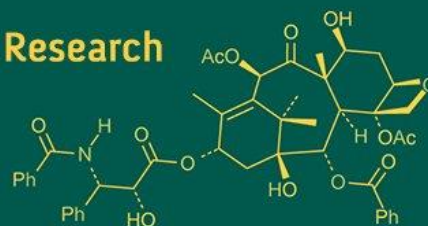
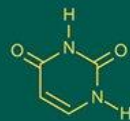


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Nutrient dynamics in soil and plant uptake as influenced by finger millet-green gram intercropping and fertilizer management

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Abstract

A field experiment entitled “Performance of Finger Millet and Green Gram Intercropping under Different Nutrient Levels” was conducted during Kharif 2024 at the Zonal Agricultural Research Station, Shendapark, Kolhapur, using a factorial randomized block design with three replications and 18 treatment combinations. The first factor comprised three cropping systems: C₁-Sole finger millet, C₂-Finger millet + green gram (4:2), and C₃-Sole green gram. The second factor consisted of six nutrient management treatments: N₁-100% RDF, N₂-75% RDF + soil application of *Azospirillum* (2 kg ha⁻¹) and PSB (2 kg ha⁻¹), N₃-N₂ + foliar spray of 2% 19:19:19 at 15 and 30 DAS, N₄-N₂ + foliar spray of 3% Panchagavya at 15 and 30 DAS, N₅-75% RDF + 25% RDN through FYM, and N₆-50% RDF + 50% RDN through FYM. The results revealed that sole finger millet and sole green gram with 100% RDF recorded the highest N, P, and K uptake. Sole green gram recorded the highest available soil nitrogen, while the finger millet + green gram (4:2) intercropping system recorded the highest available soil phosphorus and potassium after harvest. Among the nutrient management treatments, 75% RDF + 25% RDN through FYM (N₅) recorded the highest available soil N, P, and K.

Keywords: Finger millet, green gram, intercropping, interaction, fertilizers, nutrient levels, yield

Introduction

Cereal-legume intercropping is considered a sustainable agricultural practice that increases productivity by improving the utilization of key growth resources, including sunlight, soil moisture, temperature, and nutrients (Foley *et al.*, 2011)^[2]. It further enhances yield stability, reduces the impact of biotic and abiotic stresses, supports nutritional diversity, and provides greater profitability than monocropping systems (Tsubo *et al.*, 2005; Bitew *et al.*, 2019^[1, 10]). Owing to their drought tolerance, finger millet (FM) and green gram (GG) are considered a suitable intercropping combination for rainfed and drought-affected regions. Finger millet (*Eleusine coracana* L.) is a major dryland millet in India, whereas green gram (*Vigna radiata* L. Wilczek) is a nutritious, protein-rich pulse valued for its high digestibility and dietary importance. The growing demand for nutritious food and the need to sustain soil health have made soil fertility management a key challenge in modern agriculture. Continuous and imbalanced use of chemical fertilizers has resulted in nutrient depletion, soil degradation, and reduced crop productivity, threatening the sustainability of farming systems. Moreover, chemical fertilizers alone cannot maintain long-term soil productivity (Perli *et al.*, 2022)^[8]. Integrated nutrient management, involving the combined use of organic and inorganic nutrient sources, improves soil fertility and crop productivity. Therefore, a field experiment was conducted during the kharif season to evaluate the performance of finger millet-green gram intercropping under different nutrient management levels.

Material and methods Experimental site

The field experiment was conducted during the Kharif 2024 season at the Zonal Agricultural Research Station, Shendapark, Kolhapur. The site receives an average annual rainfall of 1151.6 mm over 67 rainy days, with mean maximum and minimum temperatures ranging from 25.4-33.7°C and 12.5-21.9°C, respectively. The climate is favorable for the cultivation of finger millet and green gram

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Soil characters

The soil of the experimental plot was sandy clay loam, low in available Nitrogen (196 kg ha⁻¹), medium in available phosphorus (35.3 kg ha⁻¹) and low in available potassium (194 kg ha⁻¹). The status of organic carbon content (0.67%) was high. The electrical conductivity and pH values were 0.11 dSm⁻¹ and 6.74 respectively.

Experimental details

The experiment was laid out in a Factorial Randomized Block Design (FRBD) with 18 treatment combinations and three replications. The treatments consisted of three intercropping systems: C₁: Sole finger millet, C₂: Finger millet + green gram (4:2), and C₃: Sole green gram, along with six nutrient levels (N₁-N₆). Sowing was carried out on 13 July 2024 in furrows spaced 30 cm apart. Recommended seed rates of 5 kg ha⁻¹ for finger millet and 15 kg ha⁻¹ for green gram were used. The gross and net plot sizes were 4.8 × 6.0 m and 3.6 × 4.8 m, respectively.

Observation to be recorded

Growth observations of finger millet were recorded at 15, 30, 60, and 90 DAS, and at harvest, while observations for green gram were taken at 15, 30, 45, and 60 DAS, and at harvest. Yield and yield-attributing characters were recorded after harvest. Post-harvest analyses, including soil available NPK and plant nutrient analysis, were also carried out to assess the effect of different treatments on soil fertility and crop performance.

Results and discussion

A) Plant analysis of finger millet

1. Nitrogen content (%)

The mean nitrogen content in the grain and straw of finger millet at harvest is presented in Table 1. The average nitrogen content was 1.51% in grain and 0.46% in straw. Intercropping systems, nutrient levels, and their interaction did not significantly influence the nitrogen content of either the grain or straw of finger millet.

2. Phosphorous content (%)

The data on mean phosphorous content (%) in grain and straw of finger millet at harvest shown in Table 1. Mean phosphorous content (%) in grain and straw of finger millet recorded was 0.52% and 0.16% respectively. The result indicated that intercropping, varying nutrient levels and interaction between intercropping and nutrient levels had no significant effect on phosphorous content (%) in grain and straw of finger millet.

3. Potassium content (%)

The mean potassium content in the grain and straw of finger millet at harvest is presented in Table 1. The average potassium content was 0.65% in grain and 0.75% in straw. Intercropping systems, different nutrient levels, and their interaction had no significant effect on the potassium content of either the grain or straw of finger millet.

Table 1: Mean nitrogen, phosphorous and potassium content (%) of finger millet as influenced by various treatments

Treatments	Nitrogen (%)		Phosphorous(%)		Potassium (%)	
	Grain	Straw	Grain	Straw	Grain	Straw
Intercropping						
C ₁ - Sole finger millet	1.50	0.46	0.51	0.15	0.64	0.74
C ₂ - Finger millet + Green gram (4:2)	1.52	0.47	0.53	0.17	0.66	0.76
S.Em±	0.01	0.01	0.01	0.01	0.01	0.01
CD @ 5%	NS	NS	NS	NS	NS	NS
Nutrient levels						
N ₁ -100% Recommended dose of fertilizer (RDF)	1.53	0.48	0.54	0.18	0.67	0.77
N ₂ -75% RDF + Soil application of <i>Azospirillum</i> @2 kg ha ⁻¹ and Phosphate solubilizing bacteria @ 2 kg ha ⁻¹	1.50	0.45	0.51	0.15	0.64	0.74
N ₃ -75% RDF + Soil application of <i>Azospirillum</i> (2 kg ha ⁻¹) and PSB (2 kg ha ⁻¹) + Foliar spray of 2% 19:19:19 @ 15 and 30 DAS	1.52	0.48	0.53	0.17	0.66	0.76
N ₄ -75% RDF + Soil application of <i>Azospirillum</i> (2 kg ha ⁻¹) and PSB (2 kg ha ⁻¹) + Foliar spray of Panchagavya 3% @ 15 and 30 DAS	1.52	0.48	0.53	0.17	0.66	0.76
N ₅ - 75% RDF + 25% RDN through FYM	1.49	0.45	0.50	0.14	0.63	0.73
N ₆ - 50% RDF + 50% RDN through FYM	1.50	0.45	0.51	0.15	0.64	0.74
S.Em±	0.01	0.01	0.01	0.01	0.01	0.01
CD @ 5%	NS	NS	NS	NS	NS	NS
Interaction: C × N						
S.Em±	0.01	0.01	0.01	0.01	0.01	0.01
CD @ 5%	NS	NS	NS	NS	NS	NS
General Mean	1.51	0.46	0.52	0.16	0.65	0.75

B) Yield studies of finger millet

Table 2: Grain and straw yield (q ha⁻¹) of finger millet as influenced by various treatments

Treatments	Grain yield (q ha ⁻¹)	Straw yield (q ha ⁻¹)
Intercropping		
C ₁ - Sole finger millet	27.37	34.38
C ₂ - Finger millet + Green gram (4:2)	21.27	27.94
S.Em±	0.34	1.08
CD @ 5%	1.01	3.17
Nutrient levels		

N ₁ -100% Recommended dose of fertilizer (RDF)	27.37	38.39
N ₂ -75% RDF + Soil application of <i>Azospirillum</i> @2 kg ha ⁻¹ and Phosphate solubilizing bacteria @ 2 kg ha ⁻¹	25.22	29.63
N ₃ -75% RDF + Soil application of <i>Azospirillum</i> (2 kg ha ⁻¹) and PSB (2 kg ha ⁻¹) + Foliar spray of 2% 19:19:19 @ 15 and 30 DAS	26.33	34.02
N ₄ -75% RDF + Soil application of <i>Azospirillum</i> (2 kg ha ⁻¹) and PSB (2 kg ha ⁻¹) + Foliar spray of Panchagavya 3% @ 15 and 30 DAS	24.31	33.07
N ₅ - 75% RDF + 25% RDN through FYM	23.32	29.23
N ₆ - 50% RDF + 50% RDN through FYM	19.95	22.62
S.Em±	1.75	1.87
CD @ 5%	27.37	5.50
Interaction: C × N		
S.Em±	0.84	2.65
CD @ 5%	2.48	7.77
General Mean	24.32	31.16

Table 2A: Effect of interaction on grain and straw yield (q ha⁻¹) of finger millet as influenced by various treatments

Intercropping Nutrient Levels	Grain yield (q ha ⁻¹)			Straw yield (q ha ⁻¹)		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean
N ₁	30.76	22.82	26.79	44.00	32.77	38.39
N ₂	27.82	20.79	24.31	33.89	25.36	29.63
N ₃	29.90	22.76	26.33	37.55	30.49	34.02
N ₄	28.52	21.93	25.22	36.46	29.68	33.07
N ₅	25.99	20.65	23.32	33.41	25.05	29.23
N ₆	21.20	18.70	19.95	20.97	24.28	22.62
Mean	27.37	21.27	24.32	34.38	27.94	31.16
S.Em±	0.84			2.65		
CD @ 5 %	2.48			7.77		

C) Total Uptake of NPK by finger millet (kg ha⁻¹)**1. Nitrogen Uptake (kg ha⁻¹)**

The data on mean nitrogen uptake by finger millet after harvest shown in Table 3. Mean nitrogen uptake by finger millet recorded was 51.06 (kg ha⁻¹).

a) Effect of Intercropping

The mean nitrogen uptake by finger millet was significantly influenced by the intercropping systems. The sole finger millet treatment (C₁) recorded the highest nitrogen uptake (56.60 kg ha⁻¹), whereas the finger millet + green gram (4:2) intercropping system (C₂) recorded a lower uptake (45.53 kg ha⁻¹). The higher nitrogen uptake under sole cropping may be attributed to the greater plant population per unit area, resulting in increased nutrient absorption. The comparatively lower uptake under intercropping could be due to reduced finger millet plant density and competition for available nutrients. Similar findings were reported by Willey (1979)^[11]

b) Effect of Nutrient Levels

The mean nitrogen uptake (kg ha⁻¹) by finger millet was influenced significantly by different nutrient levels harvest. Application of 100% RDF (N₁) recorded significantly highest nitrogen uptake (kg ha⁻¹) by finger millet which was at par with application of 75% RDF + Soil application of *Azospirillum* (2 kg ha⁻¹) and PSB (2 kg ha⁻¹) + Foliar spray of 2% 19:19:19 @ 15 and 30 DAS (N₃) and 75% RDF + Soil application of *Azospirillum* (2 kg ha⁻¹) and PSB (2 kg ha⁻¹) + Foliar spray of Panchagavya 3% @ 15 and 30 DAS (N₄). While, significantly lowest nitrogen uptake (kg ha⁻¹) by finger millet was recorded with the application of 50% RDF + 50% RDN through FYM (N₆) at harvest. Nitrogen, being a mobile nutrient, is absorbed in larger quantities by plants when it is abundantly available, which leads to higher total nitrogen content in both grain and straw. These results are aligned with finding of Jawahar *et al.*, (2021)^[3] who also observed direct relation between nitrogen absorption and its application.

Table 3: Mean total uptake of nutrients (Nitrogen, Phosphorous and Potassium) (kg ha⁻¹) of finger millet as influenced by different treatments

Treatments	Nitrogen uptake (kg ha ⁻¹)			Phosphorous uptake (kg ha ⁻¹)			Potassium uptake (kg ha ⁻¹)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Intercropping									
C ₁ - Sole Finger millet	40.80	15.80	56.60	13.71	5.35	19.05	17.21	25.56	42.99
C ₂ - Finger millet + Green gram (4:2)	32.26	13.27	45.53	11.17	4.77	15.94	13.89	21.17	35.06
S.Em±	0.65	0.35	0.91	0.28	0.12	0.35	0.32	0.46	0.70
CD @ 5%	1.92	1.03	2.65	0.82	0.35	1.03	0.94	1.35	2.07
Nutrient levels									
N ₁ -100% RDF	41.19	18.44	59.63	14.34	6.53	20.86	17.82	29.36	47.18
N ₂ - 75% RDF + soil application of <i>Azospirillum</i> @ 2 kg ha ⁻¹ and Phosphate solubilizing bacteria @	36.36	13.53	49.89	12.21	4.35	16.56	15.23	21.81	37.04

2 kg ha ⁻¹									
N ₃ - 75% RDF + Soil application of <i>Azospirillum</i> (2 kg ha ⁻¹) and PSB (2 kg ha ⁻¹) + Foliar spray of 2% 19:19:19 all @ 15 and 30 DAS	39.94	16.11	56.05	13.88	6.09	19.97	17.30	25.78	43.75
N ₄ - 75% RDF + Soil application of <i>Azospirillum</i> @ 2 kg ha ⁻¹ and PSB @ 2 Kg ha ⁻¹	38.34	15.74	54.08	13.37	5.95	19.32	16.65	25.14	41.79
N ₅ - 75% RDF + 25% RDN through FYM	34.84	13.17	48.00	11.75	4.21	15.96	14.78	21.45	36.23
N ₆ - 50% RDF + 50% RDN through FYM	28.50	10.22	38.73	9.08	3.21	12.30	11.51	16.64	28.15
S.Em±	1.13	0.61	1.57	0.49	0.21	0.61	0.55	0.80	1.22
CD @ 5 %	3.32	1.79	4.60	1.43	0.61	1.79	1.62	2.34	3.58
Interaction: C × N									
S.Em±	1.60	0.86	2.22	0.69	0.29	0.86	0.78	1.13	1.73
CD @ 5%	4.69	2.53	6.50	2.02	0.86	2.53	2.29	3.31	5.06
General Mean	36.53	14.54	51.06	12.44	5.06	17.49	15.55	23.36	39.02

c) Effect of Interaction

The interaction between intercropping and nutrient levels had significant effect on mean nitrogen uptake (kg ha⁻¹) by finger

millet as shown in Table 3A. The treatment combination C1N1, which involved sole finger millet with 100% RDF, recorded the maximum nitrogen uptake (67.81 kg ha⁻¹).

Table 3A: Effect of interaction on nitrogen uptake (kg ha⁻¹) of finger millet as influenced by various treatment

After Harvest	Grain			Straw			Total		
Intercropping/ Nutrient levels	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
N ₁	47.20	35.17	41.19	20.61	16.28	18.44	67.81	51.45	59.63
N ₂	41.46	31.26	36.36	15.14	11.92	13.53	56.60	43.19	49.89
N ₃	44.96	34.92	39.94	17.27	14.95	16.11	62.23	49.87	56.05
N ₄	43.18	33.50	38.34	17.13	14.34	15.74	60.31	47.84	54.08
N ₅	38.90	30.77	34.84	15.14	11.19	13.17	54.05	41.96	48.00
N ₆	29.07	27.93	28.50	9.50	10.95	10.22	38.58	38.88	38.73
Mean	40.80	32.26	36.53	15.80	13.27	14.54	56.60	45.53	51.06
S.Em±	1.60			0.86			2.22		
CD @ 5 %	4.69			2.53			6.50		

2. Phosphorous Uptake (kg ha⁻¹)

The data on mean phosphorous uptake by finger millet after harvest shown in Table 3. Mean phosphorous uptake by finger millet recorded was 17.49 (kg ha⁻¹)

a) Effect of Intercropping

Mean phosphorous uptake (kg ha⁻¹) by finger millet was significantly influenced by intercropping. Sole finger millet (4:2) (C₁) recorded the highest phosphorous uptake (19.05 kg ha⁻¹) due to higher plant density in sole finger millet as comparison to finger millet + green gram (C₂) which recorded comparatively lowest phosphorous uptake (15.94 kg ha⁻¹).

b) Effect of Nutrient Levels

The mean phosphorus uptake (kg ha⁻¹) by finger millet at harvest was significantly influenced by different nutrient

management treatments. Application of 100% RDF (N₁) recorded the highest phosphorus uptake, which was statistically at par with 75% RDF + soil application of *Azospirillum* (2 kg ha⁻¹) and PSB (2 kg ha⁻¹) + foliar spray of 2% 19:19:19 at 15 and 30 DAS (N₃). The lowest phosphorus uptake was recorded with 50% RDF + 50% RDN through FYM (N₆). The higher phosphorus uptake under N₁ may be due to increased phosphorus availability and its efficient absorption by the crop. Similar findings were reported by Jawahar *et al.* (2021) [3].

c) Effect of Interaction

The interaction between intercropping and nutrient levels had significant effect on mean phosphorous uptake (kg ha⁻¹) by finger millet as shown in Table 3B. Sole finger millet with application of 100% RDF (C₁N₁), recorded the maximum phosphorous uptake (23.10 kg ha⁻¹).

Table 3B: Effect of interaction on phosphorous uptake (kg ha⁻¹) of finger millet as influenced by various treatment

After Harvest	Grain			Straw			Total		
Intercropping/ Nutrient levels	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
N ₁	16.09	12.58	14.34	7.01	6.05	6.53	23.10	18.63	20.86
N ₂	13.91	10.50	12.21	4.75	3.95	4.35	18.66	14.45	16.56
N ₃	15.36	12.39	13.88	6.27	5.92	6.09	21.63	18.32	19.97
N ₄	14.95	11.79	13.37	6.23	5.67	5.95	21.18	17.46	19.32

N ₅	13.17	10.33	11.75	4.91	3.51	4.21	18.08	13.83	15.96
N ₆	8.75	9.42	9.08	2.92	3.51	3.21	11.67	12.92	12.30
Mean	13.71	11.17	12.44	5.35	4.77	5.06	19.05	15.94	17.49
S.Em±	0.69			0.29			0.86		
CD @5%	2.02			0.86			2.53		

3. Potassium Uptake (kg ha⁻¹)

The data on mean potassium uptake by finger millet after harvest shown in Table 3. Mean potassium uptake by finger millet recorded was 39.02 (kg ha⁻¹).

a) Effect of Intercropping

The mean potassium uptake (kg ha⁻¹) by finger millet was significantly affected by the intercropping system. The sole finger millet (4:2) (C₁) recorded the highest potassium uptake, (42.99 kg ha⁻¹) which is likely due to the higher plant density in this treatment compared to the intercropped system with green gram (C₂) (35.06 kg ha⁻¹). In contrast, the finger millet + green gram intercropping showed a comparatively lower potassium uptake, possibly due to reduced finger millet population. Similar results was found by Willey (1979) [11].

b) Effect of Nutrient Levels

The mean potassium uptake (kg ha⁻¹) by finger millet at harvest was significantly influenced by different nutrient

management treatments. Application of 100% RDF (N₁) recorded the highest potassium uptake, which was statistically at par with 75% RDF + soil application of Azospirillum (2 kg ha⁻¹) and PSB (2 kg ha⁻¹) + foliar spray of 2% 19:19:19 at 15 and 30 DAS (N₃) and 3% Panchagavya at 15 and 30 DAS (N₄). The lowest potassium uptake was recorded with 50% RDF + 50% RDN through FYM (N₆). The higher potassium uptake under N₁ may be attributed to improved potassium availability and enhanced nutrient absorption by the crop. These findings are in agreement with Jawahar *et al.* (2021) [3].

c) Effect of Interaction

The interaction between intercropping and nutrient levels had significant effect on mean potassium uptake (kg ha⁻¹) by finger millet as shown in Table 3C. Sole finger millet with application of 100% RDF (C₁N₁), recorded the maximum phosphorous uptake (53.19 kg ha⁻¹).

Table 3C: Effect of interaction on potassium uptake (kg ha⁻¹)

After harvest	Grain			Straw			Total		
Intercropping/Nutrient levels	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
N ₁	20.09	15.55	17.82	33.11	25.62	29.36	53.19	41.16	47.18
N ₂	17.53	12.93	15.23	24.74	18.87	21.81	42.28	31.80	37.04
N ₃	19.25	15.35	17.30	27.93	23.63	25.78	48.51	38.98	43.75
N ₄	18.66	14.64	16.65	27.49	22.79	25.14	46.15	37.43	41.79
N ₅	16.55	13.01	14.78	24.62	18.29	21.45	41.17	31.30	36.23
N ₆	11.17	11.85	11.51	15.45	17.83	16.64	26.62	29.68	28.15
Mean	17.21	13.89	15.55	25.56	21.17	23.36	42.99	35.06	39.02
S.Em±	0.78			1.13			1.73		
CD @ 5 %	2.29			3.31			5.06		

D) NPK content in green gram

1. Nitrogen content (%)

The data on mean Nitrogen content (%) in seed and stover of green gram green gram at harvest shown in Table 4. Mean Nitrogen content (%) in seed and stover of green gram is 3.65% and 1.36%, respectively. The result indicated that intercropping, varying nutrient levels and interaction between intercropping and nutrient levels had no significant effect on Nitrogen content (%) in seed and stover of green gram.

2. Phosphorous content (%)

The data on mean phosphorous content (%) in seed and stover of green gram green gram at harvest shown in Table 4. Mean phosphorous content (%) in seed and stover of green gram is

0.52% and 0.34%, respectively. The result indicated that intercropping, varying nutrient levels and interaction between intercropping and nutrient levels had no significant effect on phosphorous content (%) in seed and stover of green gram

3. Potassium content (%)

The data on mean potassium content (%) in seed and stover green gram after harvest shown in Table 4. Mean potassium content (%) in seed and stover of green gram is 0.98%, 1.47%, respectively. The result indicated that intercropping, varying nutrient levels and interaction between intercropping and nutrient levels had no significant effect on potassium content (%) in seed and stover of green gram.

Table 4: Mean nitrogen, phosphorous and potassium content (%) of green gram as influenced by various treatments

Treatments	Nitrogen (%)		Phosphorous (%)		Potassium (%)	
	Seed	Stover	Seed	Stover	Seed	Stover
Intercropping						
C ₃ - Sole Green gram	3.64	1.35	0.51	0.33	0.97	1.46
C ₂ - Finger millet + Green gram (4:2)	3.66	1.37	0.53	0.35	0.98	1.47
S.Em±	0.01	0.01	0.01	0.01	0.01	0.01
CD @ 5%	NS	NS	NS	NS	NS	NS
Nutrient levels						
N ₁ -100% Recommended dose of fertilizer (RDF)	3.68	1.38	0.54	0.36	1.02	1.51

N ₂ -75% RDF + Soil application of <i>Azospirillum</i> @ 2 kg ha ⁻¹ and Phosphate solubilizing bacteria @ 2 kg ha ⁻¹	3.64	1.34	0.50	0.32	0.96	1.45
N ₃ -75% RDF + Soil application of <i>Azospirillum</i> (2 kg ha ⁻¹) and PSB (2 kg ha ⁻¹) + Foliar spray of 2% 19:19:19 @ 15 and 30 DAS	3.66	1.37	0.53	0.35	0.99	1.48
N ₄ -75% RDF + Soil application of <i>Azospirillum</i> (2 kg ha ⁻¹) and PSB (2 kg ha ⁻¹) + Foliar spray of Panchagavya 3% @ 15 and 30 DAS	3.66	1.35	0.51	0.33	0.98	1.47
N ₅ - 75% RDF + 25% RDN through FYM	3.64	1.34	0.50	0.32	0.96	1.45
N ₆ - 50% RDF + 50% RDN through FYM	3.64	1.34	0.50	0.32	0.95	1.44
S.Em±	0.01	0.01	0.01	0.01	0.02	0.02
CD @ 5%	NS	NS	NS	NS	NS	NS
Interaction: C × N						
S.Em±	0.02	0.02	0.02	0.02	0.02	0.02
CD @ 5%	NS	NS	NS	NS	NS	NS
General Mean	3.65	1.36	0.52	0.34	0.98	1.47

E) Yield studies of green gram

Table 5: Seed and stover yield (q ha⁻¹) of green gram as influenced by various treatments

Treatments	Seed yield (q ha ⁻¹)	Stover yield (q ha ⁻¹)
Intercropping		
C3- Sole Green gram	13.87	29.90
C2- Finger millet + Green gram (4:2)	5.92	12.22
S.Em±	0.23	0.48
CD @ 5%	0.68	1.40
Nutrient levels		
N1-100% Recommended dose of fertilizer (RDF)	11.46	24.63
N2-75% RDF + Soil application of <i>Azospirillum</i> @2 kg ha ⁻¹ and Phosphate solubilizing bacteria @ 2 kg ha ⁻¹	9.84	21.53
N3-75% RDF + Soil application of <i>Azospirillum</i> (2 kg ha ⁻¹) and PSB (2 kg ha ⁻¹) + Foliar spray of 2% 19:19:19 @ 15 and 30 DAS	11.15	24.15
N4-75% RDF + Soil application of <i>Azospirillum</i> (2 kg ha ⁻¹) and PSB (2 kg ha ⁻¹) + Foliar spray of Panchagavya 3% @ 15 and 30 DAS	10.66	22.60
N5- 75% RDF + 25% RDN through FYM	9.04	18.50
N6- 50% RDF + 50% RDN through FYM	7.20	14.93
S.Em±	0.40	0.83
CD @ 5%	1.19	2.43
Interaction: C × N		
S.Em±	0.57	1.17
CD @ 5%	1.68	3.43
General Mean	9.89	21.06

Table 5A: Effect of interaction on seed yield and stover yield after harvest of green gram as influenced by various treatments

After harvest	Seed Yield (q ha ⁻¹)			Stover Yield (q ha ⁻¹)		
Intercropping	C3	C2	Mean	C3	C2	Mean
Nutrient levels						
N ₁	16.10	6.82	11.46	34.14	15.12	24.63
N ₂	14.35	5.33	9.84	31.75	11.31	21.53
N ₃	15.59	6.71	11.15	34.06	14.24	24.15
N ₄	14.81	6.51	10.66	32.07	13.13	22.60
N ₅	12.91	5.17	9.04	26.71	10.29	18.50
N ₆	9.43	4.97	7.20	20.65	9.21	14.93
Mean	13.87	5.92	9.89	29.90	12.22	21.06
S.Em±		0.57			1.17	
CD @ 5 %		1.68			3.43	

F) Total NPK Uptake by Green gram (kg ha⁻¹)

1. Nitrogen Uptake (kg ha⁻¹)

a) Effect of Intercropping: Nitrogen uptake (kg ha⁻¹) by green gram was significantly influenced by the cropping system. The highest nitrogen uptake (90.78 kg ha⁻¹) was recorded under sole green gram (4:2) (C₃), likely due to the higher plant population, whereas the lowest uptake (37.90 kg ha⁻¹) was observed in the finger millet + green gram intercropping system (C₂).

b) Effect of Nutrient Levels

The mean nitrogen uptake (kg ha⁻¹) by green gram at harvest was significantly influenced by different nutrient management treatments. Application of 100% RDF (N₁) recorded the highest nitrogen uptake, which was statistically at par with 75% RDF + soil application of *Azospirillum* (2 kg ha⁻¹) and PSB (2 kg ha⁻¹) + foliar spray of 2% 19:19:19 at 15 and 30 DAS (N₃) and 75% RDF + soil application of *Azospirillum* (2 kg ha⁻¹) and PSB (2 kg ha⁻¹) + foliar spray of 3% Panchagavya at 15 and 30 DAS (N₄). The lowest nitrogen

uptake was recorded with 50% RDF + 50% RDN through FYM (N₆). Higher nitrogen uptake under N₁ may be attributed to greater nitrogen availability and efficient nutrient absorption by the crop. Similar findings were reported by Srivastava and Srivastava (1994) and Pandrangi *et al.* (1991)^[9].

c) Effect of Interaction

The interaction between intercropping and nutrient levels had significant effect on mean nitrogen uptake (kg ha⁻¹) by green gram as shown in Table 6A. The treatment combination C3N1, which involved sole green gram with 100% RDF, recorded the maximum nitrogen uptake (105.82 kg ha⁻¹).

2) Phosphorous Uptake by Green gram crop

a) Effect of Intercropping: Phosphorus uptake (kg ha⁻¹) by green gram was significantly influenced by the cropping system. The highest phosphorus uptake (17.06 kg ha⁻¹) was recorded under sole green gram (4:2) (C₃), probably due to the higher plant population, whereas the lowest uptake (7.41 kg ha⁻¹) was observed in the finger millet + green gram intercropping system (C₂) at harvest.

b) Effect of Nutrient Levels

The mean phosphorus uptake (kg ha⁻¹) by green gram at harvest was significantly influenced by different nutrient management treatments. Application of 100% RDF (N₁) recorded the highest phosphorus uptake, which was statistically at par with 75% RDF + soil application of Azospirillum (2 kg ha⁻¹) and PSB (2 kg ha⁻¹) + foliar spray of 2% 19:19:19 at 15 and 30 DAS (N₃). The lowest phosphorus uptake was recorded with 50% RDF + 50% RDN through FYM (N₆). Higher phosphorus uptake under N₁ may be attributed to greater phosphorus availability and efficient uptake by the crop. Similar findings were reported by Srivastava and Srivastava (1994) and Pandrangi *et al.* (1991)^[9].

c) Effect of Interaction

The interaction between intercropping and nutrient levels had significant effect on mean phosphorous uptake (kg ha⁻¹) by green gram as shown in Table 6B. The treatment combination C3N1, which involved sole green gram with 100% RDF, recorded the maximum phosphorous uptake (21.93 kg ha⁻¹).

Table 6: Mean total uptake of nutrients (Nitrogen, Phosphorous and Potassium) (kg ha⁻¹) of green gram as influenced by different treatments

Treatments	Nitrogen uptake (kg ha ⁻¹)			Phosphorous uptake (kg ha ⁻¹)			Potassium uptake (kg ha ⁻¹)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
Intercropping									
C ₃ -Sole Green gram	50.51	40.26	90.78	6.98	9.99	17.06	13.48	43.71	57.19
C ₂ - Finger millet + Green gram (4:2)	21.32	16.58	37.90	3.14	4.27	7.41	5.83	18.03	23.86
S.Em±	0.84	0.74	1.46	0.16	0.23	0.25	0.26	0.74	0.97
CD @ 5%	2.45	2.17	4.29	0.47	0.66	0.74	0.76	2.18	2.84
Nutrient levels									
N ₁ -100% RDF	42.07	28.38	76.06	6.18	9.53	15.72	11.68	37.17	48.85
N ₂ - 75% RDF + soil application of <i>Azospirillum</i> @ 2 kg ha ⁻¹ and Phosphate solubilizing bacteria @ 2 kg ha ⁻¹	34.66	32.95	63.04	4.90	6.86	11.77	9.41	31.13	40.54
N ₃ - 75% RDF + Soil application of <i>Azospirillum</i> (2 kg ha ⁻¹) and PSB (2 kg ha ⁻¹) + Foliar spray of 2% 19:19:19 all @ 15 and 30 DAS	40.81	30.37	73.76	5.86	8.33	14.45	10.96	35.56	46.52
N ₄ - 75% RDF + Soil application of <i>Azospirillum</i> @ 2 kg ha ⁻¹ and PSB @ 2 Kg ha ⁻¹	38.90	24.81	69.27	5.43	7.32	12.75	10.37	33.05	43.43
N ₅ - 75% RDF + 25% RDN through FYM	32.89	20.03	57.71	4.53	5.94	10.47	8.67	26.81	35.48
N ₆ - 50% RDF + 50% RDN through FYM	26.18	1.28	46.21	3.44	4.80	8.24	6.84	21.50	28.34
S.Em±	1.45	3.75	2.53	0.28	0.39	0.44	0.45	1.29	1.68
CD @ 5 %	4.24	40.26	7.43	0.81	1.15	1.29	1.31	3.78	4.93
Interaction: C × N									
S.Em±	2.05	1.81	3.59	0.39	0.55	0.62	0.63	1.82	2.37
CD @ 5%	6.00	5.31	10.51	1.15	1.63	1.82	1.86	5.35	6.97
General Mean	35.92	28.42	64.34	5.06	7.13	12.23	9.65	30.87	40.53

c) Effect of Interaction

The interaction between intercropping and nutrient levels had significant effect on mean phosphorous uptake (kg ha⁻¹) by green gram as shown in Table 6B. The treatment combination C3N1, which involved sole green gram with 100% RDF, recorded the maximum phosphorous uptake (21.93 kg ha⁻¹).

3. Potassium Uptake by Green gram

a) Effect of Intercropping

Mean potassium uptake (kg ha⁻¹) by green gram was significantly influenced by intercropping. Sole green gram (4:2) (C₃) recorded the highest potassium uptake 57.19 kg ha⁻¹.

1) due to higher plant population in sole green gram as compared to finger millet + green gram (C2) which recorded comparatively lowest potassium uptake (23.86 kg ha⁻¹). Similar results were found by Willey (1979)^[11].

Table 6A: Effect of interaction on nitrogen uptake (kg ha⁻¹) of green gram as influenced by various treatment

After harvest	Grain			Straw			Total		
Intercropping/ Nutrient levels	C ₃	C ₂	Mean	C ₃	C ₂	Mean	C ₃	C ₂	Mean
N ₁	58.97	25.18	42.07	46.85	21.12	33.99	105.82	46.30	76.06
N ₂	52.05	17.26	34.66	42.51	14.24	28.38	94.56	31.51	63.04
N ₃	56.95	24.66	40.81	46.08	19.83	32.95	103.02	44.50	73.76
N ₄	53.90	23.90	38.90	42.66	18.08	30.37	96.56	41.98	69.27
N ₅	46.95	18.83	32.89	35.79	13.83	24.81	82.75	32.67	57.71
N ₆	34.27	18.10	26.18	27.68	12.38	20.03	61.95	30.47	46.21
Mean	50.51	21.32	35.92	40.26	16.58	28.42	90.78	37.90	64.34
S.Em±	2.05			1.81			3.59		
CD @ 5 %	6.00			5.31			10.51		

Table 6B: Effect of interaction on phosphorous uptake (kg ha⁻¹) of green gram as influenced by various treatments

After harvest	Seed			Stover			Total		
Intercropping / Nutrient levels	C ₃	C ₂	Mean	C ₃	C ₂	Mean	C ₃	C ₂	Mean
N ₁	8.57	3.80	6.18	13.36	5.70	9.53	21.93	9.50	15.72
N ₂	7.15	2.65	4.90	10.13	3.60	6.86	17.28	6.25	11.77
N ₃	8.00	3.71	5.86	11.34	5.31	8.33	19.87	9.03	14.45
N ₄	7.30	3.56	5.43	9.95	4.69	7.32	17.25	8.25	12.75
N ₅	6.46	2.60	4.53	8.55	3.34	5.94	15.00	5.94	10.47
N ₆	4.39	2.50	3.44	6.61	2.98	4.80	11.00	5.48	8.24
Mean	6.98	3.14	5.06	9.99	4.27	7.13	17.06	7.41	12.23
S.Em±	0.39			0.55			0.62		
CD @ 5%	1.15			1.63			1.82		

b) Effect of Nutrient Levels

The mean potassium uptake (kg ha⁻¹) by green gram at harvest was significantly influenced by different nutrient management treatments. Application of 100% RDF (N₁) recorded the highest potassium uptake, which was statistically at par with 75% RDF + soil application of Azospirillum (2 kg ha⁻¹) and PSB (2 kg ha⁻¹) + foliar spray of 2% 19:19:19 at 15 and 30 DAS (N₃). The lowest potassium uptake was recorded with 50% RDF + 50% RDN through FYM (N₆). The higher potassium uptake under N₁ may be attributed to greater potassium availability and efficient

nutrient uptake by the crop. Similar findings were reported by Srivastava and Srivastava (1994), Pandrangi *et al.* (1991), and Kumar and Yadav (2018)^[4,9].

c) Effect of Interaction

The interaction between intercropping and nutrient levels had significant effect on mean potassium uptake (kg ha⁻¹) by green gram as shown in Table 6C. The treatment combination C3N₁, which involved sole green gram with 100% RDF, recorded the maximum potassium uptake (67.84 kg ha⁻¹).

Table 6C: Effect of interaction on potassium uptake (kg ha⁻¹) of green gram as influenced by various treatment

After harvest	Seed			Straw			Total		
Intercropping/Nutrient levels	C ₃	C ₂	Mean	C ₃	C ₂	Mean	C ₃	C ₂	Mean
N ₁	16.38	6.98	11.68	51.46	22.89	37.17	67.84	29.87	48.85
N ₂	13.64	5.17	9.41	45.75	16.51	31.13	59.39	21.69	40.54
N ₃	15.23	6.69	10.96	49.95	21.17	35.56	65.18	27.86	46.52
N ₄	14.32	6.42	10.37	46.72	19.39	33.05	61.04	25.81	43.43
N ₅	12.36	4.98	8.67	38.65	14.96	26.81	51.01	19.94	35.48
N ₆	8.96	4.73	6.84	29.74	13.26	21.50	38.69	17.99	28.34
Mean	13.48	5.83	9.65	43.71	18.03	30.87	57.19	23.86	40.53
S.Em±	0.63			1.82			2.37		
CD @ 5 %	1.86			5.35			6.97		

F) Mean Available Nitrogen (kg ha⁻¹) in soil after harvest

The mean available nitrogen content in the soil following the harvest of finger millet and green gram is presented in Table 7. The average available nitrogen in the soil was recorded as 195.74 kg ha⁻¹.

a) Effect of Intercropping

Mean available nitrogen (kg ha⁻¹) in soil was significantly influenced by intercropping. Sole green gram (C3) recorded the maximum available nitrogen in soil was 197.11 (kg ha⁻¹).

While sole finger millet recorded lowest value (194.89 kg ha⁻¹). Similar results were found by Patel *et al.*, (2017)^[6].

b) Effect of Nutrient Levels: The mean available nitrogen (kg ha⁻¹) in soil was significantly influenced by different nutrient levels after harvest. Application of 75% RDF + 25% RDN through FYM (N₅) recorded significantly highest available nitrogen (kg ha⁻¹) in soil which was at par with application of 75% RDF + 25% RDN through FYM (N₆). Similar results were found by Patil and Dhonde (2009)^[6,7].

4.15.2.3 Effect of Interaction

The interaction between intercropping and nutrient levels had no significant effect on mean available nitrogen in soil after harvest of finger millet and green gram.

2. Mean Available Phosphorous (kg ha⁻¹) in soil after harvest: The data on mean available phosphorous in soil after harvest of finger millet and green gram shown in Table 7. Mean available phosphorous in soil was 38.41(kg ha⁻¹).

a) Effect of Intercropping: Mean available phosphorous (kg ha⁻¹) in soil after harvest of finger millet and green gram was influenced by intercropping. Finger millet + green gram (C₂) recorded maximum available phosphorous in soil which was (39.17 kg ha⁻¹). While sole green gram recorded lowest value (37.94 kg ha⁻¹). Similar results were finding by Patel *et al.*, (2017)^[6].

b) Effect of Nutrient Levels

Mean available phosphorus (kg ha⁻¹) in the soil after harvest was significantly influenced by different nutrient management treatments. Application of 75% RDF + 50% RDN through FYM (N₅) recorded the highest available phosphorus, which was statistically at par with 50% RDF + 50% RDN through FYM (N₆). The higher available phosphorus under these treatments may be attributed to the gradual release of phosphorus from FYM and improved soil phosphorus availability. Similar findings were reported by Patil and Dhonde (2009)^[6, 7].

c) Effect of Interaction

The interaction between intercropping and nutrient levels had no significant effect on mean available phosphorous in soil after harvest of finger millet and green gram.

Table 7: Mean available Nitrogen, Phosphorous and Potassium in soil (Kg ha⁻¹) as influenced by various treatments

Treatments	Available Nitrogen (kg ha ⁻¹)	Available Phosphorous (kg ha ⁻¹)	Available Potassium (kg ha ⁻¹)
Intercropping			
C ₁ - Sole Finger millet	194.89	38.11	258.11
C ₂ - Finger millet + Green gram (4:2)	195.22	39.17	259.83
C ₃ - Sole Green gram	197.11	37.94	257.95
S.Em±	0.42	0.30	0.44
CD @ 5 %	1.20	0.86	1.25
Nutrient levels			
N ₁ -100% Recommended dose of fertilizer (RDF)	194.00	34.92	256.11
N ₂ -75% RDF + Soil application of <i>Azospirillum</i> @ 2 kg ha ⁻¹ and Phosphate solubilizing bacteria @ 2 kg ha ⁻¹	196.71	39.73	259.83
N ₃ -75% RDF + Soil application of <i>Azospirillum</i> (2 kg ha ⁻¹) and PSB (2 kg ha ⁻¹) + Foliar spray of 2% 19:19:19 @ 15 and 30 DAS	193.38	36.45	256.38
N ₄ -75% RDF + Soil application of <i>Azospirillum</i> (2 kg ha ⁻¹) and PSB (2 kg ha ⁻¹) + Foliar spray of Panchagavya 3% @ 15 and 30 DAS	193.70	36.36	256.70
N ₅ - 75% RDF + 25% RDN through FYM	198.42	41.82	261.53
N ₆ - 50% RDF + 50% RDN through FYM	198.22	41.15	261.22
S.Em±	0.59	0.42	0.62
CD @ 5 %	1.69	1.22	1.77
Interaction: C × N			
S.Em±	1.02	0.73	1.07
CD @ 5 %	NS	NS	NS
General Mean	195.74	38.41	258.63
Initial	169	35.3	241

3. Mean Available Potassium (kg ha⁻¹) in soil after harvest: The data on mean available potassium in soil after harvest of finger millet and green gram shown in Table 7. Mean available potassium in soil was 258.63 (kg ha⁻¹)

a) Effect of Intercropping

Mean available potassium (kg ha⁻¹) in the soil after harvest of finger millet and green gram was significantly influenced by the cropping system. The finger millet + green gram intercropping system (C₂) recorded the highest available potassium (259.83 kg ha⁻¹), whereas sole green gram (C₃) recorded the lowest available potassium (257.95 kg ha⁻¹). Similar findings were reported by Patel *et al.* (2017)^[6].

b) Effect of Nutrient Levels

Mean available potassium (kg ha⁻¹) in the soil after harvest was significantly influenced by different nutrient management treatments. Application of 75% RDF + 50% RDN through FYM (N₅) recorded the highest available

potassium, which was statistically at par with 50% RDF + 50% RDN through FYM (N₆). The higher available potassium under these treatments may be attributed to the addition of FYM, which improved potassium availability in the soil. Similar findings were reported by Patil and Dhonde (2009)^[6, 7].

c) Effect of Interaction: The interaction effect between cropping systems and nutrient management treatments on mean available potassium (kg ha⁻¹) in the soil after harvest of finger millet and green gram was found to be non-significant.

Conclusions

The study revealed that intercropping had no significant effect on soil pH, EC, and organic carbon after harvest. However, available nitrogen, phosphorus, and potassium in the soil were significantly influenced by the cropping system. Sole green gram recorded the highest available nitrogen, whereas finger millet + green gram (4:2) intercropping

recorded the highest available phosphorus and potassium. The N, P, and K content in the grain and straw of both crops remained unaffected by intercropping, while nutrient uptake was significantly influenced. Sole finger millet and sole green gram recorded the highest N, P, and K uptake. Different nutrient management treatments had no significant effect on soil pH, EC, organic carbon, or nutrient content in the grain and straw of both crops. However, available soil nitrogen, phosphorus, and potassium were significantly influenced, with 75% RDF + 25% RDN through FYM (N_5) recording the highest values, which remained at par with 50% RDF + 50% RDN through FYM (N_6). The highest N, P, and K uptake by both crops was recorded under 100% RDF (N_1), which was statistically at par with 75% RDF + soil application of Azospirillum (2 kg ha^{-1}) and PSB (2 kg ha^{-1}) + foliar spray of 2% 19:19:19 at 15 and 30 DAS (N_3). The interaction between cropping systems and nutrient management treatments had no significant effect on soil available N, P, and K or on the nutrient content of grain and straw. However, total nutrient uptake was significantly influenced by the interaction. The highest total N, P, and K uptake by finger millet (67.81, 23.10, and 53.19 kg ha^{-1} , respectively) was recorded under sole finger millet with 100% RDF, while the highest uptake by green gram (105.82, 21.93, and 67.84 kg ha^{-1} , respectively) was recorded under sole green gram with 100% RDF.

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