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Impact of Potassium Fertilization on Growth and Yield of Small Millets

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Authors' contributions

This work was carried out in collaboration among all authors. Authors SK and STS designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors NA, VC and AP managed the analyses of the study. Authors SRSR, SG and KM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To evaluate the impact of varying potassium application levels on the growth and yield of small millets and to assess the economic viability of potassium fertilization in small millet farming.
Methodology: A split plot design experiment was carried out, featuring four crops as the main treatments: C_1 - Proso millet, C_2 - Barnyard millet, C_3 - Kodo millet, and C_4 - Browntop millet. Potassium fertilizer was applied at four different rates (0, 10, 20, and 30 kg/ha) as sub-treatments.

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Throughout the cropping period, various morpho-physiological traits were monitored, including plant height (cm), tiller count per plant, and yield-related metrics such as the number of panicles per plant, 1000-grain weight (g), and biomass production per plant (g). At harvest, yield data and yield attributes were recorded, followed by an economic analysis.

Results: The results indicated that, Proso millet showed a plant height increase from 75.85 to 94.37 cm, number of productive tillers (4.73) with high potassium doses, while Barnyard millet reached a maximum height of 119.13 cm, grain yield significantly increased from 1547 kg/ha without potassium to 2055 kg/ha with the highest potassium dose. Barnyard millet (achieving the highest gross return of Rs 61650/ha and a B: C ratio of 2.20 with the highest potassium dose.

Conclusion: Application of potassium 20 kg/ha, along with the recommended dose of nitrogen and phosphorus, recorded 31.8% higher yield, greater tolerance to lodging, reduced pest and disease incidence and remunerative economics in millet cultivation.

Keywords: Small millet; potassium; economics; net return; benefit cost ratio.

1. INTRODUCTION

Small millets are vital crops in rainfed semi-arid regions, but their cultivation remains limited compared to other millets, largely due to a shift towards cash crops from traditional varieties [1]. Some small millets, especially wild types, are even considered weeds. Nonetheless, these crops are important locally, flourishing on marginal lands and providing consistent yields, which contributes significantly to food security. Despite their benefits, small millets face several challenges that impede their broader cultivation and adoption [2,3].

A major issue is the inadequate management of nutrients, particularly potassium deficiency in dryland conditions [4]. Potassium is a crucial macronutrient involved in essential physiological processes such as photosynthesis, osmoregulation, and enzyme activation [5,6]. Unfortunately, potassium application is often neglected in rainfed areas, leading to soil depletion and decreased crop yields over time. This nutrient's importance has frequently been underestimated in many regions, including India, resulting in soil potassium depletion and declining crop productivity in small millets [7,8,9,10,11].

Although the role of potassium in crop nutrition is well-recognized, there is limited research on its specific impact on small millet cultivation, especially in rainfed semi-arid areas. Addressing this research gap is essential for developing sustainable agronomic practices that improve small millet productivity and resilience to environmental stresses. This study aims to evaluate the effects of varying potassium application levels on small millet growth and yield, assess the impact of potassium management on growth parameters and yield attributes, and analyze the economic viability of potassium application in small millet farming.

2. MATERIALS AND METHODS

2.1 Site Description

The primary field experiments were conducted at the Centre of Excellence in Millets, Athiyandal, during the kharif seasons of 2020 and 2021. Throughout the cropping period, the monthly mean maximum and minimum temperatures ranged between 34.4°C and 24.9°C, with relative humidity varying from 67% to 86%. Initial soil analysis indicated a soil pH of 7.0, with low available nitrogen (128.0 kg/ha), high available phosphorus (31.4 kg/ha), and medium potassium levels (140.0 kg/ha).

2.2 Experiment and Treatment Details

The field was meticulously prepared using a tractor-drawn disc plough, cultivator, and rotavator. The treatments were arranged in a split-plot design with three replications. The main plots included four crops: C1 - Proso millet, C2 - Barnyard millet, C3 - Kodo millet, and C4 - Browntop millet. In the subplots, four potassium fertilizer doses were applied: K1 - 0, K2 - 10, K3 - 20, and K4 - 30 kg/ha. The study utilized Proso millet variety ATL1, Barnyard millet variety CO (KV) 2, Kodo millet variety ATL 1, and a pre-released culture of Browntop millet. Where seeds failed to germinate, gap filling was performed 10 days after sowing. Excess seedlings in each hill were thinned 20 days after sowing to maintain proper spacing with one seedling per hill. Fertilizer was applied per hectare according to the treatment plan. Two rounds of hand weeding were conducted at 20 and 40 days after sowing, and the recommended package of practices was followed for all other management activities.

2.3 Measurements

In each experimental plot, 5 plants were randomly tagged for recording observations on growth parameters such as plant height (cm) and number of tillers per plant. Yield attributes like the number of panicles per plant, 1000-grain weight (g), biomass production per plant (g), and grain yield (kg/ha) were also measured. Economic analysis was conducted using standard methods, calculating expenses and net returns based on input prices during the 2020 and 2021 cropping seasons to determine the benefit-cost ratio (BCR).

2.4 Statistical Analysis

The collected data were subjected to statistical analysis as per the methods outlined by (12). This analysis aimed to evaluate the effects of various treatments on the growth and yield characteristics of small millets. Significant differences between treatments were determined at a 5% probability level ($p \leq 0.05$) to ensure the results were statistically robust.

3. RESULTS

From the pooled data, various potassium management practices had significant effect on the growth and yield parameters (Tables 1 & 2).

Effect of potassium on growth of small millets: The impact of different potassium doses on small millets was assessed across various growth and yield parameters. For growth parameters, plant height and the number of productive tillers were measured. The results indicated that increasing potassium doses generally enhanced plant height and tiller numbers across different millet types. Specifically, Proso millet (C_1) showed a plant height increase from 75.85 cm to 94.37 cm with potassium doses, while Barnyard millet (C_2) reached a maximum height of 119.13 cm. The number of productive tillers also improved with potassium application, with the highest count of 4.73 tillers observed in Proso millet with the highest potassium dose.

Role of potassium on dry matter production of small millets: Regarding dry matter production (Fig. 1), potassium application significantly boosted dry matter accumulation at 30 days after sowing (DAS), 60 DAS, and harvest. For instance, Barnyard millet (C_2) achieved the highest dry matter accumulation at harvest, increasing from 75.43 g/plant without potassium to 86.87 g/plant with 20 kg/ha of potassium. Similarly, Browntop millet (C_4) also showed considerable increases in dry matter across the growth stages with potassium application.

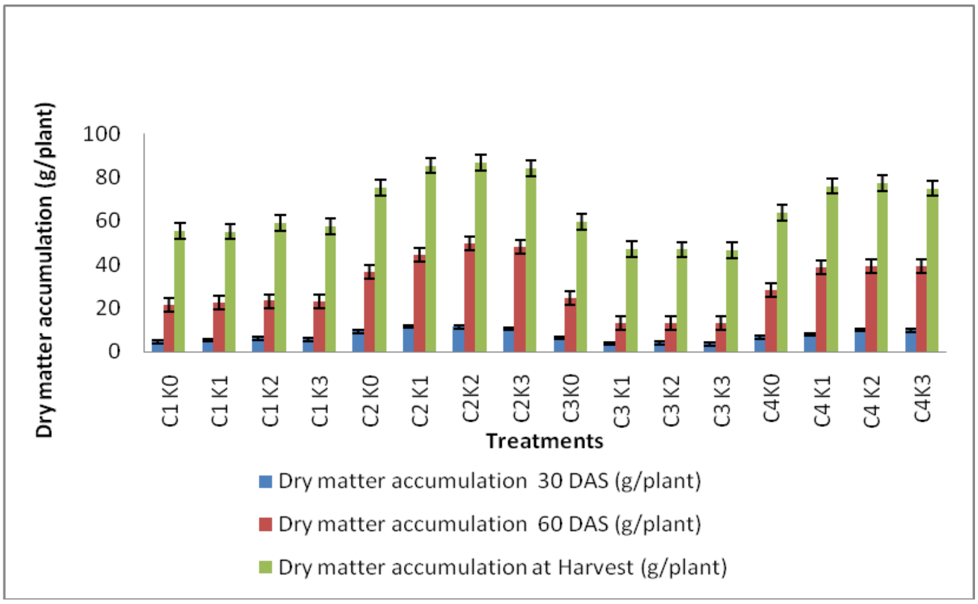

Fig. 1. Effect of potassium on dry matter production of small millets

Table 1. Role of potassium in growth of various small millets

Treatments	Plant height (cm)					No. of productive tillers				
	C_1	**C_2**	**C_3**	**C_4**	**Mean**	**C_1**	**C_2**	**C_3**	**C_4**	**Mean**
K_0	73.0	109.7	66.6	58.9	77.1	3.2	4.2	6.1	9.4	5.7
K_1	81.9	113.4	67.3	64.4	81.8	3.6	4.9	6.1	13.8	7.1
K_2	96.6	125.7	68.9	71.5	90.7	4.7	4.4	6.3	15.6	7.7
K_3	88.0	118.3	67.2	69.1	85.6	4.0	4.0	6.5	14.1	7.2
Mean	84.9	116.8	67.5	66.0		3.9	4.4	6.3	13.3	
		C	K	C x K	K x C		C	K	C x K	K x C
S.E.d.		1.58	1.52	3.07	3.04		0.28	0.35	0.66	0.69
CD (p=0.05)		3.86	3.14	6.65	6.28		0.67	0.71	1.41	1.43

Table 2. Role of potassium in yield parameters and yield of various small millets

Treatments	1000 seed weight (g)					Grain yield (t/ha)					Straw yield (t/ha)				
	C_1	**C_2**	**C_3**	**C_4**	**Mean**	**C_1**	**C_2**	**C_3**	**C_4**	**Mean**	**C_1**	**C_2**	**C_3**	**C_4**	**Mean**
K_0	4.42	5.36	3.21	2.98	3.99	0.99	1.63	1.83	2.27	1.68	1.39	2.50	2.74	3.42	2.51
K_1	4.64	5.38	4.09	3.57	4.42	1.06	1.80	2.06	2.54	1.87	1.54	2.74	3.07	3.76	2.78
K_2	4.72	7.27	4.56	3.67	5.05	1.41	2.11	2.26	2.81	2.15	2.09	3.18	3.44	4.21	3.23
K_3	4.80	6.47	4.33	3.51	4.78	1.19	1.92	2.16	2.65	1.98	1.81	2.95	3.31	4.03	3.03
Mean	4.64	6.12	4.05	3.34		1.16	1.86	2.08	2.57		1.71	2.85	3.13	3.86	
		C	K	C x K	K x C		C	K	C x K	K x C		C	K	C x K	K x C
S.E.d.		0.06	0.06	0.13	0.13		0.04	0.04	0.07	0.07		0.05	0.05	0.09	0.09
CD (p=0.05)		0.15	0.13	0.28	0.27		0.09	0.08	0.16	0.15		0.11	0.09	0.19	0.19

Table 3. Effect of potassium in harvest index and B: C ratio of various small millets

Treatments	Harvest index					B: C ratio				
	C_1	C_2	C_3	C_4	Mean	C_1	C_2	C_3	C_4	Mean
K_0	41.37	39.40	40.00	39.87	40.16	1.08	1.79	2.01	2.49	1.84
K_1	40.83	39.63	40.07	40.37	40.23	1.16	1.96	2.24	2.77	2.03
K_2	40.30	39.83	39.63	40.00	39.94	1.52	2.27	2.44	3.03	2.32
K_3	39.70	39.37	39.43	39.63	39.53	1.27	2.05	2.31	2.83	2.12
Mean	40.55	39.56	39.78	39.97		1.26	2.02	2.25	2.78	
		C	K	C x K	K x C					
S.E.d.		0.22	0.25	0.49	0.50					
CD (p=0.05)		0.53	0.52	1.04	1.04					

Effect of potassium on yield parameters and yield of small millets: In terms of yield parameters, potassium application had a notable effect on seed weight, grain yield, straw yield, and harvest index (Table 3). For example, the grain yield of Barnyard millet (C_2) increased significantly from 1547 kg/ha without potassium to 2055 kg/ha with the highest potassium dose. The harvest index also improved with potassium application, reaching a maximum of 43.43% for Proso millet (C_1) with 30 kg/ha of potassium. The economic analysis showed a positive impact on gross returns and the benefit-cost ratio, with Barnyard millet (C_2) achieving the highest gross return of Rs 61650/ha and a B: C ratio of 2.20 with the highest potassium dose.

4. DISCUSSION

The field experiments were conducted at the Centre of Excellence in Millets, Athiyandal, with the objective of evaluating the effects of varying potassium application levels on the growth and yield of small millets and analyzing the economic viability of potassium application in small millet farming [12]. The results obtained from the experiment are discussed as follows:

Potassium fertilization plays a crucial role in enhancing the growth and yield of small millets, a group of cereal crops vital for food security and nutrition in marginal and resource-poor regions [13,14,15]. By systematically evaluating the effects of varying potassium levels on multiple millet species, this research provides robust data on optimal fertilization practices that can lead to substantial yield improvements [16,17]. This is particularly significant in the context of sustainable agricultural productivity, as small millets are resilient crops capable of thriving in diverse and often challenging agro-environmental conditions [18,19,20]. The findings, which show a marked increase in yield and economic returns with appropriate potassium management, underscore the potential for improving millet production—an essential factor in addressing food security in regions where these crops are staple foods [21,22,23].

The importance of these findings becomes even more apparent when compared with similar studies conducted in tropical regions of latin america, where potassium fertilization has been investigated for various crops, including maize, rice, and beans [24,25,26]. In these studies, potassium has been shown to enhance crop resilience, improve grain quality, and increase yields, particularly in soils deficient in this nutrient [27,28,29]. However, while much of the research in latin america has focused on major staple crops, the current study's emphasis on small millets fills a critical gap, as these crops are often overlooked despite their importance in ensuring food security and nutritional diversity in tropical and subtropical regions [30,31,32]. The study's methodology, including the use of a split-plot design and comprehensive economic analysis, provides a detailed understanding of how potassium impacts both growth parameters and economic viability, which is crucial for smallholder farmers who rely on these crops for their livelihoods [33,34].

Compared to other studies in tropical latin american regions, the findings of this research are particularly valuable for informing agricultural practices that optimize productivity under varying agro-environmental conditions [35,36]. The significant yield increase, reduced pest incidence, and improved economic outcomes observed in this study demonstrate the broader applicability of potassium fertilization strategies across different regions where small millets are grown [37]. Furthermore, the study’s conclusion that a 20 kg/ha potassium application is optimal aligns with findings from other tropical research, where balanced nutrient management has been shown to enhance crop performance and sustainability. By providing a clear, economically viable strategy for improving millet production, this study contributes to the global effort to enhance food security, particularly in regions vulnerable to climate change and soil degradation [38,39].

5. CONCLUSION

The study reveals that applying 20 kg of potassium per hectare, alongside recommended nitrogen and phosphorus doses, boosted yields by 31.8% while significantly improving lodging tolerance. Potassium application also reduced pest and disease incidence compared to the control. These findings underscore that optimal potassium levels enhance nutrient uptake, bolster plant health, and elevate productivity, leading to more profitable millet cultivation.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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