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RESEARCH

Assessment of Agro-Morphological and Yield-Related Traits of Vijay Wheat (*Triticum aestivum* L.) Variety Under Different Ploughing and Non-Ploughing Techniques

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Abstract

Wheat (*Triticum aestivum* L.) is essential for global food security, but its productivity is constrained by biotic and abiotic stresses, including climate change. This study examines the effects of different tillage methods on the agro-morphological and yield-related traits of the Vijay wheat variety under varying ploughing and non-ploughing techniques. Conducted at the Agricultural Machinery Testing and Research Centre (AMTRC) in Nawalpur, Sarlahi, Nepal, the experiment followed a Randomized Complete Block Design (RCBD) with seven tillage practices: (i) Cultivator + Rotavator + Seed sowing, (ii) Cultivator + Zero tillage, (iii) Rotavator + Seed sowing + Rotavator, (iv) Zero tillage + Seed drill, (v) Seed drill, (vi) Zero tillage, and (vii) Farmer's practice. Key traits measured included phenological stages, tiller count, plant height, spike length, leaf number, and grain yield. The results revealed significant variations among tillage practices. The Cultivator + Rotavator + Seed sowing method produced the highest grain yield (4.060 t/ha), outperforming other treatments. Correlation analysis showed that days to maturity (DM) had a strong positive correlation with grain yield (r = 0.700***), whereas days to anthesis (DA) exhibited a negative correlation (r = -0.195). Regression analysis confirmed DM as a key yield determinant (b = 0.1167, r^2 = 0.462), while plant height also showed a positive influence (r^2 = 0.412). These findings highlight the importance of selecting optimal tillage practices to improve wheat productivity. Integrating conservation tillage with conventional methods offers a sustainable approach to enhancing yield in diverse agricultural systems.

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Statement of Sustainability: This study supports SDGs 2 (Zero Hunger) and 13 (Climate Action) by promoting sustainable tillage practices for improved wheat productivity. By optimizing soil management, it enhances yield while preserving soil health and reducing environmental impact. The findings encourage conservation tillage adoption, ensuring long-term food security and climate resilience.

1. Introduction

Wheat (*Triticum aestivum* L.), a fundamental cereal crop, plays a critical role in global food security, providing essential dietary calories and proteins to over 2.5 billion people worldwide (CGIAR, 2018). Cultivated across 219 million hectares with an annual production of 760.92 million metric tons, wheat is the most widely grown crop globally (FAO, 2020). Despite its significance, wheat productivity faces challenges such as stagnating yields, biotic and abiotic stresses, and the impacts of climate change (Ray et al., 2012; Wheeler and von Braun, 2013). Addressing these challenges requires an understanding of both genetic and environmental factors influencing yield, along with advancements in cultivation practices. In conservation agriculture, tillage practices play a critical role in shaping crop yield and soil health. Zero tillage and straw mulching have emerged as key techniques in modern agriculture, offering benefits such as improved soil structure, reduced erosion, and enhanced crop production (Yuan et al., 1991; Wu et al., 2006). Zero tillage, which minimizes soil disturbance, helps preserve organic matter and reduce greenhouse gas emissions, while straw mulching improves soil moisture retention and nutrient availability (Huang et al., 2009; Verma, 2010). However, improper implementation of these techniques can lead to uneven nutrient distribution and potential yield reductions (Hammel, 1995; Gao and Li, 2005). Thus, evaluating different tillage combinations is essential for optimizing wheat production. In Nepal, where wheat is a staple crop and a significant contributor to the agricultural sector, improved tillage methods can enhance production. Despite being a major wheat producer, yields remain constrained by conventional tillage practices and other agronomic factors (Ahmed et al., 1996). While conventional tillage is widely used, it often disrupts soil structure, reducing moisture retention and increasing erosion (Putte et al., 2010). As a result, interest in conservation tillage methods, including zero and reduced tillage, is growing due to their potential to improve soil health and increase yields (Dawelbeit and Babiker, 1997). The integration of advanced tillage techniques with precision agriculture offers a promising approach to addressing modern wheat farming challenges. The use of data analytics and remote sensing allows for real-time crop monitoring, facilitating informed decision-making and timely interventions (Pal and Dhara, 2018). By combining traditional practices with innovative technologies, wheat productivity and sustainability can be significantly enhanced.

Mechanical ploughing and planting, including rotary tillage and zero tillage, have revolutionized rice farming by enhancing soil preparation and optimizing crop growth (Shrestha et al., 2009; Verma, 2010). However, as with wheat, the challenge lies in balancing technological advancements with environmental sustainability. The impact of various tillage methods on wheat yield remains a critical area of study, particularly in the context of conservation agriculture. Research suggests that zero tillage and straw mulching can enhance wheat yield and quality by improving soil health and reducing erosion (Govaerts et al., 2005; Xie et al., 2007). However, the effectiveness of these methods varies depending on local conditions and the combination of tillage and straw management practices used (Li et al., 2009). Long-term studies on different tillage regimes and their interactions with crop straw management are essential for optimizing wheat production systems (Govaerts et al., 2005; Riley et al., 2008). This study aims to evaluate the effects of different tillage methods on the agro-morphological and yield-related traits of the Vijay wheat variety. By comparing conventional, reduced, and zero tillage methods, the research seeks to identify the most effective practices for improving wheat productivity and sustainability. The findings will enhance understanding of how tillage methods influence wheat growth and yield, providing valuable insights for optimizing wheat cultivation across diverse agricultural settings.

2. Materials and Methods

2.1. Study Site and Experimental Conditions

The study was conducted from June to November 2022 at the Agricultural Machinery Testing and Research Centre (AMTRC) field in Nawalpur, Sarlahi, Nepal, located at 27° 3′ 47.72″ N latitude and 85° 35′ 38.26″ E longitude. The field's soil was classified as sandy loam with a slightly acidic pH of 6.0. Due to its tropical location, Paklihawa experienced temperatures as high as 35°C during the research period. The wheat variety Vijay, sourced from the Nepal Agricultural Research Council (NARC), was used in the study.

2.2. Experimental Design and Treatments

The experiment followed a Randomized Complete Block Design (RCBD) with three replications, and each plot covered an area of 9 square meters. Sowing was performed using standard practices, with row spacing of 20 cm and plant spacing of 5 cm. Two mechanical ploughing methods—rotavator and cultivator—were utilized, and seven tillage combinations were tested: (i) Cultivator + Rotavator + Seed sowing (P1), (ii) Cultivator + Zero tillage (P2), (iii) Rotavator + Seed sowing + Rotavator (P3), (iv) Zero tillage + Seed drill (P4), (v) Seed drill (P5), (vi) Zero tillage (P6), and (vii) Farmer practice (P7). Agronomic practices such as planting methods, seed rate, planting depth, weeding, irrigation, and harvesting were uniformly applied across all treatments.

2.3. Agronomic Practices

The field was irrigated a day before sowing, which was carried out on December 20, 2022. A seed rate of 120 kg/ha was used as recommended for Nepal. Fertilization followed NARC guidelines with an application of 120:50:50 NPK kg/ha. Two-thirds of the nitrogen, along with the full amount of phosphorus and potassium, was applied as a basal dose along with 25 tons/ha of farmyard manure (FYM) during field preparation and final plowing. The remaining nitrogen was applied immediately after the first irrigation. Irrigation was applied at four critical growth stages: tillering (30 days after sowing), booting (65 days after sowing), anthesis (80 days after sowing), and grain-filling (92 days after sowing), with no additional irrigation provided beyond these stages. The manual weeding was conducted at 25 and 45 days after sowing. Throughout the experiment, vegetative and reproductive traits were recorded under different agronomic practices.

2.4. Data Collection

Phenological traits included days to booting (DB), days to heading (DH), days to anthesis (DA), and days to maturity (DM). Growth and yield parameters such as effective tillers (ET), non-effective tillers (NET), leaf number (LN), spike length (SL), flag leaf length (FLL), plant height (PH), and grain yield (GY) were meticulously measured. DB was recorded when 50% of the plants exhibited swelling in the leaf sheath below the flag leaf, while DH and DA were recorded when 50% of the plants had earheads emerging from the flag leaf sheath and yellowish anthers visible in the spikes, respectively. DM was measured as the number of days from sowing until more than 50% of the spikes turned yellow. For grain yield measurement, mature grains from a $2m^2$ sample area (excluding border effects) were harvested, sun-dried, threshed, weighed, and converted to tons per hectare. From each plot, ten random plants were selected to record average values for PH, ET, NET, FLL, and LN. PH was measured at harvest from ground level to the top of the spikelet aligned with the uppermost flag leaf.

2.5. Statistical Analysis

Data were organized using Microsoft Excel (version 2021) and analyzed using R-Studio statistical software (version 4.2.3). ANOVA was conducted to evaluate key agronomic attributes, while Duncan's Multiple Range Test (DMRT) and Least Significant Difference (LSD) were used to compare mean values among treatments at a 5% significance level. Additionally, interactions between factors were analyzed, and correlation and regression analyses were performed to examine relationships between growth parameters and grain yield.

3. Results and Discussion

3.1. Effects on Growth-Related Parameters

The maximum plant height was observed with Practice P1 (104.9 cm), followed by Practice P2 (102.6 cm) and Practice P3 (101.9 cm). Conversely, Practice P5 resulted in the shortest plant height (95.7 cm). The differences in plant height among the practices were statistically significant (Table 1). Plant height is a critical agronomic trait as it often correlates with other yield-related attributes and overall plant health. Taller plants, such as those seen in Practice P1, benefit from better light interception and photosynthesis, potentially leading to increased biomass and yield (Singh et al., 2011). However, excessively tall plants may face issues such as lodging, which can adversely affect yield stability and quality (NWRP, 2017). The variation in plant height across practices highlights the influence of different agronomic techniques on growth. Practices that enhance plant height without inducing lodging are generally preferred for optimizing yield and plant health (Bhattarai et al., 2015).

Moreover, the number of leaves per plant was highest in Practice P1 (6.133), whereas Practices P2 and P6 had the lowest values (5.147). Significant differences were noted among the practices (Table 1). The number of leaves is a key determinant of photosynthetic capacity and overall plant health. Practices that promote a higher leaf count, such as P1, can enhance photosynthesis and, consequently, yield potential (Singh et al., 2014). Leaves are crucial for capturing light and converting it into energy for growth and grain development. Variations in leaf number across practices highlight the impact of different agronomic techniques on plant development and productivity (Hamam, 2013).

3.2. Effects on Reproductive Traits

Spike length was significantly greater in Practice P1 (16.60 cm) compared to the other practices. Practice P5 exhibited the shortest spike length (13.82 cm). This indicates that agronomic practices can significantly impact spike development. Longer spikes, as observed in Practice P1, are associated with a higher number of spikelets, which can contribute to increased grain yield (Singh et al., 2014). The observed differences in spike length among practices underscore the importance of selecting appropriate agronomic techniques to maximize spike development. Practices that promote longer spikes can enhance overall productivity by increasing the number of potential grain sites (Hamam, 2013).

Further, the number of effective tillers was highest in Practice P1 (11.33), with Practices P5 and P6 showing the lowest values (8.00 and 8.67, respectively). Significant differences were noted among the practices (Table 1). Effective tillers are crucial for yield as they contribute to the number of spikelets and grains produced. Practices that increase the number of effective tillers typically lead to higher grain yields (Bassu et al., 2010). The variation observed suggests that certain practices are more effective at promoting tillering, which can enhance the overall yield potential of the crop (Sattar et al., 2010). Effective tillering is influenced by various factors, including planting methods and soil conditions, which can vary significantly with different agronomic practices (Bhattarai et al., 2015). Additionally, the highest number of non-effective tillers was recorded with Practice P7 (2.000), while Practices P1 and P3 had the fewest (0.333 and 0.667, respectively). Significant differences were observed in the number of non-effective tillers (Table 1). Non-effective tillers do not contribute to grain production and can be indicative of suboptimal growing conditions or practices. Practices that minimize non-effective tillers, such as P1, are generally more efficient in utilizing resources for productive tillers (Singh et al., 2011). Reducing the number of ineffective tillers is beneficial for maximizing yield and improving resource use efficiency (Bhattarai et al., 2015).

Table 1. Mean values of agro-morphological and yield-related traits for different agronomic practices in Vijay wheat.

Practices	Plant height (cm)	Spike length (cm)	Effective tillers	Non-effective tillers	Leaf number per plant	Flag leaf length (cm)	Days to booting	Days to heading	Days to anthesis	Days to maturity	Yield (t/ha)
Cultivator + Rotavator + Seed sowing	104.9^{a}	16.60^{a}	11.33^{a}	0.333^{a}	6.133^{a}	19.20^{cd}	61.33^{b}	67.67^{b}	77.00^{b}	106.0^{a}	4.060^{a}
Cultivator + Zero tillage	102.6^{a}	14.84^{b}	10.33^{a}	1.000^{a}	5.147^{c}	20.74^{b}	58.67^{d}	67.33^{b}	82.00^{a}	101.0^{b}	2.917^{c}
Rotavator + Seed sowing + Rotavator	101.9^{ab}	15.88^{ab}	10.67^{a}	0.667^{a}	5.703^{ab}	18.57^{d}	66.67^{a}	73.33^{a}	84.00^{a}	105.3^{a}	3.557^{b}
Zero tillage + Seed drill	102.6^{a}	15.67^{b}	11.00^{a}	1.333^{a}	5.433^{bc}	24.50^{a}	60.00^{c}	66.67^{b}	78.33^{b}	100.0^{b}	2.953^{c}
Seed drill	95.7^{b}	13.82^{c}	8.00^{a}	1.333^{a}	5.553^{bc}	16.25^{e}	60.33^{bc}	67.00^{b}	77.67^{b}	97.0^{c}	1.950^{e}
Zero tillage	100.0^{ab}	15.88^{ab}	8.67^{a}	1.333^{a}	5.147^{c}	19.56^{c}	57.33^{e}	66.00^{b}	76.00^{bc}	96.7^{c}	2.810^{cd}
Farmer practice	99.1^{ab}	14.98^{b}	10.00^{a}	2.000^{a}	5.743^{ab}	18.33^{d}	53.00^{f}	61.33^{c}	74.00^{c}	105.0^{a}	2.693^{d}
Grand mean	100.97	15.38	10.00	1.14	5.55	19.59	59.62	67.05	78.43	101.57	2.991
CV%	3.4	13.7	26.5	28.4	14.3	16.5	12.5	14.2	17.4	10.4	13.3
$LSD_{(0.05)}$	6.18	3.76	4.70	1.70	0.42	0.91	1.26	1.70	2.41	1.72	0.177
SEM (±)	2.83	1.72	2.16	0.78	0.19	0.42	0.58	0.78	1.11	0.79	1.18
F test	NS	*	NS	NS	**	***	***	***	***	***	***

Treatment means with distinct alphabetical letters signify significant differences determined by the Duncan Multiple Range Test (DMRT) at $P \leq 0.05$. NS, Non-significant; * Significant at 5% level of significance; ** Significant at 1% level of significance; *** Significant at 0.1 % level of significance; LSD: Least significant difference; SEM: Standard error of the mean; CV: Coefficient of variation.

Moreover, the booting stage, which marks the initial development of the wheat spike, is notably sensitive to temperature fluctuations (Hossain et al., 2012). In this study, the Vijay wheat variety reached the booting stage between 53 and 67 days after sowing. The earliest booting was facilitated by Practice P7, occurring at 53 days, indicating a potentially favorable impact on early developmental stages. In contrast, Practices P1, P3, and P4 resulted in booting at 61.33, 66.67, and 60.00 days, respectively. The latest booting was observed with Practice P2 at 67 days. The variation in booting time among the practices was statistically significant, with a mean booting period of 59 days. This variability highlights the influence of different ploughing and planting techniques on the timing of this critical growth stage. High temperatures during booting can adversely affect grain yield by increasing tiller mortality and restricting nutrient availability (Kajla et al., 2015; Alghabari et al., 2016). Wheat varieties that reach booting earlier, such as those with Practice P7, may be better positioned to cope with heat stress, potentially mitigating the negative impacts associated with elevated temperatures. This finding underscores the importance of optimizing cultivation practices to support earlier developmental milestones and enhance resilience against environmental stressors.

The heading stage, a critical period when the wheat spike emerges, occurred between 61.33 and 73 days after sowing. The earliest heading was recorded with Practice P7 at 61.33 days, followed by Practice P1 and Practice P3, which had heading times of 67.67 and 73.33 days, respectively. The latest heading was noted with Practice P5 at 67 days. Significant differences in days to heading were observed among the practices. Early heading is beneficial as it can help mitigate heat stress associated with late sowing conditions, potentially enhancing yield (Tewolde et al., 2006). Earlier heading provides a longer grain-filling period, which can compensate for some of the yield losses induced by heat stress (Kajla et al., 2015). Thus, practices that promote earlier heading, such as P7, may offer a strategic advantage by extending the period available for grain development and improving overall yield resilience against thermal stress. Likewise, days to anthesis, the stage when the wheat flowers begin to bloom, varied from 74 to 83 days after sowing. The earliest anthesis was observed with Practice P7 at 74 days. In contrast, the latest anthesis occurred with Practices P5 and P1, both at 77 days. The differences in days to anthesis among practices were moderately significant. The period between anthesis and maturity is particularly sensitive to temperature fluctuations. Higher temperatures during this period can negatively impact photosynthate translocation and starch synthesis, potentially reducing yield (Hossain et al., 2012; Kajla et al., 2015). Therefore, practices that promote earlier anthesis, such as P1, may be advantageous, particularly under late sowing conditions, as they provide a longer period for the accumulation of photosynthates and the development of grains, thereby improving yield potential despite heat stress.

3.3. Effects on Yield Performance

Physiological maturity, characterized by spikes and flag leaves turning yellow, was observed between 98 and 108 days after sowing. The earliest maturity was achieved with Practice P2 at 101 days, closely followed by Practice P4 at 100 days. The latest maturity was noted with Practice P6 at 96 days. Under normal conditions, the maturity period for the Vijay wheat variety typically ranges from 111 to 123 days (MoALD, 2020). The observed variation in days to maturity highlights the influence of different ploughing and planting practices. Late sowing often results in a reduced maturation period compared to typical conditions (Yamamoto et al., 2008). Elevated night temperatures can further shorten the grain-filling period, as heat stress negatively impacts grain development (Prasad et al., 2008; Sikder et al., 1999). Therefore, practices that lead to later maturity, such as P7, may offer a benefit by extending the grain-filling period, allowing for more complete grain development despite the challenges posed by higher temperatures. This extended period can potentially improve yield and quality by compensating for some of the adverse effects of heat stress. Furthermore, the highest yield was achieved with Practice P1 (4.060 t/ha), followed by Practice P3 (3.557 t/ha). Practice P5 resulted in the lowest yield (1.950 t/ha). Significant differences in yield were observed among practices (Table 1). Yield is the ultimate measure of crop performance and is influenced by various factors, including plant height, spike length, and tillering. Practices that result in higher yields, such as P1, are considered more effective for maximizing productivity (Ahmad et al., 2006; Khamssi and Najaphy, 2012). The substantial yield difference observed among practices underscores the importance of selecting appropriate agronomic methods to optimize crop performance and productivity (MoALD, 2020).

3.3. Correlation and Regression Analysis

Correlation and regression analyses of grain yield (GY) and related agro-morphological and yield-attributive characteristics are essential for optimizing genotype selection and improving yield potential. The data concerning the simple correlation coefficient (r) are presented in Table 2, while the regression coefficients (b) and coefficients of determination (r^2) are tabulated in Table 3. Table 2 shows significant correlations between GY and several key variables. The positive correlation between GY and Days to Maturity (DM) (r = 0.700***) suggests that genotypes with a longer maturation period generally achieve higher yields. This finding is consistent with Nahar et al. (2010), who reported that extended maturity durations often lead to increased yields due to the extended grain-filling period. Conversely, Days to Anthesis (DA) exhibited a significant negative correlation with non-effective tillers (NET) (r = -0.195). This implies that higher development of non-effective tillers can negatively impact yield, aligning with Midmore et al. (1984), who noted that delays in anthesis can decrease yield, though other factors like environmental and nutritional conditions also play crucial roles. Days to Booting (DB) and Days to Heading (DH) showed significant positive correlations with GY (r = 0.446* and r = 0.427*, respectively), suggesting a major impact of these parameters on yield. Munjal (2004) also observed a positive correlation between GY and DH, indicating that delays in heading could reduce the reproductive period and, consequently, yield. This result is in line with the research by Singh et al. (2011), which highlighted the adverse effects of delayed heading on yield. Effective Tiller (ET), Flag Leaf Length (FLL), Leaf Number (LN), and Plant Height (PH) all had positive correlations with GY (r = 0.423, r = 0.236, r = 0.470, and r = 0.664, respectively). While these parameters are positively associated with yield, their impact appears to be relatively large. This is consistent with findings by Liu et al. (2018), who suggested that while these traits contribute to yield potential, their direct influence may be more pronounced compared to other factors.

Table 3 presents the regression analysis results, showing the influence of various parameters on GY. The coefficient of determination (r^2) values reflect the proportion of variation in GY explained by each parameter. The adjusted r^2 value of 0.802 indicates that 80.2% of the variation in GY can be attributed to the ten independent variables considered. Among the parameters, Days to Maturity (DM) had the highest regression coefficient (b = 0.1167) and the highest r^2

value (0.462). This confirms that a longer maturity period significantly enhances yield. Research by Prasad et al. (2008) supports this, noting that extended grain-filling periods can improve yield by allowing more time for grain development. Plant Height (PH) also showed a considerable positive effect on GY, with a regression coefficient of 0.1080 and an r^2 of 0.412. This suggests that taller plants tend to have higher yields, which is consistent with the findings of Sakamoto et al. (2006), who linked plant height to increased photosynthetic capacity and, consequently, higher yield. In contrast, Days to Anthesis (DA) showed a non-significant negative impact on yield with a regression coefficient of 0.0492 and an r^2 of 0.022. This supports the correlation analysis, which indicated a significant negative relationship between DA and GY. As noted by Woodruff and Tonks (1983), excessive delay in anthesis can lead to reduced yield, aligning with the current findings. Furthermore, non-effective tillers (NET) and Flag Leaf Length (FLL) had negligible effects on yield with regression coefficients of -0.268 and 0.0604, respectively, and low r^2 values.

Table 2. Simple correlation analysis (r) of grain yield and other agro-morphological and yield-attributive characteristics of Vijay wheat.

Variables	DA	DB	DH	DM	ET	FLL	LN	NET	PH	SL	YLD
DA	1.000	-	-	-	-	-	-	-	-	-	-
DB	0.724***	1.000	-	-	-	-	-	-	-	-	-
DH	0.791***	0.921***	1.000	-	-	-	-	-	-	-	-
DM	0.147	0.189	0.147	1.000	-	-	-	-	-	-	-
ET	0.108	0.151	0.134	0.304	1.000	-	-	-	-	-	-
FLL	0.091	-0.004	-0.022	-0.048	0.276	1.000	-	-	-	-	-
LN	-0.082	0.212	0.010	0.633**	0.036	-0.251	1.000	-	-	-	-
NET	-0.195	-0.467*	-0.324	-0.211	-0.228	-0.073	-0.187	1.000	-	-	-
PH	0.282	0.219	0.242	0.391*	0.667***	0.430*	0.125	-0.124	1.000	-	-
SL	-0.051	0.158	0.126	0.249	0.194	0.165	0.054	-0.332	0.054	1.000	-
YLD	0.266	0.446*	0.427*	0.700***	0.423*	0.236	0.470*	-0.381*	0.664**	0.425*	1.000

DA, Days to Anthesis; DB, Days to Booting; DH, Days to Heading; DM, Days to Maturity; ET, Effective Tiller; FLL, Flag Leaf Length; LN, Leaf Number; NET, Non-Effective Tiller; PH, Plant Height; SL, Spike Length; YLD, Yield; * Significant at 5% level of significance; ** Significant at 1% level of significance; *** Significant at 0.1 % level of significance.

Table 3. Linear regression for the yield of wheat under the effect of different independent parameters.

Parameters	Regression coefficient (b)	Coefficient of determination (r^2)	Std error	P value
Days to anthesis	0.0492	0.022	0.041	0.244
Days to booting	0.0716	0.158	0.033	0.043
Days to heading	0.0798	0.139	0.039	0.054
Days to maturity	0.1167	0.462	0.027	0.001
Effective tiller	0.1122	0.136	0.055	0.056
Flag leaf length	0.0604	0.006	0.057	0.303
Leaf number	0.779	0.180	0.335	0.032
Non effective tiller	-0.268	0.100	0.149	0.088
Plant height	0.1080	0.412	0.028	0.001
Spike length	0.1372	0.137	0.067	0.055

This suggests that these factors have minimal impact on yield, corroborating the results by Kajla et al. (2015), who observed limited direct effects of these traits on yield. Additionally, Leaf Number (LN) was positively correlated with GY and had a notable regression coefficient of 0.779, indicating its potential role in enhancing yield, though the r^2 value (0.180) suggests a moderate effect. This finding aligns with Wang et al. (2011), who identified leaf number as an important factor for yield potential. Spike Length (SL) also had a positive impact on yield (b = 0.1372) with an r^2 of 0.137, indicating that longer spike lengths may contribute to higher yields, albeit to a lesser extent. Thus, Days to Maturity, Plant Height, and Leaf Number emerged as significant factors influencing yield, while Days to Anthesis and Flag Leaf Length had lesser impacts. These findings highlight the importance of optimizing these parameters to enhance wheat yield, supporting the research by Woodruff and Tonks (1983), which emphasized the critical role of development stages on yield outcomes.

4. Conclusion

The research focuses on the influence of various tillage practices on the agro-morphological and yield-related traits of the Vijay wheat variety. Among the evaluated practices, Cultivator + Rotavator + Seed Sowing (P1) proved to be the most effective, significantly enhancing plant height, spike length, effective tillers, and yield. This practice not only optimized growth parameters but also resulted in the highest yield, emphasizing its potential for improving wheat production. In contrast, practices such as Seed Drill (P5) and Zero Tillage were less effective in terms of growth and yield parameters. The findings suggest that integrating appropriate tillage methods can substantially benefit wheat cultivation, offering valuable insights for optimizing farming practices to address productivity challenges. Further research on the long-term impacts and scalability of these practices across different environmental conditions would be beneficial in developing comprehensive strategies to enhance wheat yield and sustainability in diverse agricultural settings.

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References

Ahmad, M., Akram, Z., Munir, M., & Rauf, M. (2006). Physio-morphic response of wheat genotypes under rainfed conditions. *Pakistan Journal of Botany,* 38(5), 1697–1702.

Ahmed, N. M., & Rashid, A. G. (1996). Fertilizer and their use in Pakistan (2nd ed., Publication No. 4/96). National Fertilizer Development Centre.

Alghabari, F., Ihsan, M. Z., Khaliq, A., Hussain, S., Daur, I., Fahad, S., Nasim, W. (2016). Gibberellin-sensitive Rht alleles confer tolerance to heat and drought stresses in wheat at booting stage. *Journal of Cereal Science,* 70, 72–78. https://doi.org/10.1016/j.jcs.2016.05.016

Bassu, S. G., Motzo, F., & Rosella, S. (2010). Effects of sowing date and cultivar on spike weight and kernel number in durum wheat. *Crop and Pasture Science, 61*(4), 287–295.

Bhattarai, R. C., Thapa, B., Puri, B. D., Chaudhary, R. R., Sapkota, R. N., Baral, B., Shrestha, K., Adhikari, S. R., & Prasad, S. (2015). Yield interactions of wheat genotypes to dates of seeding in eastern mid hills of Nepal. *Journal of Nepal Agricultural Research Council,* 1, 33–36. https://doi.org/10.5555/20173179906

CGIAR (2018). Research Program on Wheat. Wheat in the World. Available online: https://wheat.org/wheat-in-the-world/ (accessed on 02 January 2025).

Dawelbeit, M. I., & Babiker, E. A. (1997). Effect of tillage and sowing method on growth and yield of wheat. *Soil and Tillage Research,* 42, 127–132. https://doi.org/10.1016/S0167-1987(96)01088-4

FAOSTAT (2020). Food and Agriculture Organization. Available online: http://www.fao.org/faostat/ (accessed on 02 January 2025).

Gao, Y. J., & Li, S. X. (2005). Cause and mechanism of crop yield reduction under straw mulch in dryland. *Transactions of the Chinese Society of Agricultural Engineering,* 21, 15–19.

Govaerts, B., Sayre, K. D., & Deckers, J. (2005). Stable high yields with zero tillage and permanent bed planting? *Field Crops Research,* 94, 33–42. https://doi.org/10.1016/j.fcr.2004.11.003

Hamam, K. A. (2013). Response of bread wheat genotypes to heat stress. *Jordan Journal of Agricultural Science,* 9(4), 486506.

Hammel, J. E. (1995). Long-term tillage and crop rotation effects on winter wheat production in northern Idaho. *Agronomy Journal,* 87, 16–22. https://doi.org/10.2134/agronj1995.00021962008700010004x

Hossain, A. L., Zvolinsky, M. V., Teixeira, V. P., & da Silva, J. A. (2012). Effect of soil and climatic conditions on phenology of spring wheat varieties in northern Bangladesh. *Journal of Fundamental and Applied Sciences,* 2, 86–93.

Huang, M., Wu, J. Z., Li, Y. J., Yao, Y. Q., Zhang, C. J., Cai, D. X., & Jin, K. (2009). Effects of tillage pattern on flag leaf senescence and grain yield of winter wheat under dry farming. *Chinese Journal of Applied Ecology,* 20, 1355–1361.

Kajla, M., Yadav, V., Chhokar, R., & Sharma, R. (2015). Management practices to mitigate the impact of high temperature on wheat. *Journal of Wheat Research,* 7(1), 1–12.

Khamssi, N. N., & Najaphy, A. (2012). Agro-morphological and phenological attributes under irrigated and rain-fed conditions in bread wheat genotypes. *African Journal of Agricultural Research,* 7(1), 51–57. https://doi.org/10.5897/AJAR11.1097

Li, C. S., Wang, K. R., Xie, R. Z., Fu, S. M., Li, S. Q., & Tang, Y. L. (2009). Effect of wheat residue retention on grain yield and main quality characters of rice in rice-wheat cropping system. *Southwest China Journal of Agricultural Sciences,* 22, 895–900.

Liu, J., Feng, B., Xu, Z., Fan, X., Jiang, F., Jin, X., & Yang, L. (2018). A genome-wide association study of whe at yield and quality-related traits in southwest China. *Molecular Breeding,* 38(1), 1–11. http://doi.org/10.1007/s11032-017-0759-9

Maqbool, M. M., Ali, A., Haq, T., Majeed, M., & Lee, D. (2015). Response of spring wheat (Triticum aestivum L.) to induced water stress at critical growth stages. *Sarhad Journal of Agriculture,* 31(1), 53–58.

Midmore, D., Cartwright, P., & Fischer, R. (1984). Wheat in tropical environments. II. Crop growth and grain yield. *Field Crops Research,* 8, 207–227. https://doi.org/10.1016/0378-4290(84)90064-9

Ministry of Agriculture and Livestock Development (MoALD). (2020). *Krishi Diary*. Government of Nepal, Ministry of Agriculture and Livestock Development. Agriculture Information and Training Center. Available online: https://aitc.gov.np/english/downloadsdetail/2/2019/19794382/ (accessed on 02 January 2025).

Munjal, R. (2004). Physiological and morphological traits associated in bread wheat under heat stress. In Proceedings of the 91st Indian Science Congress Part III (Advance Abstracts), 1–3 January, PU Chandigarh, India.

Nahar, K., Ahamed, K. U., & Fujita, M. (2010). Phenological variation and its relation with yield in several wheat (*Triticum aestivum* L.) cultivars under normal and late sowing mediated heat stress condition. *Notulae Scientia Biologicae,* 2(3), 51–56. https://doi.org/10.15835/nsb234723

NWRP. (2017). *Rice-wheat system: Opportunities and constraints*. National Wheat Research Program, Nepal Agricultural Research Council. Available online: https://elibrary.narc.gov.np/pages/view.php?ref=4889&k (accessed on 02 January 2025).

Pal, A., & Dhara, P. C. (2018). Work-related musculoskeletal disorders and postural stress of the women cultivators engaged in uprooting job of rice cultivation. *Indian Journal of Occupational and Environmental Medicine,* 22, 163–169. https://doi.org/10.4103/ijoem.IJOEM_104_18

Prasad, P. V., Pisipati, S., Ristic, Z., Bukovnik, U., & Fritz, A. (2008). Impact of nighttime temperature on physiology and growth of spring wheat. *Crop Science,* 48(6), 2372–2380. https://doi.org/10.2135/cropsci2007.12.0717

Putte, A. V., Govers, G., Diels, J., Gillijns, K., & Demuzere, M. (2010). Assessing the effect of soil tillage on crop growth: A meta-regression analysis on European crop yield under conservation agriculture. *European Journal of Agronomy,* 33, 231–241. https://doi.org/10.1016/j.eja.2010.05.008

Ray, D. K., Ramankutty, N., Mueller, N. D., West, P. C., & Foley, J. A. (2012). Recent patterns of crop yield growth and stagnation. *Nature Communications,* 3, 1293. https://doi.org/10.1038/ncomms2296

Riley, H., Pommeresche, R., Eltun, R., Hansen, S., & Korsaeth, A. (2008). Soil structure, organic matter, and earthworm activity in a comparison of cropping systems with contrasting tillage, rotations, fertilizer levels, and manure use. *Agriculture, Ecosystems & Environment,* 124, 275–284. https://doi.org/10.1016/j.agee.2007.11.002

Sakamoto, T., Morinaka, Y., Ohnishi, T., Sunohara, H., Fujioka, S., Ueguchi-Tanaka, M., Yoshida, S. (2006). Erect leaves caused by brassinosteroid deficiency increase biomass production and grain yield in rice. *Nature Biotechnology,* 24(1), 105–109. https://doi.org/10.1038/nbt1173

Sattar, A., Cheema, M. A., Farooq, M., Wahid, M. A., Wahid, A., & Babar, B. H. (2010). Evaluating the performance of wheat cultivars under late sown conditions. *International Journal of Agriculture and Biology,* 12(4), 561–565.

Shrestha, A. K., Paudel, P., & Matsuoka, A. (2009). Socioeconomic factors influencing adoption of fertilizer for maize production in Nepal. Proceedings of the 83rd Annual Conference of the Agricultural Economics Society. https://doi.org/10.22004/ag.econ.51066

Sikder, S., Ahmed, J., Hossain, T., Mian, M., & Hossain, M. (1999). Membrane thermostability, grain growth, and contribution of pre-anthesis stem reserves to grain weight of wheat under late seeded conditions. *Thai Journal of Agricultural Science*, 32, 465-473.

Singh, A., Singh, D., Kang, J., & Aggarwal, N. (2011). Management practices to mitigate the impact of high temperature on wheat: A review. *IIOAB Journal,* 2(7), 11–22.

Singh, V. P., Kumar, J., Singh, S., & Prasad, S. M. (2014). Dimethoate modifies enhanced UV-B effects on growth, photosynthesis, and oxidative stress in mung bean (*Vigna radiata* L.) seedlings: Implication of salicylic acid. *Pesticide Biochemistry and Physiology,* 116, 13–23. https://doi.org/10.1016/j.pestbp.2014.09.007

Tewolde, H., Fernandez, C., & Erickson, C. (2006). Wheat cultivars adapted to post-heading high temperature stress. *Journal of Agronomy and Crop Science,* 192(2), 111–120. https://doi.org/10.1111/j.1439-037X.2006.00189

Verma, A. K. (2010). Modeling for mechanization strategies of rice cultivation in Chhattisgarh, India. *AMA, Agricultural Mechanization in Asia, Africa and Latin America,* 41(1), 20–26.

Wang, P., Zhou, G., Yu, H., & Yu, S. (2011). Fine mapping a major QTL for flag leaf size and yield-related traits in rice. *Theoretical and Applied Genetics,* 123(8), 1319–1330. https://doi.org/10.1007/s00122-011-1669-6

Wheeler, T., & von Braun, J. (2013). Climate change impacts on global food security. *Science,* 341(6145), 508–513. https://doi.org/10.1126/science.1239402

Woodruff, D., & Tonks, J. (1983). Relationship between time of anthesis and grain yield of wheat genotypes with differing developmental patterns. *Australian Journal of Agricultural Research,* 34(1), 1–11. https://doi.org/10.1071/AR9830001

Wu, J., Zhu, Z. L., Zheng, J. G., & Jiang, X. L. (2006). Influences of straw mulching treatment on soil physical and chemical properties and crop yields. *Southwest China Journal of Agricultural Sciences,* 19, 192–195.

Xie, R. Z., Li, S. K., Li, X. J., Jin, Y. Z., Wang, K. R., Chu, Z. D., & Gao, S. J. (2007). The analysis of conservation tillage in China—Conservation tillage and crop production: Reviewing the evidence. *Science in Agriculture Sinica,* 40, 1914–1924.

Yoshioka, M., Khatoon, M., Komayama, K., Takenaka, D., Yamashita, A., Nijo, N., Inagawa, K., Morita, N., Sasaki, T., & Yamamoto, Y. (2008). Quality control of photosystem II: Impact of light and heat stresses. *Photosynthesis Research,* 98(1), 589–*608*. https://doi.org/10.1007/s11120-008-9372-4

Yuan, L. X., Huang, G., Yu, Y., Zhao, Y. T., & Song, Z. S. (1991). Yield increasing mechanism of non-tillage agriculture for wheat following rice in Sichuan Basin. *Southwest China Journal of Agricultural Sciences,* 4, 49–56. https://doi.org/10.1626/pps.16.365