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Evaluation of intercropping elephant-foot yam (*Amorphophallus paeoniifolius*) with pulses for yield, economics, corm quality and soil health

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Abstract

The field experiments were conducted at ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, to assess the feasibility of intercropping elephant-foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson] with various pulse crops, during 2017-19. The factorial randomized block design with three elephant-foot yam varieties (Gajendra, Sree Padma and Sree Athira), three pulse crops [greengram, *Vigna radiata* (L.) R. Wilczek. (var. Co-Gg-7), blackgram, *Vigna mungo* (L.) Hepper (var. Co-6), and soybean, *Glycine max* (L.) Merr. (var. JS-95-60)], and two fertility levels. Averaging over two years, yield of elephant-foot yam under intercropping (32.82 t/ha) was comparable to sole cropping (35.90 t/ha), with a slight decrease of 8.58%. The combination of elephant-foot yam var. Gajendra + soybean under full fertility level resulted in higher yield (66.40 t/ha), corm equivalent yield (66.77 t/ha), production efficiency (247.30 kg/ha/day), equivalent energy (239.91×10^3 MJ/ha), net income (₹ 10, 09, 856/ha), B:C ratio (3.20) and added profit of ₹ 2,33,164/ha over sole cropping of elephant-foot yam var. Gajendra (46.48 t/ha, 172.45 kg/ha/ day, 167.33×10^3 MJ/ha). These intercropping systems did not adversely affect the soil chemical properties or biochemical constituents of corms, underscoring the viability of intercropping elephant-foot yam with pulses as a sustainable practice.

Key word: Intercropping, Productivity, Profit, Corm quality, Soil fertility, Sole crop

Elephant-foot yam, [*Amorphophallus paeoniifolius* (Dennst.) Nicolson] is valued for its economic and nutritional benefits in south India's tropics. This crop has a long growth cycle and requires substantial space. Still, it is adaptable to various agroecological zones and resistant to pests and diseases, making it vital for food security and profitable farming (Suja *et al*. 2012). It yields significant returns, enhancing its status as a food and commercial crop (Suja *et al*. 2012; Nedunchezhiyan *et al*. 2008). Crop diversification is an adaptation strategy to increase productivity, especially under climate change (Nedunchezhiyan *et al*. 2022; Suja *et al*. 2025). However, potential of elephant-foot yam in cropping systems, which could boost yield and profits, still needs to be explored (Sunitha and Kumar 2018).

In tropical agriculture, integrating elephant-foot yam into existing farms is increasingly seen as a sustainable solution to challenges like shrinking land for smallholders in Kerala and rising input costs (Krishnakumar *et al*. 2013; Remya and Suja 2018). Intercropping with bananas, for instance, increases yield and profits, improves soil health, supports biodiversity, and uses land more efficiently (Krishnakumar *et al*. 2013; Remya and Suja 2024). Intercropping elephant-foot yam, while beneficial, also poses challenges, such as managing crop-weed interactions and nutrient dynamics, which influence the soil microclimate and crop productivity (Remya and Suja 2024). The success of integrating elephant-foot yam with short-duration leafy vegetables, varies significantly with environmental factors, including soil quality improvement (Babu *et al*. 2017).

Advancing elephant-foot yam intercropping in tropical regions requires novel agricultural practices and effective management to enhance its profitability and environmental sustainability (Suja *et al*. 2023). Although research points to potential productivity and soil health benefits, detailed studies on intercropping elephant foot yam with pulses are sparse. This research gap is critical, as understanding the interactions between elephant foot yam and pulses across diverse conditions could improve crop yields and soil health, informing sustainable agricultural strategies and policies.

The lack of data on specific intercropping combinations of elephant-foot yam varieties and pulse crops under different fertility levels in south India's humid tropics underscores the need for focused research. Exploring these plant interactions within different nutrient management frameworks is essential for optimizing yields and enhancing profitability, ultimately contributing to more effective cropping strategies and better agricultural outcomes in tropical regions. The present experiment was thus undertaken to find out the suitability of pulses like greengram, blac gram and soybean as intercrops.

MATERIALS AND METHODS

Field experiments to evaluate the productivity of intercropping systems with elephant- foot yam

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were conducted from March to December across two consecutive years (2017-2019) at ICAR-Central Tuber Crops Research Institute (CTCRI), Thiruvananthapuram, Kerala, India, situated at 8°29' N latitude, 76°57' E longitude, and an elevation of 52 meters. This location is characterized by a humid tropical climate, with average annual rainfall of 1672 mm and mean annual maximum and minimum temperatures of 31.82°C and 23.82°C, respectively. The relative humidity averaged 85.97%. During the crop growth periods of the first and second years, rainfall recorded was 1695 mm and 1575 mm, with maximum temperatures of 31.44°C and 32.07°C and minimum temperatures of 23.24°C and 24.41°C, respectively. The relative humidity was 81.58% during the first year and 88.77% during the second year. The soil of the research site is a well-drained acid Ultisol with pH 4.92 and is characterized by low available N (187.93 kg/ha), high available P (232.92 kg/ha), available K (368.28 kg/ha) and organic C (0.79%) contents.

The factorial randomized block design with treatments consisting of factorial combinations of three elephant-foot yam varieties: 'Gajendra,' 'Sree Padma,' and 'Sree Athira'; three pulse crops: green gram (var. Co-Gg-7), black gram (var. Co-6), and soybean (var. JS-95-60); and two fertility levels was followed. The first fertility level included full farmyard manure (FYM) and full nitrogen (N), without phosphorus (P) but with full potassium (K) (FYM at 25 t/ha, NPK at 100:0:150 kg/ha). The second fertility level was half of FYM and N with full K (FYM at 12.5 t/ha, NPK at 50:0:150 kg/ha). The P was provided to legume in the system. Sole crops of all elephant-foot yam varieties were grown with a full dose of FYM and NPK (FYM at 25 t/ha, NPK at 100:50:150 kg/ha) as the controls for comparative purposes.

Elephant-foot yam was planted annually in March 2017 and 2018. Each plot, measuring 4.5 m × 4.5 m, was arranged with plants spaced at 90 cm × 90 cm, following the cultural practices recommended (KAU 2016). In between two rows of elephant-foot yam, two rows of the respective pulse crops were sown the following day, using an inter-row spacing of 30 cm and intra-row spacing of 15 cm, with a seeding rate of 20 kg/ha, thus establishing an additive intercropping system. Before planting, farmyard manure was applied directly to planting pits for elephant-foot yam, consistent with the assigned treatments. The pulse crops received a basal application of NPK at 20:30:30 kg/ha, with full doses of P and K and half the N dose administered at planting. The remaining N was top dressed 15-20 days after sowing (DAS). For elephant-foot yam, half doses of N and K were applied one week after sprouting, with the remaining fertilizers applied one month later, coinciding with routine weeding and earthing-up operations.

Pulse yields were recorded in kg/ha, while fresh corm yield of elephant-foot yam was estimated in tons per hectare from the net plants at harvest. Biochemical analyses of yam corms for dry matter, starch, total sugars, crude protein, ash and crude fibre were conducted following standard methods (AOAC, 2005; Dubios *et al.* 1956). Soil chemical properties —pH, organic carbon, and available nutrients (N, P, K)—were evaluated using standard protocols (Page *et al.* 1982) at the end of each cropping year. Based on the yield of the component crops, corm equivalent yield, production efficiency and energy equivalent yield were worked out.

Economic performance was analyzed by calculating total cost of cultivation and gross return, which included all average input and labor costs against the market price of the produce during the study period. Net return per hectare was computed as the difference between gross return and total cost of cultivation. The benefit:cost ratio was calculated by dividing gross income by total cost. Additionally, added profit from intercropping relative to the respective sole cropping systems was determined.

Differences among treatments were analysed using a two-way analysis of variance (ANOVA) in a randomized block design, for each year separately. Treatment means were compared using the critical difference at the 0.05 significance level, utilizing SAS statistical software (Version 9.3).

RESULTS AND DISCUSSION

Yield of elephant foot yam and pulse crops: In the first year, the yield of elephant foot yam under intercropping with pulses (14.16 t/ha) maintained close parity with that of sole cropping (15.53 t/ha), with a marginal reduction of 8.82% (Fig. 1). Among the elephant foot yam varieties, Gajendra (18.78 t/ha) proved superior to Sree Padma (13.16 t/ha) and Sree Athira (10.54 t/ha). Effect of pulse crops on yield of elephant foot yam was not significant. Fertility levels too did not impart significant effect on the yield of elephant foot yam, suggesting that a potential reduction in fertility requirements could be considered. Interestingly, a half fertility regime led to an 18% boost in elephant foot yam yields (Fig. 2). When assessing pulse crops, black gram emerged as the most compatible for intercropping with elephant foot yam as evidenced by a significantly higher yield (228.58 kg/ha). However, neither the varieties of elephant foot yam nor the fertility levels significantly affected the grain yield of the pulse crops (Fig. 3). In the subsequent year, the yield of elephant foot yam under intercropping with pulse crops (51.49 t/ha) were again comparable to sole cropping (56.27 t/ha), with only 8.5% decrease (Fig. 1). The effect of varieties of elephant foot yam and the type of pulse on the yield of elephant foot-yam was not significant.

On an average, over the two years, the yield of elephant foot yam when intercropped with pulses (32.82 t/ha) closely matched the yield from sole cropping systems (35.90 t/ha), with a slight reduction of 8.58% (Fig. 1). This consistency over two years suggests that intercropping elephant foot yam with pulses could be a viable practice without significant yield penalties, potentially enabling reduced fertilizer inputs and associated cost savings.

System productivity and profitability: With respect to system productivity, in the first year, among the treatment combinations, elephant foot yam var. Gajendra + black gram under full fertility level resulted in corm yield (21.60 t/ha), corm equivalent yield (22.10 t/ha), production efficiency (122.80 kg/ha/day) and equivalent energy (79.82 × 10^3 MJ/ha) on par with sole cropping of elephant foot yam var. Gajendra (22.53 t/ ha, 125.16 kg/ ha/day, 81.11 × 10^3 MJ/ha) (Table 1).

In the second year, control vs treatment was not significant for corm yield, corm equivalent yield, production efficiency and equivalent energy. This suggests that the treatment effects on these system efficiency parameters were less pronounced compared to control and treatment groups. However, combination of elephant-foot yam var. Gajendra with soybean under full fertility resulted in remarkable improvements with higher yield (66.40 t/ha), corm equivalent yield (66.77 t/ha), production efficiency (247.30 kg/ha/day) and equivalent energy (239.91 × 10^3 MJ/ha), over sole cropping of elephant foot yam var. Gajendra (46.48 t/ha, 172.45 kg/ ha/day, 167.33 × 10^3 MJ/ha) (Table 1).

The study on intercropping elephant-foot yam with pulses reveals that despite a minor yield reduction compared to sole cropping, the impact is sufficiently tiny to suggest intercropping as a feasible practice with minimal yield compromises (Dodiya *et al.* 2018). Similarly, Misra *et al.* (2016) reported that intercropping does not significantly diminish the productivity of the main crop and can remain economically viable. Research by Ilakiya *et al.* (2023) supports that intercropping in elephant foot yam, especially with short-duration vegetable crops, optimizes land use and suppresses weeds, enhancing yield efficiency under integrated management systems.

The good performance of Gajendra, consistently observed across various studies, underscores its suitability for intercropping with pulses, contributing positively to both economic returns and soil health by potentially reducing fertilizer requirements (Blomme *et al.* 2016). Furthermore, research indicates that integrating elephant foot yam with crops like black gram does not adversely affect the main crop yield or economic viability, thus endorsing the sustainability of such agricultural practices (Jogi and Lahre 2020).

Averaging over two years, among the treatment combinations, elephant foot yam var. Gajendra + soybean under full fertility level resulted in higher net income (₹ 10, 09, 856 per ha), B:C ratio (3.20) and added profit of ₹ 2,33,164 per ha over sole crop (Table 2). The observed increases in net income and benefit-cost ratios illustrate the financial benefits of these systems. Specifically, intercropping with soybeans can fix atmospheric nitrogen, reduce the need for synthetic fertilizers, and cut production costs (Ghosh *et al.* 2009).

Corm quality and soil chemical properties: As depicted in Fig. 4 and Fig. 5, the comparative analysis indicates that intercropping did not significantly alter the corm biochemical composition or the soil chemical properties. The parameters evaluated included soil pH, organic C content, electrical conductivity, available N, P and K, as well as exchangeable Ca. The stability of these parameters across different cropping systems suggests that intercropping elephant foot yam with pulses does not detrimentally affect the quality of the corms or the fertility and health of the soil. This finding reinforces the viability of intercropping as a sustainable agricultural practice that maintains crop quality (Glaze-Corcoran *et al.* 2020) and soil fertility (Mousavi and Eskandari 2011).

The treatments resulted in a range of outcomes for dry matter content, with no significant deviations from control observations. Starch percentages varied slightly, indicating that specific treatments may influence carbohydrate accumulation within the corms. Sugar content, reflective of immediate corm sweetness and post-harvest quality, remained stable across treatments, suggesting that intercropping does not adversely affect the palatability of the corms. Crude protein levels, essential for nutritional value assessments, exhibited negligible fluctuations, ensuring that the protein quality of the corms was preserved. Similarly, ash content, indicative of the total mineral content, showed consistency across the different treatments. Lastly, crude fibre percentages were maintained, suggesting that the corms' structural integrity and dietary fibre content were unaffected.

The preservation of soil and corm quality in elephant-foot yam-pulse intercropping system points to efficient resource utilization and reduced nutrient competition, characteristics of well-managed intercropping systems (Fung *et al.* 2019). By stabilizing crop biochemical attributes and promoting soil health, intercropping fits into sustainable agricultural strategies, aligning with international efforts to improve food security and environmental sustainability (Silva *et al.* 2022). The, intercropping elephant-foot yam with pulses like soybean is a feasible and sustainable option for higher productivity, profit and soil restoration. Thus, the study has resulted

Table 1. Effect of cropping systems involving elephant foot-yam and fertility levels on system productivity

Treatment	Corm yield (t/ha)		Pulse yield (kg/ha)		Equivalent energy (*10^3 MJ/ha)		Corm equivalent yield (t/ha)		Production efficiency (kg/ha/day)	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year	First year	Second year
GajendraGgF1	16.82	54.83	143.50	180.50	62.22	199.51	17.08	55.51	94.91	205.58
GajendraGgF2	19.50	51.02	81.86	105.60	71.11	184.91	19.64	51.42	109.11	190.43
GajendraBgF1	21.60	55.56	174.10	240.00	79.82	202.82	22.10	56.43	122.80	208.98
GajendraBgF2	18.34	39.13	83.80	97.90	67.00	142.03	18.58	39.49	103.22	146.25
GajendraSbF1	16.84	66.40	32.59	75.30	61.00	239.91	16.96	66.77	94.23	247.30
GajendraSbF2	19.59	54.81	33.30	90.00	70.92	198.37	19.72	55.26	109.54	204.66
PadmaGgF1	10.06	56.19	152.58	190.30	38.01	204.54	10.35	56.91	57.48	210.78
PadmaGgF2	15.20	44.71	75.77	128.00	55.62	162.48	15.34	45.19	85.25	167.39
PadmaBgF1	13.58	48.71	329.93	428.80	52.77	180.40	14.53	50.27	80.71	186.17
PadmaBgF2	9.57	53.13	372.86	413.00	38.83	196.13	10.64	54.63	59.11	202.33
PadmaSbF1	15.12	56.37	63.99	70.60	55.19	203.76	15.36	56.72	85.35	210.08
PadmaSbF2	15.43	58.59	55.95	62.50	56.21	211.66	15.64	58.90	86.89	218.16
AthiraGgF1	7.10	49.84	125.67	140.10	27.03	181.08	7.33	50.37	40.74	186.55
AthiraGgF2	15.86	56.92	112.38	125.30	58.43	206.40	16.07	57.39	89.30	212.56
AthiraBgF1	10.28	44.49	148.25	205.60	38.76	162.59	10.71	45.24	59.50	167.54
AthiraBgF2	13.95	45.66	262.51	422.20	53.31	169.35	14.70	47.19	81.69	174.79
AthiraSbF1	5.56	51.96	33.90	98.20	20.40	188.22	5.68	52.45	31.57	194.28
AthiraSbF2	10.49	38.44	28.58	120.50	38.11	139.79	10.60	39.04	58.89	144.59
Sole Gajendra	22.53	46.48	-		81.11	167.33	22.53	46.48	125.16	172.15
Sole Sree Padma	12.96	61.05	-	-	46.66	219.76	12.96	61.04	72.01	226.09
Sole Sree Athira	11.11	61.28	-	-	40.00	220.59	11.11	61.28	61.73	226.95
CD (0.05)	NS	NS	NS	45.20	NS	NS	NS	NS	NS	NS

Table 2. System profitability as affected by cropping systems involving elephant-foot yam and fertility levels (average of two years)

Treatment	Corm yield (t/ha)	Pulse yield (kg/ha)	Gross income (₹/ha)	Gross cost (₹/ha)	Net income (₹/ha)	B:C ratio	Added profit (₹/ha)
GajendraGgF1	35.82	124.54	1272443	462980	809463	2.75	32771
GajendraGgF2	35.25	160.93	1258007	452330	805677	2.78	28985
GajendraBgF1	38.58	136.00	1370012	468830	901182	2.92	124490
GajendraBgF2	28.74	79.56	1017276	458180	559096	2.22	-217596
GajendraSbF1	41.62	61.32	1468856	459000	1009856	3.20	233164
GajendraSbF2	37.20	111.81	1324357	448350	876007	2.95	99315
PadmaGgF1	33.13	140.32	1180542	462980	717562	2.55	-146559
PadmaGgF2	29.96	252.30	1086386	452330	634056	2.40	-230064
PadmaBgF1	31.15	371.49	1143942	468830	675112	2.44	-189008
PadmaBgF2	31.35	221.72	1129380	458180	671200	2.46	-192921
PadmaSbF1	35.75	63.24	1263752	459000	804752	2.75	-59369
PadmaSbF2	37.01	98.04	1314980	448350	866630	2.93	2510
AthiraGgF1	28.47	125.48	1015283	462980	552303	2.19	-283449
AthiraGgF2	36.39	159.11	1297622	452330	845292	2.87	9540
AthiraBgF1	27.39	285.25	999906	468830	531076	2.13	-304675
AthiraBgF2	29.81	180.38	1069382	458180	611202	2.33	-224549
AthiraSbF1	28.76	77.20	1022020	459000	563020	2.23	-272731
AthiraSbF2	24.46	28.58	861982	448350	413632	1.92	-422120
Sole Gajendra	34.51		1207692	431000	776692	2.80	
Sole Sree Padma	37.00	-	1295120	431000	864120	3.00	
Sole Sree Athira	36.19	-	1266751	431000	835751	2.94	

Table 3. Effect of cropping systems on corm biochemical composition

Treatment	Dry matter %	Starch FW %	Sugar FW (%)	Crude protein FW (%)	Ash DW (%)	Crude fibre DW (%)
GajendraGgF1	23.27	16.92	0.42	4.55	4.37	1.25
GajendraGgF2	21.35	15.63	0.38	4.42	4.00	1.40
GajendraBgF1	27.70	16.35	0.40	4.54	5.40	1.35
GajendraBgF2	24.07	15.64	0.40	3.21	4.28	1.35
GajendraSbF1	26.05	17.98	0.40	4.34	4.33	1.55
GajendraSbF2	24.21	14.60	0.35	4.06	4.61	1.50
PadmaGgF1	21.43	15.71	0.40	3.77	3.64	1.45
PadmaGgF2	24.24	18.45	0.41	4.09	4.54	1.60
PadmaBgF1	24.04	17.68	0.43	3.63	4.39	1.41
PadmaBgF2	19.00	14.50	0.36	3.33	5.18	1.71
PadmaSbF1	21.24	14.77	0.37	3.62	4.88	1.47
PadmaSbF2	22.67	17.41	0.39	3.64	4.42	1.45
AthiraGgF1	18.07	14.08	0.32	4.36	5.07	1.93
AthiraGgF2	22.76	15.56	0.39	4.67	4.21	1.80
AthiraBgF1	24.03	17.80	0.45	4.38	4.42	1.47
AthiraBgF2	23.46	15.73	0.40	3.81	4.25	1.45
AthiraSbF1	28.40	17.54	0.45	4.56	3.52	1.45
AthiraSbF2	21.91	13.12	0.32	3.43	5.07	1.40
Sole Gajendra	25.07	17.47	0.42	4.35	4.22	1.45
Sole Sree Padma	21.53	15.05	0.37	4.01	4.25	1.60
Sole Sree Athira	22.32	16.39	0.42	3.81	4.16	1.80
CD (0.05)	NS	NS	NS	NS	NS	NS

Gg-Greengram; Bg-Blackgram; Sb-Soybean; F_1-full dose of FYM and N, no P, full K (FYM @ 25 t/ha; NPK @ 100:0:150 kg/ha); F_2-half dose of FYM and N, no P, full K (FYM @ 12.5 t/ha; NPK @ 50:0:150 kg/ha)

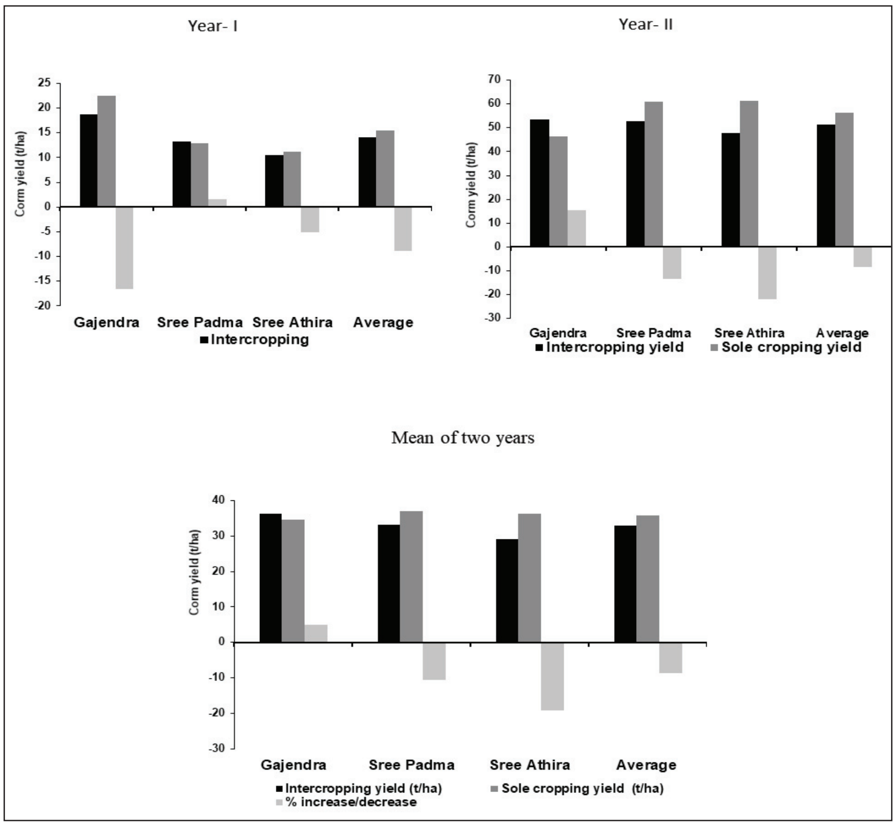

Fig. 1. Corm yield: intercropping vs sole cropping in elephant-foot yam

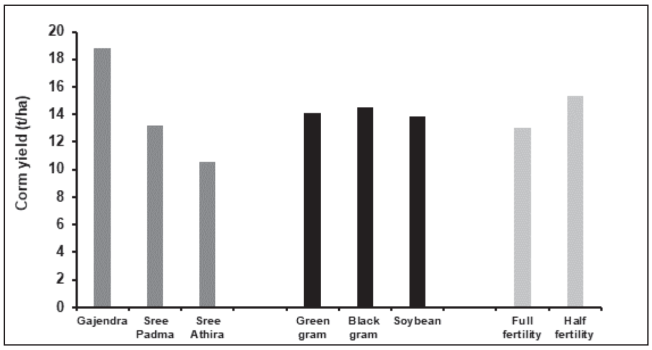

Fig. 2. Effect of varieties, type of pulse crop and fertility levels on corm yield of elephant-foot yam

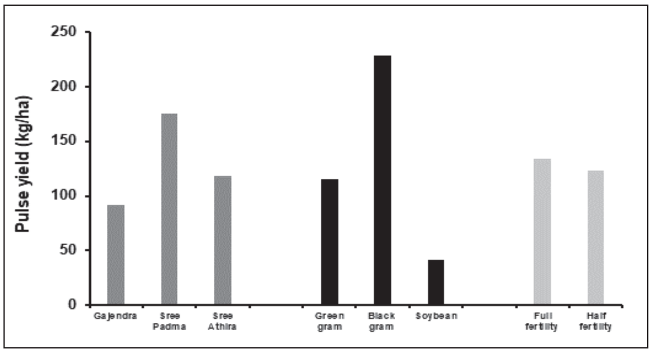

Fig. 3. Effect of varieties, type of pulse crop and fertility levels on grain yield of pulse

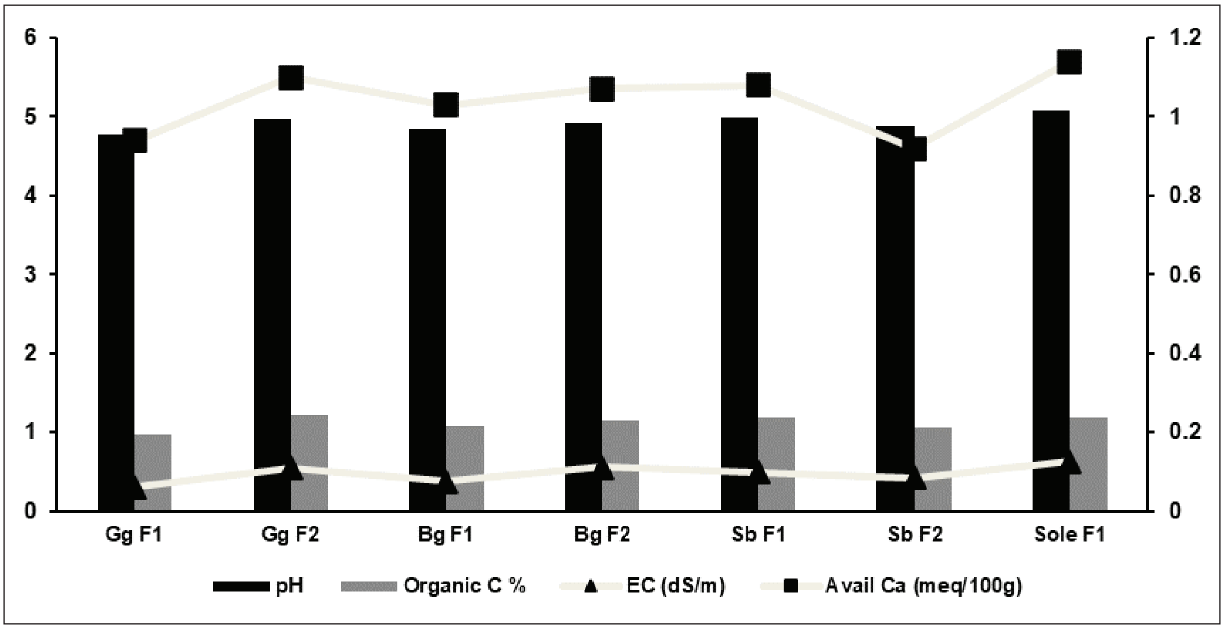

Fig. 4. Effect of pulses × fertility levels on pH, organic C, EC and exchangeable Ca

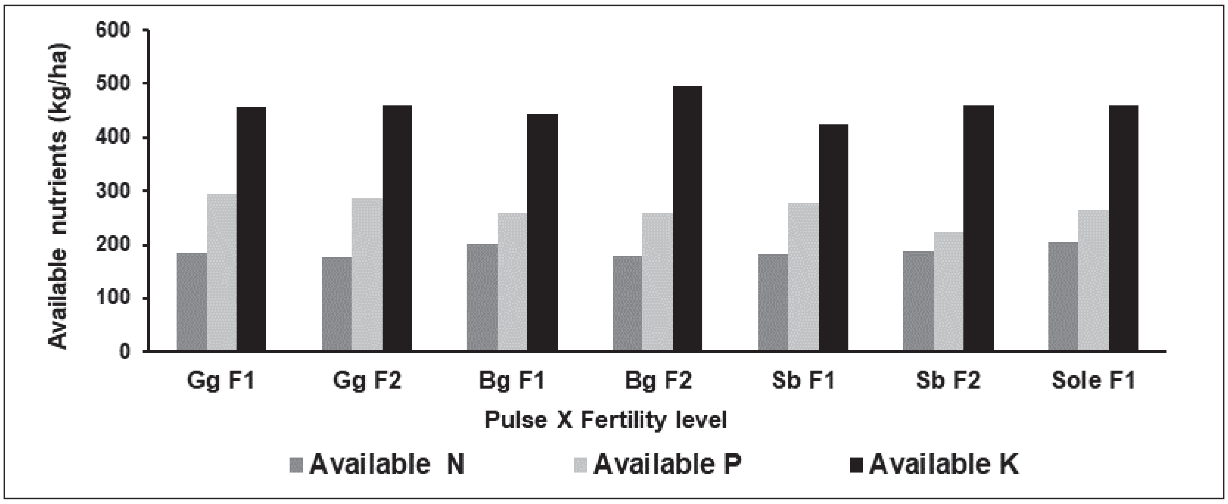

Fig. 5. Effect of pulses × fertility levels on available N, P and K in soil

in the development of a feasible elephant-foot yam-based cropping system involving pulses that will help to diversify our food basket, achieve self-sufficiency and offer resilience under climate change.

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