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Optimizing Seed Rate and Cutting Frequency for Enhanced Berseem (*Trifolium alexandrinum* L.) Growth and Fodder Yield under Irrigated Conditions of Tandojam, Sindh

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Abstract

Berseem (Trifolium alexandrinum L.) is a premier winter forage legume in Pakistan, valued for its high crude protein content (18–22%) and biological nitrogen fixation. However, fodder productivity in irrigated Sindh remains suboptimal due to a lack of location-specific agronomic recommendations, particularly for seed rate and cutting management. This study, conducted during the winter season of 2016–2017 at Tandojam, evaluated the effects of three seed rates (12, 16 and 20 kg ha^{-1}) and three cutting regimes (no cut, one cut at 30 days after sowing [DAS] and two cuts at 30 and 60 DAS) on berseem growth and yield. A factorial randomized complete block design with three replications was employed. Data on plant height, leaves per plant, branches per plant, green fodder yield and dry fodder yield were subjected to two-way ANOVA. All traits were significantly ($p < 0.05$) influenced by seed rate, cutting regime and their interaction. The combination of a 20 kg ha^{-1} seed rate with a single cut at 30 DAS produced the highest plant height (80.0 cm), leaves per plant (75.5), branches per plant (39.1), green fodder yield (82,470 kg ha^{-1}) and dry fodder yield (7,618 kg ha^{-1}). The two-cut regime reduced overall productivity, as the second cut coincided with the coldest winter period, limiting crop regrowth. For irrigated conditions in Sindh, a seed rate of 20 kg ha^{-1} with a single cut at 30 DAS is recommended. Future research should explore higher seed rates, alternative cultivars and integrated nutrient management strategies.

Keywords: Berseem; Cutting management; Fodder yield; *Trifolium alexandrinum*, Seed rate

INTRODUCTION

Livestock farming is a critical component of Pakistan's rural economy, contributing approximately 62% to agricultural value addition and 14% to the national GDP (Government of Pakistan [GoP], 2024; Pakistan Economic Survey, 2025). Despite a livestock population exceeding 231 million animals, a substantial deficit in green fodder supply persists. National average fodder yields remain around 49 t ha^{-1}, significantly below the achievable potential (GoP, 2024; Leghari *et al.*, 2018). This shortage is particularly acute during two lean periods: November–January and May–June, when fresh forage becomes scarce and expensive (Rasheed & Ahmad, 2025). Addressing this fodder gap is a priority for enhancing agricultural sustainability in Pakistan.

Berseem (*Trifolium alexandrinum* L.) is the dominant winter forage legume across South Asia and the Middle East, prized for its rapid growth, multi-cut potential and high crude protein content (18–22% on a dry matter basis) (El Nahrawy, 2011). As a nitrogen-fixing species via symbiosis with *Rhizobium* bacteria, berseem requires no nitrogen fertilizer and improves soil fertility for subsequent cereals (Khan *et al.*, 2014; Rao & Chopra, 1990; Singh *et al.*, 2014). While well-managed berseem can yield over 100 t ha^{-1} of green fodder, average farmer yields are only about 65 t ha^{-1}, indicating a large yield gap attributable to suboptimal agronomic practices (Leghari *et al.*, 2018). Two critical, yet often poorly optimized, management factors are seed rate and cutting schedule. Seed rate determines plant population density. Insufficient rates allow weed proliferation and inefficient resource use, while excessive rates intensify intraspecific competition, reducing individual plant growth and increasing lodging risk (Anil Kumar *et al.*, 2009; Hussain *et al.*, 2002). Recent evidence suggests that a seed rate of 15 kg ha^{-1} maximized tiller density and increased forage yield by 2.85% compared to 20 kg ha^{-1} (Anjum *et al.*, 2024). Furthermore, balanced phosphorus and potassium fertilization can enhance plant height (76 cm) and fodder yield (82 t ha^{-1}), indicating that seed rate interacts with other nutrient factors (Akram *et al.*, 2023).

Cutting management, including the timing and frequency of harvest, profoundly affects berseem regrowth and total yield. An appropriately timed first cut can break apical dominance, stimulate branching and improve canopy light penetration (Sardana & Narwal, 2000). Conversely, excessive cutting frequency or delayed cutting can deplete root carbohydrate reserves, impairing regrowth, particularly under cool temperatures (Boote *et al.*, 2010). Iqbal *et al.* (2025) reported that sowing in mid-to-late October with a single cut at 75 DAS optimized the trade-off between yield and nutritional quality. Similarly, Ali *et al.* (2025) found that early November sowing produced taller plants (51.7 cm) and higher dry matter (11.1 t ha^{-1}).

Importantly, most existing cutting recommendations for Sindh are extrapolated from studies in Punjab (Pakistan) or subtropical India, which experience milder winters than Sindh, where average minimum temperatures drop to ~8°C. Agronomic practices validated in warmer regions may not be suitable for the cooler conditions of Tandojam. No published study has specifically investigated the interactive effects of seed rate and cutting regime on berseem performance under the agro-climatic conditions of Tandojam, Sindh. This study was designed to address this knowledge gap. The specific objectives were: (1) to quantify the individual effects of seed rate and cutting regime on berseem growth and yield and (2) to identify the optimal combination of these factors for irrigated conditions in Tandojam.

MATERIALS AND METHODS

Site description

The field experiment was conducted at the Agronomy Section, Agriculture Research Institute (ARI), Tandojam, Hyderabad, Sindh, Pakistan, during the *rabi* (winter) season of 2016–2017. The site features a semi-arid climate with a mean minimum winter temperature of 8°C, a mean maximum of 25°C and negligible rainfall during the cropping season. The soil was a silty clay loam with pH 7.8 (1:2 soil:water), electrical conductivity 0.42 dS m^{-1}, organic matter 0.85%, available phosphorus 8.6 mg kg^{-1} and available potassium 152 mg kg^{-1}.

Experimental layout and treatments

A two-factor factorial arrangement was employed within a randomized complete block design (RCBD) with three replications. Individual plot size was 4 m × 3 m (12 m^2), with 1 m alleys between plots and 1.5 m between blocks. The factors were:

- **Seed rate (S):** S_1 = 12 kg ha^{-1}, S_2 = 16 kg ha^{-1}, S_3 = 20 kg ha^{-1}.
- **Cutting regime (C):** C_1 = no cut (final harvest only at 90 days after sowing, DAS); C_2 = one cut at 30 DAS + final harvest at 90 DAS; C_3 = two cuts at 30 and 60 DAS + final harvest at 90 DAS.

The nine treatment combinations were replicated three times, totaling 27 plots. The berseem variety 'Punjab Berseem' (accession AARI 11), obtained from the Ayub Agricultural Research Institute, Faisalabad, was broadcast-sown on 15 November 2016.

Crop management

The seedbed was prepared by deep plowing, followed by two harrowings and planking to achieve a fine tilth. A basal dose of diammonium phosphate (18% N, 46% P_2O_5) was broadcast and incorporated at 60 kg P_2O_5 ha^{-1}. No nitrogen fertilizer was applied, relying on biological nitrogen fixation. The crop was surface-irrigated every 7–10 days (nine irrigations total). Weeds were manually removed by hoeing twice (at 20 and 40 DAS). Pest and disease pressure was negligible, requiring no chemical control.

Data collection

Growth traits: At each cutting event and at the final harvest, five plants were randomly selected and tagged per plot. Plant height (cm from ground to the highest leaf tip), number of leaves per plant and number of branches per plant were recorded. Each treatment mean thus represented 15 observations (5 plants × 3 replicates).

Fodder yield: At each harvest, herbage from a central 1 m^2 quadrat (0.5 m × 2.0 m) was cut 5 cm above ground level and weighed fresh using a portable electronic balance. Green fodder yield (kg ha^{-1}) was calculated by extrapolation from the quadrat weight. A ~500 g subsample (fresh weight) per plot was oven-dried at 70°C for 48 hours to constant weight to determine dry matter percentage and compute dry fodder yield (kg ha^{-1}). For multi-cut treatments (C_2 and C_3), yields from all cuts were summed for total seasonal yield.

Statistical analysis

Data were analyzed using Statistix 10.0 software. A two-way ANOVA for a factorial RCBD was performed for each response variable. Homogeneity of variances was confirmed using Bartlett's test. Treatment means were compared using Fisher's least significant difference (LSD) test at $\alpha = 0.05$. Means within a column sharing no common lowercase letter are significantly different ($p < 0.05$).

RESULTS AND DISCUSSION

Growth traits

Seed rate, cutting regime and their interaction significantly ($p < 0.05$) affected plant height, leaves per plant and branches per plant (Tables 1 & 3), corroborating previous reports on the importance of these factors in shaping berseem canopy architecture (Sardana & Narwal, 2000).

Effect of seed rate: Across all cutting regimes, increasing the seed rate from 12 to 20 kg ha^{-1} progressively increased all growth parameters (Table 1). While high plant density typically intensifies competition for resources, potentially reducing per-plant size (Harper, 1977), the seed rates tested (12–20 kg ha^{-1}) were relatively low. The observed positive response likely reflects benefits such as faster canopy closure, improved light interception and potentially enhanced root system development promoting nodulation, which outweighed competitive effects. Hussain *et al.* (2002) similarly reported increases in plant height and branching up to 30 kg ha^{-1}, with declines only at 40 kg ha^{-1}, suggesting a competition threshold above 20 kg ha^{-1}. Anjum *et al.* (2024) also found that 15 kg ha^{-1} optimized tiller density, indicating that optimal seed rates are environment- and variety-specific.

Effect of cutting regime: A single cut at 30 DAS (C_2) resulted in significantly taller plants and greater leaf and branch numbers compared to no cut (C_1) or two cuts (C_3) at the same seed rate (Table 1). This is attributed to the removal of apical dominance, which releases axillary buds from inhibition, stimulates branching and improves canopy light penetration (Sardana & Narwal, 2000). The two-cut regime (C_3) yielded the poorest final growth, as the second cut occurred in mid-January, the coldest period (mean minimum 8°C). Low temperatures reduce photosynthetic rates and limit the replenishment of root carbohydrate reserves necessary for vigorous regrowth (Boote *et al.*, 2010; Musa *et al.*, 2021). Insufficient warm days remained post-February for full recovery, consistent with Iqbal *et al.* (2025), who found that cutting at 75 DAS optimized yield-quality balance, while a second cut under cool conditions reduces regrowth potential.

Seed rate × cutting interaction: The significant interaction ($p < 0.05$, Table 3) for all growth traits indicates synergistic effects. The combination S_3C_2 (20 kg ha^{-1} + one cut at 30 DAS) produced the maximum plant height (80.0 cm), leaves per plant (75.5) and branches per plant (39.1) (Table 1). The positive effect of a single cut was amplified at higher seed rates, suggesting that the branching response to early cutting is most effectively expressed when initial plant density is high. This interaction aligns with findings by Ali *et al.* (2025) for early-sown berseem and represents, to our knowledge, the first quantified measurement of this interaction for Tandojam conditions

Table 1. *Effect of seed rate and cutting regime on growth parameters of berseem. Tandojam,* rabi *2016–2017.*

Seed rate (kg ha^{-1})	Cutting regime	Plant height (cm)	Leaves plant^{-1}	Branches plant^{-1}
12	C_1 no cut	39.0 f	30.6 f	15.1 f

Seed rate (kg ha⁻¹)	Cutting regime	Plant height (cm)	Leaves plant⁻¹	Branches plant⁻¹
12	C_2 one cut, 30 DAS	44.0 e	38.4 e	18.8 e
12	C_3 two cuts, 30+60 DAS	41.0 f	33.8 f	17.3 f
16	C_1 no cut	53.0 d	44.1 d	23.8 d
16	C_2 one cut, 30 DAS	54.3 d	55.4 c	28.5 c
16	C_3 two cuts, 30+60 DAS	50.0 d	47.9 d	25.9 d
20	C_1 no cut	62.6 c	65.3 b	32.9 b
20	C_2 one cut, 30 DAS	80.0 a	75.5 a	39.1 a
20	C_3 two cuts, 30+60 DAS	75.0 b	71.5 a	36.4 a
LSD ($p < 0.05$)		2.23	1.58	0.84

Means in a column followed by different letters are significantly different at $p < 0.05$. $n = 15$ per treatment mean (5 plants × 3 replicates). DAS = days after sowing.

Fodder yield

Seed rate, cutting regime and their interaction had highly significant effects ($p < 0.05$) on both green and dry fodder yields (Tables 2 & 3), with patterns similar to those observed for growth traits but with larger absolute differences.

Effect of seed rate: Green and dry yields increased consistently with seed rate from 12 to 20 kg ha^{-1} across all cutting regimes. At the lowest seed rate (12 kg ha^{-1}), green yields ranged from 31,039 to 33,703 kg ha^{-1}, while at the highest rate (20 kg ha^{-1}), they ranged from 44,328 to 82,470 kg ha^{-1}. Notably, combining the highest seed rate with optimal cutting more than doubled the yield compared to the lowest seed rate. This response, attributed to rapid canopy closure and enhanced light interception (Anjum *et al.*, 2024), did not plateau at 20 kg ha^{-1}, suggesting the true optimum may be higher. Future trials should include rates of 25 and 30 kg ha^{-1} to define the upper limit. Furthermore, Rasheed and Ahmad (2025) demonstrated that additional phosphorus and potassium (90 kg P ha^{-1} + 60 kg K ha^{-1}) can boost green yield to 111 t ha^{-1}, highlighting the importance of integrated nutrient management.

Effect of cutting regime: Across all seed rates, a single cut at 30 DAS (C_2) produced the highest total seasonal green and dry yields (Table 2). This finding contradicts the assumption that more cuts invariably increase total yield. The reduced productivity of the two-cut regime (C_3) is climatically driven. The first cut (≈15 December) was followed by the coldest period (January, mean min 8°C), during which low temperatures suppress photosynthesis and prioritize root maintenance over shoot regrowth (Boote *et al.*, 2010). The subsequent 60-day regrowth period (30–90 DAS) allowed for compensatory growth as temperatures rose in February. However, a second cut at 60 DAS (mid-January) removed the modest biomass accumulated during the cold spell, leaving only 30 days for regrowth before final harvest insufficient time under cool conditions. In contrast, studies from warmer Indian regions (winter minima 12–14°C, longer growing seasons up to 120 days) reported maximum yields with three cuts (Meena *et al.*, 2017; Singh *et al.*, 2019), underscoring the critical role of environment in determining optimal cutting frequency.

Seed rate × cutting interaction: The highly significant interaction ($p < 0.05$, Tables 2 & 3) was substantial in practical terms. At the lowest seed rate (12 kg ha^{-1}), cutting regime had minimal impact on green yield (range 31,039–33,703 kg ha^{-1}). However, at the highest seed rate (20 kg ha^{-1}), the single-cut treatment (C_2) yielded 82,470 kg ha^{-1} compared to only 44,328 kg ha^{-1} for the no-cut treatment (C_1) a difference exceeding 38 t ha^{-1}. This demonstrates that the yield benefit of a high seed rate is fully realized only when combined with an early single cut. Adopting a higher seed rate without adjusting the cutting schedule fails to capture the potential yield gain (e.g., S_3C_1: 44,328 kg ha^{-1} vs. S_2C_2: 63,567 kg ha^{-1}).

Table 2. *Effect of seed rate and cutting regime on green and dry fodder yield of berseem. Tandojam,* rabi *2016–2017.*

Seed rate (kg ha^{-1})	Cutting regime	Green yield (kg ha^{-1})	Dry yield (kg ha^{-1})
12	C_1 no cut	31,039 f	2,985 e
LSD			

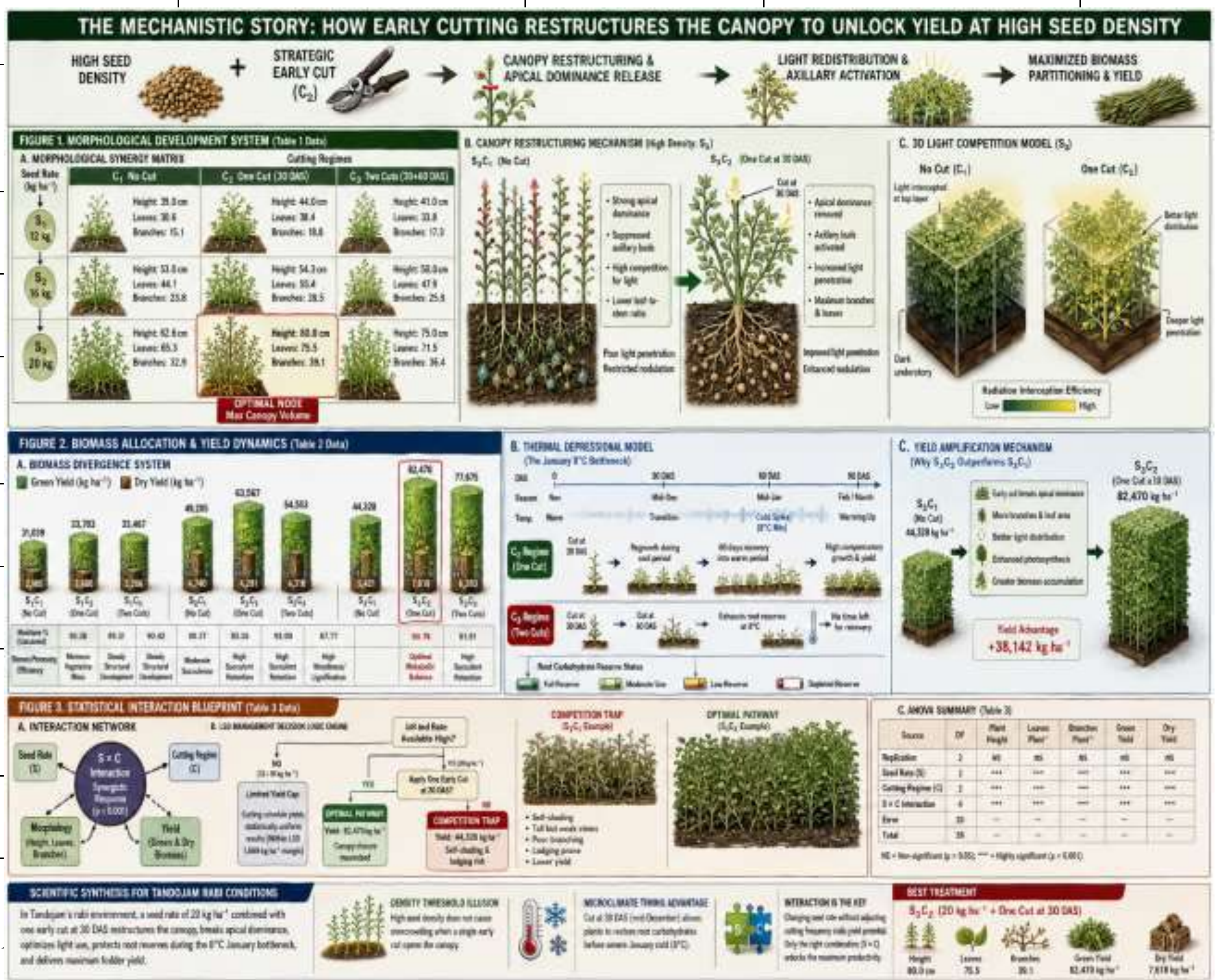

Fig 1. *Seed Rate and Cutting Regime Effects on Canopy Architecture and Fodder Yield in Berseem*

CONCLUSION

This study demonstrates that under the irrigated, cool winter conditions of Tandojam, Sindh, maximizing berseem fodder yield requires the simultaneous optimization of seed rate and cutting regime, as their interaction significantly influences productivity. Increasing seed rate to 20 kg ha^{-1} consistently enhanced growth and yield parameters. A single cut at 30 DAS produced substantially higher seasonal yield than either no cut or two cuts; the failure of the two-cut regime was attributable to the second cut coinciding with the coldest winter period, limiting regrowth.

The strong synergistic interaction indicates that the full benefit of a higher seed rate is only realized when combined with an early single cut. Therefore, for irrigated zones of Sindh, a seed rate of 20 kg ha^{-1} with a single cut at 30 DAS is recommended, which can be expected to yield approximately 82 t ha^{-1} of green fodder and 7.6 t ha^{-1} of dry matter. This research provides the first quantified assessment of the seed rate × cutting interaction for berseem in Sindh, offering a robust evidence base for extension services and farmer advisories in the province.

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Conflict of Interest

The authors declare that there is no conflict of interest

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