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Growth and productivity of wheat as affected by tillage and nutrient practices in the mid hills of Himachal Pradesh

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Abstract

A field experiment was conducted during *rabi* 2022-23 and 2023-24 at Palampur following split plot design with three tillage practices in main plot and five nutrient managements in sub plot, replicated thrice. A significant improvement in plant growth and productivity with zero tillage with residue retention (ZTR) while it was lowest in zero tillage. INM system significantly improved crop growth and productivity, at par with RDF. It was followed by combined application of inorganic fertilizers and nano-urea and organic farming practices. The natural farming system was poor in performance. The grain yield in ZTR was about 3% and 14% greater than CT and ZT over the years. The grain yield in INM was 11.6%, 19.8% and 29.3% higher than integrated application of inorganic fertilisers and nano-urea, organic farming practices and natural farming practices, respectively in pooled ears. Thus, ZTR along with INM can be practiced for long term sustainability and productivity of wheat.

Key words: Growth parameters, Natural farming, Organic farming, yield attributes, Zero tillage with residue,

Wheat (*Triticum aestivum* L.) is one of the most prevalent cereal crops in India, serving as a staple food for a vast majority of the population and contributing significantly to the agricultural economy (Ramadas *et al*., 2020). It is widely cultivated across the country, with the Indo-Gangetic Plains being the primary wheat growing region. However, the mid-hills of India, including Himachal Pradesh, also hold great potential for wheat cultivation due to their favorable agro-climatic conditions. In Himachal Pradesh, wheat is a key *rabi* crop that not only supports local food security but also sustains the livelihoods of small and marginal farmers in the region (Devi and Kaur, 2022).

Conventional tillage (CT), the traditional method of land preparation involving repeated ploughing, has been widely practiced in wheat cultivation. However, it is increasingly recognized as an unsustainable practice due to its adverse effects, including soil erosion, loss of organic matter and structural degradation (Derpsch *et al*., 2024). These challenges are particularly acute in the mid-hills, where the fragile ecosystems are prone to topsoil loss, negatively impacting long term agricultural productivity. Transitioning to zero tillage offers a sustainable alternative, involving minimal soil disturbance and the direct sowing of wheat into unplowed fields. Zero tillage not only conserves energy and reduces production costs but also improves soil health and moisture retention, critical for the region's undulating terrain (Kumari *et al*., 2023). Practicing zero tillage along with residue retention further enhances soil organic matter, reduces evaporation and stabilizes soil temperature, making it an effective strategy for improving wheat productivity while maintaining environmental sustainability.

Nutrient management plays a pivotal role in optimizing wheat growth and yield, particularly in the resource constrained environments of the mid-hills. The use of the recommended dose of inorganic fertilizers ensures that crops receive essential nutrients in balanced proportions, fostering healthy growth and maximizing yield potential (Sharma and Sharma 2020). However, continuous reliance on inorganic fertilizers degraded soil health, stagnated crop productivity and increased environmental pollution, therefore, necessitating alternate nutrient management

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strategies (Yadav *et al*., 2019; Chandel *et al*. 2023). Integrated Nutrient Management (INM), which combines chemical fertilizers with organic amendments like farmyard manure, compost and bio-fertilizers, offers a more holistic approach. INM enhances nutrient use efficiency, improves soil fertility and reduces reliance on chemical inputs (Sharma *et al*. 2018). In recent years, innovative fertilizers like nano urea have gained attention for their ability to deliver nitrogen in a highly efficient form, minimizing application rates and environmental impact while boosting productivity (Babu *et al*., 2022).

Sustainable practices such as organic farming and natural farming are also gaining prominence in wheat cultivation. Organic farming emphasizes the use of natural inputs like compost, vermicompost and green manure to maintain soil health and produce chemical free wheat, catering to the growing demand for environmentally friendly agricultural products (Manchala *et al*., 2017; Noori *et al*. 2023). Natural farming, as promoted under Himachal Pradesh's zero-budget natural farming initiative, eliminates the use of synthetic inputs entirely, relying on local resources such as cow dung, urine, and bio-enhancers (Chakraborty 2022). This approach aligns with the goals of ecological conservation and sustainable agricultural development while improving soil vitality and supporting the livelihoods of smallholder farmers (Pathak *et al*. 2024).

The integration of sustainable tillage practices like zero tillage with effective nutrient management strategies offers immense potential for enhancing wheat productivity in the mid-hills of India. By addressing the challenges of conventional systems and prioritizing soil health, these approaches can ensure a sustainable future for wheat cultivation in this unique agro-climatic region.

Materials and methods

A field experiment was conducted on wheat during *rabi* 2022-23 and 2023-24 at the Research Farm, Department of Agronomy, COA, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur (32°6' N latitude and 76°3' E longitude). The soil was silty clay loam in the texture with pH 5.36, organic carbon (8.10 g kg^{-1}), medium in available N (285 kg ha^{-1}) and available P_2O_5 (18.4 kg ha^{-1}) and high in K_2O (293 kg ha^{-1}). The region received more rainfall during *rabi* 2022-23 than *rabi* 2023-24; as total rainfall during the respective crop seasons were 590.1 mm and 360 mm. The mean relative humidity during *rabi* 2022-23 and *rabi* 2023-24 ranged between 26.1 to 77.2 and 53.40 to 72.65 per cent, respectively. The mean maximum temperature ranged from 13.7 °C to 29.3 °C during *rabi* 2022-23 and respective range during *rabi* 2023-24 was 13.6 °C to 35.0 °C, while mean minimum temperature ranged from 2.7 to 16.5 °C and 1.8 to 21.4 °C, during *rabi* 2022-23 and 2023-24, respectively.

The experiment comprised of fifteen treatments and was laid out in split plot design with three replications. The treatments in main plots included conventional tillage (CT), zero tillage with residue retention (ZTR) and zero tillage without residue retention (ZT). The sub plot treatments comprised of Recommended dose of fertilizers (RDF), 50% RDN + 100% PK (basal) + foliar spray of nano-urea @ 4ml l^{-1} (30 and 60 DAS), Integrated Nutrient Management (INM): 50% RDF + 5.0 t ha^{-1} vermicompost + *Azotobacter* + PSB, Organic farming practice (OFP): 7.5 t ha^{-1} Vermicompost + *Azotobacter* + PSB + 4 sprays of vermiwash @ 10% at 30, 45, 60 and 75 DAS and Subhash Palekar Natural Farming practice (SPNF). The plots under zero tillage were cleaned by removing the stones, stubbles and weeds. The plots for conventional tillage were prepared with the help of a power tiller then levelled. Clean and bold seeds were selected and treated with *Azotobacter* and PSB in INM and OFP and with beejamrit @ 1 litre per 10 kg of seeds in case of SPNF before sowing. The recommended dose of nitrogen, phosphorous and potassium were 120:60:30 kg ha^{-1}. The data on emergence count at 15 DAS, plant height, drymatter production, number of tillers, developmental stages, yield attributes and yield were recorded and subjected to statistical analysis. Leaf area was measured with help of leaf area meter at heading stage of wheat and LAI was worked out using the formula given below:

$$\text{Leaf area index (LAI)} = \frac{\textit{Total leaf area}}{\textit{Ground area}}$$

The data were statistically analyzed as suggested by Gomez and Gomez (1984). The critical differences (CD) were estimated for parameters with significant impacts at the 5% probability level.

Results and Discussions

Effect of tillage and nutrient managements on growth parameters of wheat

A glance at the data regarding the effect of different tillage and nutrient management systems on the different growth parameters of wheat, enshrined in Table 1, indicated that the plant height, dry matter accumulation, number of tillers m^{-2} and LAI was significantly influenced by different tillage and nutrient management methods during both *rabi* 2022-23 and 2023-24. However, during both the years, the emergence count recorded at 15 DAS was found to be non-significant, *w.r.t.,* to varied tillage and nutrient practices. Among the tillage practices, during both the seasons *i.e. rabi* 2022-23 and *rabi* 2023-24, wheat grown with ZTR recorded more plant height, dry matter accumulation, number of tillers m^{-2} and LAI significantly, although it was at par with CT practices. The lowest growth parameters were found when zero tillage was adopted without the retention of residues. In the first year, in ZTR, the plant height, dry matter accumulation, number of tillers m^{-2} and LAI was found to be 3.4 %, 3.2 %, 3.6 % and 2.2 % higher than CT and 10.4 %, 11.9 %, 10.7 % and 6.1 % higher than ZT, respectively. In the succeeding year, the same pattern was followed, however, the values were slightly higher than the previous year. The plant height, dry matter accumulation, number of tillers m^{-2} and LAI in ZTR was 4.8 %, 4.2 %, 3.6 % and 1.9 % higher than CT and 12.5 %, 12.7 %, 10.5 % and 6.5 % higher than ZT, respectively. ZTR preserved soil moisture by reducing evaporation, ensuring better water availability for the crop, which enhanced photosynthesis, leaf development and biomass accumulation (Gandhamanagenahalli *et al*., 2024). The gradual decomposition of crop residues, released essential nutrients like nitrogen, which enhanced crop growth and resulted in taller plants, higher dry matter production, more tillers and increased LAI of wheat. ZT lacked these benefits, leading to reduced soil moisture and nutrient availability, resulting in lower growth attributes (Modak *et al*., 2020). CT provided some initial benefits by loosening the soil, which could improve early growth and nutrient uptake of the crop. However, soil disturbance could have led to nutrient losses and degradation over time, thereby limiting growth at later stages (Liu *et al*., 2021). Although CT performed similarly to ZTR, it lacked the long-term benefits of residue retention, such as improved soil health and moisture conservation.

Amongst the nutrient management systems, the treatments varied significantly with each other in terms

Table 1: Effect of tillage and nutrient managements on growth parameters of wheat

Treatments	Emergence count at 15 DAS		Plant height (cm)		Dry matter accumulation (g m^{-2})		Number of tillers m^{-2}		Leaf area index (LAI)	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
Tillage practices										
C_1	137.8	138.1	95.6	98.9	845.5	878.03	241.2	242.0	4.04	4.12
C_2	138.2	140.1	98.8	103.6	872.5	914.61	245.7	249.6	4.14	4.20
C_3	134.0	134.3	89.5	92.1	779.7	811.60	224.8	228.1	3.91	3.95
SEm±	1.9	2.9	0.9	1.4	10.3	15.1	1.5	2.0	0.02	0.03
CD (P=0.05)	NS	NS	3.7	5.5	40.4	59.4	5.9	7.7	0.09	0.11
Nutrient management practices										
M_1	138.8	140.1	101.8	105.2	951.4	984.1	251.9	252.2	4.16	4.19
M_2	137.5	139.0	95.3	98.3	886.3	922.7	237.8	240.6	4.04	4.09
M_3	140.8	141.4	105.6	110.5	992.3	1030.3	261.2	260.7	4.25	4.29
M_4	134.4	135.0	88.6	91.9	725.1	770.7	224.6	228.7	3.91	3.99
M_5	131.9	132.0	81.8	85.3	607.8	632.5	210.8	217.3	3.79	3.89
SEm±	2.7	3.4	1.6	1.9	20.1	19.1	3.8	3.5	0.04	0.04
CD (P=0.05)	NS	NS	4.7	5.6	58.7	55.6	11.0	10.3	0.11	0.10

Where, C_1: Conventional tillage, **C_2**: Zero tillage with Residue, **C_3**: Zero tillage without residue, **M_1**: RDF, **M_2**: 50% RDN + 100% PK + nano-urea @ 4 ml l^{-1} (30 and 60 DAS), **M_3**: INM-50% RDF + 5 t ha^{-1} VC + *Azotbacter*+ PSB, **M_4**: OF-7.5 t ha^{-1} VC + *Azotbacter* + PSB + vermi wash @ 10% (30, 45, 60 and 75 DAS), **M_5**: Subhash Palekar's Natural Farming practices of plant height, dry matter accumulation, number of tillers m^{-2} and LAI**,** during both the years. The INM system significantly improved crop growth, during both *rabi* 2022-23 and 2023-24, which was at par with the recommended dose of inorganic NPK. It was followed by combined application of inorganic fertilizers and nano-urea and organic farming practices. The least growth attributes were observed in the natural farming system. INM integrates organic inputs with inorganic fertilizers, which ensured a continuous nutrient supply throughout the crop growth stages. Organic components might have enhanced soil structure and microbial activity, while chemical fertilizers met the crop's immediate nutrient demands (Sharma *et al*. 2014). The synergistic effect allowed the plant to maintain vigorous growth and accumulate more dry matter at all stages of development. RDF provided the necessary quantities of NPK promoting vegetative growth and biomass accumulation. Nano-urea, being a highly efficient nitrogen source, helped improve nutrient uptake through foliar application (Babu *et al*., 2022). However, its effect was probably short lived compared to the long-term benefits of organic inputs in INM. In organic farming, nutrients from manure and compost were released slowly, which limited crop growth during periods of high nutrient demand (Koutroubas *et al*., 2016). This led to reduced crop growth and dry matter accumulation compared to systems that used readily available inorganic fertilizers. Natural farming relied on minimal external inputs and soil biological processes to provide nutrients. However, these inputs often failed to meet the crop nutrient demands during critical growth phases, leading to poor growth (Sharma *et al*., 2023).

The growth attributes of wheat were found to be higher in the second year than the first, despite receiving lower rainfall in the second year. This could be attributed to the residual and cumulative effects of the practices implemented in first year. ZTR practices improved soil structure, reduced compaction and enhanced root penetration, resulting in higher plant height, dry matter, tillers and LAI. Similarly, in terms of nutrient management practices, the residual effect of slow-release nutrients like P and K probably improved soil fertility over time, supporting better plant development in the second year.

The developmental phases were not significantly impacted by both tillage practices and nutrient management practices during both years of study

Table 2: Effect of tillage and nutrient managements on developmental stages of wheat

Treatments	Days to maximum tillering		Days to 50 % heading		Days to maturity	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
Tillage practices						
C_1	109.5	110.3	120.4	121.1	176.7	177.2
C_2	108.7	108.7	120.1	120.9	175.1	175.9
C_3	111.2	112.4	121.9	122.6	178.1	178.3
SEm±	0.7	0.8	0.5	0.4	0.8	0.6
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Nutrient management practices						
M_1	109.2	110.1	120.4	121.1	176.0	176.7
M_2	109.7	110.4	120.7	121.5	176.6	177.1
M_3	108.9	109.6	120.1	120.6	175.7	176.1
M_4	110.5	110.9	121.2	121.9	177.2	177.7
M_5	110.7	111.3	121.5	122.5	177.9	178.2
SEm±	0.7	0.6	0.5	0.5	0.9	0.7
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Where, C_1: Conventional tillage, **C_2**: Zero tillage with Residue, **C_3**: Zero tillage without residue, **M_1**: RDF, **M_2**: 50% RDN + 100% PK + nano-urea @ 4 ml l^{-1} (30 and 60 DAS), **M_3**: INM-50% RDF + 5 t ha^{-1} VC + *Azotbacter*+ PSB, **M_4**: OF-7.5 t ha^{-1} VC + *Azotbacter* + PSB + vermi wash @ 10% (30, 45, 60 and 75 DAS), **M_5**: Subhash Palekar's Natural Farming practices

(Table 2). The number of days required by a crop to achieve a particular phenophase is a varietal character and depends on weather conditions, mainly temperature varying slightly due to the cultivation practices.

Effect of tillage and nutrient managements on yield and yield attributes of wheat

Data on the effect of various tillage techniques and nutrient management options and their interaction on yield attributing characters recorded during the harvest of wheat for both 2022-23 and 2023-24 are presented in Table 3. All the yield and yield attributes namely number of spikes, number of grains per spike, seed yield, straw yield and biological yield, except 1000 grain weight were found to be significantly affected by different treatments during the two years of experimentation. In both years, ZTR produced the highest number of spikes, number of grains per spike, seed yield, straw yield and biological yield, however, it was statistically at par with CT. ZT demonstrated in significantly least yield and yield attributing characters. The grain yield in ZTR was 2.7 % and 12.7 % greater than that in CT and ZT in *rabi* 2022-23 and 3.1 % and 14.5 % during *rabi* 2023-24, respectively. Similarly, the straw yield of wheat in ZTR was 2.6 % and 11.0 % greater than that in CT and ZT in *rabi* 2022-23 and 2.3 % and 11.3 % during *rabi* 2023-24, respectively This might be attributed to the presence of residue retention in ZTR which could have improved soil moisture, reduced temperature fluctuations and enhanced nutrient cycling (Shilpa *et al*., 2022). On the other hand, CT though effective due to better soil aeration and weed control, might lead to moisture loss and soil compaction over time (Liu *et al*., 2021), making it comparable but slightly less effective than ZTR. ZT exhibited the lowest yield and yield attributes due to reduced soil moisture availability and less organic matter (Modak *et al*., 2020), which might have hindered root development and nutrient uptake.

In terms of nutrient management, INM resulted in the highest namely number of spikes, number of grains per spike, seed yield, straw yield and biological yield during both *rabi* 2022-23 and 2023-24, though it was at par with RDF. This was followed by the combined use of traditional fertilizers and nano-urea and OFP. Natural farming recorded the lowest yield and yield attributes significantly. In the first year, the grain yield was obtained to be significantly higher with INM (4045 kg ha^{-1}) which was at par with RDF (3868 kg ha^{-1}). It was followed by integrated application of

Table 3: Effect of tillage and nutrient managements on yield and yield attributes of wheat

Treatments	No. of spikes per m^2		No. of grain spike^{-1}		Test weight (g)		Grain yield (kg ha^{-1})		Straw yield (kg ha^{-1})		Biological yield (kg ha^{-1})	
	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
Tillage practices												
C_1	229	235	40.8	42.5	40.5	41.0	3394	3567	5506	5675	8900	9426
C_2	235	241	42.0	43.1	41.1	41.3	3517	3730	5667	5897	9184	9669
C_3	216	218	39.0	40.8	40.3	40.3	3114	3257	5094	5286	8208	8595
SEm±	3	4.0	0.4	0.4	0.5	0.6	58	79	87	98	108	159
CD (P =0.05)	11	16	1.7	1.4	NS	NS	226	309	341	385	425	625
Nutrient management practices												
M_1	238	242	42.3	43.3	41.0	41.4	3878	4029	6146	6330	10014	10359
M_2	228	236	40.6	42.4	40.7	41.0	3706	3767	5754	5946	9330	9713
M_3	246	249	43.6	44.4	41.4	42.1	4059	4240	6400	6606	10445	10846
M_4	216	221	39.1	41.3	40.3	40.2	2855	3070	4788	5043	7633	8153
M_5	204.0	208	37.4	39.5	39.9	39.5	2387	2486	4024	4172	6398	6658
SEm±	3	4	0.5	0.6	0.6	0.6	99	90	133	131	212	201
CD (P =0.05)	9	13	1.3	1.8	NS	NS	288	261	387	481	618	585

C_1: Conventional tillage, **C_2**: Zero tillage with Residue, **C_3**: Zero tillage without residue, **M_1**: RDF, **M_2**: 50% RDN + 100% PK + nano-urea @ 4 ml l^{-1} (30 and 60 DAS), **M_3**: INM-50% RDF + 5 t ha^{-1} VC + *Azotbacter*+ PSB, **M_4**: OF-7.5 t ha^{-1} VC + *Azotbacter* + PSB + vermi wash @ 10% (30, 45, 60 and 75 DAS), **M_5**: Subhash Palekar's Natural Farming practices inorganic fertilisers and nano-urea (3576 kg ha^{-1}) and organic farming practices (2845 kg ha^{-1}). The least seed yield was noticed under natural farming (2374 kg ha^{-1}). The trend was alike in the *rabi* 2023-24, where the grain yield obtained with INM and RDF, with both being statistically similar. The grain yield in INM was 12.4 %, 20.4 % and 29.5 % higher than integrated application of inorganic fertilisers and nano-urea, organic farming practices and natural farming practices. The straw yield followed the same trend as grain yield and ranged from 4020 to 6397 kg ha^{-1} and 4196 to 6629 kg ha^{-1}, in first and second year, respectively. The biological yield in INM was 7.6 %, 11.6 % and 19.6 % higher in the first and 7.4 %, 10.5 % and 18.7 % greater in the second year, as compared to integrated application of inorganic fertilisers and nano-urea, organic farming practices and natural farming practices, respectively. INM combined organic and inorganic fertilizers, ensuring both immediate and long term nutrient availability, promoting healthy crop growth and spike formation (Hetta *et al*., 2024). RDF also performed well by providing sufficient nutrients, though it could not improve soil structure or microbial activity like INM (Verma *et al*., 2018; Kaur *et al*., 2022). Inorganic fertilizer + nano-urea resulted in slightly fewer spikes, likely due to the slow release nature of nano-urea, which might have delayed nitrogen availability at critical growth stages. Organic farming practices performed inferiorly to other inorganic treatment because of slow nutrient release from organic inputs, which might not fully meet the crop's nutrient demand at peak growth stages (Koutroubas *et al*., 2016). Natural Farming due to minimal external inputs, resulting in restricted nutrient availability and suboptimal crop growth (Sharma *et al*. 2023).

The yield and yield attributes for both tillage and nutrient management practices were found to be higher in the second year than first year, might be due to residual affect of the decomposition of crop residues and nutrient managements leading to improvement in soil structure, building organic matter and increasing the activity of micro-organisms resulting in better nutrient availability, hence greater yields and yield attributes. Also, the total rainfall during the first year was more than the second, however, heavy rainfall at the later stages of wheat crop in the first year might have lowered the grain yield in the first year as compared to second. While, in the following year, uniform rainfall along with supplemental irrigation improved the yield and yield attributes.

The interaction between the various tillage and nutrient management practices was found to be non-significant on the number of spikes, number of grains per spike, seed yield, straw yield, biological yield and harvest index.

Conclusion

The field experiment demonstrated that administration of zero tillage with the retention of residues and integrated nutrient management significantly improved the growth and productivity of wheat. The plant height, dry matter accumulation, tillering, yield and yield attributes enhanced significantly in ZTR and INM as compared to ZT and other nutrient management practices, especially compared to organic and natural farming practices. Presence of residues in ZTR contributed to the addition of soil organic matter and improved soil moisture and nutrient cycling resulting better plant growth. INM practices ensured both immediate and long term nutrient availability, promoting healthy crop growth and productivity.

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