plant height of wheat under FYM application over no FYM. In comparison of control with other treatments, it was observed that all treatments except T_1(CT,Hydro,RDF), T_2 (CT,Hydro,Int), T_3 (CT,Micro,RDF) and T_4 (CT,Micro,Int) at 60 DAS, and T_1(CT,Hydro,RDF) and T_3 (CT,Micro,RDF) at 90 DASwere found to be significantly better than control in terms of plant height in both years of wheat. The tallest plants were observed in T_6 (CT+M,Hydro,Int) at all stages (Table 2). This is relatable to positive effects of mulch and integrated nutrient management on crop.

Dry matter accumulation

The data on dry matter accumulation in wheat is presented in Table 3. Conventional tillage+mulch resulted in significantly higher dry matter accumulation (896.7 g/m^2) as compared to other tillage practices. This was followed by zero tillage+ mulch (833.3 g/m^2). This may be attributed to better weed control and enhanced moisture retaining capacity in these treatments, resulting in increased dry matter production. Lowest dry matter accumulation was noted under conventional tillage, which may be due to sub surface soil compaction that causes hindrance to plant growth, thus reducing dry matter production. Akter *et al.,* 2018 reported similar results. Seed priming had no significant effect on dry matter accumulation of wheat. It was observed that Integrated nutrient management (50% N through FYM +50% N and rest of P and K through inorganic sources) resulted in significantly higher dry matter accumulation (868.6 g/m^2) over RDF(recommended dose of fertilizers) in wheat. Higher dry matter production in integrated nutrient management may be because organic manures supply both macro and micro nutrients and also increases the availability of native nutrients in soil, resulting in increased vegetative growth of plants. Furthermore, combined application of organic and inorganic sources supply adequate amount of nutrients to plants which increases translocation of photosynthates from source to sink and enhances dry matter production (Singh et *al.,* 2017b). The results are in line with Kavinder *et al.,* 2019. It was found that all treatments except T_1 and T_3 at 60 DAS; T_3 at 90 DAS; T_1, T_2, T_3 and T_4 at 120 DAS; T_1, T_2, T_3, T_4, T_9 and T_{11} at harvest were found to be significantly better than control in terms of dry matter accumulation during both years of study. T_6 (CT+M,Hydro,Int) resulted in highest dry matter accumulation at all stages (Table 4).

Leaf Area Index

The data on leaf area index of wheat is presented in Table 5.Among different tillage practices, conventional tillage along with mulch resulted in significantly higher leaf area index (2.43) in wheat during both years of experiment. This may be attributed to the fact that mulching increased the availability of conserved moisture in the soil and significantly enhanced plant water use efficiency and leaf area. Similar results were reported by

Table 1: Effect of tillage practices, seed priming and nutrient management on plant height of wheat at periodic intervals

	Plant Height (cm)									
	60 DAS		90 DAS		120 DAS		150 DAS		Harvest	
CT	26.9	27.7	37.1	38.0	58.7	60.1	92.0	93.6	94.0	95.5
CT + Mulch	31.9	32.9	43.6	44.7	65.8	67.5	104.5	106.3	106.7	108.4
ZT + Mulch	28.5	29.4	40.9	42.0	62.5	64.1	98.2	99.9	100.2	101.8
SEm±	0.7	0.7	1.2	1.1	0.8	0.9	1.5	1.5	1.4	1.4
LSD (P=0.05)	**2.0**	**2.0**	**3.4**	**3.2**	**2.4**	**2.5**	**4.2**	**4.3**	**4.0**	**4.1**
Seed priming										
Hydro priming	29.5	30.4	41.1	42.1	63.0	64.5	99.3	101.0	101.4	103.0
Micronutrient priming	28.7	29.6	40.0	41.1	61.7	63.2	97.2	98.9	99.2	100.8
SEm±	0.6	0.6	1.0	0.9	0.7	0.7	1.2	1.2	1.1	1.1
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nutrient management										
RDF	28.4	29.3	39.1	40.2	61.1	62.7	95.9	97.6	98.0	99.6
Integrated	29.8	30.8	42.0	43.0	63.6	65.1	100.6	102.3	102.6	104.2
SEm±	0.6	0.6	1.0	0.9	0.7	0.7	1.2	1.2	1.1	1.1
LSD (P=0.05)	**NS**	**NS**	**2.8**	**2.6**	**2.0**	**2.0**	**3.5**	**3.5**	**3.3**	**3.4**
Control vs others										
Control	24.5	25.3	32.4	33.3	52.9	54.3	80.5	82.0	82.4	83.9
Others	29.1	30.0	40.5	41.6	62.3	63.9	98.2	99.9	100.3	101.9
SEm±	1.0	1.0	1.7	1.6	1.2	1.3	2.1	2.2	2.0	2.1
LSD (P=0.05)	**3.0**	**3.0**	**5.0**	**4.7**	**3.5**	**3.7**	**6.2**	**6.4**	**5.9**	**6.0**

***CT: Conventional tillage, ZT: Zero tillage, Micronutrient priming: Zn (0.5%), Mn (0.1%), RDF: Recommended dose of fertilizers, Integrated: 50% N through FYM + 50% N and rest of P and K through inorganic sources, Control: CT, no priming, RDF**

Table 2: Effect of different treatments and control onplant height of wheat at periodic intervals

Treatments	Plant Height (cm)									
	60 DAS		90 DAS		120 DAS		150 DAS		Harvest	
T1 CT,Hydro,RDF	26.6	27.5	35.7	37.1	57.7	59.1	90.6	92.2	92.3	93.9
T2 CT,Hydro,Int	27.4	28.3	39.8	40.3	60.7	62.1	95.4	97.0	97.4	98.9
T3 CT, Micro,RDF	26.5	27.4	34.3	35.7	56.7	58.1	88.6	90.2	90.8	92.3
T4 CT, Micro,Int	26.8	27.8	38.4	39.0	59.6	61.1	93.5	95.1	95.4	97.0
T5 CT+M,Hydro,RDF	30.7	31.7	42.9	44.0	65.9	67.6	102.5	104.3	105.4	107.2
T6 CT+M,Hydro,Int	34.6	35.6	45.3	46.5	67.3	69.0	109.3	111.1	111.5	113.4
T7 CT+M, Micro,RDF	30.3	31.3	42.1	43.2	63.4	65.0	99.6	101.3	101.7	103.5
T8 CT+M, Micro,Int	32.1	33.1	44.2	45.3	66.6	68.2	106.5	108.3	108.1	109.6
T9 ZT+M,Hydro,RDF	28.4	29.3	40.2	41.2	61.6	63.1	97.5	99.2	99.2	100.8
T10 ZT+M,Hydro,Int	29.3	30.3	42.4	43.4	64.6	66.2	100.3	102.0	102.4	104.0
T11 ZT+M, Micro,RDF	27.7	28.6	39.4	39.7	61.4	63.0	96.6	98.3	98.4	100.0
T12 ZT+M, Micro,Int	28.6	29.5	41.7	43.6	62.5	64.0	98.5	100.2	100.8	102.4
T13 Control	24.5	25.3	32.4	33.3	52.9	54.3	80.5	82.0	82.4	83.9
SEm±	1.0	1.0	1.7	1.6	1.2	1.3	2.1	2.2	2.0	2.1
LSD control vs others **(P=0.05)**	**3.0**	**3.0**	**5.0**	**4.7**	**3.5**	**3.7**	**6.2**	**6.4**	**5.9**	**6.0**

***CT: Conventional tillage, ZT: Zero tillage, M: Mulch, Hydro: Hydropriming, Micro: Micronutrient priming Zn (0.5%), Mn (0.1%), RDF: Recommended dose of fertilizers, Int: 50% N through FYM + 50% N and rest of P and K through inorganic sources, Control: CT, no priming, RDF**

Table 3: Effect of tillage practices, seed priming and nutrient management on dry matter accumulation of wheat at periodic intervals

	Dry matter accumulation (g/m²)									
	60 DAS		**90 DAS**		**120 DAS**		**150 DAS**		**Harvest**	
CT	95.5	97.0	207.3	209.0	503.1	504.6	752.3	761.2	774.2	797.2
CT + Mulch	106.1	107.8	249.4	251.3	626.1	628.2	866.0	878.2	881.2	896.7
ZT + Mulch	100.5	102.1	223.1	224.8	565.8	567.7	780.7	791.5	809.3	833.3
SEm±	1.1	1.3	3.7	3.8	11.0	11.6	12.6	13.1	20.2	20.6
LSD (P=0.05)	**3.3**	**3.8**	**10.9**	**11.0**	**32.2**	**33.9**	**36.7**	**38.1**	**58.8**	**60.2**
Seed priming										
Hydro priming	101.4	103.0	229.4	231.1	570.9	572.8	812.8	824.9	825.2	846.1
Micronutrient priming	100.1	101.6	223.9	225.6	559.0	560.9	786.5	795.7	817.9	838.7
SEm±	0.9	1.1	3.1	3.1	9.0	9.5	10.3	10.7	16.5	16.8
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nutrient management										
RDF	99.3	100.7	220.0	221.8	551.8	552.3	771.8	782.7	795.9	816.2
Integrated	102.1	104.0	233.2	235.0	578.1	581.4	827.5	837.9	847.2	868.6
SEm±	0.9	1.1	3.1	3.1	9.0	9.5	10.3	10.7	16.5	16.8
LSD (P=0.05)	**2.7**	**3.1**	**8.9**	**9.0**	**26.3**	**27.7**	**29.9**	**31.1**	**48.0**	**49.1**
Control vs others										
Control	90.6	92.0	186.3	187.8	474.0	475.6	717.3	727.1	732.3	752.3
Others	100.7	102.3	226.6	228.4	565.0	566.8	799.6	810.3	821.6	842.4
SEm±	1.7	1.9	5.5	5.5	16.2	17.1	18.5	19.2	29.7	30.4
LSD (P=0.05)	**4.9**	**5.6**	**16.1**	**16.2**	**47.4**	**49.9**	**54.0**	**56.1**	**86.6**	**88.6**

***CT: Conventional tillage, ZT: Zero tillage, Micronutrient priming: Zn (0.5%), Mn (0.1%), RDF: Recommended dose of fertilizers, Integrated: 50% N through FYM + 50% N and rest of P and K through inorganic sources, Control: CT, no priming, RDF**

Table 4: Effect of different treatments and control on dry matter accumulation of wheat at periodic intervals.

Treatments	Dry matter accumulation (g/m²)									
	60 DAS		**90 DAS**		**120 DAS**		**150 DAS**		**Harvest**	
T_1 CT,Hydro,RDF	94.4	95.1	205.6	207.2	499.9	492.9	737.3	749.6	770.9	793.7
T_2 CT,Hydro,Int	97.5	99.9	214.5	216.1	513.6	523.5	756.2	769.0	780.0	803.2
T_3 CT, Micro,RDF	93.5	94.3	198.6	200.3	494.4	496.1	739.4	748.4	769.6	792.4
T_4 CT, Micro,Int	96.6	98.7	210.7	212.4	504.4	506.1	776.1	777.8	776.2	799.4
T_5 CT+M,Hydro,RDF	105.5	107.2	245.8	247.7	619.0	621.2	810.2	821.6	857.8	873.0
T_6 CT+M,Hydro,Int	108.5	110.3	261.5	263.5	645.6	647.9	1009.0	1022.9	920.8	936.7
T_7 CT+M, Micro,RDF	103.6	105.3	235.8	237.6	605.8	607.9	789.8	801.2	843.6	858.5
T_8 CT+M, Micro,Int	106.7	108.4	254.6	256.5	633.8	635.9	855.1	867.1	902.6	918.3
T_9 ZT+M,Hydro,RDF	100.4	101.9	218.7	220.4	554.0	555.8	778.0	788.8	766.9	790.0
T_{10} ZT+M,Hydro,Int	101.9	103.5	230.2	231.9	593.5	595.4	786.4	797.3	855.0	880.1
T_{11} ZT+M, Micro,RDF	98.6	100.1	215.8	217.5	537.8	539.7	775.9	786.6	766.6	789.6
T_{12} ZT+M, Micro,Int	101.3	102.9	227.6	229.4	577.9	579.8	782.5	793.3	848.8	873.7
T_{13} Control	90.6	92.0	186.3	187.8	474.0	475.6	717.3	727.1	732.3	752.3
SEm±	1.7	1.9	5.5	5.5	16.2	17.1	18.5	19.2	29.7	30.4
LSD control vs others**(P=0.05)**	**4.9**	**5.6**	**16.1**	**16.2**	**47.4**	**49.9**	**54.0**	**56.1**	**86.6**	**88.6**

***CT: Conventional tillage, ZT: Zero tillage, Micronutrient priming: Zn (0.5%), Mn (0.1%), RDF: Recommended dose of fertilizers, Integrated: 50% N through FYM + 50% N and rest of P and K through inorganic sources, Control: CT, no priming, RDF**

Akter *et al.,* 2018 who found that higher leaf area index was obtained with straw mulching in wheat as compared to no mulching. Moreover, Scopel *et al.,* (2004) has also concluded that increased quantity of surface residue in field was found to have a significant effect on plant available water, which reduced water stress and resulted in increased LAI. The lowest leaf area index (1.97) was found in conventional tillage, which was in accordance with Meena *et al.,* 2018 . Seed priming methods had no significant effect on leaf area index in wheat during both years of study. Nutrient management practices significantly effected leaf area index of wheat at different intervals except at 60 DAS, during both years. Significantly higher leaf area index was obtained from Integrated nutrient management (50% N through FYM +50% N and rest of P and K through inorganic sources) as compared to RDF (recommended dose of fertilizers). This can be explained by the fact that FYM contain more number of nitrogen fixing, phosphate solubilising and other beneficial microbes, antibiotics, enzymes, vitamins, etc., which resulted in enhanced growth of plants thereby increasing leaf area. This may also be attributed to better integration of organic manures and chemical fertilizers which may have provided sufficient nutrients at active growth stage, thus resulting in increased leaf area (Fazily et *al.,* 2021). The results are in close conformity with Kumar *et al.,* 2017 who reported higher leaf area index of wheat with integrated application of inorganic and organic sources of nutrients. It was observed that all the treatments were significantly better than control. The highest leaf area index was observed in T_6 (CT+M,Hydro,Int), at all stages of crop growth (Table 6).

Crop growth rate

Data pertaining to crop growth rate of wheat is reported in table 7.Different tillage practices significantly effected crop growth rate of wheat upto 120 DAS in both years of study. Significantly higher crop growth rate was found under conventional tillage+ mulch (12.56 g/m^2/day**)** which was followed by zero tillage +mulch (11.43 g/m^2/day). This may be due to fine and loose soil structure under conventional tillage along with positive benefits of mulch (improved nutrient and moisture availability) which increased crop growth rate of crop. Moreover, residues used as mulch contain substantial amounts of plant nutrients, as reported by Das *et al.,* 2015. The results are in line with Qamar *et al.,* 2015 who noted increased growth parameters of wheat under conventional tillage and mulch. Hydropriming and micronutrient priming showed no significant difference in terms of crop growth rate of wheat. Crop growth rate was significantly effected by nutrient management practices at 60 DAS in both years of wheat. Integrated nutrient management (50% N through FYM +50% N and rest of P and K through inorganic sources) resulted in significantly higher crop growth rate over RDF(recommended dose of fertilizers). This might be explained by the fact that organic sources provide balanced supply of nutrients which increased dry matter production of crops, resulting in enhanced crop growth rate. The plants under integrated nutrient management had comparatively easily extractable and more availability of nutrients as compared to RDF which resulted in better crop growth rate. Kavinder *et al.,* 2019 also reported similar results. All treatments except T_1(CT,Hydro,RDF) and T_3 (CT,Micro,RDF) were significantly better than control in terms of crop growth rate at 60 and 90 DAS in wheat. The highest crop growth rate was found in T_6 (CT+M,Hydro,Int) (Table 8).

Relative growth rate

Data on relative growth rate of wheat has been depicted in table 9. Significantly higher relative growth rate was noted under conventional tillage+ mulch, which was followed by zero tillage+ mulch at 60 DAS. This may be due to higher dry matter production in conventional tillage and mulch as a result of improved soil conditions and uptake of nutrients by crop. Mulch creates favourable environment for enhanced nutrient uptake which could be attributed to improvement in soil biological health, thus resulting in improved growth rate of plants. The results are in line with Ijaz and Ali 2007 who reported higher dry matter of wheat in mulched plots as compared to unmulched plots. Seed priming methods had no significant effect on relative growth rate of wheat, during both years of study.Relative growth rate was found significantly higher under Integrated nutrient management (50% N through FYM +50% N and rest of P and K through inorganic sources) as compared to RDF (recommended dose of fertilizers) at 60 DAS. This can be possibly explained by the fact that the combined application of organic manuresand mineral fertilizers results in optimizing soil nutrient pool and enhances crop growth rate. The results are in close conformity with Kumar *et al.*, 2020. It was found that all treatments except T_1 (CT,Hydro,RDF), T_3 (CT,Micro,RDF) and T_4 (CT, Micro,Int) at 60 DAS resulted in significantly higher relative growth rate than control. T_5 (CT+M,Hydro,RDF), T_6 (CT+M,Hydro,Int) and T_8 (CT+M, Micro,Int)were best treatments in terms of relative growth rate (Table 10).

Table 5: Effect of tillage practices, seed priming and nutrient management on leaf area index of wheat at periodic intervals

	Leaf Area Index							
	60 DAS		90 DAS		120 DAS		150 DAS	
Tillage practices	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
CT	1.33	1.37	3.19	3.24	2.41	2.49	1.88	1.97
CT + Mulch	1.60	1.65	3.61	3.68	2.80	2.89	2.31	2.43
ZT + Mulch	1.45	1.49	3.40	3.46	2.59	2.67	2.10	2.20
SEm±	0.06	0.06	0.04	0.04	0.04	0.05	0.04	0.04
LSD (P=0.05)	**0.16**	**0.17**	**0.12**	**0.12**	**0.13**	**0.14**	**0.12**	**0.12**
Seed priming								
Hydro priming	1.48	1.52	3.43	3.50	2.63	2.71	2.12	2.23
Micronutrient priming	1.44	1.48	3.37	3.43	2.57	2.65	2.07	2.17
SEm±	0.05	0.05	0.03	0.03	0.04	0.04	0.03	0.03
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nutrient management								
RDF	1.44	1.48	3.35	3.40	2.55	2.62	2.04	2.15
Integrated	1.49	1.53	3.45	3.52	2.65	2.74	2.15	2.26
SEm±	0.05	0.05	0.03	0.03	0.04	0.04	0.03	0.03
LSD (P=0.05)	**NS**	**NS**	**0.10**	**0.10**	**0.11**	**0.12**	**0.09**	**0.10**
Control vs others								
Control	1.22	1.25	2.62	2.66	1.90	1.96	1.52	1.61
Others	1.46	1.50	3.40	3.46	2.60	2.68	2.10	2.20
SEm±	0.08	0.08	0.06	0.06	0.07	0.07	0.06	0.06
LSD (P=0.05)	**0.24**	**0.25**	**0.17**	**0.18**	**0.19**	**0.21**	**0.17**	**0.18**

***CT: Conventional tillage, ZT: Zero tillage, Micronutrient priming: Zn (0.5%), Mn (0.1%), RDF: Recommended dose of fertilizers, Integrated: 50% N through FYM + 50% N and rest of P and K through inorganic sources, Control: CT, no priming, RDF**

Table 6: Effect of different treatments and control onleaf area index of wheat at periodic intervals

Treatments	Leaf Area Index							
	60 DAS		90 DAS		120 DAS		150 DAS	
T1 CT,Hydro,RDF	1.35	1.38	3.18	3.22	2.35	2.40	1.85	1.94
T2 CT,Hydro,Int	1.36	1.40	3.28	3.33	2.53	2.62	1.95	2.05
T3 CT, Micro,RDF	1.30	1.33	3.08	3.13	2.36	2.42	1.79	1.88
T4 CT, Micro,Int	1.33	1.36	3.24	3.29	2.42	2.50	1.91	2.01
T5 CT+M,Hydro,RDF	1.58	1.63	3.59	3.67	2.78	2.88	2.29	2.41
T6 CT+M,Hydro,Int	1.64	1.69	3.69	3.77	2.88	2.98	2.38	2.51
T7 CT+M, Micro,RDF	1.57	1.61	3.52	3.59	2.71	2.80	2.26	2.37
T8 CT+M, Micro,Int	1.61	1.66	3.63	3.69	2.81	2.90	2.32	2.44
T9 ZT+M,Hydro,RDF	1.42	1.46	3.38	3.44	2.57	2.65	2.07	2.17
T10 ZT+M,Hydro,Int	1.52	1.56	3.48	3.54	2.68	2.76	2.19	2.30
T11 ZT+M, Micro,RDF	1.40	1.44	3.32	3.38	2.50	2.58	2.00	2.10
T12 ZT+M, Micro,Int	1.44	1.48	3.41	3.47	2.61	2.69	2.13	2.24
T13 Control	1.22	1.25	2.62	2.66	1.90	1.96	1.52	1.61
SEm±	0.08	0.08	0.06	0.06	0.07	0.07	0.06	0.06
LSD control vs others**(P=0.05)**	**0.24**	**0.25**	**0.17**	**0.18**	**0.19**	**0.21**	**0.17**	**0.18**

***CT: Conventional tillage, ZT: Zero tillage, M: Mulch, Hydro: Hydropriming, Micro: Micronutrient priming Zn (0.5%), Mn (0.1%), RDF: Recommended dose of fertilizers, Int: 50% N through FYM + 50% N and rest of P and K through inorganic sources, Control: CT, no priming, RDF**

Table 7: Effect of tillage practices, seed priming and nutrient management on crop growth rate of wheat at periodic intervals

	Crop growth rate (g/m²/day)							
	60 DAS		**90 DAS**		**120 DAS**		**150 DAS**	
Tillage practices	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
CT	1.59	1.62	3.73	3.73	9.86	9.85	8.31	8.55
CT + Mulch	1.77	1.80	4.78	4.78	12.55	12.56	8.00	8.33
ZT + Mulch	1.68	1.70	4.08	4.09	11.42	11.43	7.16	7.46
SEm±	0.02	0.02	0.14	0.14	0.40	0.41	0.52	0.51
LSD (P=0.05)	**0.06**	**0.06**	**0.40**	**0.41**	**1.16**	**1.21**	**NS**	**NS**
Seed priming								
Hydro priming	1.69	1.72	4.27	4.27	11.39	11.39	8.06	8.40
Micronutrient priming	1.67	1.69	4.13	4.13	11.17	11.18	7.58	7.83
SEm±	0.02	0.02	0.11	0.11	0.32	0.34	0.42	0.42
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nutrient management								
RDF	1.66	1.68	4.02	4.04	11.06	11.02	7.33	7.68
Integrated	1.70	1.73	4.37	4.37	11.50	11.55	8.31	8.55
SEm±	0.02	0.02	0.11	0.11	0.32	0.34	0.42	0.42
LSD (P=0.05)	**0.05**	**0.05**	**0.33**	**NS**	**NS**	**NS**	**NS**	**NS**
Control vs others								
Control	1.51	1.53	3.19	3.19	9.59	9.59	8.11	8.39
Others	1.68	1.71	4.20	4.20	11.28	11.28	7.82	8.12
SEm±	0.03	0.03	0.20	0.21	0.58	0.61	0.76	0.75
LSD (P=0.05)	**0.08**	**0.09**	**0.59**	**0.60**	**NS**	**NS**	**NS**	**NS**

***CT: Conventional tillage, ZT: Zero tillage, Micronutrient priming: Zn (0.5%), Mn (0.1%), RDF: Recommended dose of fertilizers, Integrated: 50% N through FYM + 50% N and rest of P and K through inorganic sources, Control: CT, no priming, RDF**

Table 8: Effect of different treatments and control oncrop growth rate of wheat at periodic intervals

Treatments	**Crop growth rate (g/m²/day)**							
	60 DAS		**90 DAS**		**120 DAS**		**150 DAS**	
T1CT,Hydro,RDF	1.57	1.59	3.71	3.74	9.81	9.52	7.91	8.56
T2 CT,Hydro,Int	1.63	1.67	3.90	3.87	9.97	10.24	8.09	8.19
T3 CT, Micro,RDF	1.56	1.57	3.50	3.53	9.86	9.86	8.17	8.41
T4 CT, Micro,Int	1.61	1.65	3.80	3.79	9.79	9.79	9.06	9.06
T5 CT+M,Hydro,RDF	1.76	1.79	4.68	4.68	12.44	12.45	6.37	6.68
T6 CT+M,Hydro,Int	1.81	1.84	5.10	5.10	12.80	12.81	12.11	12.50
T7 CT+M, Micro,RDF	1.73	1.76	4.41	4.41	12.33	12.34	6.13	6.45
T8 CT+M, Micro,Int	1.78	1.81	4.93	4.94	12.64	12.65	7.38	7.70
T9 ZT+M,Hydro,RDF	1.67	1.70	3.94	3.95	11.18	11.18	7.47	7.77
T10 ZT+M,Hydro,Int	1.70	1.73	4.27	4.28	12.11	12.12	6.43	6.73
T11 ZT+M, Micro,RDF	1.64	1.67	3.91	3.91	10.73	10.74	7.94	8.23
T12 ZT+M, Micro,Int	1.69	1.71	4.21	4.22	11.68	11.68	6.82	7.12
T13 Control	1.51	1.53	3.19	3.19	9.59	9.59	8.11	8.39
SEm±	0.03	0.03	0.20	0.21	0.58	0.61	0.76	0.75
LSD control vs others**(P=0.05)**	**0.08**	**0.09**	**0.59**	**0.60**	**NS**	**NS**	**NS**	**NS**

***CT: Conventional tillage, ZT: Zero tillage, M: Mulch, Hydro: Hydropriming, Micro: Micronutrient priming Zn (0.5%), Mn (0.1%), RDF: Recommended dose of fertilizers, Int: 50% N through FYM + 50% N and rest of P and K through inorganic sources, Control: CT, no priming, RDF**

Biological yield

Data pertaining to biological yield of wheat is given in Table 11. Significantly higher biological yield of wheat was obtained under conventional tillage+ mulch (9.19 t/ha), which was followed by zero tillage+ mulch (8.76 t/ha). Higher biological yield under these treatments may be because of enhanced growth parameters due to positive effects of mulch such as increased nutrient availability, moisture conservation and improved soil physical, chemical and microbial properties. Similar results were reported by Ali *et al.,* 2016. Significantly higher yields in happy seeder than in conventional tillage are reported (Sip et al., 2009). Zero tillage and crop residues retention on soil surface increased the organic matter content in soil (Lal et al., 2003) and was more supportive for dry land crop production (Baumhardt and Jones, 2002). Seed priming methods had no significant effect on biological yield of wheat. It was further observed that Integrated nutrient management(50% N through FYM +50% N and rest of P and K through inorganic sources) resulted in significantly higher biological yield (8.75 t/ha) of wheat as compared to RDF(recommended dose of fertilizers) in both years. This can be explained by the fact that addition of organic manure provide balanced and continous supply of nutrient, which may have enhanced dry matter production in plants. Shah and Ahmad 2006 also reported similar results. Mohan *et al.,* 2018 also reported higher yield of wheat under integrated nutrient management because of balanced proportion and adequate amounts of nutrients supplied to crop at growth stages which improved yield attributing characters. Comparison of control with other treatments revealed that all treatments except T_1(CT,Hydro,RDF) and T_3 (CT,Micro,RDF) resulted in significantly higher biological yield of wheat as compared to control, during both years of research. The highest biological yield was obtained in T_6 (CT+M,Hydro,Int) (8.80 and 9.29 t/ha, during first and second years, respectively) in both years (Table 12).

Table 9: Effect of tillage practices, seed priming and nutrient management on relative growth rate of wheat at periodic intervals

	Relative growth rate (g/g/day)							
	60 DAS		90 DAS		120 DAS		150 DAS	
CT	0.076	0.076	0.026	0.026	0.030	0.029	0.013	0.014
CT + Mulch	0.078	0.078	0.028	0.028	0.031	0.031	0.011	0.011
ZT + Mulch	0.077	0.077	0.027	0.026	0.031	0.031	0.011	0.011
SEm±	0.0002	0.0002	0.001	0.001	0.001	0.001	0.001	0.001
LSD (P=0.05)	**0.001**	**0.001**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.002**
Seed priming								
Hydro priming	0.077	0.077	0.027	0.027	0.030	0.030	0.012	0.012
Micronutrient priming	0.077	0.077	0.027	0.026	0.030	0.030	0.011	0.012
SEm±	0.0002	0.0002	0.001	0.001	0.001	0.001	0.001	0.001
LSD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Nutrient management								
RDF	0.077	0.077	0.026	0.026	0.031	0.030	0.011	0.012
Integrated	0.077	0.077	0.027	0.027	0.030	0.030	0.012	0.012
SEm±	0.0002	0.0002	0.001	0.001	0.001	0.001	0.001	0.001
LSD (P=0.05)	**0.0005**	**0.001**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Control vs others								
Control	0.075	0.075	0.024	0.024	0.031	0.031	0.014	0.014
Others	0.077	0.077	0.027	0.027	0.030	0.030	0.012	0.012
SEm±	0.0003	0.0003	0.001	0.001	0.001	0.001	0.001	0.001
LSD (P=0.05)	**0.001**	**0.001**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

***CT: Conventional tillage, ZT: Zero tillage, Micronutrient priming: Zn (0.5%), Mn (0.1%), RDF: Recommended dose of fertilizers, Integrated: 50% N through FYM + 50% N and rest of P and K through inorganic sources, Control: CT, no priming, RDF**

Table 10: Effect of different treatments and control onrelative growth rate of wheat atperiodic intervals

Treatments	**Relative growth rate (g/g/day)**							
	60 DAS		**90 DAS**		**120 DAS**		**150 DAS**	
T1CT,Hydro,RDF	0.076	0.076	0.026	0.026	0.030	0.029	0.013	0.013
T2 CT,Hydro,Int	0.076	0.077	0.026	0.026	0.029	0.029	0.013	0.013
T3 CT, Micro,RDF	0.076	0.076	0.025	0.025	0.030	0.030	0.013	0.014
T4 CT, Micro,Int	0.076	0.077	0.026	0.026	0.029	0.029	0.014	0.014
T5 CT+M,Hydro,RDF	0.078	0.078	0.028	0.028	0.031	0.031	0.009	0.009
T6 CT+M,Hydro,Int	0.078	0.078	0.029	0.029	0.030	0.030	0.015	0.015
T7 CT+M, Micro,RDF	0.077	0.078	0.027	0.027	0.031	0.031	0.009	0.009
T8 CT+M, Micro,Int	0.078	0.078	0.029	0.029	0.030	0.030	0.010	0.010
T9 ZT+M,Hydro,RDF	0.077	0.077	0.026	0.026	0.031	0.031	0.011	0.012
T10 ZT+M,Hydro,Int	0.077	0.077	0.027	0.027	0.032	0.031	0.009	0.010
T11 ZT+M, Micro,RDF	0.077	0.077	0.026	0.026	0.030	0.030	0.012	0.013
T12 ZT+M, Micro,Int	0.077	0.077	0.027	0.027	0.031	0.031	0.010	0.010
T13 Control	0.075	0.075	0.024	0.024	0.031	0.031	0.014	0.014
SEm±	0.0003	0.0003	0.001	0.001	0.001	0.001	0.001	0.001
LSD control vs others**(P=0.05)**	**0.001**	**0.001**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

***CT: Conventional tillage, ZT: Zero tillage, M: Mulch, Hydro: Hydropriming, Micro: Micronutrient priming Zn (0.5%), Mn (0.1%), RDF: Recommended dose of fertilizers, Int: 50% N through FYM + 50% N and rest of P and K through inorganic sources, Control: CT, no priming, RDF**

Table 11: Effect of tillage practices, seed priming and nutrient management on biological yield of wheat

	Biological yield (ton/ha)	
Tillage practices	2020-21	2021-22
CT	7.66	7.95
CT + Mulch	8.70	9.19
ZT + Mulch	8.45	8.76
SEm±	0.10	0.09
LSD (P=0.05)	**0.28**	**0.27**
Seed priming		
Hydro priming	8.30	8.67
Micronutrient priming	8.23	8.60
SEm±	0.08	0.08
LSD (P=0.05)	**NS**	**NS**
Nutrient management		
RDF	8.14	8.51
Integrated	8.39	8.75
SEm±	0.08	0.08
LSD (P=0.05)	**0.23**	**0.22**
Control vs others		
Control	7.31	7.63
Others	8.27	8.63
SEm±	0.14	0.14
LSD (P=0.05)	**0.42**	**0.40**

***CT: Conventional tillage, ZT: Zero tillage, Micronutrient priming: Zn (0.5%), Mn (0.1%), RDF: Recommended dose of fertilizers, Integrated: 50% N through FYM + 50% N and rest of P and K through inorganic sources, Control: CT, no priming, RDF**

Table 12: Effect of different treatments and control on biological yield of wheat

Treatments	Biological yield (ton/ha)	
T_1 CT,Hydro,RDF	7.53	7.77
T_2 CT,Hydro,Int	7.84	8.19
T_3 CT, Micro,RDF	7.48	7.66
T_4 CT, Micro,Int	7.78	8.18
T_5 CT+M,Hydro,RDF	8.68	9.17
T_6 CT+M,Hydro,Int	8.80	9.29
T_7 CT+M, Micro,RDF	8.62	9.10
T_8 CT+M, Micro,Int	8.70	9.18
T_9 ZT+M,Hydro,RDF	8.25	8.73
T_{10} ZT+M,Hydro,Int	8.73	8.86
T_{11} ZT+M, Micro,RDF	8.32	8.63
T_{12} ZT+M, Micro,Int	8.49	8.81
T_{13} Control	7.31	7.63
SEm±	0.14	0.14
LSD control vs others**(P=0.05)**	**0.42**	**0.40**

***CT: Conventional tillage, ZT: Zero tillage, M: Mulch, Hydro: Hydropriming, Micro: Micronutrient priming Zn (0.5%), Mn (0.1%), RDF: Recommended dose of fertilizers, Int: 50% N through FYM + 50% N and rest of P and K through inorganic sources, Control: CT, no priming, RDF**

Conclusion

It was concluded from present study that better growth of wheat plants and enhanced biological yield resulted from conventional tillage+ mulch, which was followed by zero tillage+ mulch. It was further revealed that seed priming methods had no significant effect on growth and yield studies of wheat. Among nutrient management practices, integrated nutrient management proved to be superior in terms of growth parameters and biological yield of wheat. Based on these results of study, it is suggested to follow conventional tillage along with residue retention and integrated nutrient management in rainfed wheat in Himachal Pradesh.

Conflict of interest

The authors declare that they have no conflict of interest.

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