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Performance of phosphorus and potassium foliar nutrition on growth, yield and economics of kharif grain sorghum

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ABSTRACT

A field experiment was conducted during kharif 2025 at the Agricultural Research Station, Hagari, Ballari district, *Karnataka* (Northern Dry Zone, Zone-III) to study the effect of graded levels of soil-applied phosphorus and potassium (recommended phosphorus and potassium, RPK) combined with foliar sprays of monopotassium phosphate (MKP, 0:52:34) on the growth, yield and economics of kharif grain sorghum hybrid CSH-16. Twelve treatments comprising 50 and 75 per cent RPK and 100 per cent recommended dose of fertilizer (RDF) each combined with foliar MKP at 0.4, 0.5 and 0.6 per cent sprayed at 30 and 45 days after sowing (DAS), along with RDF + water spray, RDF alone and an absolute control (without RPK), were laid out in a randomized complete block design with three replications. Application of 100 per cent RDF with two foliar sprays of 0.6 per cent MKP at 30 and 45 DAS (T_9) recorded the taller plants, higher leaf area index, dry matter production, earhead weight, number of grains per earhead, grain weight, grain yield (3588 kg ha^{-1}), stover yield (10368 kg ha^{-1}), gross returns (Rs. 1,63,841 ha^{-1}), net returns (Rs. 1,10,120 ha^{-1}) and benefit cost ratio (3.05) and was statistically on par with several other RDF and 75 per cent RPK-based foliar treatments. The lower values for all growth, yield and economic parameters were recorded where no phosphorus and potassium were applied. Grain yield increased by about 42.6 per cent and net returns by about 55.8 per cent over the unfertilized control with RDF + 0.6 per cent MKP.

Keywords: *Kharif* sorghum, Foliar nutrition, Monopotassium phosphate, Phosphorus, Potassium, Grain yield, Economics

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench), one of the principal dryland cereals of the semi-arid tropics, combines high photosynthetic (C_4) efficiency with deep rooting and marked drought tolerance, allowing it to perform on marginal, moisture-limited land where other cereals fail economically. In India, *kharif* sorghum occupies about 36.6 per cent of the total sorghum area, yet average productivity remains well below the crop's genetic potential, largely because it is grown on nutrient-deficient, rainfed soils under imbalanced, purely soil-based fertilization (Anon., 2024) [1].

Phosphorus and potassium rank next to nitrogen in importance for sorghum. Phosphorus governs root proliferation, energy transfer (ATP/ADP) and reproductive development, while potassium activates more than sixty enzyme systems, regulates stomatal function and drives assimilate translocation to developing grain - a function of particular value under the intermittent moisture stress typical of *kharif* cultivation (Marschner, 2011) [2]. However, a large share of soil-applied phosphorus is rapidly fixed in Indian soils and potassium is prone to leaching in light-textured dryland soils, so recovery of soil-applied P and K by the crop is often poor despite adequate dosing (Pesini *et al.*, 2024) [3].

Foliar nutrition offers a complementary route that bypasses soil fixation, delivering nutrients directly into leaf metabolism within hours and is particularly valuable at high-demand growth stages when root uptake is constrained (Sathishkumar *et al.*, 2020) [4]. Monopotassium phosphate (MKP, 0:52:34), a fully water-soluble, chloride-free source supplying both P and K, is well suited to this purpose and has been reported to improve growth, nutrient status and yield of sorghum and other cereals (Hussein *et al.*, 2010; Rafiullah *et al.*, 2021) [5, 6]. Information on how *kharif* sorghum responds to graded reductions in basal soil P and K combined with stage-specific foliar MKP sprays remains limited under Indian rainfed conditions (Prajapati *et al.*, 2023) [7]. The present study was therefore undertaken to evaluate the efficacy of phosphorus and potassium foliar nutrition on the growth, yield and economics of *kharif* grain sorghum.

Materials and Methods

The field experiment was conducted during *kharif* 2025 at the Agricultural Research Station, Hagari, Ballari district, *Karnataka*, situated in the Northern Dry Zone of *Karnataka* (Zone III). The experimental site was located at 15°13' N latitude, 77°05' E longitude and 414 m above mean sea level. The soil was a medium black *Vertisol* with clay texture containing 26.46 per cent sand, 22.38 per cent silt and 51.16 per cent clay. Initial soil pH was 7.58, electrical conductivity was 0.52 dS m⁻¹, organic carbon was 5.02 g kg⁻¹ and available N, P₂O₅, K₂O and DTPA-Zn were 258.20, 41.80, 423.35 kg ha⁻¹ and 0.35 mg kg⁻¹, respectively. The experiment was laid out in a randomized complete block design with twelve treatments and replicated thrice using CSH-16 grain sorghum. The crop was sown on 15th July 2025 at 45 cm × 15 cm spacing with a seed rate of 7.5 kg ha⁻¹. The gross and net plot sizes were 22.95 and 12.15 m², respectively. The experiment consisted of twelve treatments involving different levels of recommended phosphorus and potassium (RPK) in combination with foliar application of monopotassium phosphate (MKP). The treatments were T₁: 50 per cent RPK + foliar spray of 0.4 per cent MKP at 30 and 45 DAS; T₂: 50 per cent RPK + foliar spray of 0.5 per cent MKP at 30 and 45 DAS; T₃: 50 per cent RPK + foliar spray of 0.6 per cent MKP at 30 and 45 DAS; T₄: 75 per cent RPK + foliar spray of 0.4 per cent MKP at 30 and 45 DAS; T₅: 75 per cent RPK + foliar spray of 0.5 per cent MKP at 30 and 45 DAS; T₆: 75 per cent RPK + foliar spray of 0.6 per cent MKP at 30 and 45 DAS; T₇: RDF + foliar spray of 0.4 per cent MKP at 30 and 45 DAS; T₈: RDF + foliar spray of 0.5 per cent MKP at 30 and 45 DAS; T₉: RDF + foliar spray of 0.6 per cent MKP at 30 and 45 DAS; T₁₀: RDF + water spray at 30 and 45 DAS; T₁₁: RDF alone; and T₁₂: without recommended phosphorus and potassium (control). Here, RDF denotes the recommended dose of fertilizers, RPK denotes the recommended phosphorus and potassium dose and MKP denotes monopotassium phosphate (0:52:34 N:P₂O₅:K₂O) and it was applied as foliar spray at 30 and 45 DAS at 0.4, 0.5 or 0.6 per cent according to treatment. Recommended crop-management practices were followed uniformly. Plant height, number of leaves, leaf area and leaf area index were recorded at 30, 60, 90 DAS and harvest. For dry matter production, plants were separated into leaves, stem and earhead and oven-dried at 65 °C to constant weight. Yield attributes and grain and stover yields were recorded at harvest. Recommended fertilizer dose (RDF) was 100:75:37.5:15 kg N:P₂O₅:K₂O:ZnSO₄ ha⁻¹. Farmyard manure at 5.5 t ha⁻¹ was applied uniformly except in T₁₂. Half of the nitrogen and the full quantity of P, K and ZnSO₄ according to treatment were applied basally, while the remaining half of nitrogen was side-dressed at about 30 days after sowing (DAS). Furrow irrigation was followed, with protective irrigations scheduled at critical crop growth stages. Five plants were randomly selected and tagged in each plot for recording observations. The data were subjected to analysis of variance appropriate for Randomized complete block design. Significance of treatment effects was tested at the 5 per cent probability level following the procedure described by Panse and Sukhatme (1967) [8].

Results and Discussion

Growth parameters

Growth contributing characters, viz., plant height, leaf area, leaf area index and total dry matter production, recorded at harvest, as influenced by foliar nutrition of phosphorus and potassium, are presented

in Table 1.

Plant height

At harvest, plant height was significantly influenced by phosphorus and potassium management through foliar nutrition. The maximum plant height was recorded with T₉ (RDF + 0.6 % MKP) (182.9 cm), which was on par with T₄ (168.9 cm), T₅ (173.7 cm), T₆ (175.6 cm), T₇ (177.3 cm), T₈ (179.1 cm), T₁₀ (171.7 cm) and T₁₁ (169.2 cm). The minimum plant height was recorded under T₁₂ (without recommended P and K) (155.4 cm). The taller plants were observed under T₉ may be attributed to adequate P and K availability during active vegetative growth. Phosphorus supports energy transfer and root development, while potassium promotes cell expansion, enzyme activity and assimilate translocation. Similar improvement in sorghum growth with foliar nutrient application was reported by Hussein *et al.* (2010) [5], Lagad *et al.* (2020) [9] and Sawane *et al.* (2024) [5, 9, 10].

Leaf area

Leaf area at harvest differed significantly among the nutrient management treatments. The maximum leaf area was recorded under T₉ (34.3 dm² plant⁻¹) and was on par with T₄ (30.2), T₅ (31.3), T₆ (31.7), T₇ (32.3), T₈ (33.0), T₁₀ (31.3) and T₁₁ (30.8 dm² plant⁻¹). The minimum leaf area was recorded under T₁₂ (23.5 dm² plant⁻¹). The greater leaf area under T₉ indicates improved leaf development under adequate P and K nutrition. Similar responses to foliar nutrient application in sorghum were reported by Hussein *et al.* (2010) [5] and Lagad *et al.* (2020) [5, 9].

Leaf area index

Leaf area index (LAI) was significantly influenced by the nutrient management treatments. The higher LAI was recorded under T₉ (5.08) and was on par with T₄ (4.47), T₅ (4.64), T₆ (4.69), T₇ (4.78), T₈ (4.89), T₁₀ (4.63) and T₁₁ (4.56). The lower LAI was recorded under T₁₂ (3.48). The higher LAI under T₉ was associated with greater leaf area and better canopy development. Adequate P and K supply supports leaf growth, photosynthetic activity and efficient utilization of intercepted radiation. The greater canopy development under T₉ therefore contributed to higher biomass accumulation. (Marschner, 2011; Pettigrew, 2008) [2, 11]. The lower LAI under T₁₂ indicates restricted canopy development resulting from inadequate P and K supply. The positive association between canopy development and productivity is also consistent with observations reported for sorghum under improved nutrient management (Ajeigbe *et al.*, 2018) [12].

Total dry matter production

Total dry matter production at harvest was significantly influenced by phosphorus and potassium management. The maximum total dry matter was recorded under T₉ (204.64 g plant⁻¹) and was on par with T₆ (196.27), T₇ (198.73) and T₈ (201.24 g plant⁻¹). The minimum dry matter production was recorded under T₁₂ (151.44 g plant⁻¹). The greater dry matter production under T₉ may be attributed to the combined effect of improved plant growth, larger leaf area and higher LAI. Adequate P promotes energy metabolism and root activity, while K supports photosynthesis, enzyme activation and assimilate translocation. The resulting improvement in canopy development favoured greater biomass production. Similar responses to improved nutrient supply have been reported in sorghum by Lagad *et al.* (2020) [9] and Roy and Khandaker (2010) [9, 13].

Table 1. Growth parameters of *kharif* grain sorghum at harvest as influenced by foliar nutrition of phosphorus and potassium

Treatment	Plant height (cm)	Leaf area (dm ² plant ⁻¹)	LAI	Total dry matter production (g plant ⁻¹)
T ₁	164.3	26.4	3.90	166.47
T ₂	166.6	27.7	4.10	174.51
T ₃	167.5	28.6	4.24	180.87

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Treatment	Plant height (cm)	Leaf area (dm ² plant ⁻¹)	LAI	Total dry matter production (g plant ⁻¹)
T ₄	168.9	30.2	4.47	186.59
T ₅	173.7	31.3	4.64	192.61
T ₆	175.6	31.7	4.69	196.27
T ₇	177.3	32.3	4.78	198.73
T ₈	179.1	33.0	4.89	201.24
T ₉	182.9	34.3	5.08	204.64
T ₁₀	171.7	31.3	4.63	190.01
T ₁₁	169.2	30.8	4.56	188.20
T ₁₂	155.4	23.5	3.48	151.44
S.Em.±	4.9	1.5	0.22	3.58
C.D. (P = 0.05)	14.4	4.4	0.65	10.49

Yield parameters

The economic yield of a crop results from the integration of growth processes occurring throughout the crop-growth cycle and is ultimately governed by the availability of light, water, temperature and nutrients. The yield components, viz., earhead weight, Number of grains per earhead, 1000-grain weight, grain yield, stover yield and harvest index, as as influenced by foliar nutrition of phosphorus and potassium, are presented in Table 2.

Earhead weight

Earhead weight varied significantly among treatments. T₉ recorded the maximum earhead weight (82.7 g), followed by T₈ (82.0 g), T₇ (80.7 g), T₆ (79.7 g), T₅ and T₁₀ (78.7 g) which was found was statistically on par with each other, while T₁₂ recorded lower earhead weight of 69.3 g. The positive response agrees with evidence from sorghum showing improved yield components under adequate P and K supply (Hussein *et al.*, 2010; Ajeigbe *et al.*, 2018) [5, 12] and with recent work on foliar nutrient supplementation in sorghum (Giri *et al.*, 2024) [14].

1000-seed weight

The 1000-seed weight was not significantly influenced by the nutrient treatments. Numerically, the higher 1000-seed weight was recorded under T₉ (34.2 g), followed by T₈ (33.8 g), whereas the lower value was recorded under T₁₂ (31.5 g). The non-significant response of 1000-seed weight indicates that individual seed mass was relatively stable across nutrient treatments. Although T₉ recorded the higher numerical value, the yield advantage was therefore not primarily due to increased individual seed weight. The greater grain yield under im-

proved P and K nutrition was more closely associated with overall crop growth and earhead development.

Grain yield

Grain yield was significantly influenced by nutrient management. T₉ recorded the higher grain yield of 3588 kg ha⁻¹ and was on par with T₄, T₅, T₆, T₇, T₈, T₁₀ and T₁₁. Grain yield under these treatments ranged from 3311 to 3547 kg ha⁻¹. The lower grain yield was recorded under T₁₂ (2516 kg ha⁻¹). The higher grain yield under T₉ was associated with improved plant growth, canopy development, dry matter production and earhead weight. Adequate P supports energy transfer and reproductive development, while K enhances photosynthetic activity and assimilate translocation towards developing grains. Foliar MKP at critical growth stages may have supplemented the basal nutrient supply and supported grain formation and filling. Similar beneficial effects of P and K nutrition on sorghum yield have been reported by Hussein *et al.* (2010) [5], Ajeigbe *et al.* (2018) [12] and Giri *et al.* (2024) [5, 12, 14].

Stover yield

Stover yield showed significant variation among the treatments. T₉ recorded the higher stover yield of 10368 kg ha⁻¹ and was on par with T₄, T₅, T₆, T₇, T₈, T₁₀ and T₁₁. The lower stover yield was recorded under T₁₂ (7213 kg ha⁻¹). The higher stover yield under T₉ corresponded with greater plant height, leaf area, LAI and total dry matter production. Adequate P and K nutrition promotes vegetative growth, photosynthesis and carbohydrate accumulation, resulting in greater above-ground biomass. The lower stover yield under T₁₂ was consistent with its poorer vegetative growth and lower dry matter production. Similar responses have been reported by Roy *et al.* (2010) [13], Lagad *et al.* (2020) [9] and Qamar *et al.* (2022) [13, 9, 15].

Table 2. Yield attributes and yield of *kharif* grain sorghum as influenced by foliar nutrition of phosphorus and potassium

Treatment	Weight of earhead (g)	Number of grains earhead ⁻¹	1000 grains weight (g)	Grain weight (g plant ⁻¹)	Grain yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)	Harvest index
T ₁	70.0	1152	32.2	44.3	2859	7833	0.267
T ₂	70.7	1209	32.4	44.7	2999	8428	0.262
T ₃	70.7	1260	32.4	44.7	3040	8494	0.264
T ₄	74.3	1305	32.8	47.1	3311	9473	0.259
T ₅	78.7	1377	32.9	49.7	3432	9342	0.269
T ₆	79.7	1388	33.2	50.4	3460	9934	0.258
T ₇	80.7	1404	33.3	51.0	3490	9931	0.260
T ₈	82.0	1429	33.8	51.0	3547	9970	0.262
T ₉	82.7	1447	34.2	52.5	3588	10368	0.257
T ₁₀	78.7	1358	32.9	49.7	3418	9737	0.260
T ₁₁	74.7	1343	32.9	47.2	3344	9742	0.256

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Treatment	Weight of earhead (g)	Number of grains earhead ⁻¹	1000 grains weight (g)	Grain weight (g plant ⁻¹)	Grain yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)	Harvest index
T ₁₂	69.3	998	31.5	43.9	2516	7213	0.259
S.E.m.±	3.0	59	0.9	1.9	111	344	0.003
C.D. (P = 0.05)	8.8	174	NS	5.7	325	1008	NS

Harvest index

Harvest index was not significantly influenced by the nutrient treatments. The values ranged from 0.256 to 0.269, with the higher numerical value recorded under T₅ (0.269), while T₉ recorded 0.257 and T₁₁ recorded the lower value of 0.256.

Economics

The economics of *kharif* grain sorghum cultivation, viz., cost of cultivation, gross returns, net returns and benefit-cost ratio, as influenced as influenced by foliar nutrition of phosphorus and potassium, are presented in Table 3 and depicted in Fig. 1. The differences in economic returns were mainly associated with variation in grain and stover productivity among the treatments.

Cost of cultivation

The cost of cultivation increased with increasing levels of soil-applied phosphorus and potassium and foliar MKP application. The higher cost of cultivation was recorded under RDF + 0.6 per cent MKP (T₉) (Rs. 53,721 ha⁻¹), followed by RDF + 0.5 per cent MKP (T₈) (Rs. 53,516 ha⁻¹) and RDF + 0.4 per cent MKP (T₇) (Rs. 53,281 ha⁻¹). The lower cost was recorded under T₁₂, without recommended phosphorus and potassium (Rs. 44,033 ha⁻¹). The higher cost under T₉ was mainly due to greater expenditure on fertilizers and foliar MKP application.

Gross returns

Gross returns were significantly higher under T₉ (Rs. 1,63,841 ha⁻¹) and were on par with T₈ (Rs. 1,61,125 ha⁻¹), T₇ (Rs. 1,58,879 ha⁻¹), T₆ (Rs. 1,57,771 ha⁻¹), T₁₀ (Rs. 1,55,656 ha⁻¹), T₅ (Rs. 1,54,978 ha⁻¹), T₁₁ (Rs. 1,52,932 ha⁻¹) and T₄ (Rs. 1,50,908 ha⁻¹). In contrast, T₁₂ recorded significantly lower gross returns (Rs. 1,14,696 ha⁻¹). The higher gross returns under T₉ were mainly due to its greater grain

and stover yields. Adequate P and K nutrition, supplemented through foliar MKP, improved crop growth and productivity, thereby increasing the value of produce. The results agree with Ramgir (2025) [16], who observed higher gross returns in sorghum with foliar micronutrient spray and by Naidu *et al.* (2024) [17], who recorded higher gross returns with foliar phosphorus and MKP application in *Bt* cotton.

Net returns

Net returns were significantly higher under T₉ (Rs. 1,10,120 ha⁻¹) and were on par with T₈ (Rs. 1,07,609 ha⁻¹), T₆ (Rs. 1,05,770 ha⁻¹), T₇ (Rs. 1,05,598 ha⁻¹), T₅ (Rs. 1,03,159 ha⁻¹), T₁₀ (Rs. 1,03,036 ha⁻¹), T₁₁ (Rs. 1,01,476 ha⁻¹) and T₄ (Rs. 99,433 ha⁻¹). The lower net returns were recorded under T₁₂ (Rs. 70,663 ha⁻¹). The higher net returns under T₉ resulted from greater gross returns obtained from higher grain and stover productivity, which more than compensated for the additional expenditure on fertilizers and foliar MKP. The lower net returns under T₁₂ were mainly associated with reduced crop productivity. Similar findings were reported by Yerawar (2022) [18] in sorghum and Naidu *et al.* (2024) [17] in *Bt* cotton.

Benefit-cost ratio

The benefit-cost ratio was significantly higher under T₉ (3.05) and was on par with T₆ (3.03), T₈ (3.01), T₅ (2.99), T₇ (2.98), T₁₁ (2.97), T₁₀ (2.96) and T₄ (2.93). The lower benefit-cost ratio was recorded under T₁₂ (2.60).

The higher benefit-cost ratio under T₉ was attributed to the greater returns obtained from improved grain and stover productivity, which offset the additional cost of fertilizer and foliar MKP application. Thus, the improvement in productivity under adequate P and K nutrition was reflected in better economic returns. Similar improvement in benefit-cost ratio with nutrient management has been reported in sorghum by Ramgir (2025) [16].

Table 3. Economics of *kharif* grain sorghum cultivation as influenced by foliar nutrition of phosphorus and potassium

Treatment	Cost of cultivation (Rs. ha ⁻¹)	Gross returns (Rs. ha ⁻¹)	Net returns (Rs. ha ⁻¹)	B:C
T ₁	49,195	129,242	80,047	2.63
T ₂	49,571	136,203	86,632	2.75
T ₃	49,777	137,923	88,146	2.77
T ₄	51,475	150,908	99,433	2.93
T ₅	51,819	154,978	103,159	2.99
T ₆	52,001	157,771	105,770	3.03
T ₇	53,281	158,879	105,598	2.98
T ₈	53,516	161,125	107,609	3.01
T ₉	53,721	163,841	110,120	3.05
T ₁₀	52,620	155,656	103,036	2.96
T ₁₁	51,456	152,932	101,476	2.97
T ₁₂	44,033	114,696	70,663	2.60
S.E.m.±	-	5043	5043	0.10
C.D. (P = 0.05)	-	14790	14790	0.28

Conclusion

Application of 75 % RPK with two foliar sprays of monopotassium phosphate (0.4-0.6 %) at 30 and 45 DAS sustained the growth, yield attributes, yield and profitability of *kharif* grain sorghum at levels statistically comparable with full RDF supplemented by the same foliar

sprays. The best overall performance was recorded with RDF + 0.6 per cent MKP [T₉: grain yield (3588 kg ha⁻¹), net returns (Rs. 1,10,120 ha⁻¹) and B:C (3.05)]. For resource-constrained rainfed conditions, foliar application of 0.4 per cent MKP with 75 per cent RPK is recommended as it can save 25 per cent of basal phosphorus and potassium without compromising productivity or profitability.

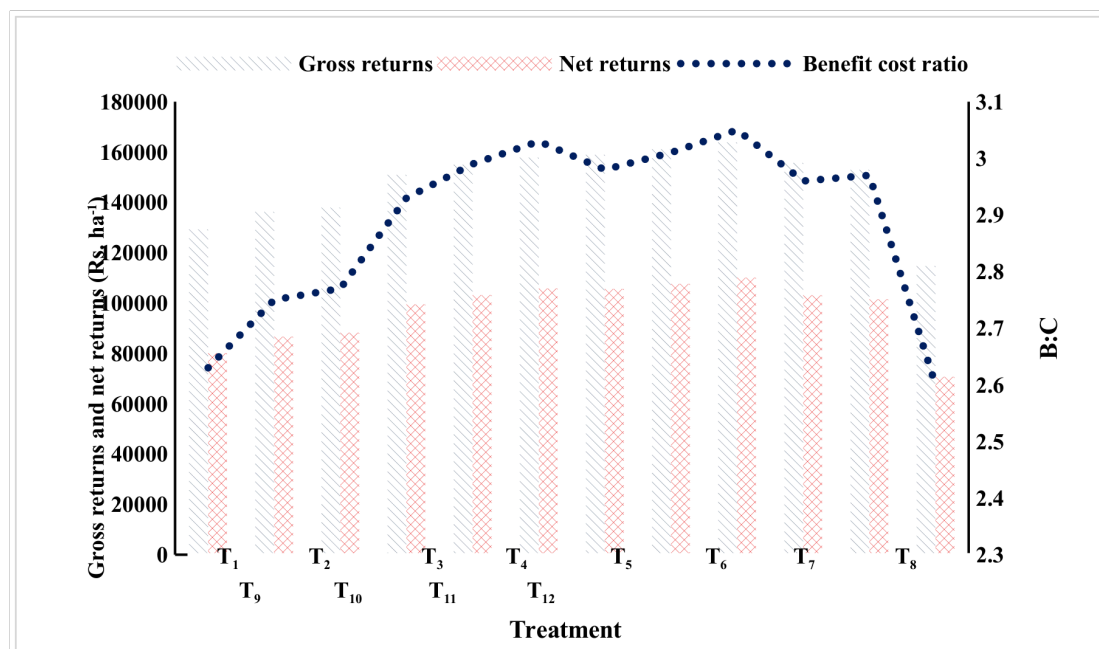


Figure 1. Economics of *kharif* grain sorghum cultivation as influenced by foliar nutrition of phosphorus and potassium

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