



RESEARCH ARTICLE

Optimising baby corn-green gram intercropping through spatial arrangement for enhanced productivity and soil health

Vishwakarma Kumar¹, Vishram Ram¹, Dilip Kumar Chaurasiya², Balram Yadav^{1*}, Amit Kumar³, Piyush Kumar^{4*}, Abid Tariq⁵, Mehreena Khursheed⁵, Dhamni Patyal⁶, Tajamul Aziz Alaie⁷ & Aman Tutlani⁸

¹Department of Agronomy, School of Natural Resources Management, College of Post Graduate Studies in Agricultural Sciences (CPGS-AS), Central Agricultural University (CAU), Umiam 793 030, Meghalaya, India

²Department of Plant Pathology, Faculty of Agricultural Sciences, GLA University, Mathura 281 406, Uttar Pradesh, India

³Department of Agronomy, Dr. Rammanohar Lohiya Avadh University, Ayodhya 224 001, Uttar Pradesh, India

⁴Division of Plant Pathology, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura 193 201, Jammu and Kashmir, India

⁵Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura 193 201, Jammu and Kashmir, India

⁶Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu 180 005, Jammu and Kashmir, India

⁷Skill Faculty of Agriculture, Shri Vishwakarma skill university, Palwal, Haryana 121 102, India

⁸Division of Genetics and Plant Breeding, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura 193 201, Jammu and Kashmir, India

*Correspondence email - balramyadav244200@gmail.com; rdpiyush001@gmail.com

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Abstract

Intercropping cereals with legumes can mitigate moisture and nutrient stress while enhancing system productivity and soil health. Optimal crop geometry is crucial in such systems for efficient resource use. A field experiment was conducted during the zaid season of 2022 at the College of Post Graduate Studies in Agricultural Sciences (CPGS-AS) experimental farm, (Central Agricultural University, Imphal), Umiam, to evaluate the effect of different planting arrangements of baby corn (*Zea mays* L.) and green gram (*Vigna radiata* L.) on growth, yield and post-harvest soil fertility under North Eastern Hill (NEH) conditions. The study followed a randomised block design (RBD) with 8 treatments: sole baby corn (T1), sole green gram (T2), 1:1 additive series (T3), 1:1 replacement series (T4), 1:2 additive series (T5), 2:2 paired row planting (T6), 2:2 additive series (T7) and 3:3 strip planting (T8), each replicated thrice. Planting patterns significantly influenced growth, physiological traits, yield components, grain and stover yields and harvest index. Among treatments, 3:3 strip planting (T8) was the most productive and resource-efficient, with superior competition indices and biological efficiency. While sole green gram (T2) enhanced residual soil fertility the most, T3 and T5 intercropping systems were comparable. The 3:3 strip arrangement also offered the highest economic returns and resource-use efficiency, suggesting it as a suitable strategy for summer cultivation in Meghalaya, where land often remains fallow during this season.

Keywords: biological efficiency; intercropping; productivity; spatial arrangement

Introduction

Baby corn is harvested at an immature stage within two days of silk emergence and before pollination and is characterised by its small, tender and de-husked ears (1). Ideal market-preferred ears are light yellow in colour, measure 10 to 12 cm in length and have a diameter of 1.0 to 1.5 cm, with well-arranged kernel rows. From a nutritional standpoint, baby corn is a valuable vegetable, rich in essential nutrients including carbohydrates, protein, fat, sugars, vitamins and minerals. It is especially notable for its high phosphorus (P) content, providing approximately 86 mg per 100 g of the edible portion significantly higher than the 21–57 mg found in many other vegetables (2). Pulses play a vital role in the national diet, serving as an affordable and readily available source of high-quality protein, particularly important in predominantly vegetarian populations.

They are also a key component of sustainable agricultural systems, owing to their ability to fix atmospheric nitrogen, deep root systems and significant contribution to soil organic matter through leaf litter (3).

Among the various pulse crops, green gram (*Vigna radiata* L.) holds particular importance. It thrives well under hot and dry summer conditions and is regarded as one of the most resilient and adaptable pulse crops (4). Cereal-legume intercropping systems offer greater stability compared to monocropping of staples like rice, wheat and maize, particularly in terms of enhancing soil fertility, improving crop yields and providing better economic returns. These systems also help mitigate the risks associated with relying on a single crop (5). One of the key advantages of intercropping cereals with legumes is the increased total biomass production, attributed

to more efficient dry matter partitioning. While cereals tend to be heavy feeders that primarily extract nutrients from the upper soil layers, legumes contribute positively by fixing atmospheric nitrogen (N) and thereby enriching soil fertility, which also reduces intra-crop competition for limited soil nutrients (6).

Crop geometry refers to the spatial arrangement of plants within a field, which plays a crucial role in optimising resource use and maximising the interception of solar radiation. Proper crop geometry enhances photosynthetic efficiency, leading to better growth and higher yields. In intercropping systems, the spatial configuration of component crops is a critical management practice that can significantly influence light interception and overall productivity (7). The growth performance, yield attributes and final yields of such systems largely depend on the way crops are spatially arranged (8).

Given the importance of crop layout, it is vital to determine the optimal crop geometry for baby corn, particularly when intercropped with green gram. However, limited research has been conducted on how different planting patterns of baby corn intercropped with green gram influence crop performance and postharvest soil fertility, especially under the specific agro-climatic conditions of the Northeastern Hill (NEH) region during the summer season. Despite several studies on intercropping, limited information is available on how different intercropping geometries compare with sole cropping systems in terms of overall system productivity and efficiency under NEH conditions. The NEH region is characterised by unique agro-climatic conditions, fragile ecosystems and low-input farming practices, necessitating location-specific optimisation of cropping systems.

The present study was undertaken to evaluate the growth performance, yield attributes and intercropping efficiency of baby corn (*Zea mays* L.) and green gram (*V. radiata*) under different planting geometries. Intercropping systems, particularly those involving cereals and legumes, are known to enhance resource use efficiency, improve soil fertility and increase productivity compared to monocropping. The study also aimed to determine the effects of various spatial arrangements on the growth behaviour of both component crops and to assess the resulting changes in soil fertility status after harvest. This holistic approach offers valuable insights into optimising cereal-legume intercropping systems for enhanced

productivity, efficient land use and sustainable soil health management, particularly under the agro-climatic conditions of the NEH region.

Material and Methods

Experimental area

An experiment was carried out during the summer season of 2022 at the experimental farm of the College of Post-Graduate Studies in Agricultural Sciences, Umiam, Ri-Bhoi district, Meghalaya. The site is geographically located between 91°18' to 92°18' E longitude and 25°40' to 26°20' N latitude, at an elevation of approximately 950 m above mean sea level. The region experiences a subtropical humid climate, characterised by high rainfall and cool winters. The monsoon typically commences in the first fortnight of June and continues until the end of September, with a gradual decline in precipitation beginning in late September and complete withdrawal by early October. During the cropping period, the average weekly maximum and minimum temperatures were recorded at 26.05 °C and 16.33 °C, respectively. The average relative humidity throughout the growing season was 86.78 %, indicating a highly humid environment. The total rainfall received during the crop duration amounted to 232.52 cm, ensuring adequate moisture availability for crop growth (Fig. 1).

Experimental layout

The experimental field was prepared following standard agronomic practices recommended for the cultivation of baby corn (*Z. mays*) and green gram (*V. radiata*). The experiment was conducted using a randomised block design (RBD) comprising 8 treatments, each replicated three times. The treatments included: sole cropping of baby corn (T1), sole cropping of green gram (T2), baby corn + green gram in a 1:1 additive series (T3), baby corn + green gram in a 1:1 replacement series (T4), baby corn + green gram in a 1:2 additive series (T5), paired row planting of baby corn + green gram in a 2:2 pattern (T6), baby corn + green gram in a 2:2 additive series (T7) and strip intercropping of baby corn + green gram in a 3:3 pattern (T8). This layout was designed to evaluate the influence of different spatial arrangements and intercropping strategies on crop performance and system productivity (Supplementary Fig. 1).

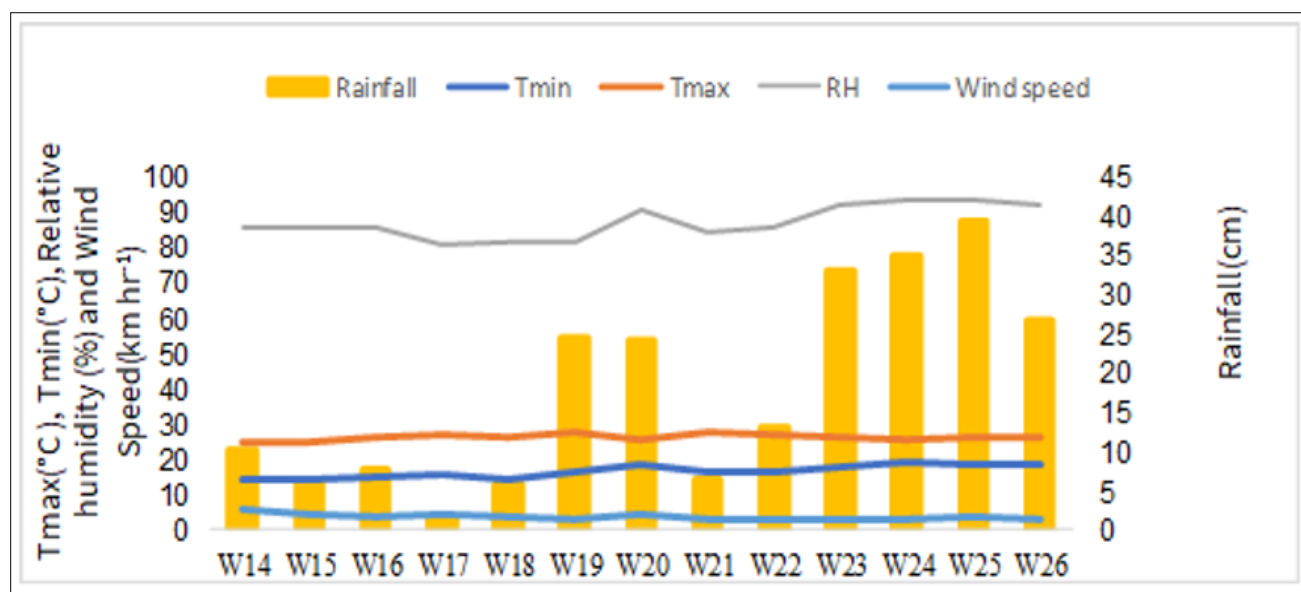


Fig. 1. Weather parameters meteorological week Influencing crop growth period April to June 2022.

Crop establishment practices

Healthy, bold and disease-free seeds of both crops were used for sowing. The crops were sown on 2 April 2022 under suitable soil moisture conditions. Baby corn was sown by the line sowing method at a depth of approximately 5 cm. In sole cropping, a spacing of 50 × 25 cm (row × plant spacing) was maintained. The recommended seed rate of baby corn was 15 kg ha⁻¹. In intercropping treatments, the spacing and plant population were adjusted according to the respective treatment geometry. In additive series treatments, the full seed rate of baby corn was maintained, whereas in replacement series treatments, the seed rate was proportionately reduced based on the crop proportion.

Green gram was also sown by the line sowing method at a depth of 3–5 cm. In sole cropping, a spacing of 20 × 10 cm (row × plant spacing) was maintained with a seed rate of 20 kg ha⁻¹. In intercropping systems, the seed rate and plant population of green gram were adjusted according to whether the treatment followed additive or replacement principles. In additive series, the full recommended seed rate was retained in addition to baby corn, while in replacement series treatments, it was proportionately reduced (Supplementary Fig. 2).

Data collection and analysis

For each experimental plot, five representative plants were randomly selected excluding the border rows and tagged for consistent data collection. Observations on growth and yield attributes were recorded from these tagged plants. Growth parameters were measured at 20, 40 and 60 days after sowing (DAS), while yield attributes were assessed at 60 DAS and at harvest.

At harvest, both plant and grain samples were collected from each plot, oven-dried at 65 °C to a constant weight and finely ground using a mechanical grinder. The ground samples were then subjected to nutrient analysis to determine the concentrations of N, P and potassium (K) using standard laboratory protocols. Nitrogen content was estimated using the Kjeldahl digestion method, while P was determined by the vanado-molybdo phosphoric yellow colour method. Potassium content was measured using a flame photometer. All analytical procedures followed the methods described by Jackson (9).

In addition, postharvest soil samples were collected from each treatment plot to evaluate residual soil fertility. The available N, P and K in the soil were analysed using the previously described methods (Table 1) and results were expressed in kg ha⁻¹. This allowed assessment of nutrient depletion or enrichment across different intercropping treatments.

Statistical analysis

All collected data were subjected to statistical analysis using the analysis of variance (ANOVA) technique as per the method described by Gomez and Gomez (10). The level of significance for 'F' and 't' tests was set at $p = 0.05$. Where treatment differences were found to be significant, the critical difference (CD) was computed for mean comparison. Duncan's multiple range test (DMRT) was employed for post-hoc mean separation and correlation analyses were conducted to examine relationships among growth, yield and soil fertility parameters using IBM SPSS Statistics version 23.

Results and Discussion

Growth parameters

Plant height, leaf area, leaf area index (LAI) and dry matter accumulation were significantly influenced by planting patterns (Fig. 2).

Plant height

Different planting patterns in the intercropping system significantly influenced plant height across all growth stages. The 1:1 additive series intercropping (T3) recorded the tallest plants for both baby corn and green gram throughout the crop growth period, whereas the shortest plants were consistently observed under sole cropping treatments. This indicates a positive interaction between component crops in the T3 arrangement, possibly due to enhanced resource utilisation and reduced intraspecific competition.

Planting geometry created a more favourable growth environment for both component crops. Increased legume presence likely enhanced N availability in the rhizosphere through biological N fixation, indirectly benefiting the associated millets under the rainfed, low-input conditions prevailing in the NEH region (11, 12). Improved nitrogen nutrition is known to stimulate cell division and internodal elongation, which is reflected in increased plant height. Similar improvements in cereal growth under additive millet-legume intercropping systems have been reported earlier from eastern and north-eastern India (13, 14).

Leaf area

Significant variations in leaf area were observed among the different planting patterns. Sole cropping treatments T1 (sole baby corn) and T2 (sole green gram) consistently produced the highest leaf area at all recorded growth stages. In contrast, the lowest leaf area was recorded in the 1:2 additive series (T5) and the 1:1 additive series (T3), suggesting possible competition for light, nutrients and space under intercropping conditions, particularly in denser additive systems. These findings align with earlier reports that well-planned spatial designs in cereal-legume intercropping systems enhance ecological efficiency by minimising direct competition and maximising complementary resource use (15, 16).

Table 1. Physical and chemical properties of experimental soil

Soil properties	Value	Methods	Reference
1. Soil physical properties			
Coarse sand (%)	2.20	Buoyoucos Hydrometer Method	(10)
Fine sand (%)	6.90		
Silt (%)	15.66		
Clay (%)	21.00		
2. Soil chemical properties			
Available N (kg ha ⁻¹)	190.21	Modified alkaline permanganate	(11)
Available P ₂ O ₅ (kg ha ⁻¹)	13.49	Brays method (0.025 N HCl)	(12)
Available K ₂ O (kg ha ⁻¹)	190.43	1 N NH ₄ OAc extract	(13)
Organic carbon (%)	0.90	Dichromate Wet Oxidation	(14)
Soil pH	5.13	Potentiometry	(15)

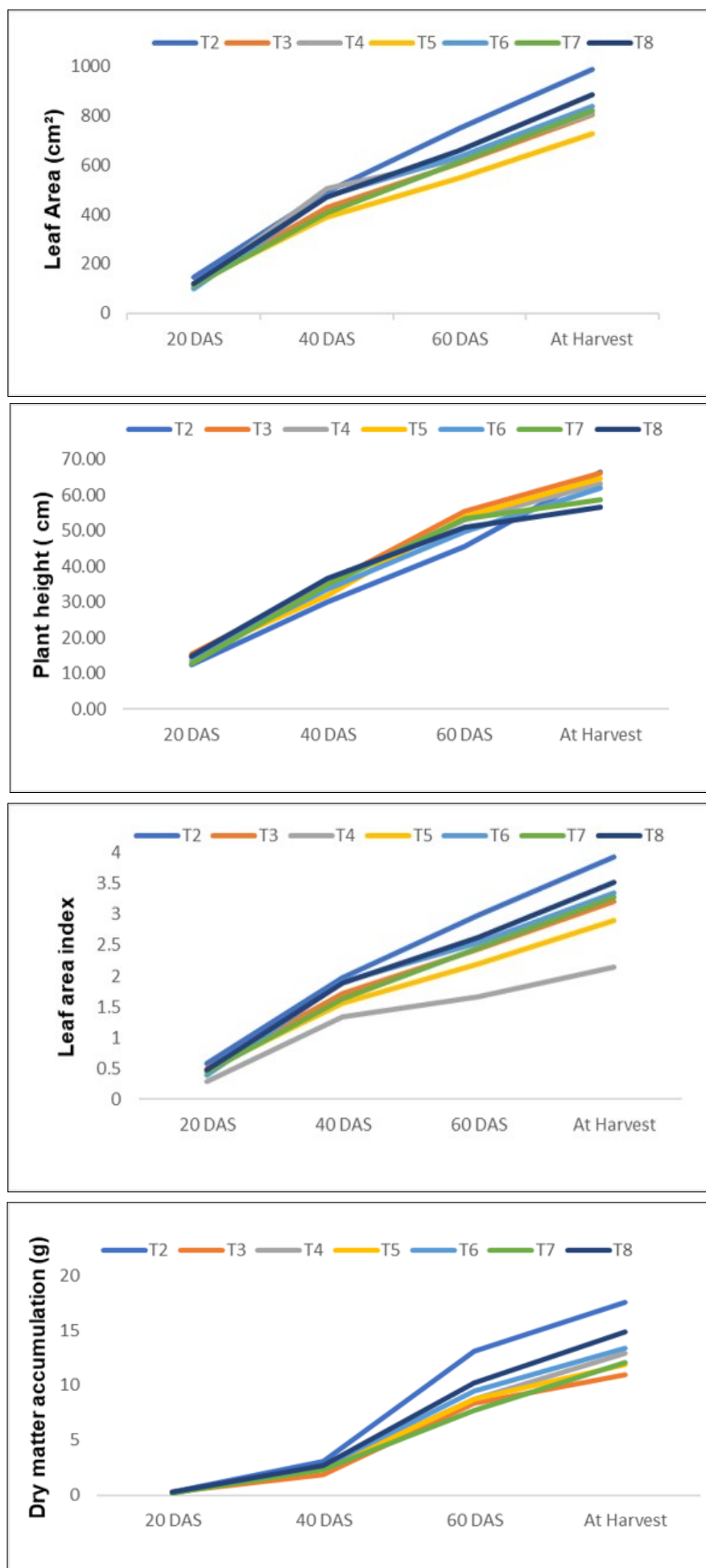


Fig. 2. Crop growth parameters as influenced by different planting patterns in baby corn + green gram intercropping system.

Leaf area index

The LAI followed a trend like that of leaf area. The highest LAI values for both baby corn and green gram were recorded under sole cropping (T1 and T2, respectively) across all growth stages. Among the intercropping treatments, the lowest LAI for green gram was found in the 1:1 replacement series (T4), while baby corn exhibited the lowest LAI in the T3 and T5 additive series treatments. These findings imply that sole cropping provided optimal canopy development, whereas intercropping treatments, particularly additive systems, may have caused mutual shading, reducing effective leaf area exposure.

The results revealed that planting geometry significantly influenced the growth parameters of baby corn and green gram. The tallest plants recorded under the 1:1 additive series may not necessarily indicate superior growth performance, as this treatment exhibited comparatively lower leaf area and LAI. This suggests that the increased plant height could be attributed to shade-induced elongation (etiolation) under intensified interspecific competition for light, rather than enhanced biomass production. In contrast, treatments with relatively higher leaf area and LAI reflected better canopy development and photosynthetic surface, which are more reliable indicators of growth efficiency. The presence of legumes likely contributed to a denser but well-structured canopy, improving light penetration and utilisation. Similar improvements in LAI under cereal-legume intercropping have been reported by previous researchers (7, 13, 17).

Earlier interpretations related to enhanced resource-use efficiency and nitrogen fixation in intercropping systems have been reconsidered. While cereal-legume associations are generally known to improve nutrient dynamics and system efficiency, the present study did not include direct measurements of physiological traits or soil nutrient status to substantiate these mechanisms. Therefore, such explanations should be viewed as potential or theoretical advantages supported by existing literature rather than definitive outcomes of this experiment. Overall, the findings highlight the importance of spatial arrangement in influencing crop growth, while also indicating the need for further investigation involving detailed physiological assessments (e.g., light interception, photosynthetic rate) and soil nutrient analysis to better understand the underlying mechanisms governing intercropping performance.

Dry matter accumulation

Dry matter accumulation varied significantly among the different planting arrangements. The sole cropping of green gram (T2) resulted in the highest dry matter production across all growth stages. Notably, the 3:3 strip intercropping (T8) did not differ significantly from T2, indicating its effectiveness in maintaining biomass accumulation under intercropping conditions. In baby corn, dry matter accumulation was highest under sole cropping (T1) and exhibited a progressive increase with crop age in all treatments. The maximum accumulation was recorded at harvest, highlighting the cumulative growth response to favourable planting conditions in both sole and efficient intercropping patterns.

To assess the growth performance of baby corn and green gram, key parameters including plant height, leaf area, LAI and dry matter accumulation were recorded at various growth stages. The analysis revealed significant differences in most growth attributes of both crops across the observation intervals, except plant height at 20 days after sowing (DAS), which showed no significant variation.

Notably, sole cropping of both baby corn and green gram, as well as the 3:3 strip intercropping system, exhibited markedly higher values for leaf area, LAI and dry matter accumulation compared to the 1:1 additive series intercropping treatment. This may be attributed to the optimal spacing available in sole cropping, which reduces competition for light and nutrients and provides better access to natural resources such as aeration, solar radiation and optimal humidity. Additionally, in the 3:3 strip planting of baby corn, the nitrogen-fixing effect of legumes may have contributed to a higher net assimilation rate. This trend aligns with the findings reported by previous researchers, who also observed similar results (18). These findings align well with earlier reports highlighting the role of spatial complementarity in improving biomass accumulation in intercropping systems (11, 12).

Physiological parameters

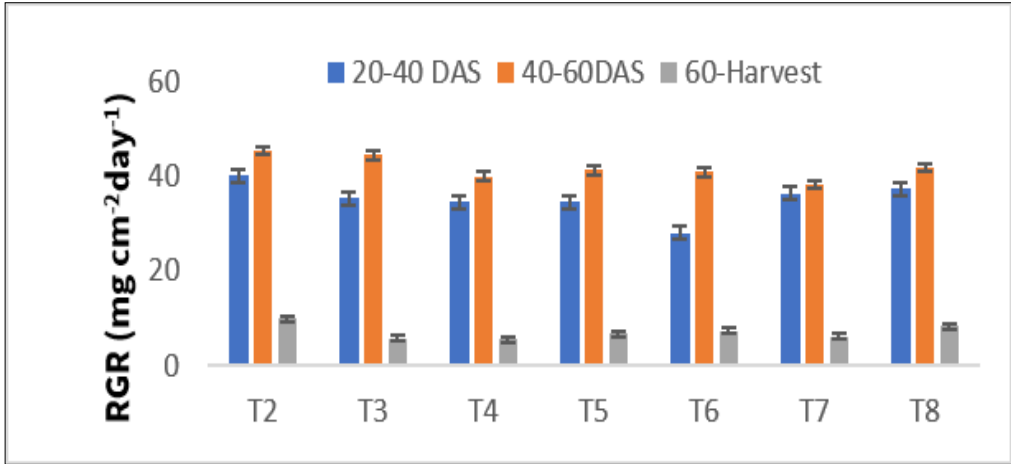
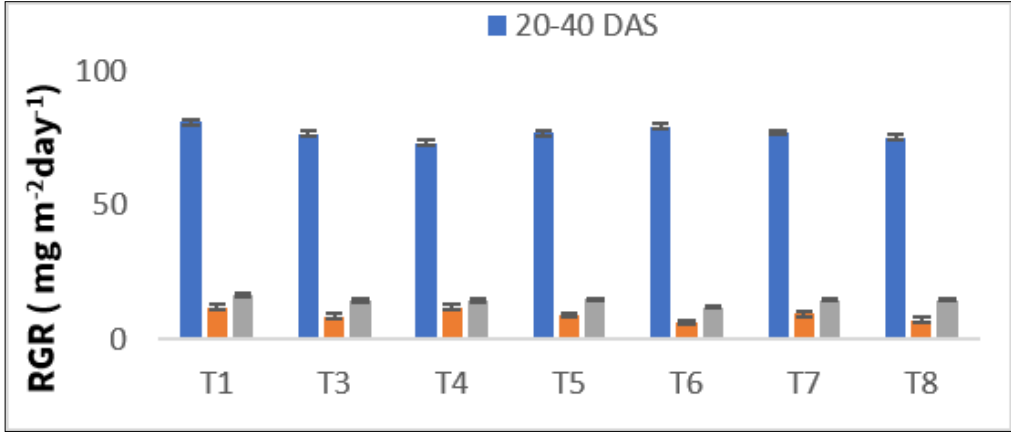
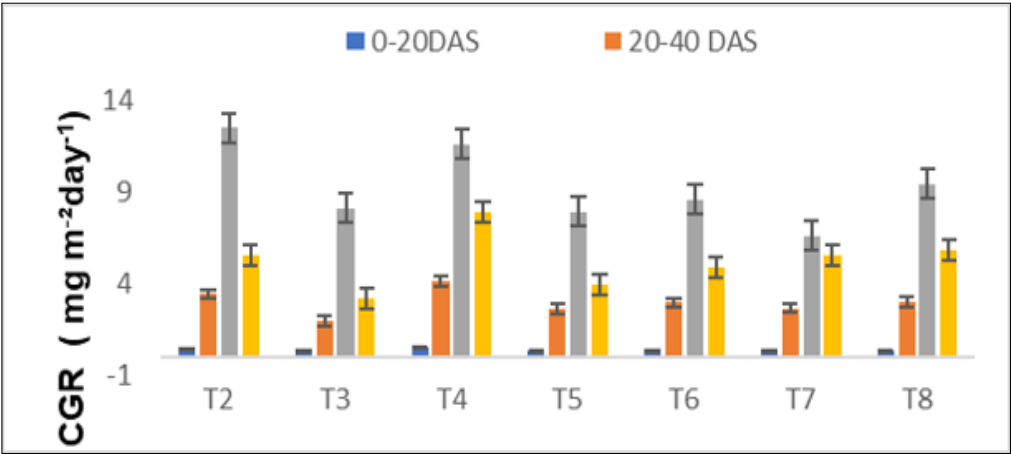
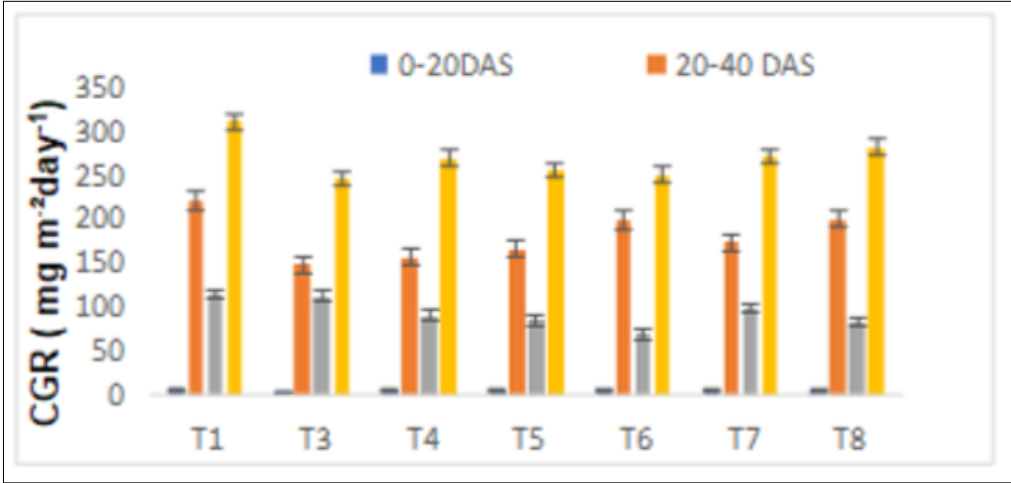
Physiological parameters were significantly influenced by planting patterns (Fig. 3).

Crop growth rate

The crop growth rate (CGR) of both baby corn and green gram was significantly influenced by planting pattern. Sole cropping of baby corn (T1) recorded the highest CGR across all growth stages, reflecting enhanced resource utilisation and biomass accumulation in the absence of interspecific competition. However, the 3:3 strip intercropping pattern (T8) produced CGR values statistically comparable to T1, indicating that this spatial arrangement effectively reduces competitive stress and supports balanced growth under intercropping. In the case of green gram, the highest CGR was observed under the 1:1 replacement series (T4) during the early growth stages (up to 60 DAS), while during the later stages (60 DAS to harvest), CGR under T4 was statistically similar to sole cropping (T2). This suggests that green gram performs efficiently under moderate competition in the replacement series, particularly during its initial growth period. This indicates that green gram maintained satisfactory biomass accumulation under the replacement series without showing a consistent growth disadvantage relative to sole cropping. Since environmental variables such as light interception, canopy temperature, or radiation-use efficiency were not directly measured in the present study, the differences in CGR are interpreted strictly based on biomass accumulation patterns under varying spatial arrangements rather than specific physiological mechanisms. This effect is particularly important under the rainfed, low-input conditions of the NEH region, where soil nitrogen is often a limiting factor (11, 12).

Relative growth rate

Relative growth rate (RGR) exhibited a crop-specific and time-specific pattern. Baby corn recorded the maximum RGR during the 0–20 DAS interval under sole cropping (T1), highlighting rapid early-stage growth when grown without interspecific interference. In contrast, green gram attained its peak RGR during the 40–60 DAS period under sole cropping (T2), reflecting its vegetative vigour during the mid-growth phase. These results indicate that both crops achieve their highest physiological growth efficiency in the absence of intercropping competition. The variation in RGR among treatments may be attributed to differences in plant population density and spatial distribution; however, no direct physiological measurements were made to determine the exact cause of these differences. This confirms that spatial arrangement plays a critical role in optimising growth efficiency in intercropping systems (19).



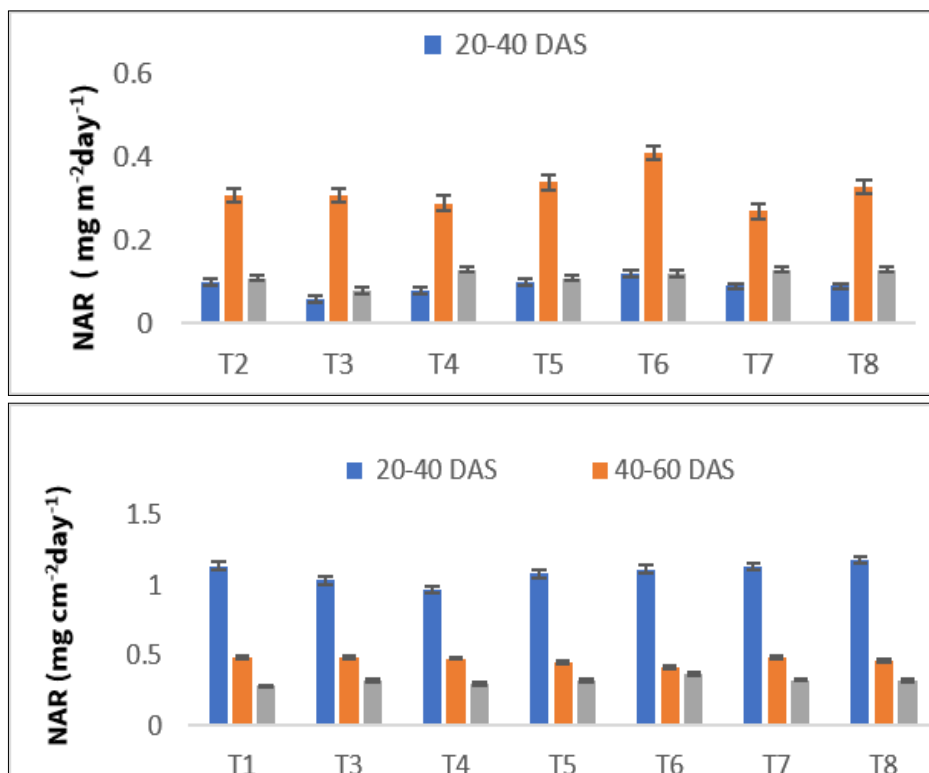


Fig. 3. Physiological parameters as influenced by different planting patterns in baby corn + green gram intercropping system.

Net assimilation rate

Net assimilation rate (NAR) varied significantly across treatments and crop stages. For green gram, intercropping had a marked influence during the 20–40 and 40–60 DAS periods, with reductions observed in additive and replacement series due to competitive stress. For baby corn, the highest NAR values were observed during the 60 DAS to harvest stage under sole cropping and the 2:2 paired row planting patterns (T7), which provided sufficient spacing and light interception. Similarly, green gram also recorded higher NAR values during the 20–40 DAS period under the 2:2 paired row planting, suggesting that this planting geometry effectively balanced intra- and interspecific competition to favour assimilation efficiency in both crops.

In the case of green gram, the highest CGR was observed in the 1:1 replacement series (T4) during most growth intervals, except between 60 DAS and harvest, where it was comparable to the sole cropping treatment. This suggests that balanced spatial distribution in the replacement series provided favourable growth conditions for green gram during the early and mid-vegetative stages. The RGR patterns also followed a similar trend. For baby corn, the maximum RGR was observed during the 0–20 DAS interval under sole cropping, followed by a gradual decline as the crop progressed toward maturity a typical growth pattern due to the shift from vegetative to reproductive development. In contrast, green gram exhibited its highest RGR during the 40–60 DAS period under sole cropping, likely reflecting peak vegetative expansion before pod development. The NAR, which reflects the efficiency of photosynthate production per unit leaf area, peaked for baby corn between 60 DAS and harvest and for green gram between 20–40 DAS. Notably, the 2:2 paired row intercropping arrangement recorded the highest NAR values for both crops. This may be attributed to the favourable light interception and canopy structure in this arrangement, which enhanced photosynthetic activity. However, at later growth stages, increased leaf area may have contributed to reduced NAR due to mutual shading and declining photosynthetic efficiency, as

previously reported by earlier researchers (20). These findings corroborate earlier reports that additive intercropping improves light-use efficiency and photosynthetic performance by optimising canopy stratification (13, 14).

The growth analysis in terms of CGR, RGR and NAR was significantly influenced by different planting geometries. Higher values of these parameters observed under certain intercropping systems may indicate more efficient utilisation of available resources compared to other treatments. However, the earlier attribution of these improvements to reduced interspecific competition and enhanced light interception has been reconsidered. In the absence of direct measurements of light availability, canopy structure, or radiation use efficiency, such explanations cannot be conclusively established.

Therefore, the observed variations in CGR, RGR and NAR among treatments should be interpreted as treatment effects arising from differences in spatial arrangement and crop interactions, rather than definitive evidence of improved physiological efficiency. While similar trends have been reported in cereal-legume intercropping systems in previous studies, the underlying mechanisms in the present experiment remain inferred rather than empirically validated. These findings underscore the importance of planting geometry in influencing crop growth dynamics, while also highlighting the need for future studies incorporating microclimatic observations and physiological measurements, such as light interception, canopy architecture and radiation use efficiency, to better elucidate the mechanisms driving these responses.

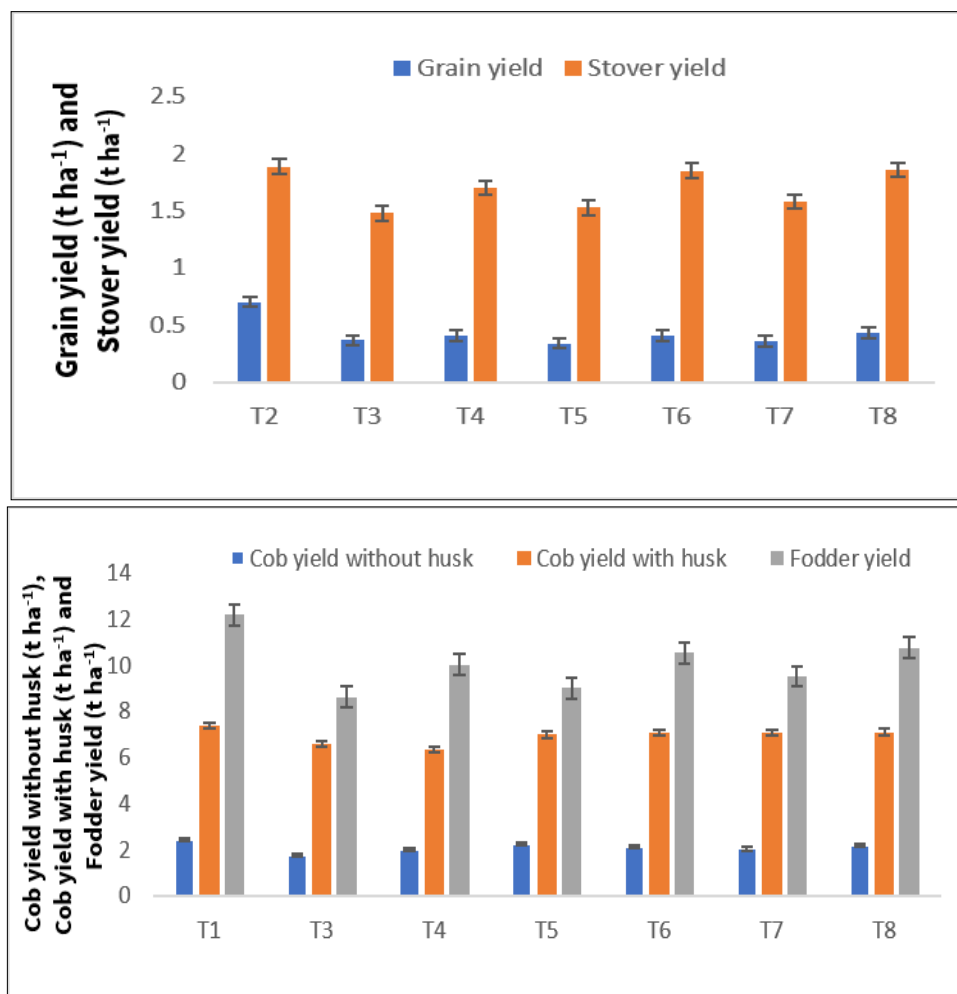
Yield performance

Yield performance was significantly affected by different planting patterns (Fig. 4, Table 2). Sole planting of baby corn recorded the highest cob yield, which was statistically at par with the 3:3 strip intercropping system but significantly superior to the 1:1 additive series intercropping. The sole baby corn planting yielded 46.32 % higher cob yield compared to the 1:1 additive intercropping system.

Table 2. Yield (t ha^{-1}) of baby corn and green gram as influenced by different planting patterns in baby corn + green gram intercropping system

Treatments	Cob yield without husk	Cob yield with husk	Fodder yield	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
T1	2.59a	7.38a	29.50a				
T2				0.70a	1.88a	2.59a	27.15a
T3	1.77c	6.61bc	20.89c	0.37b	1.48c	1.84c	20.15b
T4	2.00bc	6.36c	24.2bc	0.41b	1.70abc	2.11bc	19.26b
T5	2.19b	6.9abc	21.8bc	0.34b	1.53bc	1.87c	18.22b
T6	2.13bc	7.08ab	25.5ab	0.40b	1.85ab	2.25b	17.98b
T7	2.06bc	7.07ab	23.0bc	0.36b	1.58abc	1.94c	18.82b
T8	2.25ab	7.12ab	26.0ab	0.43b	1.86a	2.49ab	18.81b
SE(m) $\pm$	0.02	0.20	1.27	0.03	0.10	0.09	1.76
LSD ($p = 0.05$)	0.08	0.60	3.93	0.10	0.30	0.29	5.42

LER: land equivalent ratio; LEC: land equivalent coefficient; ATER: area time equivalent ratio; MAI: monetary advantage index; SE(m) $\pm$: standard error of mean; LSD: least significant difference. - indicates not applicable.

**Fig. 4.** Yield as influenced by different planting patterns in baby corn + green gram intercropping system.

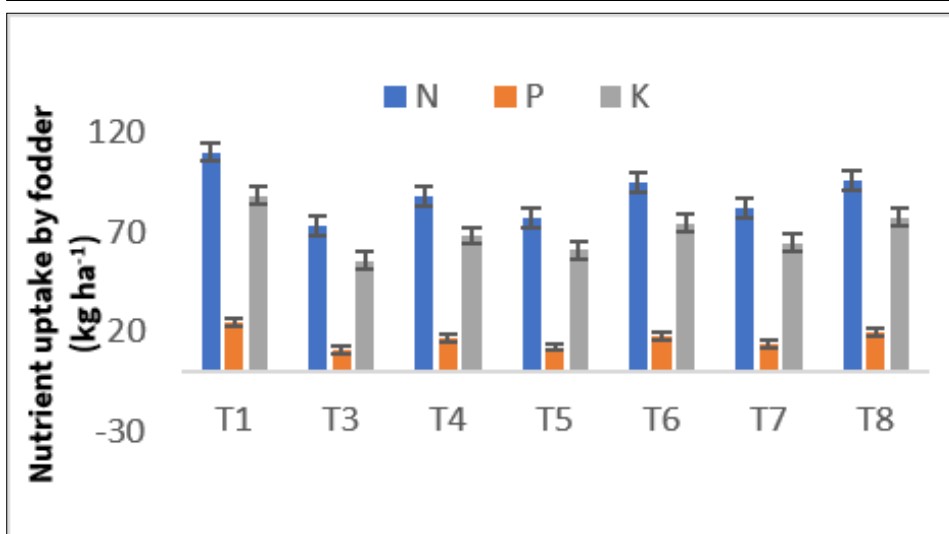
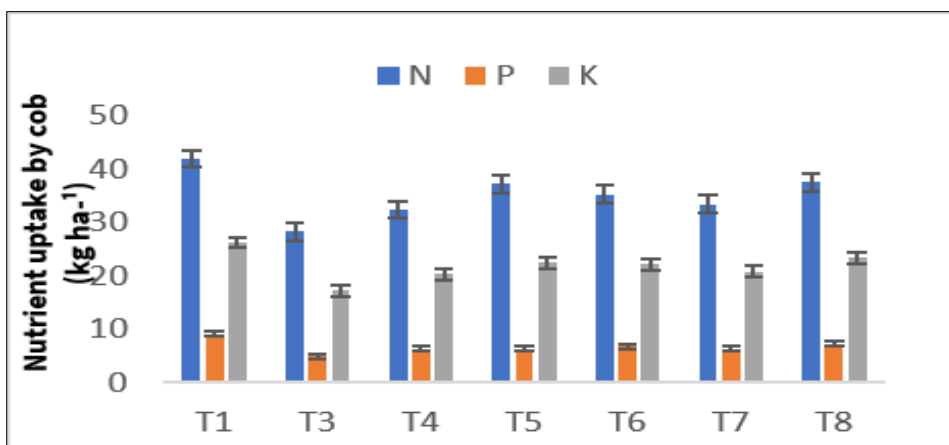
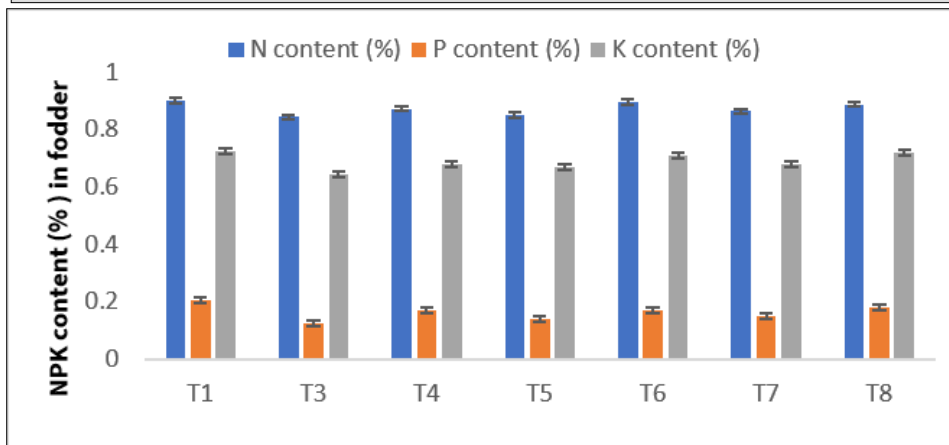
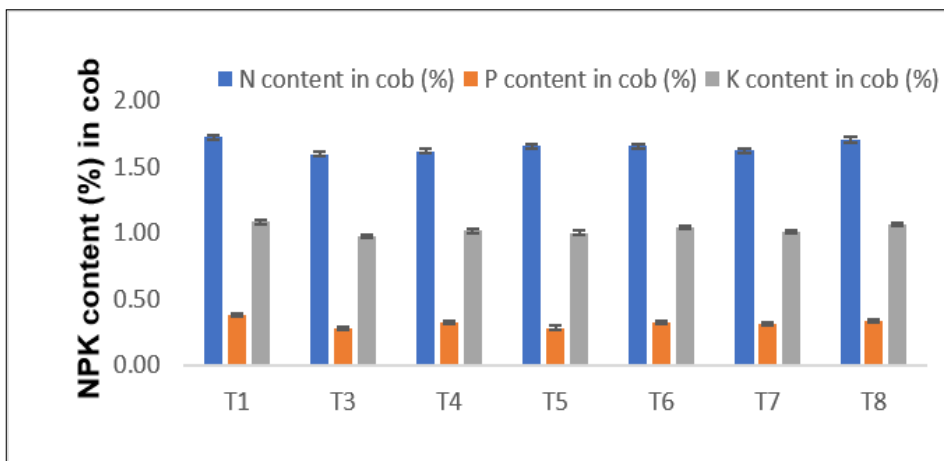
In the case of green gram, sole cropping also resulted in markedly higher yields, recording an 89.18 % increase over the 1:1 baby corn + green gram intercropping and a 75 % increase compared to the 2:2 paired row planting system.

These results suggest that interspecific competition in intercropping systems can limit yield potential, particularly when spatial arrangements are not optimised for legume performance. The findings of the present study are consistent with earlier reports by previous researchers, which also highlighted the yield advantages of sole cropping over certain intercropping configurations (21, 22). The wider row spacing of maize in the present study provided sufficient inter-row space for the accommodation of leguminous intercrops, thereby facilitating efficient utilisation of both above- and below-ground resources. In cereal-legume intercropping systems, yield advantages are often attributed to the superior competitive

ability and stable yield performance of the cereal component, which compensates for any reduction in legume yield under intercropped conditions (14). Similar trends were evident in the present experiment, where millet performance played a key role in determining overall system productivity.

Nutrient status of crops

No significant differences were observed in the N, P and K content of the cob and fodder among the various intercropping treatments were affected by different planting patterns (Fig. 5 and 6). However, sole planting of baby corn recorded the highest N, P and K concentrations in the cob, along with the maximum nutrient uptake by both cob and fodder, followed closely by the 3:3 strip intercropping system. Similarly, sole cropping of green gram resulted in the highest N, P and K uptake by the plant, while the



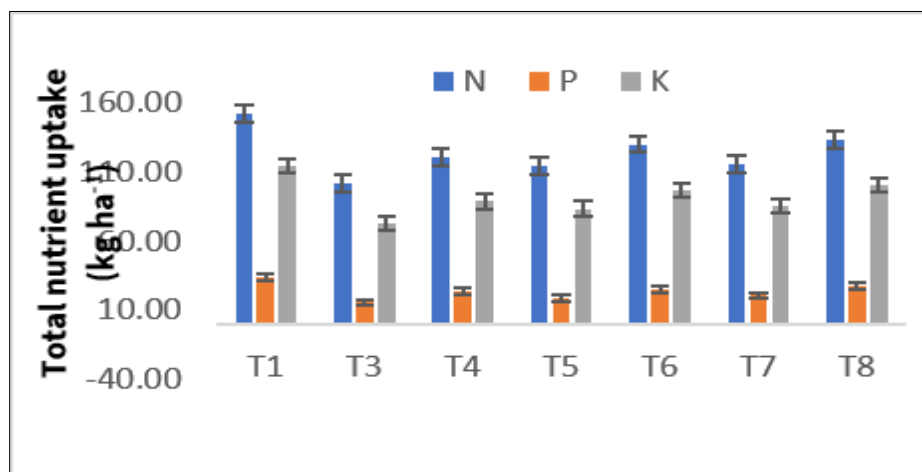
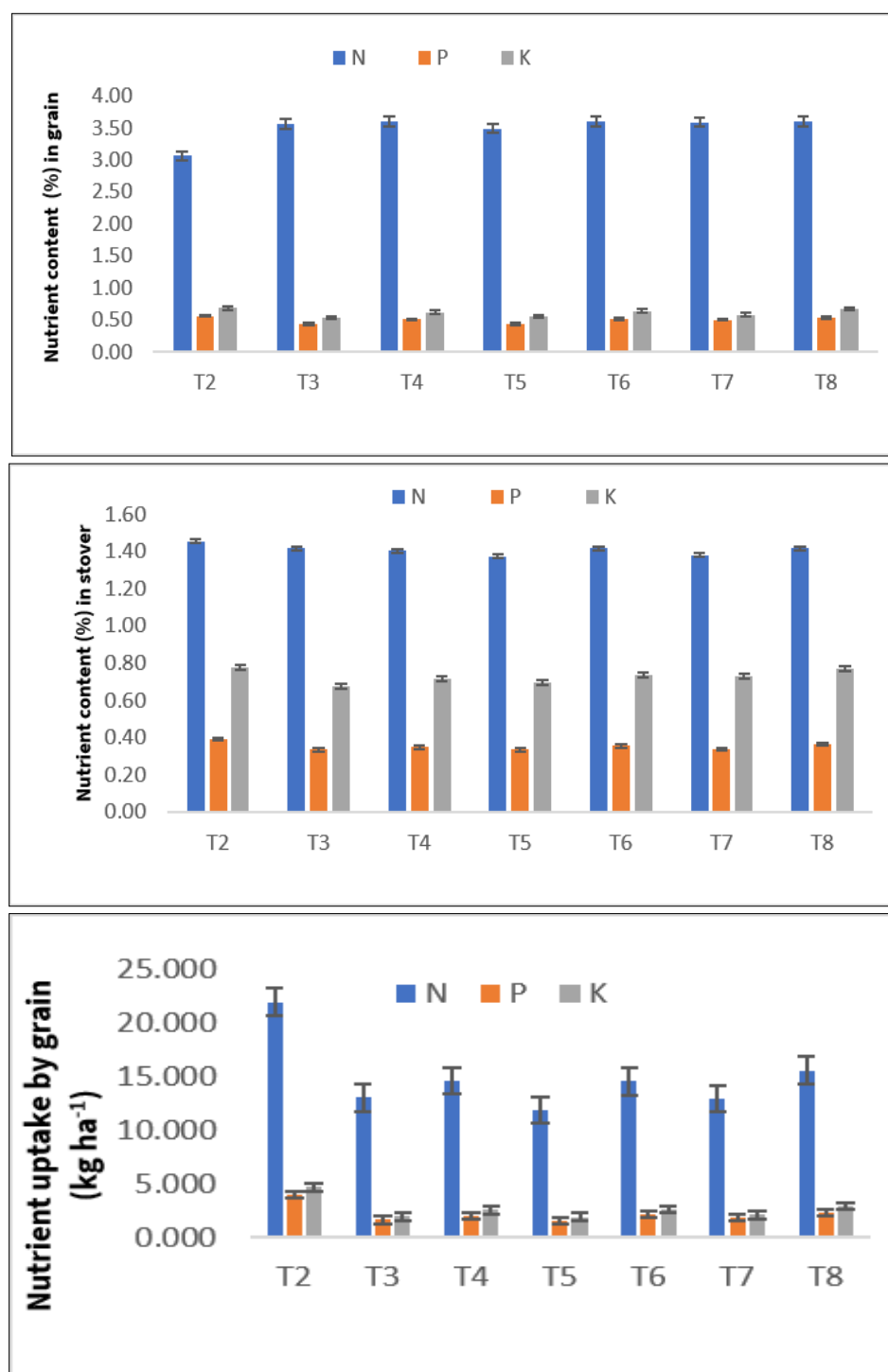


Fig. 5. Nitrogen, phosphorus and potassium (NPK) content and uptake by baby corn as influenced by different planting patterns in baby corn + green gram intercropping system.



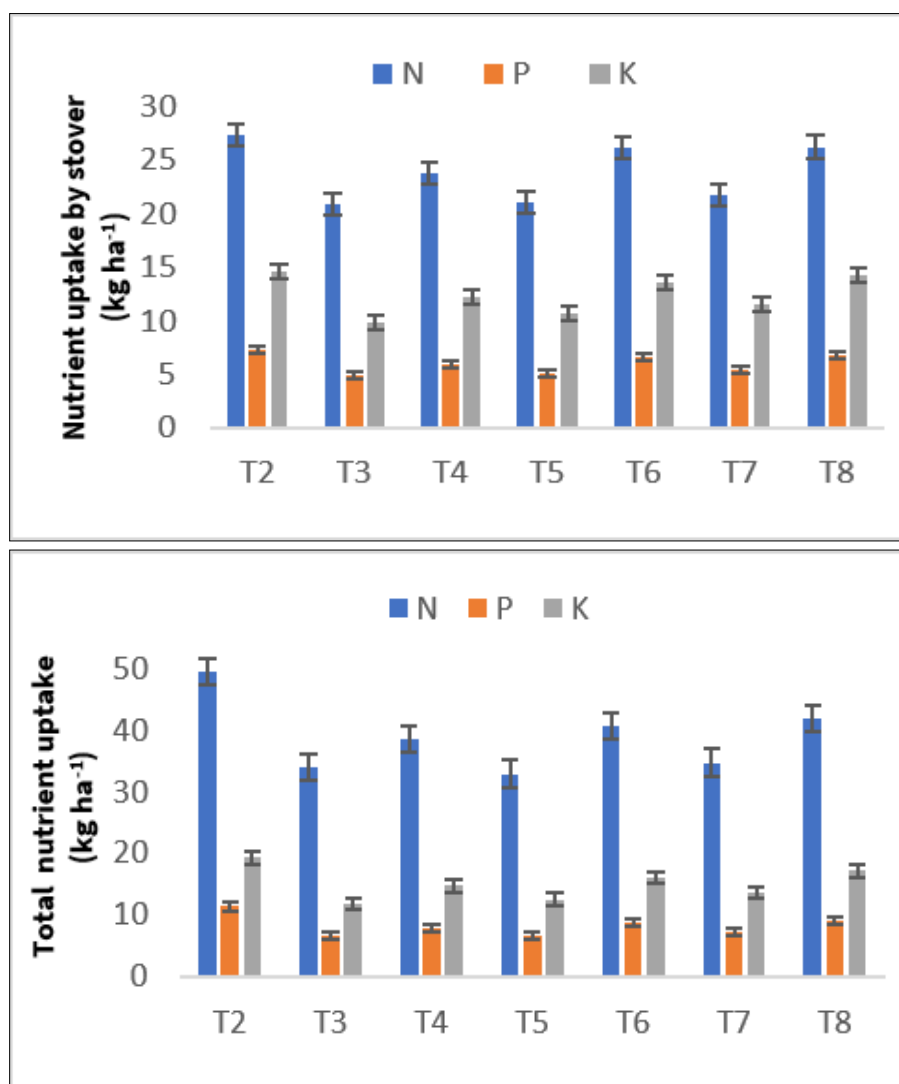


Fig. 6. Nitrogen, phosphorus and potassium (NPK) content and uptake by green gram as influenced by different planting patterns in the baby corn + green gram intercropping system.

lowest nutrient uptake was observed under the 1:2 additive intercropping series, indicating reduced nutrient acquisition due to increased interspecific competition.

The nutrient content (N, P and K) of green gram did not differ significantly among the various planting geometries, indicating that nutrient concentration in plant tissues remained relatively stable across treatments. However, total nutrient uptake exhibited noticeable variation among treatments. This difference in uptake can be primarily attributed to variations in biomass production rather than changes in nutrient concentration *per se*. Treatments that produced higher biomass accumulated greater total amounts of nutrients, resulting in increased uptake values. Thus, the enhanced nutrient uptake observed under certain intercropping systems should be interpreted because of improved crop growth and yield performance rather than a direct effect on nutrient concentration. These findings highlight the importance of distinguishing between nutrient content and total uptake when evaluating nutrient dynamics in intercropping systems. Such stability in nutrient content has been widely reported in cereal-legume intercropping systems, where variations in cropping pattern often alter biomass and yield rather than the elemental composition of plant tissues (13, 17).

Soil chemical parameters after harvest

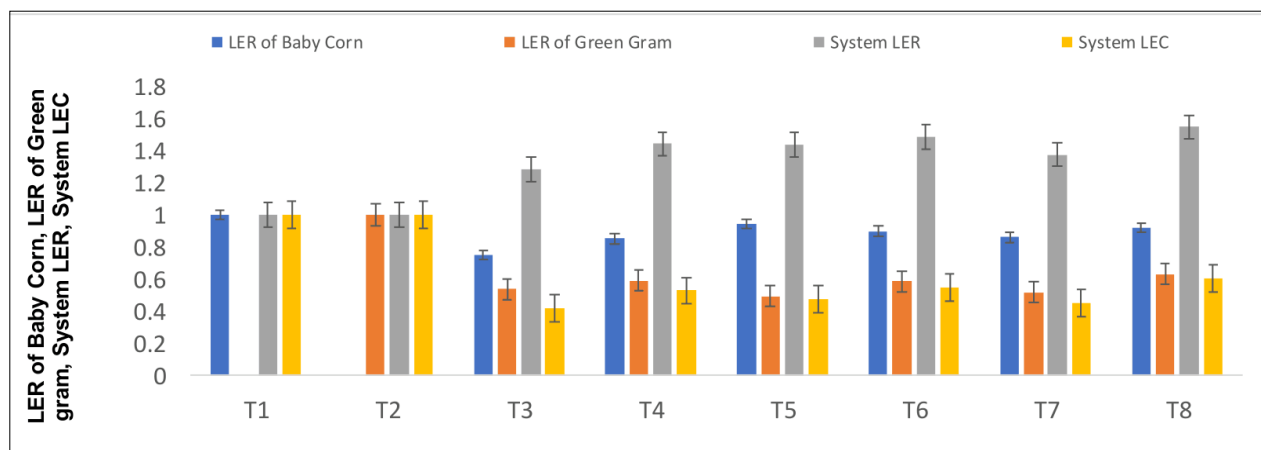
Soil chemical parameters after harvest were significantly affected by different planting patterns (Fig. 7, Table 3). Soil pH remained relatively stable across all planting patterns following harvest. The highest pH was recorded under sole baby corn cropping (5.14), while lower pH values were observed in the sole green gram, 1:2 additive series and 2:2 paired row planting treatments. In contrast, significant differences were noted in soil organic carbon content, with the sole green gram treatment recording the highest value (0.94 %), indicating its beneficial effect on soil organic matter. Furthermore, planting patterns that included green gram enhanced the availability of soil nitrogen, phosphorus and potassium, with sole green gram cropping yielding the highest available NPK levels, while sole baby corn cropping recorded the lowest. This highlights the soil-enriching effect of legume inclusion in intercropping systems.

Nutrient content (N, P, K) in cob and fodder did not differ significantly among intercropping treatments; however, total uptake was maximum in sole baby corn, followed by T8. Similarly, green gram recorded maximum N, P and K uptake under sole cropping, while the lowest was in dense additive systems. Previous studies also observed higher nutrient uptake in sole maize compared to maize-legume intercropping (23, 24).

Table 3. Soil attributes after harvest as influenced by different planting patterns in baby corn + green gram intercropping system

Treatments Table	Soil pH	SOC (%)	N (kg ha ⁻¹)	P (kg ha ⁻¹)	K (kg ha ⁻¹)
T1	5.14	0.88c	184.82c	12.57c	176.73c
T2	4.94	0.94a	225.18a	17.10a	218.62a
T3	5.07	0.91abc	217.53a	15.94ab	195.96abc
T4	5.10	0.90bc	192.88bc	14.97ab	189.31bc
T5	4.94	1.01abc	220.31a	16.45ab	214.62ab
T6	5.07	0.96abc	206.17ab	15.59ab	193.09abc
T7	4.97	0.91bc	193.08bc	15.07ab	191.10bc
T8	5.13	0.90bc	196.22bc	13.31bc	189.26bc
SE(m) ±	0.11	0.04	5.87	1.05	7.81
LSD (<i>p</i> = 0.05)	NS	0.12	17.79	3.19	23.70

SOC: soil organic carbon; N: available nitrogen; P: available phosphorus; K: available potassium; SE(m)±: standard error of mean; LSD: least significant difference; NS: non-significant.

**Fig. 7.** Soil chemical property after harvest as influenced by different planting patterns in baby corn + green gram intercropping system.

Postharvest soil fertility status showed that systems involving green gram improved soil organic carbon and available NPK compared to sole baby corn. Sole green gram recorded the highest soil organic carbon (0.94 %) and available NPK, owing to its biological N fixation and organic matter contribution. Legume-based systems have been reported to enhance nutrient cycling and microbial activity (14). Similar trends have been reported in cereal-legume intercropping systems in rainfed environments (25, 26).

Competition indices

Land equivalent ratio (LER), area time equivalent ratio (ATER) and monetary advantage index (MAI) were significantly affected by different planting patterns (Fig. 8, Table 4). Among the various spatial arrangements evaluated, the 3:3 strip intercropping system of baby corn + green gram (T8) was found to be more remunerative and biologically efficient than sole cropping of either crop. This system exhibited favourable competition indices, indicating a balanced and complementary interaction between the component crops. Additionally, higher values of LER, ATER and MAI were recorded under the 3:3 strip system, reflecting superior resource use efficiency, crop complementarity and economic viability.

These results underscore the advantage of this planting geometry in maximising both biological productivity and profitability over sole cropping systems. Balanced competition and efficient resource partitioning in strip systems enhanced overall system productivity, corroborating earlier reports on cereal-legume intercropping efficiency (6). This highlights the productivity advantage of intercropping systems; wherein higher yields are obtained through more efficient use of land resources. Similar findings were observed in previous reports (27).

The competition indices evaluated in the study varied significantly among different planting geometries, indicating differences in the degree of interspecific interaction between component crops. Certain intercropping systems exhibited more favourable competition indices, suggesting better overall system performance compared to others. However, the earlier interpretation attributing these advantages to balanced resource partitioning has been reconsidered. In the absence of direct measurements related to light interception, nutrient dynamics, or temporal complementarity, the underlying mechanisms governing these interactions cannot be conclusively established. Therefore, the observed improvements in competition indices should be

Table 4. Yield advantage parameters of intercropping as influenced by different planting patterns in baby corn + green gram intercropping system

Treatments	Partial LER of baby corn	Partial LER of green gram	System LER	System LEC	Area time equivalent ratio	MAI
T1	1.00a	-	1.00b	1.00a	1.00b	-
T2	-	1.00a	1.00b	1.00a	1.00b	-
T3	0.74b	0.53bc	1.28ab	0.42b	1.22ab	34127b
T4	0.85ab	0.59bc	1.44a	0.53b	1.37a	55275ab
T5	0.94ab	0.49c	1.44a	0.47b	1.37a	59894ab
T6	0.89ab	0.58bc	1.48a	0.55b	1.42a	62719ab
T7	0.85ab	0.51bc	1.38a	0.45b	1.31ab	50904ab
T8	0.91ab	0.63b	1.55a	0.60b	1.47a	70584a
SE(m)±	0.06	0.04	0.10	0.07	0.10	11478
LSD (<i>p</i> = 0.05)	0.19	0.12	0.31	0.23	0.29	34813

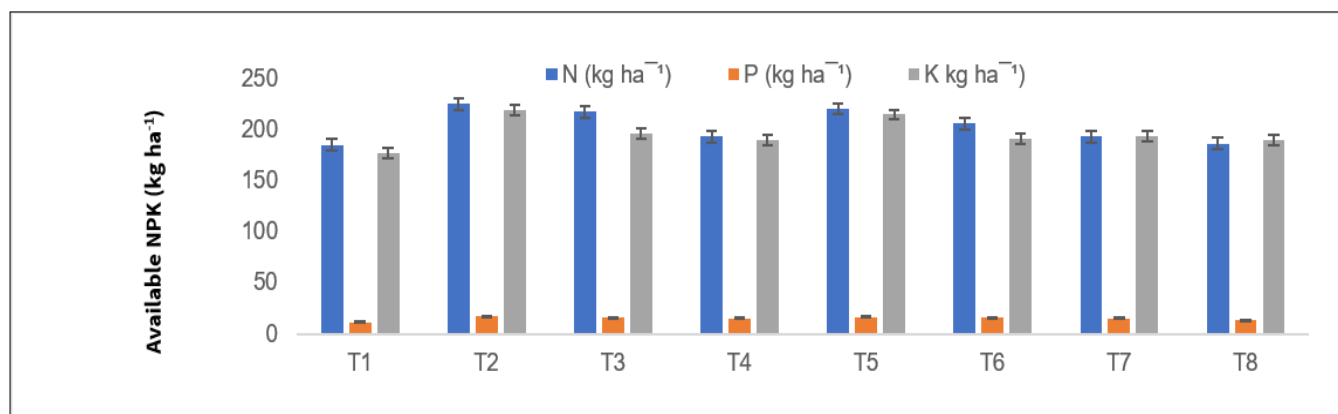


Fig. 8. Biological efficiency and competition indices as influenced by different planting patterns in baby corn + green gram intercropping system.

interpreted as outcomes of spatial arrangement and crop interaction patterns rather than definitive evidence of efficient resource partitioning.

While cereal-legume intercropping systems are often associated with complementary use of growth resources, such explanations in the present study remain inferred from existing literature rather than experimentally validated. These findings emphasise the importance of planting geometry in influencing crop interactions, while also highlighting the need for future investigations incorporating detailed physiological and ecological measurements, such as canopy light distribution, root dynamics and nutrient sharing, to better understand the mechanisms driving intercropping advantages.

Conclusion

Among the various planting patterns studied, the 3:3 strip intercropping of baby corn + green gram proved to be the most remunerative and biologically efficient, outperforming sole cropping in terms of competition indices and resource use. The inclusion of green gram, a legume, helped in maintaining residual soil fertility, comparable to its sole cropping system. Therefore, the 3:3 strip planting pattern offers a sustainable and profitable option for regions like Meghalaya, where summer fallows can be effectively utilised through intercropping. The present study demonstrated that planting geometry significantly influences the growth dynamics, system productivity and nutrient uptake of baby corn–green gram intercropping systems under Northeastern Hill (NEH) conditions. Intercropping treatments, particularly additive series, generally performed better during active growth stages and resulted in higher overall productivity compared to sole cropping systems. However, variations in physiological parameters such as crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) were primarily driven by spatial arrangement and crop interactions rather than confirmed differences in resource-use efficiency. Nutrient uptake differences among treatments were largely associated with biomass production, as nutrient concentrations remained statistically similar. While improved competition indices suggest better system performance under certain intercropping arrangements, the underlying mechanisms such as resource partitioning and complementarity remain inferred and require further validation through detailed physiological and ecological studies.

Farmer recommendation

Intercropping of baby corn with green gram in additive series (e.g., 1:1) is recommended for NEH regions to improve system productivity, nutrient uptake and land-use efficiency compared to sole cropping. However, proper management of planting density and row arrangement is essential to minimise competition, particularly for light. Balanced row ratios (such as 2:1 or 3:1) along with suitable nutrient management and timely agronomic practices can further enhance performance. Field-level validation is suggested for location-specific refinement.

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Authors' contributions

VK carried out the experiment, recorded observations and analysed the data. VR guided the research by formulating the research concept and DKC and BY approved the final manuscript. AK and PK participated in the design of the study, performed the statistical analysis and reviewed the manuscript. AT¹, MK and TAA contributed to conducting the experiment and helped edit, summarise and revise the manuscript. AT² and DP helped summarise and revise the manuscript. All authors read and approved the final manuscript. [AT¹ stands for Abid Tariq and AT² stands for Aman Tutlani].

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

References

1. Bairagi S, Pandit MK, Sidhya P, Adhikary S, Koundinya AVV. Impacts of date of planting and crop geometry on growth and yield of baby corn. *J Crop Weed*. 2015;11(2):127–31.
2. Rani R, Sheoran RK, Soni PG, Kaith S, Sharma A. Baby corn: a wonderful vegetable. *Int J Sci Environ Technol*. 2017;6(2):1407–12.

3. Ali M, Gupta S, Kumar S. Pulses production in India: retrospect and prospects. New Delhi: Indian Council of Agricultural Research; 2014.
4. Sekhon HS. Production technology of pulses. Ludhiana: Punjab Agricultural University; 2008.
5. Himmelstein J, Ares A, Gallagher D, Myers J. A meta-analysis of intercropping systems: impacts on productivity and profitability in smallholder farming. *Agron Sustain Dev*. 2017;37(2):40.
6. Meena RK, Meena BL, Meena VS, Verma JR. Improved nutrient availability and productivity through legume intercropping in cereal-based systems. *Indian J Agron*. 2015;60(2):203–7.
7. Undie UL, Uwah DF, Attou EE. Effect of intercropping and crop arrangement on growth and yields of late season maize/soybean mixtures in the humid environment of south southern Nigeria. *J Agric Sci*. 2012;4(4):37–50. <https://doi.org/10.5539/jas.v4n4p37>
8. Muhammad D, Ali A, Tahir M, Khalid F. Effect of different planting patterns on yield and yield components of maize and mungbean. *Pak J Life Soc Sci*. 2010;8(2):95–8.
9. Jackson ML. Soil chemical analysis-advanced course: a manual of methods useful for instruction and research in soil chemistry, physical chemistry of soils, soil fertility and soil genesis. Madison (WI): University of Wisconsin; 1973.
10. Gomez KA, Gomez AA. Statistical procedures for agricultural research. 2nd ed. New York: John Wiley & Sons; 1984. p. 324.
11. Peoples MB, Brockwell J, Herridge DF, Rochester IJ, Alves BJR, Urquiaga S, et al. The contributions of nitrogen-fixing crop legumes to the productivity of agricultural systems. *Symbiosis*. 2009;48(1-3):1–17. <https://doi.org/10.1007/BF03179980>
12. Beedy TL, Snapp SS, Akinnifesi FK, Sileshi GW. Impact of legume intercropping on soil fertility and maize yield in sub-Saharan Africa. *Agron J*. 2010;102(1):150–60.
13. Ghosh PK, Manna MC, Bandyopadhyay KK, Ajay, Wanjari RH, Hati KM, et al. Intercropping of maize and soybean in semi-arid tropics: system productivity, resource-use efficiency and soil fertility. *Field Crops Res*. 2006;96(2-3):375–87. <https://doi.org/10.1016/j.fcr.2005.05.009>
14. Tamta S, Kumar S, Singh V. Effect of planting geometry on growth and yield of cereal-legume intercropping systems. *J Pharmacogn Phytochem*. 2019;8(4):1500–4.
15. Keating BA, Carberry PS. Resource capture and use in intercropping: solar radiation. *Field Crops Res*. 1993;34(3-4):273–301. [https://doi.org/10.1016/0378-4290\(93\)90118-7](https://doi.org/10.1016/0378-4290(93)90118-7)
16. Zhang F, Li L. Using competitive and facilitative interactions in intercropping systems enhances crop productivity and nutrient-use efficiency. *Plant Soil*. 2003;248(1-2):305–12. <https://doi.org/10.1023/A:1022352229863>
17. Willey RW. Intercropping-its importance and research needs: Part 1. Competition and yield advantages. *Field Crops Abstr*. 1979;32(1):1–10.
18. Alom MS, Paul NK, Quayyum MA. Production potential of different varieties of hybrid maize (*Zea mays* L.) with groundnut (*Arachis hypogaea* L.) under intercropping system. *Bangladesh J Agric Res*. 2010;35(1):51–64. <https://doi.org/10.3329/bjar.v35i1.5866>
19. Singh SP, Singh NP. Production potential and economics of cereal-legume intercropping systems. *Indian J Agron*. 2001;46(3):386–92.
20. Salam MA, Moniruzzaman AFM, Chowdhury SI. Growth analysis in mungbean. *Bangladesh J Nucl Agric*. 1987;3:58–61.
21. Das AK, Khaliq QA, Haider ML. Effect of planting configurations on yield and yield components in maize + soybean and maize + bushbean intercropping system. *Int J Exp Agric*. 2013;3(1):38–45.
22. Banik P, Midya A, Sarkar BK, Ghose SS. Wheat and chickpea intercropping systems in an additive series experiment: advantages and weed smothering. *Eur J Agron*. 2006;24(4):325–32. <https://doi.org/10.1016/j.eja.2005.10.010>
23. Sangakkara UK, Richner W, Schneider MK, Stamp P. Impact of intercropping beans (*Phaseolus vulgaris* L.) and sunhemp (*Crotalaria juncea* L.) on growth, yields and nitrogen uptake of maize (*Zea mays* L.) grown in the humid tropics during the minor rainy season. *Maydica*. 2003;48(3):233–8.
24. Mandal MK, Banerjee M, Banerjee H, Pathak A, Das R. Evaluation of cereal-legume intercropping systems through productivity and competition ability. *Asian J Sci Technol*. 2014;5(3):233–7.
25. Ghosh PK. Growth, yield, competition and economics of groundnut/cereal fodder intercropping systems in the semi-arid tropics of India. *Field Crops Res*. 2009;110(2):144–50.
26. Ravisankar N, Pramanik SC, Rai RB. Influence of intercropping systems on productivity and economics under rainfed conditions. *Indian J Agron*. 2020;65(2):152–7.
27. Ananthi T, Amanullah MM, Somasundaram E. Intercropping systems for enhancing productivity and resource use efficiency under rainfed conditions. *Madras Agric J*. 2017;104(1-3):32–6.

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