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Fodder potential of triticale (× *Tritisecale* Wittmack) genotypes in Nepal: Evaluation of biomass and seed productivity

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ABSTRACT
Triticale (× *Triticosecale* Wittmack) is a hybrid cereal combining the high grain quality and yield potential of wheat with the adaptability and resilience of rye. This study evaluated the performance of three triticale cultivars (Bolt, Wintermax and Crackerjack) and recommended cultivars of wheat and oat for winter fodder and seed production across four ecological regions in Nepal. A randomized complete block design (RCBD) with three replications was used to assess fodder yield and quality, and seed production over two consecutive years. Fodder yield varied significantly ($p<0.001$) among cultivars and locations, with Oat-RC demonstrating the highest biomass production, followed by TC-Wintermax, which outperformed TC-Bolt and TC-Crackerjack. The crude protein content ranged between 9.09% and 9.87%, with TC-Crackerjack exhibiting the best on fiber composition analysis. Seed yield was significantly influenced by genotype and locations, with TC-Bolt achieving the highest yield, particularly at Dhunche and Khumaltar, while TC-Wintermax demonstrated stable performance across sites. The study highlights the adaptability of triticale to Nepal's diverse agro-ecological conditions and its potential as a sustainable alternative for winter fodder and grain production. The findings provide valuable insights for optimizing region-specific cultivar recommendations to enhance livestock nutrition and agricultural sustainability.

Keywords: Fodder yield, biomass, nutrient composition, seed yield, seed yield attributing characters

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INTRODUCTION

Triticale (× *Triticosecale* Wittmack) is a hybrid cereal derived from a cross between wheat (*Triticum* spp.) and rye (*Secale cereale* L.), combining the high yield potential and grain quality of wheat with the adaptability and disease resistance of rye, making it suitable for diverse agro-ecological conditions (Ammar et al, 2004; Xu and Sun, 2024). Initially developed in the late 19th century, triticale has gained significance as a fodder and grain crop due to its superior biomass production, resistance to environmental stress, and ability to thrive in marginal lands (McGoverin et al 2011). These attributes make it a promising fodder alternative during harsh winter season for sustainable livestock production, particularly in diverse agro-ecological regions like those found in Nepal.

Nepali agriculture is characterized by its diverse topography, which ranges from the lowland Terai to the mid-hills and high mountains. The variations in elevation and climate significantly affect the growth and productivity of fodder crops. Studies indicated that ecological factors such as temperature, soil fertility, and rainfall distribution impact the yield, adaptability and fodder quality of different triticale cultivars (Derejko et al 2020). Accordingly, the productivity and quality of triticale as fodder and seed vary significantly across different ecological regions due to variations in climate, soil fertility, and management practices (Bezabih et al 2019). Understanding these variations is critical for selecting region-specific triticale cultivars that optimize both biomass and seed yield. In Nepal where livestock farming is a crucial component of the agricultural system, identifying high-yielding and nutritionally superior triticale cultivars is essential to enhancing fodder availability and ensuring sustainable agricultural practices, particularly in the context of mitigating the severe winter feed deficit. However, limited research assessing the comparative performance of different triticale cultivars under distinct agro-climatic zones in Nepal has been a bottleneck to recommending the most suitable cultivar for winter fodder as well as seed production.

This study evaluated the fodder yield and quality, and seed yield of various triticale cultivars across different ecological regions of Nepal while at the same time provided insights into the suitability of triticale as a fodder and seed crop in varying environmental conditions and contribute to the development of region-specific recommendations for farmers and policymakers. The findings are expected to help optimize fodder production strategies and improve livestock nutrition, ultimately supporting the sustainability of Nepal’s mixed farming systems.

MATERIALS AND METHODS

A study was carried out in four research stations under Nepal Agricultural Research Council (NARC) across different ecological regions: Pasture and Fodder Research Station in Dhunche, Rasuwa, a high hill ecology at an altitude of 1,950 meters above sea level with a cool winter; National Pasture and Fodder Research Program in Khumaltar, Lalitpur, a middle hill ecology at an altitude of 1,320 meters above sea level with a moderately cool winter; Directorate of Agricultural Research (DoAR) in Khajura, Banke, a Western Terai ecology at an altitude of 180 meters above sea level with a dry winter and a warm, humid summer; and DoAR in Tarahara, Sunsari, an Eastern Terai ecology at an altitude of 110 meters above sea level with a dry winter and a humid summer.

The experiment was carried out from November 2020 to May 2022. In the first year, the experiment focused on fodder yield and quality, while in the second year, the study was conducted to evaluate seed yield. The triticale cultivars; Bolt, Wintermax and Crackerjack along with recommended cultivars of wheat and oat were compared for their fodder and seed yield with their yield contributing attributes at on-station during those consecutive years. The seeds of the Bolt and Wintermax cultivars were obtained from Plant Research Ltd., Canterbury, New Zealand, while the Crackerjack cultivar seeds were sourced from Australia (Pariyar et al 2019).

Treatments:

TC-Bolt = Triticale cultivar Bolt
TC-Wintermax = Triticale cultivar Wintermax
TC-Crackerjack= Triticale cultivar Crackerjack
Wheat-RC = Recommended cultivar of Wheat ('WK 1204' cultivar at Dhunche and Khumaltar, 'Banganga' cultivar at Nepalgunj and 'Vijay' cultivar at Tarahara locations)
Oat- RC = Recommended cultivar of Oat ('Ganesh' cultivar at Dhunche, 'Netra' cultivar at Khumaltar, 'Nandini' cultivar at Nepalgunj and 'Amritdhara' cultivar at Tarahara)

The experiment was conducted using a randomized complete block design (RCBD) with three replications, and each plot measured 12 m^2. The seed rate was 90 kg ha^{-1}, with a fertilizer application rate of 60:40:30 kg ha^{-1} ($N:P_2O_5:K_2O$). Sowing took place in November second week, and fertilizers were applied in the form of urea, di-ammonium phosphate, and muriate of potash. Seeds were sown continuously in rows spaced 25 cm apart and were treated with Vitavax at a rate of 2.0 g kg^{-1} before sowing. A total of three weedings were carried out at monthly intervals, and irrigation was provided twice- once during the vegetative stage and again at the heading stage. In the first-year experiment, the first cutting was performed at 60 days after sowing (DAS), followed by two additional cuttings at 30-day intervals. However, in the second-year experiment, no cuttings were taken for the seed crop.

The green fodder was weighed in all three cuts and total fodder yield was calculated. Date of sowing and date of seed maturity were recorded and days taken to seed maturity calculated. Plant height, number of leaves $plant^{-1}$, number of reproductive tillers $plant^{-1}$ were recorded at the time of seed maturity. Fodder dry matter (DM) content, crude protein (CP) content and total mineral content was determined by using Proximate Analysis (AoAC 1990) and fiber fractions were analysed by using Georing and Van Soest (1970) protocol in the laboratory of National Animal Nutrition Research Center, Khumaltar, Lalitpur. The data obtained in both of the years were analysed by using jamovi™ (The jamovi project 2020).

RESULTS

Fodder yield

The fodder dry matter yield (FDMY) of different triticale cultivars evaluated across four locations- Dhunche, Khumaltar, Tarahara, and Khajura- based on yield measurements from three successive cuts and total fodder dry matter yield is presented in Table (1). The results indicate significant variation ($p<0.001$) in fodder productivity across cultivars and locations. Among the genotypes, Oat-RC consistently exhibited the highest fodder yield across all locations and cuts, with the highest total fodder yield (TFY) at Khajura. The TC-Wintermax ranked second in overall performance, demonstrating high yields at Khumaltar, Tarahara, and Khajura. The triticale cultivars Bolt and Crackerjack produced moderate yields, with TC-Bolt slightly outperforming TC-Crackerjack in certain locations. In contrast, Wheat-RC consistently exhibited the lowest fodder yields across all locations, confirming its inferior productivity in comparison to the other treatments.

Table 1. Fodder dry matter yield of different cultivars of triticale and recommended cultivars of oat and wheat across different location

Treatment	Fodder dry matter yield															
	Dhunche				**Khumaltar**				**Tarahara**				**Khajura**			
	FC	**SC**	**TCt**	**TFY**	**FC**	**SC**	**TCt**	**TFY**	**FC**	**SC**	**TCt**	**TFY**	**FC**	**SC**	**TCt**	**TFY**
TC-Bolt	3.61±0.62^{b}	2.19±0.23^{b}	1.13±0.11^{c}	6.93±0.34^{c}	3.27±0.47^{b}	3.18±0.14^{b}	1.09±0.17^{b}	7.54±0.39^{c}	4.31±1.17^{c}	3.63±1.22^{cd}	1.45±0.65^{c}	9.39±1.06^{c}	5.71±1.19^{b}	4.58±1.22^{c}	1.24±0.02^{b}	11.53±1.34^{c}
TC-Wintermax	2.11±0.81^{d}	4.16±1.12^{a}	2.14±0.62^{b}	8.41±0.87^{b}	3.68±0.94^{b}	5.49±1.66^{a}	2.78±0.22^{a}	11.95±1.07^{a}	3.43±0.85^{cd}	7.14±1.89^{a}	5.46±1.43^{a}	16.03±1.98^{a}	4.17±1.26^{c}	7.99±1.79^{a}	4.56±0.58^{a}	16.72±2.78^{a}
TC-Crackerjack	2.86±0.66^{c}	1.13±0.31^{c}	2.09±0.26^{b}	6.08±0.44^{d}	2.36±0.46^{c}	3.86±1.26^{b}	3.19±0.63^{a}	9.41±1.33^{b}	5.72±1.26^{b}	4.16±0.97^{c}	4.12±0.89^{b}	14.00±2.39^{b}	3.11±0.87^{d}	6.89±2.13^{b}	4.36±1.04^{a}	14.36±3.08^{b}
Wheat-RC	1.28±0.24^{e}	1.98±0.22^{b}	0.78±0.09^{d}	4.04±0.18^{e}	1.49±0.77^{d}	1.26±0.72^{c}	1.03±0.38^{b}	3.78±1.06^{d}	2.13±0.25^{d}	3.18±1.05^{d}	1.17±0.55^{c}	6.48±1.02^{d}	3.72±1.17^{cd}	3.11±0.72^{d}	0.97±0.31^{c}	7.80±1.47^{d}
Oat-RC	4.49±1.01^{a}	4.39±0.99^{a}	2.69±0.42^{a}	11.57±0.98^{a}	4.62±0.86^{a}	5.34±1.08^{a}	2.93±0.47^{a}	12.89±0.99^{a}	7.32±2.10^{a}	5.43±1.19^{b}	3.56±0.29^{b}	16.31±2.34^{a}	7.79±1.63^{a}	6.24±0.98^{b}	4.76±1.33^{a}	18.79±3.18^{a}
F-probability	<0.001	<0.001	<0.001	<0.001	<0.01	<0.001	<0.05	<0.001	<0.001	<0.01	<0.001	<0.001	<0.01	<0.001	<0.001	<0.001

FC= First cut, SC= Second cut, TCt= Third cut, TFY= Total fodder yield, TC= triticale cultivar, RC=Recommended cultivar. The mean having similar superscript in a column are statistically similar (p>0.05).

Statistical analysis further supports these trends, with Oat-RC and TC-Wintermax frequently showed the similar results, indicating their comparable performance in different locations. On the contrary, TC-Bolt and TC-Crackerjack were often statistically similar (p>0.05), though both yielded less than TC-Wintermax. Wheat-RC consistently showed statistically lowest (p>0.05) yields, confirming its significantly lower productivity compared to all other cultivars. Overall, Oat-RC emerged as the most productive cultivar, making it the optimal choice for maximizing fodder yield. Among the triticale genotypes, TC-Wintermax demonstrated the best overall performance, ranking second in total yield and outperforming TC-Bolt and TC-Crackerjack in most environments. Wheat-RC was the least productive genotype, suggesting it may not be a viable option for high-yield fodder production in different locations.

Nutrient composition of fodders

Table (2) presents the nutrient composition of fodder from different triticale cultivars along with the recommended cultivars of wheat and oat. The nutrient composition of the tested cultivars varied significantly, particularly in fiber fractions and mineral content. The statistically similar (P>0.05) CP values across cultivars suggest that protein content does not vary extensively. However, differences in fiber and associated components (ADF, ADL, HC and C) indicate variation in digestibility and overall fodder quality. Higher cellulose and hemicellulose contents in certain cultivars suggest better potential for energy availability. Regarding mineral balance, TC-Crackerjack had the highest phosphorus content (0.76%), while TC-Bolt contained the highest calcium (1.26%). Overall, TC-Crackerjack emerged as the most nutritionally balanced cultivar among the triticale varieties, offering a combination of competitive CP content, improved digestibility, and a favorable mineral profile. The Oat-RC showed its high protein and cellulose content. In contrast, TC-Bolt exhibited higher fiber and lignin content, while TC-Wintermax had relatively lower protein and mineral content.

Table 2. Nutrient composition of fodders from different treatments harvested at 60 DAS

Treatment	CP, %	NDF, %	ADF, %	ADL, %	HC, %	C, %	Ca, %	P, %
TC-Bolt	9.42±0.13	69.32±0.95	56.55±2.51^{a}	24.94±1.50^{a}	12.77±3.40^{c}	31.61±1.98^{a}	1.26±0.41^{a}	0.35±0.14^{c}
TC-Wintermax	9.09±1.07	67.253.46	52.91±0.40^{a}	20.93±1.08^{c}	14.22±3.63^{b}	32.10±1.16^{a}	0.90±0.07^{c}	0.53±0.14^{b}
TC-Crackerjack	9.70±1.25	65.71±1.32	46.88±6.27^{b}	24.40±3.52^{ab}	18.84±6.79^{a}	22.48±8.15^{b}	1.14±0.24^{ab}	0.76±0.43^{a}
Wheat-RC	9.36±0.44	65.25±4.14	53.05±4.47^{a}	22.90±3.21^{b}	12.08±4.69^{c}	30.14±7.47^{a}	1.06±0.17^{bc}	0.36±0.10^{c}
Oat-RC	9.87±0.65	66.19±4.00	55.24±0.41^{a}	22.32±1.91^{bc}	12.61±2.28^{c}	32.92±1.89^{a}	1.21±0.52^{ab}	0.60±0.27^{b}
F-probability	NS	NS	<0.001	<0.05	<0.05	<0.01	<0.05	<0.001

DAS= Days after sowing, TC= Triticale cultivar, RC= Recommended cultivar, CP= Crude protein, NDF= Neutral detergent fiber, ADF= Acid detergent fiber, ADL= Acid detergent lignin, HC= Hemicellulose, C= Cellulose, Ca= Calcium, P= Phosphorus, TC= Triticale cultivar, RC= Recommended cultivar; The mean having similar superscript in a column are statistically similar ($p>0.05$).

Seed yield attributing characters

The results of seed-attributing characters of triticale cultivars along with the recommended cultivars of wheat and oat is presented in Table (3). Plant height exhibited highly significant differences ($p<0.001$) across all locations. Among the treatments, Oat-RC recorded the tallest ($p<0.01$) plants across all locations, with the highest values observed in Khajura and Tarahara. The TC-Bolt had the second-highest plant height in most locations, except in Khajura, where TC-Wintermax outperformed it. In contrast, TC-Crackerjack and Wheat-RC consistently exhibited the shortest plant height across locations.

Significant variation ($p<0.01$) was observed in the number of leaves per plant among treatments across all locations. Oat-RC produced the highest number of leaves plant^{-1}, ranging from 5.46 to 7.40 leaves. The TC-Bolt followed closely, with leaf numbers varying from 4.46 to 5.93. On the other hand, TC-Crackerjack and Wheat-RC had the lowest leaf counts across locations.

The number of reproductive tillers plant^{-1} also showed statistically significant differences ($p< 0.05$) across locations. The TC-Bolt exhibited the highest number of reproductive tillers, particularly in Khajura (13.73), and performed well in Dhunche and Khumaltar. The Oat-RC showed moderate tillering in most locations but had relatively lower tiller counts in Khajura. On the other hand, the TC-Crackerjack recorded the lowest reproductive tillers, with the lowest value in Tarahara (3.20).

Overall, Oat-RC demonstrated superior performance in plant height and number of leaves across locations, though its reproductive tillering varied. The treatment TC-Bolt exhibited strong performance in both plant height and reproductive tillers, suggesting its potential for higher yield. Other treatments TC-Wintermax and Wheat-RC displayed moderate performance, whereas TC-Crackerjack consistently exhibited the lowest values across all measured traits.

Table 3. Seed attributing characters of different cultivars of triticale, wheat and oat

Treatment	Plant height, cm				Number of leaves $Plant^{-1}$				No of reproductive tillers $plant^{-1}$			
	Dhunche	Khumaltar	Tarahara	Khajura	Dhunche	Khumaltar	Tarahara	Khajura	Dhunche	Khumaltar	Tarahara	Khajura
TC-Bolt	114.40±22.38^{a}	104.80±10.78^{b}	97.13±7.31^{b}	100.67±4.47^{b}	4.46±0.91^{b}	4.60±0.63^{b}	5.33±0.89^{b}	5.93±0.79^{b}	8.93±3.86^{a}	7.53±1.95^{a}	4.33±1.34^{b}	13.73±2.96^{a}
TC-Wintermax	92.80±9.25^{bc}	96.86±7.66^{b}	82.00±6.35^{c}	109.06±3.10^{b}	4.13±0.74^{c}	4.53±0.51^{b}	3.93±0.70^{c}	5.60±0.82^{b}	5.20±2.21^{cd}	6.00±1.19^{b}	4.66±1.71^{b}	10.00±1.64^{b}
TC-Crackerjack	83.00±19.91^{cd}	91.60±5.17^{b}	65.26±17.43^{d}	97.33±3.47^{c}	4.20±1.20bc	4.53±0.51^{b}	3.40±0.50^{c}	5.66±0.72^{b}	4.66±2.76^{d}	3.86±0.91^{c}	3.20±0.41^{c}	9.06±1.22^{b}
Wheat-RC	80.73±7.44^{d}	76.26±13.05^{bc}	78.00±5.58^{cd}	96.00±3.86^{c}	4.06±0.88^{c}	4.53±0.51^{b}	4.00±0.75^{c}	4.40±0.82^{c}	6.73±2.40^{bc}	5.20±0.94^{b}	4.20±2.11^{b}	5.20±0.67^{c}
Oat-RC	99.80±22.25^{ab}	123.47±12.82^{a}	172.80±4.87^{a}	194.87±16.11^{a}	5.46±1.30^{a}	6.13±0.83^{a}	6.80±1.74^{a}	7.40±1.24^{a}	7.80±3.76^{ab}	5.40±0.82^{b}	5.86±2.72^{a}	5.73±4.71^{c}
F-probability	<0.01	<0.001	<0.001	<0.001	<0.05	<0.01	<0.001	<0.05	<0.01	<0.01	<0.001	<0.001

TC= Triticale cultivar, RC= Recommended cultivar
The mean having similar superscript in a column are statistically similar (p>0.05)

Days to seed maturity

Figure (1) illustrates the number of days required for seed maturity across four locations for different treatments. The results indicate that TC-Bolt and TC-Crackerjack exhibited the longest duration to reach seed maturity, particularly in Dhunche and Khumaltar (201 days each). These cultivars also displayed similar maturity durations in Tarahara and Khajura (196 days each), highlighting a little late-maturing characteristics. In contrast, TC-Wintermax and Wheat-RC matured earlier, with TC-Wintermax exhibiting the shortest maturity period in Khajura (179 days), along with relatively shorter durations in Khumaltar (191 days) and Tarahara (194 days). The Oat-RC had the shortest maturity duration overall, particularly in Khumaltar (180 days), Tarahara (190 days), and Khajura (179 days), making it a strong candidate for early harvesting. The wheat-RC showed a maturity trend aligned with that of TC-Wintermax.

These findings indicate that TC-Bolt and TC-Crackerjack are late-maturing cultivars, while Oat-RC and TC-Wintermax exhibit early maturity potential, making them well-suited for regions with shorter crop cycles, particularly in crop adjustment of spring rice cultivation. Furthermore, Khajura consistently showed a shorter maturity duration compared to Dhunche and Khumaltar, highlighting the impact of location-specific factors on seed maturity.

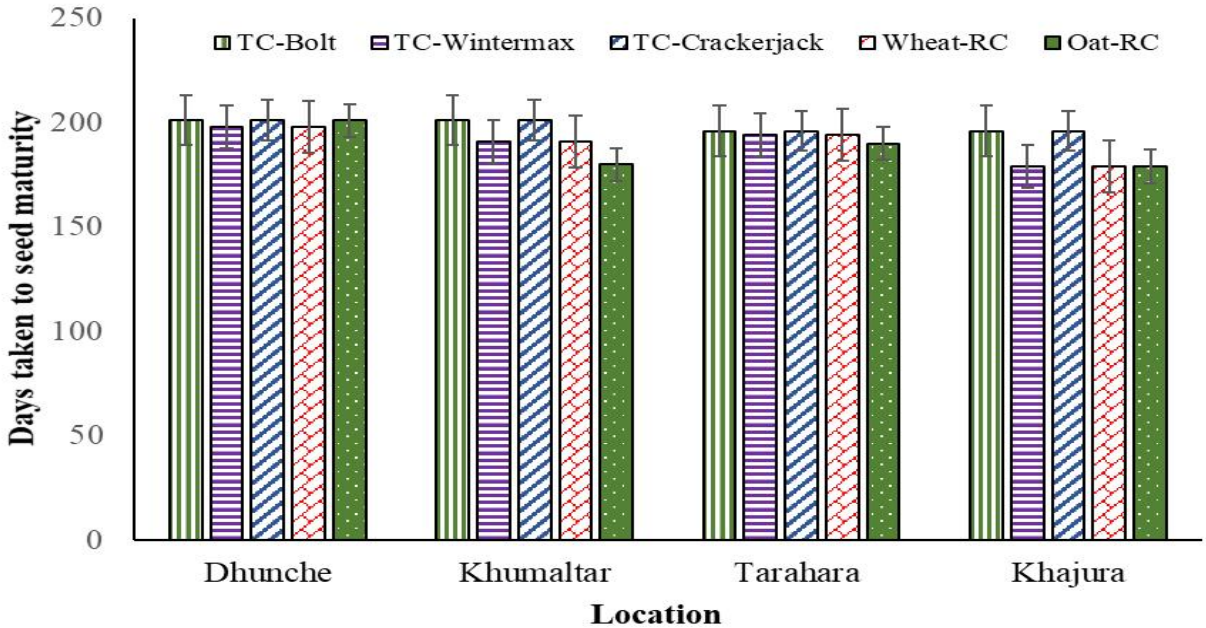

Figure 1. Days taken to seed maturity for different cultivars of triticale and recommended cultivars of wheat and fodder oat

Seed yield

The seed yield of different triticale, wheat, and fodder oat genotypes varied significantly ($p<0.001$) across the four experimental locations; Dhunche, Khumaltar, Tarahara, and Khajura (Table 4). Among the locations, Dhunche and Khumaltar exhibited significantly higher yields ($p<0.001$), whereas Tarahara consistently recorded lower yields across all genotypes.

Among the evaluated genotypes, TC-Bolt demonstrated superior seed yield performance in Dhunche, Khumaltar and Khajura, but exhibited a marked reduction in Tarahara. The TC-Wintermax exhibited stable performance across locations, with moderate to high yields, particularly in Khajura and Tarahara. The TC-Crackerjack yielded lower seed production, particularly in Khajura. Similarly, Wheat-RC showed competitive performance, particularly in Khajura and Tarahara, closely aligning with the yield of TC-Wintermax. In contrast, Oat-RC consistently recorded the lowest yields across all locations, suggesting lesser potential for seed production than triticale cultivars.

Overall, TC-Bolt emerged as the highest-yielding genotype across all locations, except for Tarahara, where its performance was considerably lower. The TC-Wintermax and Wheat-RC exhibited the most stable yields across environments, making them promising candidates for broad adaptability. In contradiction, Oat-RC was the least productive genotype, underscoring its limited agronomic potential for seed production relative to triticale and wheat genotypes.

Table 4. Seed yield of different triticale, wheat and fodder oat genotypes across four locations

Treatment	Seed yield, kg ha^{-1}			
	Dhunche	**Khumaltar**	**Tarahara**	**Khajura**
TC-Bolt	4733.3±319.97^{a}	4500.0±731.92^{a}	2333.3±487.95^{b}	3563.3±203.07^{c}
TC-Wintermax	3800.00±223.60^{b}	4000.00±368.39^{b}	2733.33±175.93^{a}	3896.67±272.07^{b}
TC-Crackerjack	3333.3±258.19^{c}	3650.0±287.72^{c}	2500.00 ±422.57^{d}	2423.3±63.43^{c}
Wheat-RC	3400.00±223.60^{c}	3866.66±129.0.9^{bc}	3233.33±212.69^{a}	3843.33±105.67^{a}
Oat-RC	2700.00±169.03^{d}	2490.00±359.86^{d}	1433.33±129.09^{bc}	2746.67±88.77^{d}
F-probability	<0.001	<0.001	<0.001	<0.001

TC= Triticale cultivar, RC= Recommended cultivar. The mean having similar superscript in a column are statistically similar (p>0.05).

DISCUSSION

The study assessing the potential of triticale cultivars (×*Triticosecale* Wittmack) for winter fodder and seed production in Nepal presents valuable insights into the adaptability, yield potential, and nutritional value of triticale in diverse agro-climatic conditions. In the variation in topography and climate of Nepal, the selection of suitable cultivars for fodder and seed production is critical to improving livestock nutrition and optimizing agricultural sustainability (Khanal et al 2022). The findings of this study align with previous research emphasizing the good adaptability of triticale to wider topography and climate and its potential as a high-yielding fodder crop (Ammar et al 2004; Derejko 2020; Xu and Sun 2024).

The results of the study indicate significant variations in fodder yield among different triticale, wheat, and oat cultivars across four ecological regions. Notably, the recommended oat cultivar (Oat-RC) consistently outperformed all other treatments in total fodder yield, highlighting its superiority in biomass production. This finding corroborates previous studies that identify oat as a robust fodder crop with high yield potential (Bibi et al 2021). Among triticale cultivars, Wintermax demonstrated the highest fodder yield, significantly surpassing Bolt and Crackerjack across all locations. This suggests that Wintermax possesses superior adaptability and vigor in the tested environments, a characteristic of triticale in diverse climatic conditions (McGoverin et al 2011).

Despite its moderate yield, the triticale cultivar Crackerjack demonstrated superior digestibility potential due to reduced fiber content and competitive CP levels. This balance between yield and quality makes it a promising choice for livestock feed, as digestibility and nutrient composition are essential for ruminant nutrition (Ayalew et al 2018). In contrast, wheat (Wheat-RC) recorded the lowest fodder yield across all locations, further highlighting its limitations as a winter fodder alternative. Fiber analysis showed that TC-Bolt had the highest NDF and ADF levels, suggesting lower digestibility compared to other triticale cultivars. In contrast, TC-Crackerjack had the lowest fiber content, indicating better digestibility and fodder quality. The lignin content (ADL), which influences digestibility, was lowest in TC-Wintermax, reinforcing its potential as an easily digestible fodder option (Ayalew et al 2018). The variation in fiber and lignin composition among the cultivars underlines the importance of selecting triticale genotypes based on both yield and nutritional quality. But the laboratory analysis of the fodders from only one cut was taken which was the limitation of this study.

The study also evaluated seed yield attributes, an essential factor for triticale adoption as a dual-purpose crop. Plant height, a critical determinant of biomass accumulation, varied significantly across locations and cultivars. Oat-RC exhibited the tallest plant height, followed by TC-Bolt and TC-Wintermax. This trend is consistent with previous studies demonstrating that taller plants often correlate with higher biomass and yield potential in small grains (Akdenizi et al 2024).

The overall seed yield data further support the advantages of Wintermax as a better triticale cultivar for Nepali agro-ecological conditions. Its superior yield performance, coupled with high fodder production, highlights its suitability for integrated farming systems that require both grain and fodder outputs. The TC-Crackerjack, despite its slightly lower seed yield, remains a promising alternative due to its improved digestibility and balanced mineral composition.

This study provides critical insights for Nepalese farmers and policymakers regarding optimal winter fodder and seed production strategies. The findings suggest that the Oat-RC is the most productive fodder crop, but its potential for dual-purpose use is limited compared to triticale cultivars. Wintermax is the most promising triticale cultivar, combining high fodder and seed yields with moderate digestibility. Crackerjack offers a balance between yield and fiber quality, making it an appropriate alternative for quality fodder production. Bolt, though productive, has higher fiber and lignin content, which may limit its digestibility compared to the other triticale cultivars. Wheat-RC consistently underperformed in both fodder and seed yield, making it less suitable for winter fodder production.

CONCLUSION

The assessment of triticale cultivars for winter fodder and seed production in Nepal confirms the suitability of triticale as a sustainable alternative to traditional winter cereals. Wintermax emerged as the top-performing triticale cultivar, offering the highest fodder and seed yields, whereas Crackerjack demonstrated superior digestibility and nutrient balance. The findings reinforce the need for region-specific recommendations, considering both yield potential and fodder quality. Further research on triticale's long-term adaptability, economic viability, and farmer adoption rates would enhance its role in Nepal's mixed farming systems.

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Authors' Contributions
RPG, DP, AR, JH, and MPR contributed to the conceptualization and design of the research. RPG, DP, KKS, and RA were responsible for field implementation, data management, and analysis. Additionally, RPG, AR, JH, KA, DP, MPR, and EJS played a role in the import of new germplasm, provided guidance for the study, and assisted in manuscript preparation.

Conflicts of Interest
The authors have no relevant conflict of interests.

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