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Influence of organic and inorganic fertilizers on the growth attributes of black gram (*Vigna mungo*) under Moringa (*Moringa oleifera*) based agroforestry systems

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Abstract

A field experiment was conducted during 2024–2025 at Forest Nursery and Research Center, SHUATS, Prayagraj to study the effect of integrated nutrient management on the growth of black gram (*Vigna mungo* L.) in (Moringa) *Moringa oleifera* based agroforestry system. The experiment was laid out in randomized block design with 22 treatment combinations and three replications in black gram variety “Shekhar-2”. Treatments were different levels of recommended dose of fertilizer (RDF) with FYM, poultry manure, vermicompost and Rhizobium culture. Growth characteristics like plant height, dry matter accumulation per plant, number of leaves and number of branches were observed at different growth stages. All growth parameters were significantly different for the treatments. The treatment T₂₂ (75% RDF + 5 t ha⁻¹ vermicompost + Rhizobium culture) recorded the maximum plant height (12.32, 34.60 and 51.32 cm), dry matter accumulation (2.03, 10.49 and 26.04 g plant⁻¹), number of leaves (7.30, 24.92 and 43.24 plant⁻¹) at 20, 40 and 60 DAS respectively and number of branches (5.03 and 6.73 plant⁻¹) at 40 and 60 DAS respectively. The control (T₁) however had the lowest values for all growth attributes. The better performance of T₂₂ may be due to the synergistic effects of inorganic nutrients, vermicompost and Rhizobium in improving nutrient availability, uptake and vegetative growth. Therefore, 75% RDF + 5 t ha⁻¹ Vermicompost + Rhizobium culture treatment was most effective in improving growth and biomass production of black gram under the experimental conditions.

Keywords: Agroforestry systems, black gram, FYM, growth parameter, poultry manure, rhizobium, vermicompost

Introduction

Agroforestry is a sustainable land use system that integrates trees with agricultural crops to enhance productivity, soil fertility, biodiversity and environmental sustainability. Trees recycle nutrients from deep soil layers and deposit organic matter as litterfall. They can also offer farmers additional products and income. Agroforestry is practiced in 25.32 million ha (8.2%) of the geographical area of India and it indicates its importance in sustainable agricultural production (Dhyani *et al.*, 2013) ^[6]. It helps to offset climate change by storing carbon as tree biomass and soil organic matter (Garritty, 2004) ^[9].

Moringa oleifera is a promising multipurpose tree for tropical and subtropical agroforestry systems due to its fast growth, drought tolerance, low input needs and wide range of nutritional, medicinal and economic uses (Fuglie, 2001) ^[8]. It has leaves rich in nutrients that decay quickly and may have a role in nutrient cycling and soil fertility. In addition, its potential for biomass production and carbon sequestration may offer further ecological benefits (Leone *et al.*, 2015; Adekiya *et al.*, 2020) ^[1, 11]. Moringa based agroforestry system can contribute to diversify farm income through leaves, seeds and wood and thus increase resilience in smallholder farming systems (Foidl *et al.*, 2001) ^[7].

Black gram (*Vigna mungo* L.) is an important short duration pulse crop which is highly preferred for its high nutritional value, adaptability and fixing atmospheric nitrogen. It contains 22-24% protein and 56.6-59.6% carbohydrate. It is best suited for tropical and sub-tropical agro-climatic zones, The short duration of its growth makes it suitable for multiple and intercropping systems with agroforestry (Tomar *et al.*, 2011, Selvakumar *et al.*, 2012) ^[19, 16].

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However, the availability of nutrients is an important factor affecting crop productivity, especially where crops are grown in association with trees. Integrated Nutrient Management (INM) is a practice of combined use of inorganic fertilizers, organic manures and biofertilizers for increasing nutrient-use efficiency, maintaining soil health and ensuring long-term productivity (Meena *et al.*, 2015; Dhakal *et al.*, 2016) [13, 5]. Organic amendments such as vermicompost, farmyard manure and poultry manure can improve the soil physical properties, microbial activity and nutrient availability, whereas Rhizobium inoculation may improve the biological nitrogen fixation in legumes (Vessey, 2003; Bhatt *et al.*, 2013) [21, 3].

Vermicompost as an organic source of nutrients provides slowly available nutrients and biologically active compounds which can improve root growth, nutrient uptake and crop productivity (Arancon *et al.*, 2004) [2]. FYM improves soil aggregation, water holding capacity and microbial activity and contributes organic matter and nutrients (Gaur, 1999; Ghosh *et al.*, 2004) [10, 11]. Well composted poultry manure has the potential to enhance soil fertility and provide readily available nutrients because of relatively high nutrient concentration and rapid mineralization (Gupta & Sharma, 2010; Sridhar *et al.*, 2013) [12, 17]. Rhizobium also has a symbiotic association with leguminous crops and helps in the fixation of atmospheric nitrogen which improves the nitrogen nutrition and crop productivity (Meena *et al.*, 2016; Bhavya *et al.*, 2018) [14, 4].

Moringa oleifera based agroforestry system along with INM

(integrated nutrient management) can be a promising approach for improvement of black gram productivity enhancement of soil health, resource use efficiency and sustainability. In this context, the present study was undertaken to assess the influence of integrated nutrient management strategies involving chemical fertilizers, organic manures and biofertilizers on growth of black gram grown under moringa based agroforestry system. The experimental objectives were to evaluate the growth attributes under different treatments and compare the efficiency of INM practices in agroforestry systems. The findings are intended to guide sustainable nutrient management strategies and optimize legume-based intercropping under integrated farming systems.

Materials and Methods

The study was conducted during 2024-2025 at Forest Nursery and Research Center of College of Forestry, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj located at six km. from Prayagraj city on Rewa road south of Yamuna River. Prayagraj city is located at latitude 28.87° N and longitude 81.15° E at an elevation of 98 meters above mean sea level. Prayagraj is located in the southeast of Uttar Pradesh and has a tropical to sub-tropical climate with extremes of summers and winters. The temperature can drop to 5°C in winter especially in December and January. In summer it can get above 45°C. The bulk of the annual rainfall of 1100 mm is received during the monsoon autumn (July to September) with a few scattered showers in the winter.

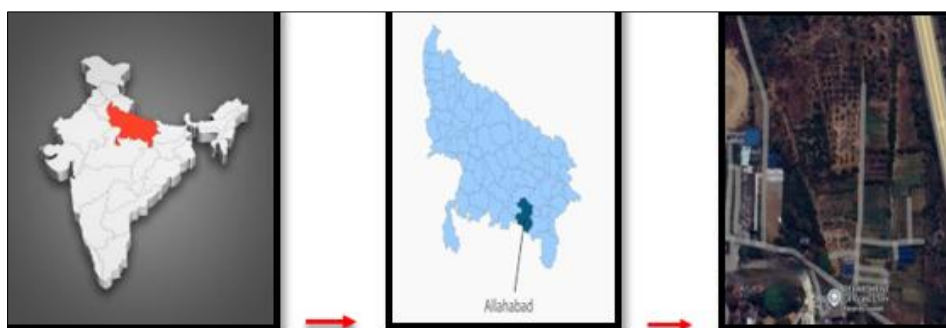


Fig 1: Study Area (Forest Nursery and Research Center) at College of Forestry, SHUATS, Prayagraj, Uttar Pradesh

The experiment was conducted in a *Moringa* plantation having spacing of $9 \times 9 \text{ m}^2$. The experiment was carried out in randomized block design (RBD) with three replications under the moringa based agroforestry system with Black gram variety “Shekhar-2” as test crop. Each replication consisted of 22 treatment combinations and there were 66 plots of $2 \times 2 \text{ m}^2$. The 22 treatments were control; 0, 50 and 75% RDF along with Rhizobium culture; 0, 50 and 75% RDF in combination with 2.5

and 5 t ha^{-1} FYM, poultry manure and vermicompost supplemented with Rhizobium culture. The treatments were designated as T_1 to T_{22} respectively. The black gram seeds were manually planted at a rate of 25 kg/ha in furrows between the alleys of the moringa trees. The growth parameters of black gram i.e. number of plants height, dry matter accumulation per plant, number of leaves per plant, and number of branches per plant was recorded at 20, 40 and 60 days after sowing (DAS).

Table 1: Treatment Combinations of Research Experiment

Symbol	Treatment Combinations
T_1	Control
T_2	RDF 0% + Rhizobium culture
T_3	RDF 0% + 2.5t/ha FYM + Rhizobium culture
T_4	RDF 0% + 5t/ha FYM + Rhizobium culture
T_5	RDF 0% + 2.5t/ha POULTRY MANURE + Rhizobium culture
T_6	RDF 0% + 5t/ha POULTRY MANURE + Rhizobium culture
T_7	RDF 0% + 2.5t/ha VERMICOMPOST + Rhizobium culture
T_8	RDF 0% + 5t/ha VERMICOMPOST+ Rhizobium culture
T_9	RDF 50%+ Rhizobium culture
T_{10}	RDF 50% + 2.5t/ha FYM + Rhizobium culture
T_{11}	RDF 50% + 5t/ha FYM + Rhizobium culture
T_{12}	RDF 50% + 2.5t/ha POULTRY MANURE + Rhizobium culture

T ₁₃	RDF 50% + 5t/ha POULTRY MANURE + Rhizobium culture
T ₁₄	RDF 50% + 2.5t/ha VERMICOMPOST +Rhizobium culture
T ₁₅	RDF 50% + 5t/ha VERMICOMPOST +Rhizobium culture
T ₁₆	RDF 75%+ Rhizobium culture
T ₁₇	RDF 75% + 2.5t/ha FYM + Rhizobium culture
T ₁₈	RDF 75% + 5t/ha FYM + Rhizobium culture
T ₁₉	RDF 75% + 2.5t/ha POULTRY MANURE +Rhizobium culture
T ₂₀	RDF 75% + 5t/ha POULTRY MANURE +Rhizobium culture
T ₂₁	RDF 75% + 2.5t/ha VERMICOMPOST +Rhizobium culture
T ₂₂	RDF 75% + 5t/ha VERMICOMPOST +Rhizobium culture

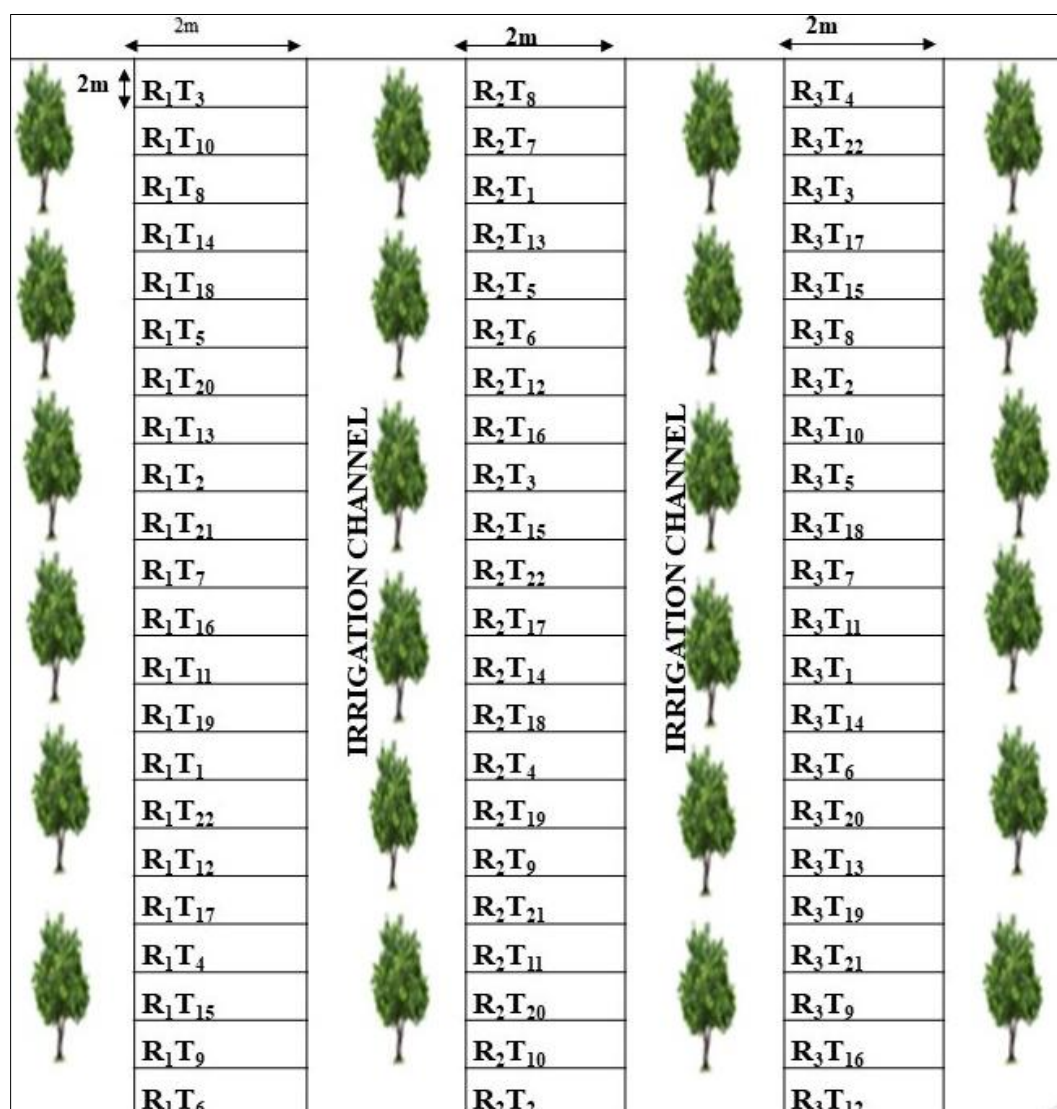


Fig 2: Experimental Layout

Results and Discussion

The data presented in Tables 2 to 5 reveal that the black gram differed significantly with different integrated nutrient management (INM) treatments in Agroforestry (AF) during the years 2024-2025. Growth parameters were recorded at three crop growth stages i.e. 20, 40 and 60 days after sowing (DAS). The pre-harvest data on the plant height, dry matter accumulation per plant, number of leaves per plant, and number of branches per plant of black gram are presented in Table 2 to 5 under Moringa based Agroforestry System which revealed that there were significant differences between combination of inorganic and organic fertilizers on the growth parameters.

The integrated nutrient management treatments had significant effect on plant height at 20, 40 and 60 DAS. The range was 8.37-

12.32 cm, 26.13-34.60 cm and 39.01-51.32 cm, respectively (Table 2). The T₂₂ (75% RDF + 5 t ha⁻¹ vermicompost + Rhizobium culture) gave the highest plant height at 20 (12.32 cm), 40 (34.60 cm) and 60 DAS (51.32 cm) while the minimum was observed under T₁ (Control) with plant height of 8.37, 26.13 and 39.01 cm, respectively. T₂₂ was closely followed by T₂₀, T₁₈, T₂₁ and T₁₉ at 60 DAS. The enhanced plant height under integrated nutrient management may be due to improved availability and utilization of nutrients and enhanced biological activity due to organic manure and Rhizobium inoculation. Similar improvements in growth of black gram under integrated nutrient management have been reported by (Sharma *et al.*, 2019 and Verma *et al.*, 2025) [20, 17].

Table 2: Effect of Integrated Nutrient Management on the Plant Height of Black Gram (*Vigna mungo*) under Moringa (*Moringa oliefera*) based Agroforestry System

Treatment	Treatment Combination	Plant Height (cm) at 20 DAS	Plant Height (cm) at 40 DAS	Plant Height (cm) at 60 DAS
T ₁	Control	8.37	26.13	39.01
T ₂	RDF 0% + Rhizobium culture	8.62	26.64	39.87
T ₃	RDF 0% + 2.5t/ha FYM + Rhizobium culture	9.01	27.37	41.05
T ₄	RDF 0% + 5t/ha FYM + Rhizobium culture	9.56	28.49	42.56
T ₅	RDF 0% + 2.5t/ha POULTRY MANURE + Rhizobium culture	9.21	27.86	41.70
T ₆	RDF 0% + 5t/ha POULTRY MANURE + Rhizobium culture	10.31	30.25	44.33
T ₇	RDF 0% + 2.5t/ha VERMICOMPOST + Rhizobium culture	9.41	28.10	42.23
T ₈	RDF 0% + 5t/ha VERMICOMPOST+ Rhizobium culture	11.44	32.62	48.02
T ₉	RDF 50%+ Rhizobium culture	8.82	27.03	40.49
T ₁₀	RDF 50% + 2.5t/ha FYM + Rhizobium culture	11.61	32.95	48.51
T ₁₁	RDF 50% + 5t/ha FYM + Rhizobium culture	11.75	33.23	48.81
T ₁₂	RDF 50% + 2.5t/ha POULTRY MANURE + Rhizobium culture	11.63	33.01	48.60
T ₁₃	RDF 50% + 5t/ha POULTRY MANURE + Rhizobium culture	11.89	33.44	49.09
T ₁₄	RDF 50% + 2.5t/ha VERMICOMPOST +Rhizobium culture	11.69	33.14	48.68
T ₁₅	RDF 50% + 5t/ha VERMICOMPOST +Rhizobium culture	12.02	33.67	49.36
T ₁₆	RDF 75%+ Rhizobium culture	9.09	27.69	41.45
T ₁₇	RDF 75% + 2.5t/ha FYM + Rhizobium culture	12.12	33.87	49.58
T ₁₈	RDF 75% + 5t/ha FYM + Rhizobium culture	12.22	34.11	49.98
T ₁₉	RDF 75% + 2.5t/ha POULTRY MANURE +Rhizobium culture	12.15	33.97	49.77
T ₂₀	RDF 75% + 5t/ha POULTRY MANURE +Rhizobium culture	12.27	34.30	50.28
T ₂₁	RDF 75% + 2.5t/ha VERMICOMPOST +Rhizobium culture	12.19	34.04	49.87
T ₂₂	RDF 75% + 5t/ha VERMICOMPOST +Rhizobium culture	12.32	34.60	51.32
SE(m)		0.21	0.51	0.88
CD 5%		0.61	1.47	2.51

Table 3: Effect of Integrated Nutrient Management on the Dry Matter Accumulation per Plant of Black Gram (*Vigna mungo*) under Moringa (*Moringa oliefera*) based Agroforestry System

Treatment	Treatment Combination	Dry Matter Accumulation per Plant (g/plant) at 20 DAS	Dry Matter Accumulation per Plant (g/plant) at 40 DAS	Dry Matter Accumulation per Plant (g/plant) at 60 DAS
T ₁	Control	0.90	6.42	16.30
T ₂	RDF 0% + Rhizobium culture	0.97	6.67	17.03
T ₃	RDF 0% + 2.5t/ha FYM + Rhizobium culture	1.11	7.27	18.67
T ₄	RDF 0% + 5t/ha FYM + Rhizobium culture	1.27	7.97	20.43
T ₅	RDF 0% + 2.5t/ha POULTRY MANURE + Rhizobium culture	1.19	7.57	19.43
T ₆	RDF 0% + 5t/ha POULTRY MANURE + Rhizobium culture	1.45	8.55	22.20
T ₇	RDF 0% + 2.5t/ha VERMICOMPOST + Rhizobium culture	1.24	7.83	20.03
T ₈	RDF 0% + 5t/ha VERMICOMPOST+ Rhizobium culture	1.63	9.28	23.70
T ₉	RDF 50%+ Rhizobium culture	1.03	6.95	17.70
T ₁₀	RDF 50% + 2.5t/ha FYM + Rhizobium culture	1.71	9.56	24.40
T ₁₁	RDF 50% + 5t/ha FYM + Rhizobium culture	1.78	9.81	24.90
T ₁₂	RDF 50% + 2.5t/ha POULTRY MANURE + Rhizobium culture	1.73	9.66	24.47
T ₁₃	RDF 50% + 5t/ha POULTRY MANURE + Rhizobium culture	1.85	10.06	25.20
T ₁₄	RDF 50% + 2.5t/ha VERMICOMPOST +Rhizobium culture	1.76	9.76	24.77
T ₁₅	RDF 50% + 5t/ha VERMICOMPOST +Rhizobium culture	1.91	10.23	25.53
T ₁₆	RDF 75%+ Rhizobium culture	1.07	7.13	18.23
T ₁₇	RDF 75% + 2.5t/ha FYM + Rhizobium culture	1.94	10.31	25.67
T ₁₈	RDF 75% + 5t/ha FYM + Rhizobium culture	1.97	10.40	25.80
T ₁₉	RDF 75% + 2.5t/ha POULTRY MANURE +Rhizobium culture	1.95	10.32	25.70
T ₂₀	RDF 75% + 5t/ha POULTRY MANURE +Rhizobium culture	1.99	10.45	25.93
T ₂₁	RDF 75% + 2.5t/ha VERMICOMPOST +Rhizobium culture	1.96	10.37	25.77
T ₂₂	RDF 75% + 5t/ha VERMICOMPOST +Rhizobium culture	2.03	10.49	26.04
SE(m)		0.02	0.10	0.28
CD 5%		0.07	0.29	0.80

Dry matter accumulation increased progressively with the advancement of crop growth and it differed significantly among the nutrient management treatments. The dry matter accumulation at 20, 40 and 60 DAS ranged from 0.90–2.03, 6.42–10.49 and 16.30–26.04 g plant⁻¹ respectively (Table 3). The maximum dry matter accumulation was recorded under T₂₂ (75% RDF + 5 t ha⁻¹ vermicompost + Rhizobium culture) at 20 DAS i.e., 2.03 g plant⁻¹, 40 DAS i.e., 10.49 g plant⁻¹ and at 60 DAS 26.04 g plant⁻¹, while the minimum was recorded under T₁ (Control) i.e., (0.90,

6.42 and 16.30 g plant⁻¹ respectively). At 60 DAS, T₂₂ was followed by T₂₀, T₁₈, T₂₁ and T₁₉. Higher accumulation of dry matter under integrated nutrient management might be attributed to the better nutrient availability and uptake, which in turn lead to the better vegetative growth and biomass production. The similar improvement in accumulation of dry matter with integrated application of RDF, vermicompost and Rhizobium was reported in black gram and mungbean (Singh *et al.*, 2022; Pankaj *et al.*, 2020; and Gupta *et al.*, 2025) [18, 15, 12].

Table 4: Effect of Integrated Nutrient Management on the Number of Leaves per Plant of Black Gram (*Vigna mungo*) under Moringa (*Moringa oleifera*) based Agroforestry System

Treatment	Treatment Combination	No. of Leaves per Plant at 20 DAS	No. of Leaves per Plant at 40 DAS	No. of Leaves per Plant at 60 DAS
T ₁	Control	4.43	18.71	30.39
T ₂	RDF 0% + Rhizobium culture	4.61	19.17	31.13
T ₃	RDF 0% + 2.5t/ha FYM + Rhizobium culture	4.96	19.91	32.38
T ₄	RDF 0% + 5t/ha FYM + Rhizobium culture	5.41	20.84	34.08
T ₅	RDF 0% + 2.5t/ha POULTRY MANURE + Rhizobium culture	5.15	20.28	33.03
T ₆	RDF 0% + 5t/ha POULTRY MANURE + Rhizobium culture	5.99	22.09	36.32
T ₇	RDF 0% + 2.5t/ha VERMICOMPOST + Rhizobium culture	5.29	20.59	33.59
T ₈	RDF 0% + 5t/ha VERMICOMPOST + Rhizobium culture	6.59	23.35	40.25
T ₉	RDF 50%+ Rhizobium culture	4.80	19.51	31.69
T ₁₀	RDF 50% + 2.5t/ha FYM + Rhizobium culture	6.71	23.70	40.89
T ₁₁	RDF 50% + 5t/ha FYM + Rhizobium culture	6.84	23.93	41.33
T ₁₂	RDF 50% + 2.5t/ha POULTRY MANURE + Rhizobium culture	6.73	23.74	41.02
T ₁₃	RDF 50% + 5t/ha POULTRY MANURE + Rhizobium culture	6.96	24.09	41.77
T ₁₄	RDF 50% + 2.5t/ha VERMICOMPOST + Rhizobium culture	6.79	23.85	41.21
T ₁₅	RDF 50% + 5t/ha VERMICOMPOST + Rhizobium culture	7.06	24.27	42.13
T ₁₆	RDF 75%+ Rhizobium culture	5.05	20.05	32.68
T ₁₇	RDF 75% + 2.5t/ha FYM + Rhizobium culture	7.13	24.42	42.51
T ₁₈	RDF 75% + 5t/ha FYM + Rhizobium culture	7.21	24.59	42.81
T ₁₉	RDF 75% + 2.5t/ha POULTRY MANURE + Rhizobium culture	7.17	24.44	42.55
T ₂₀	RDF 75% + 5t/ha POULTRY MANURE + Rhizobium culture	7.27	24.73	43.04
T ₂₁	RDF 75% + 2.5t/ha VERMICOMPOST + Rhizobium culture	7.19	24.52	42.71
T ₂₂	RDF 75% + 5t/ha VERMICOMPOST + Rhizobium culture	7.30	24.92	43.24
SE(m)		0.16	0.28	0.65
CD 5%		0.44	0.80	1.85

Number of Leaves plant⁻¹ increased progressively with crop age and was significantly different between treatments. At 20, 40 and 60 DAS, it was in the range of 4.43-7.30, 18.71-24.92 and 30.39-43.24 leaves plant⁻¹ respectively (Table 4). Maximum number of leaves was observed under T₂₂ (75% RDF + 5 t ha⁻¹ vermicompost + Rhizobium culture) and minimum was observed under T₁ (Control) at all stages. The maximum number of leaves plant⁻¹

(43.24) was recorded by T₂₂ at 60 DAS which was closely followed by T₂₀ (43.04) and T₁₈ (42.81). Better leaf production resulting in better vegetative growth might be due to improved availability and uptake of nutrients under integrated nutrient management. Similar results were also reported in pulse crops by Singh *et al.*, 2023^[18] and Pankaj *et al.*, 2020^[15].

Table 5: Effect of Integrated Nutrient Management on the Number of Branches per Plant of Black Gram (*Vigna mungo* L.) under Moringa (*Moringa oleifera*) based Agroforestry System

Treatment	Treatment Combination	No. of Branches per Plant at 40 DAS	No. of Branches per Plant at 60 DAS
T ₁	Control	2.22	4.02
T ₂	RDF 0% + Rhizobium culture	2.36	4.21
T ₃	RDF 0% + 2.5t/ha FYM + Rhizobium culture	2.62	4.57
T ₄	RDF 0% + 5t/ha FYM + Rhizobium culture	3.05	4.95
T ₅	RDF 0% + 2.5t/ha POULTRY MANURE + Rhizobium culture	2.79	4.71
T ₆	RDF 0% + 5t/ha POULTRY MANURE + Rhizobium culture	3.33	5.29
T ₇	RDF 0% + 2.5t/ha VERMICOMPOST + Rhizobium culture	2.97	4.85
T ₈	RDF 0% + 5t/ha VERMICOMPOST + Rhizobium culture	3.70	5.67
T ₉	RDF 50%+ Rhizobium culture	2.48	4.37
T ₁₀	RDF 50% + 2.5t/ha FYM + Rhizobium culture	3.93	5.90
T ₁₁	RDF 50% + 5t/ha FYM + Rhizobium culture	4.15	6.17
T ₁₂	RDF 50% + 2.5t/ha POULTRY MANURE + Rhizobium culture	3.94	6.01
T ₁₃	RDF 50% + 5t/ha POULTRY MANURE + Rhizobium culture	4.39	6.37
T ₁₄	RDF 50% + 2.5t/ha VERMICOMPOST + Rhizobium culture	4.05	6.11
T ₁₅	RDF 50% + 5t/ha VERMICOMPOST + Rhizobium culture	4.62	6.42
T ₁₆	RDF 75%+ Rhizobium culture	2.57	4.50
T ₁₇	RDF 75% + 2.5t/ha FYM + Rhizobium culture	4.84	6.49
T ₁₈	RDF 75% + 5t/ha FYM + Rhizobium culture	4.87	6.65
T ₁₉	RDF 75% + 2.5t/ha POULTRY MANURE + Rhizobium culture	4.63	6.55
T ₂₀	RDF 75% + 5t/ha POULTRY MANURE + Rhizobium culture	4.94	6.69
T ₂₁	RDF 75% + 2.5t/ha VERMICOMPOST + Rhizobium culture	4.82	6.60
T ₂₂	RDF 75% + 5t/ha VERMICOMPOST + Rhizobium culture	5.03	6.73
SE(m)		0.03	0.04
CD 5%		0.08	0.11

The number of branches plant⁻¹ increased with crop age and was significantly different among treatments. Branches at 40 and 60 DAS ranged from 2.22–5.03 and 4.02–6.73 plant⁻¹ respectively (Table 5). Maximum number of branches was recorded under T₂₂ (75% RDF + 5 t ha⁻¹ vermicompost + Rhizobium culture 5.03 and 6.73 plant⁻¹ respectively and minimum under T₁ (Control) i.e., 2.22 and 4.02 plant⁻¹. At 60 DAS, T₂₂ was followed by T₂₀ (6.69) and T₁₈ (6.65 plant⁻¹). The increased branching under integrated nutrient management could be attributed to better availability and

uptake of nutrients leading to luxuriant vegetative growth. Integrated nutrient management reported a similar improvement in branching in pulse crops by Singh *et al.*, 2023^[18] and Pankaj *et al.*, 2020^[15]. These results indicate that integrating RDF 75% + 5t/ha VERMICOMPOST +Rhizobium culture (T₂₂) consistently enhanced the growth of black gram, demonstrating the benefits of combined chemical and organic nutrient management under agroforestry (Figure 3).

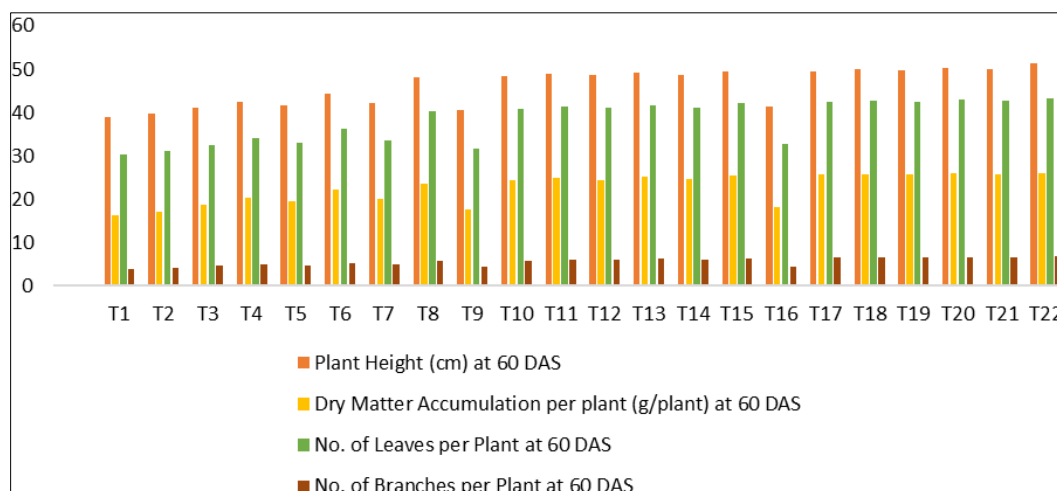


Fig 3: Effect of Integrated Nutrient Management on the Growth Attributes of Black Gram (*Vigna mungo* L.) under Moringa (*Moringa oleifera*) based Agroforestry System at 60 DAS

Conclusion

The integrated nutrient management treatments significantly improved black gram growth characteristics compared to the control. T₂₂ (75% RDF + 5 t ha⁻¹ Vermicompost + Rhizobium culture) had the highest plant height, dry matter accumulation, number of leaves and number of branches at respective growth stages under all treatments, while lowest values were observed under T₁ (Control). The enhanced performance of T₂₂ might be due to the combined and synergistic effects of inorganic nutrients, vermicompost and Rhizobium leading to better nutrient availability, uptake and vegetative growth. Therefore, the treatment 75% RDF + 5 t ha⁻¹ Vermicompost + Rhizobium culture was found to be the most effective treatment for enhancing the growth and biomass production of black gram under the experimental conditions

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