EFFECT OF PHOSPHORUS AND CALCIUM ON YIELD AND GROWTH OF FODDER TURNIP (*BRASSICA RAPA L.*) DURING LEAN PERIOD

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SUMMARY

A field experiment was conducted at the Forage Research and Management Centre, ICAR-National Dairy Research Institute, Karnal, Haryana, during the *Rabi* season in 2024-25 to study the effect of Phosphorus and Calcium management on growth, yield and economics of fodder turnip (*Brassica rapa L.*) during the lean period. The experiment consisted of six treatments (T_1: Control, T_2: No Phosphorus (P), T_3: 75% RDF of P, T_4: 100% RDF of P, T_5: 75% RDF of P + Foliar application of Calcium, T_6: 100% RDF of P + Foliar application of Calcium) in a randomised block design with five replications. The results revealed that significantly higher plant height at harvest (73.94 cm), number of leaves per plant (19.40), and leaf area (796.6 cm²) were observed in T_6 (100% RDF of P + foliar application of calcium), outperforming all treatments with the highest crop growth rate (13.90 g/m²/day), green fodder yield (68.78 t/ha) and dry fodder yield (7.14 t/ha), registering 49.43 % and 46.31 % gains in green and dry fodder, respectively, over the control. Treatment T_6 also recorded the maximum benefit-cost ratio (5.09).

Key words: Calcium, green fodder, lean period, phosphorus, turnip

India is among the leading countries in milk production and livestock population, but lags in milk productivity compared to developed countries (Ponnusamy *et al.*, 2021). Lower milk productivity is due to insufficient availability of green, nutritious and succulent fodder, which becomes scarce in the lean period from November to February (Kour *et al.*, 2023). Additionally, traditional livestock feed crops are being diverted for biofuel production, increasing feed costs (Bahinipati *et al.*, 2023). The growing need to expand feed production on limited land underscores the necessity of exploring alternative crops. Root crops, such as turnip, may be used as excellent livestock feed (Barchiesi-Ferrari and Chihuailaf, 2019).

Turnip belongs to the genus Brassica in the Brassicaceae family and is a short-duration, *Rabi*-season crop that adapts well to multiple cropping systems. It can also be grown as a catch crop between the harvesting of the kharif crop and the sowing of the *Rabi* crops. Turnips, which are used for fodder in livestock feeding, generally mature with larger storage roots (Neilsen *et al.* 2008). Phosphorus is important for the optimum growth and development of turnip. It is a constituent of adenosine triphosphate (ATP) and cytidine triphosphate (CTP), aiding in seed germination, root growth, strong stems, better yield, and quality. Calcium, as a divalent cation (Ca^{2+}), helps build and maintain strong cell walls and membranes, supports storage processes inside the vacuole, and also takes part in sending signals within the cell, especially in the cytosol (Marschner, 1995).

Calcium-phosphorus interactions in Brassica are governed by both soil-phase chemistry and physiological uptake dynamics. In Indian calcareous soils, calcium phosphate frequently dominates the soil P fraction, with Olsen's extractable P often below 5 mg/kg even when total P is adequate (Pal *et al.*, 2012). Foliar calcium carbonate applications bypass this Ca-P limitation by providing Ca²z directly through the cuticle, strengthening cell walls and complementing P-driven ATP-mediated energy transfer in actively growing leaves (Marschner *et al.*, 1996; Habib *et al.*,

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1999). In *Brassica rapa*, calcium and phosphate dosage together influenced structural and sensory attributes of green mustard, although not vegetative growth per se (Aryandhita and Kastono, 2021), suggesting that the response to Ca in Brassica is trait-specific, with cell-wall firmness, leaf area, and storage-root development being more responsive than fresh biomass. The present investigation was therefore initiated to study the effect of phosphorus and calcium on the yield and growth of fodder Turnip (*Brassica rapa L.*) during the lean period.

MATERIALS AND METHODS

A field experiment was conducted during the *Rabi* season of 2024-25 at the Research Farm of the Forage Research and Management Centre, ICAR-National Dairy Research Institute, Karnal, Haryana (29°45' N, 76°58' E; 245 m above mean sea level), situated in the North-Western Zone of Haryana under a sub-tropical climate with hot-humid summers and cold winters (max 47 °C; min 4 °C in December-January), on a clay-loam soil that was neutral in reaction (pH 7.0), low in available N (193.9 kg/ha), medium in available P (21.6 kg/ha) and organic C (0.59 %), and non-saline (EC 0.27 dS/m); the experiment was laid out in a Randomised Block Design with six treatments; T_1: Control (no P, no foliar Ca), T_2: No phosphorus, T_3: 75 % RDF of P, T_4: 100 % RDF of P, T_5: 75 % RDF of P + foliar Ca, T_6: 100 % RDF of P + foliar Ca with five replications.

The 100 % RDF of 80 kg N + 60 kg P, O… + 30 kg K, O/ha was supplied through urea, single super phosphate and muriate of potash, with nitrogen applied in two equal splits (half as basal dose at time of sowing + half at 25 DAS) and full potassium and treatment-wise phosphorus applied basally at time of sowing; foliar $CaCO_3$ was sprayed at 25 and 45 DAS using a knapsack sprayer fitted with a flood-jet nozzle; variety Purple Top (temperate-group turnip) was sown at 5-7 kg/ha with rows spaced 30 cm apart and thinned to 15 cm between plants at the true-leaf stage; pendimethalin (1 kg a.i./ha) was applied as a pre-emergence herbicide at sowing followed by hand-weeding at 15 and 30 DAS; irrigations were applied 7 days before sowing (pre-sowing irrigation) and subsequently on 6 and 26 November 2024; the crop was harvested at 68 DAS; green fodder yield was recorded from a central 1 m² area per net plot and converted to t/ha, while dry fodder yield was derived as DM% × GFY/100 with plant samples oven-dried at 60-70 °C to constant weight; and experimental data were analysed by analysis of variance appropriate to the Randomised Block Design, with treatment means compared using the least significant difference test at $\alpha = 0.05$ (Chandel, 1984).

RESULTS AND DISCUSSION

Growth parameters

The data presented in Table 1 revealed that the highest plant height at harvest (73.94 cm) was recorded in T_6 (100% RDF of P + foliar application of Calcium), which significantly exceeded T_4 (100% RDF of P; 68.20 cm) by 5.74 cm. T_4 stood at par with T_5 (75% RDF of P + foliar application of Calcium; 66.14 cm), while T_1 (control), T_2 (No Phosphorus) and T_3

TABLE 1
Effect of the application of phosphorus and foliar-applied calcium on the plant height, number of leaves, leaf width, leaf length, and leaf area of the fodder turnip

Treatments	Plant Height (cm)		Number of leaves		Leaf width (cm)		Leaf length (cm)		Leaf area (cm^2)	
	30 DAS	At Harvest	30 DAS	At Harvest	30 DAS	At Harvest	30 DAS	At Harvest	30 DAS	At Harvest
T_1: Control	29.80	56.96	5.95	10.00	10.06	14.22	26.66	54.90	333.8	472.4
T_2: No Phosphorus (P)	30.60	57.92	6.38	10.80	12.38	16.38	27.04	54.34	374.9	532.7
T_3: 75% RDF of P	32.51	58.06	7.15	13.40	12.62	16.84	28.22	56.30	453.1	655.9
T_4: 100% RDF of P	34.35	68.20	8.15	16.20	15.46	20.12	28.82	65.90	647.3	735.3
T_5: 75% RDF of P+ foliar application of Calcium	34.09	66.14	7.42	14.40	13.48	18.32	27.98	63.48	598.9	699.6
T_6: 100% RDF of P+ foliar application of Calcium	36.74	73.94	9.13	19.40	16.66	21.62	30.80	71.83	667.3	796.6
SE (m) ±	1.39	1.75	0.39	0.90	0.22	0.43	1.13	1.77	10.84	13.30
C.D. (p=0.05)	NS	5.17	1.17	2.66	0.64	1.28	NS	5.22	31.99	39.25

(75% RDF of P) remained mutually at par at harvest, recording 56.96, 57.92 and 58.06 cm, respectively. At 30 DAS, treatment differences were non-significant, although T_6 was numerically higher than control (29.80 cm) by 23.3%. The integrated P + foliar Ca regime thereby raised plant height by 23.3% at 30 DAS and 29.7% at harvest. A similar result was previously reported by Khetran (2016) for *Brassica rapa* 'Purple Top White Globe', where P-driven primary-nutrient management significantly enhanced turnip biomass under field conditions. 100% RDF of P + foliar application of Calcium (T_6) also had the highest number of leaves per plant at 30 DAS (9.13) and at harvest (19.40), compared to 5.95 and 10 in T_1 (control), representing proportional gains of 53.11% and 94%, respectively. At 30 DAS, T_6 was at par with T_4 (8.15), while at harvest, T_6 surpassed both T_4 (100% RDF of P) and T_5 (75% RDF of P + foliar application of Calcium), which recorded 16.20 and 14.40 leaves, respectively.

The same hierarchy held for leaf width and leaf length, as recorded in Table 1. The 100% RDF of P + foliar application of Calcium (T_6) produced the widest leaves at both stages (16.66 cm at 30 DAS and 21.62 cm at harvest) and was significantly higher than T_4 (100% RDF of P; 68.20 cm) which recorded 15.46 cm at 30 DAS and 20.12 cm at harvest, while T_3 (75% RDF of P) remained at par with T_2 (No Phosphorus) at 30 DAS. For leaf length, T_6 recorded 30.80 cm, 15.53% longer than the control (T_1), which recorded 26.66 cm at 30 DAS, but this difference was not statistically significant. At harvest, T_6 (71.83 cm) significantly outpaced T_1 (54.90 cm) by 30.83%, with T_4 (100% RDF of P) at par with T_5 (75% RDF of P + foliar application of Calcium), which observed 65.90 cm and 63.48cm, respectively. Leaf area integrated both dimensions above, at 30 DAS, the highest value, 667.3 cm², was recorded in T_6 (100% RDF of P + foliar application of Calcium), which was at par with T_4 (100% RDF of P), observed 647.3 cm². Both treatments T_6 and T_4 significantly outpaced T_5 (75% RDF of P + foliar application of Calcium), T_3 (75% RDF of P), T_2 (No Phosphorus) and T_1 (Control), with recorded leaf area values 598.9 cm², 453.1 cm², 374.9 cm², and 333.8 cm², respectively. At harvest, the same hierarchy held, but the differences sharpened: T_6 (796.6 cm²) significantly outpaced T_4 (735.3 cm²) by 61.3 cm², while T_4 stood at par with T_5 (699.6 cm²) and both significantly exceeded T_3 (75% RDF of P), T_2 (No Phosphorus) and T_1 (control). The integrated 100% RDF of P + foliar application of Calcium regime thereby raised leaf area by 2-fold at 30 DAS and 1.7-fold at harvest over control (T_1). It is because of the foliar application of calcium, which is directly absorbed by plant leaves, leading to increased leaf firmness and greater nutrient accumulation by enhancing overall plant health. Our outcomes are in line with those of Jung *et al.* (1998) for fodder turnip and consistent with the calcium-driven growth response in *B. rapa* subsp. *chinensis* reported by Zahro *et al.* (2024).

The data presented in Table 2 indicated that total plant dry weight accumulated most strongly in T_6 (100% RDF of P + foliar application of Calcium), reaching 8.41 g at 30 DAS and 32.43 g at harvest. This was a 46% advantage over T_1 (control), which recorded only 3.75 g at 30 DAS and 22.20 g at harvest, in line with the parallel gain in leaf area reported above. At 30 DAS, T_4 (100% RDF of P; 6.63 g) was at par with T_5 (75% RDF of P + foliar application of Calcium; 6.21 g). At harvest, T_6 surpassed T_4 (29.16 g) by 3.27 g, and T_4 in turn exceeded T_3 (75% RDF of P). Crop growth rate mirrored the gradient, T_6 (13.90 g/

TABLE 2

Effect of P and Ca management on the total plant dry weight, crop growth rate (CGR) and relative growth rate (RGR) of fodder turnip

Treatments	Plant dry weight at 30 DAS (g)	Plant dry weight at harvest (g)	CGR (g/m²/day)	RGR (g/g/day)
T_1: Control	3.75	22.20	10.68	0.047
T_2: No Phosphorus	4.79	24.70	11.52	0.043
T_3: 75% RDF of P	4.93	27.42	13.02	0.045
T_4: 100% RDF of P	6.63	29.16	13.04	0.039
T_5: 75% RDF of P+foliar application of Calcium	6.21	26.77	11.90	0.039
T_6: 100% RDF of P+foliar application of Calcium	8.41	32.43	13.90	0.035
SE (m) ±	0.14	0.44	0.29	0.0009
C.D. (p=0.05)	0.43	1.30	0.86	0.0026

TABLE 3
Effect of P and Ca management on the fresh root weight, dry root weight, fresh shoot weight, dry shoot weight, green fodder yield and dry fodder yield of fodder turnip

Treatments	Fresh root weight (g)		Dry root weight (g)		Fresh shoot weight (g)		Dry shoot weight (g)		Yield (t/ha)	
	At 30 DAS	At Harvest	At 30 DAS	At Harvest	At 30 DAS	At Harvest	At 30 DAS	At Harvest	GFY*	DFY*
T_1: Control	15.28	104.54	1.52	10.48	20.29	106.34	2.23	11.71	46.03	4.88
T_2: No Phosphorus	18.06	118.42	1.80	11.98	27.06	114.68	2.98	12.71	50.75	5.43
T_3: 75% RDF of P	19.29	139.78	1.93	13.98	27.31	121.29	3.00	13.44	58.02	6.03
T_4: 100% RDF of P	22.35	145.22	2.23	14.56	40.03	132.78	4.40	14.60	61.77	6.42
T_5: 75% RDF of P+foliar application of Calcium	20.19	133.46	2.02	13.20	38.16	124.09	4.19	13.57	57.17	5.89
T_6: 100% RDF of P+foliar application of Calcium	27.66	161.72	2.76	16.25	51.37	148.05	5.64	16.18	68.78	7.14
SE (m) ±	0.68	3.45	0.06	0.34	1.10	2.18	0.12	0.23	0.99	0.12
C.D. (p=0.05)	2.02	10.18	0.20	1.00	3.27	6.45	0.35	0.70	2.94	0.37

GFY* green fodder yield, DFY* dry fodder yield.

TABLE 4
Effect of P and Ca management on the cost of cultivation, gross return, net return, and B: C ratio of fodder turnip

Treatments	Cost of Cultivation (Rs./ha)	Gross Return (Rs./ha)	Net Return (Rs./ha)	B: C ratio
T_1: Control	28,701	1,15,075	86,374	4.01
T_2: No Phosphorus	30,533	1,26,875	96,342	4.16
T_3: 75% RDF of P	32,851	1,42,925	1,10,074	4.35
T_4: 100% RDF of P	33,260	1,54,425	1,21,165	4.64
T_5: 75% RDF of P+foliar application of Calcium	33,336	1,45,050	1,11,714	4.35
T_6: 100% RDF of P+foliar application of Calcium	33,760	1,71,950	1,38,190	5.09

m²/day) at par with T_4 (13.04 g/m²/day) and T_3 (13.02 g/m²/day), yet relative growth rate inverted the order (T_6 lowest at 0.035 g/g/day, T_1 highest at 0.047 g/g/day). Because RGR = (1/W) · (dW/dt) Scales inversely with standing biomass (W), T_6's larger W at harvest mechanically depressed its RGR (0.035 g/g/day) relative to the smaller-W T_1 control (0.047 g/g/day), a size-dependent artefact, not a decline in physiological efficiency.

Green fodder and dry fodder yield

Yield attributes, fresh root weight, fresh shoot weight, green fodder yield and dry fodder yield have been recorded at 30 DAS and harvest. The data presented in Table 3 revealed that T_6 (100% RDF of P + foliar application of Ca) achieves the highest fresh root weight and fresh shoot weight at both 30 DAS and harvest. However, the lowest fresh root and shoot weight was observed in T_1. Dry root weight, the storage-organ component of the below-ground biomass, mirrored the above-ground pattern: T_6 accumulated the maximum root weight at both 30 DAS (2.76 g) and harvest (16.25 g). T_1 (control) recorded the minimum (1.52 g and 10.48 g, respectively). Dry shoot weight followed the same T_1-T_6 gradient seen in fresh weight, peaking in T6 (5.64 g at 30 DAS; 16.18 g at harvest) and bottoming in the T_1 control (2.23 g and 11.71 g). Green and dry fodder yields were also found to be maximum in T_6, which was 68.78 t/ha and 7.14 t/ha, respectively, and were statistically superior to other treatments. Minimum green and dry fodder yields were observed in T_1 (control), i.e., 46.03 t/ha and 4.88 t/ha, respectively (Table 3). Application of 100% RDF of P with foliar application of Calcium significantly increased the green and dry fodder yield by 49.43% and 46.31%, respectively, over T_1 (control). The results conformed to the findings of Uikey *et al.* (2015) for fodder turnip at NDRI Karnal and are consistent with the foliar calcium response documented for *Brassica rapa* L. by Aryandhita and Kastono (2021), where foliar Ca was used to bypass the negative Ca-phosphate interaction in soil.

ECONOMICS

A cost-benefit analysis was conducted to assess the economic feasibility of the phosphorus-calcium integration package under smallholder dairy-farm conditions. The data presented in Table 4 revealed that the cost of cultivation was lowest in T_1 (control, ^{1} 28,701/ha) and highest in T_6 (100% RDF of P + foliar application of Calcium, Rs. 33,760/ha), with the absolute difference between T_1 and T_6 being only Rs. 5,059/ha (17.6% higher). Despite this modest cost premium, T_6 generated the highest gross return (Rs. 1,71,950/ha), net return (Rs. 1,38,190/ha) and benefit-cost ratio (5.09), significantly surpassing T_4, T_5, T_3, T_2 and control. Improvement of 60 % profitability in T_6, confirming that the additional input cost of Ca was repaid several-fold through higher biomass realised at lean-period farm-gate prices (Kour *et al.*, 2023).

The B: C ratio of 5.09 indicates that every Rs. 1 invested in the integrated package returned Rs. 5.09, an improvement of Rs. 1.08 over the control, well above the immediate-adoption threshold for forage innovations in the Indo-Gangetic plains (García *et al.*, 2007; Kour *et al.*, 2023). These findings corroborate earlier reports that balanced primary- and secondary-nutrient integration consistently produces the largest net monetary advantage in *Rabi* Brassica crops and support the recommendation that the T_6 nutrient package (100% RDF of P + foliar application of Calcium) is the most economically viable practice for fodder turnip cultivation by small and marginal dairy farmers during the *Rabi* lean period.

CONCLUSIONS

The one-year study conclusively demonstrates that 100% RDF of P + foliar application of calcium increased growth and yield of fodder turnip, improving biomass without compromising short-term soil fertility. Hence, the 100% RDF of P + foliar application of calcium is the recommended nutrient-management package for fodder turnip in the *Rabi* lean period.

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