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Response of Blackgram (*Vigna mungo* L.) Cultivars for Nipping and Graded Levels of Nitrogen for Higher Productivity under Irrigated Conditions

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Abstract: Blackgram (*Vigna mungo* L.) holds significant importance among grain legumes, particularly in terms of its production and productivity. Over the years, the decline in the cultivation area of this crop has become increasingly evident due to its persistently low yields. Many technologies are being implemented to improve the yield, and nipping is one of them. The main objective of this paper was to standardize the nipping timing and graded levels of nitrogen (N) application on growth and seed yield in blackgram cultivars under irrigated conditions. A study with three blackgram cultivars (cv.), three levels of N, and three intervals of nipping was taken up during the winter and monsoon seasons of 2018 and 2019, respectively. The study revealed that blackgram cv. VBN8 recorded a higher plant height of 49.52 cm, a higher number of branches (4.08), a higher number of pods per plant (47.75), a higher seed yield of 882 kg.ha^{-1}, and a benefit cost ratio (B:C ratio) of 2.49. Among the graded levels of nutrients, applications of 125% N and 100% phosphorus (P) and potassium (K) recorded the highest growth and yield attributes, with a B:C ratio of 2.33. Nipping at 25 days after sowing (DAS) registered a higher number of branches (4.08), more pods per plant (48.14), and a seed yield of 902 kg.ha^{-1} with a B:C ratio of 2.36. Higher N, P, and K uptake was observed in blackgram VBN8, with an application of 150% recommended N and 100% P and K and nipping at 25 DAS. To conclude, application of 125% recommended N and 100% P and K and nipping at 25 DAS were found to be significant in enhancing the productivity of blackgram and NPK uptake, and resulted in 14% more profit than no nipping treatments.

Keywords: blackgram; cultivars; fertilizer; nipping; yield; profitability

1. Introduction

Pulses are often referred to as the "poor man's meat" due to their crucial dietary significance for millions of individuals in developing countries. Pulses are indispensable in Indian agriculture, as they significantly improve the soil fertility by harnessing atmospheric N through nodules, thereby enhancing N fixation. However, since the Green Revolution, pulses have been ignored, making their productivity low in India. India has to import lots of pulses every year to meet demand, so boosting pulse productivity is a big challenge to meet national and local needs [1]. Blackgram (*Vigna mungo* L.) holds significant importance among pulses and it is cultivated in an area of 4.63 million hectares with production of 2.78 million tonnes and productivity of 987 kg.ha^{-1}. In Tamil Nadu, blackgram is cultivated in an area of 4.07 lakh hectares, with total production of 2.69 lakh tonnes and productivity of 660 kg.ha^{-1} [2]. The per capita availability of pulses has rapidly declined from 70 g in 1959 to 53.8 g per capita per day in 2021–2022, falling short of the minimum requirement of 84 g per capita per day as recommended by the Indian Council of Medical Research. This decrease is contributing to malnutrition among the expanding population [3,4]. However, the average productivity of the crop is much below that 596 kg.ha^{-1} and 496 kg.ha^{-1} in India and Tamil Nadu, respectively [2]. Key obstacles to enhancing productivity include poor soil quality, inadequate crop growth, soil fertility issues, and improper fertilization practices, particularly in irrigated conditions.

Historically, much of the focus on advancing production technologies for pulses has centred on experimentation with various traditional agronomic approaches. However, researchers are now attempting to reshape crop architecture by implementing agronomic practices such as nipping. Nipping, an essential agronomic practice involving the removal of the apical bud, serves to mitigate apical dominance, foster increased branching, improve pod set percentage, establish better source-sink balance, and ultimately enhance plant productivity [5,6]. Although nipping is traditionally undertaken by farmers, the associated benefits have lacked scientific documentation [7]. Nipping, the process of removing or clipping terminal buds, holds significant importance in agronomy, particularly in the cultivation of pulses. By curbing the dominance of apical buds, nipping fosters lateral growth, leading to the emergence of more productive branches and ultimately boosting yield. Nipping, also known as pinching, is an agricultural practice applied to Blackgram where the apical bud or the top portion of the main stem is removed. This technique is employed to encourage branching and improve overall growth by modifying the plant's architecture and yield.

Among various crop management strategies, apical bud nipping is frequently recommended across different crops to augment both yield and quality. This cultural practice aids in effective photosynthate synthesis and translocation from source to sink, leading to increased seed mass [6,8,9]. Nipping in chickpea (*Cicer arietinum* L) cultivation emerges as a vital factor in augmenting both yield and its contributing parameters. When the vertical growth of the plant is arrested or restricted, it generally induces the growth of lateral branches [10]. Early-stage foliage nipping can effectively boost the number of branches while curbing excessive vegetative growth, thereby enhancing overall crop yield [11]. Moreover, nipping at different growth stages has shown to increase the number of branches and pods, consequently amplifying chickpea yield [12–14]. By promoting the development of side shoots or branches, nipping enhances photosynthetic activity, resulting in greater accumulation of photosynthates and ultimately leading to larger seed size and increased yield [15,16]. Seed yield and net returns of *Cicer arietinum* were maximum with nipping at 30 or 40 DAS, along with the application of 20 kg N + 40 kg P per hectare indicating the effect of nipping in gram cv. 'Dohad yellow', and reported an increase in yield attributing characters like pods per plant, test weight, and seed yield per plant [17]. They opined that the higher yield might be due to a higher number of pods per plant, test weight, and seed weight per plant.

Water stands as the foremost essential input for agricultural production, yet its availability is increasingly constrained by the unpredictable patterns of rainfall and increasing demands from other sectors [18,19]. Globally, agriculture utilizes over 80% of all freshwater resources, with the majority dedicated to crop cultivation [20]. Rainfed agriculture, predominant in developing countries, contributes 60% of total production, relying primarily on soil moisture from rainfall. Despite irrigation accounting for only 20% of cultivated land, it yields 40% of total food production. To meet escalating food demands and ensure nutritional security, the Food and Agriculture Organization (FAO) projects an expansion of irrigated land to approximately 45 million hectares across 93 developing nations by 2030 [21,22]. Applying irrigation water during critical growth stages without reducing yield is an effective approach to enhancing both yield and water productivity in pulses. Several studies [23,24] have reported an increase in pulse seed yield from 40 to 50% through proper management of irrigation and fertilizer application.

Fertilizer is one of the most essential and critical inputs expected for higher productivity of pulses. Imbalanced application of nutrients is one of the main abiotic constraints inhibiting the production of pulses. Biological N fixation is the inbuilt mechanism that enables legume crops to reach 80–90% of their N demand. Hence, a minor quantity of 15–25 kg N ha^{-1} is satisfactory to meet the fulfilment of many of the pulse crops [25]. Appropriate quantities of nutrients in appropriate proportions at the required time, practiced through proper methods of application (4Rs—Right quantity/source, Right time, Right method, and Right place) in a balanced manner increases the productivity levels of most crops [25]. Blackgram is a legume crop that responds well to N and P application. In India, many investigators have commenced studies on the varietal response and fertilizer needs of blackgram. In one of the studies, the application of 100% Recommended Dose of Fertilizers (RDF) 20:60:20 kg of N, P, and K respectively and 20 kg S ha^{-1} registered significantly greater yield attributing parameters, seed yield, and stover yield of blackgram [26]. Blackgram fertilized with 25:50:50 kg of N, P_2O_5, and K_2O, respectively, separately or in various combinations, recorded seed yields in the range of 691.7 kg.ha^{-1} in the unfertilized control to 941.4 kg.ha^{-1}. The later treatment gave the highest leaf area per plant and number of seed $pods^{-1}$. The application of 20 kg.ha^{-1} of N fertilizer produced a considerable increase in yield attributes and crop productivity of blackgram than the control [27].

Generally, in blackgram, the application of a higher dose of nitrogenous fertilizers boosts the plant height and vegetative growth and reduces the flower production and pod development, which causes lower yield. It may be corrected by altering the morphology of the blackgram canopy through nipping. The lateral dormant buds may be activated by nipping, which arrests the terminal growth and in turn increases the lateral branches, leading to a greater chance for the development of source and sink characters in pulses, ultimately leading to an increase in the yield and productivity of blackgram. Similar kinds of studies and research findings were not reported earlier in Tamil Nadu, India. Hence, the current study has been proposed to develop an N and nipping schedule for higher productivity of blackgram cultivars under irrigated conditions, besides increasing and sustaining the soil's fertility.

The seed yield and quality need to be enhanced by adopting certain agronomic practices and scientific seed production techniques. The main objectives of the experiment were to standardize the suitable nipping timing and graded levels of N application for blackgram cultivars (cv.) under irrigated conditions and to study the effect on the flowering pattern, seed filling, seed maturity, and seed yield of blackgram cultivars under the irrigated conditions of semi-arid climatic conditions in India.

2. Materials and Methods

The experiment was conducted during the winter and monsoon seasons of 2018 and 2019, respectively, at the National Pulses Research Centre, Tamil Nadu Agricultural University (TNAU), Vamban, Pudukkottai District, Tamil Nadu, India. The experiment was laid out in a split plot design with three replications. The treatments were three cultivars of blackgram Factor A: V_1—VBN6, V_2—VBN8 and V_3—ADT5, Factor B: Three levels of Nitrogen (Recommended Dose of Fertilizer, RDF of N) F_1—100% of RDF of N (25 kg N ha^{-1}), F_2—125% of RDF of N (31.25 kg N ha^{-1}), and F_3—150% of RDF of N (37.50 kg N ha^{-1}) and Factor C: Four nipping schedules, namely N_0: No nipping, N_1: Nipping at 20 days after sowing (DAS), N_2: Nipping at 25 DAS, and N_3: Nipping at 30 DAS. Sowing was taken during winter and monsoon seasons as per the treatment schedule. Details of the date of nipping and harvesting are given in a schematic diagram in Figure 1.

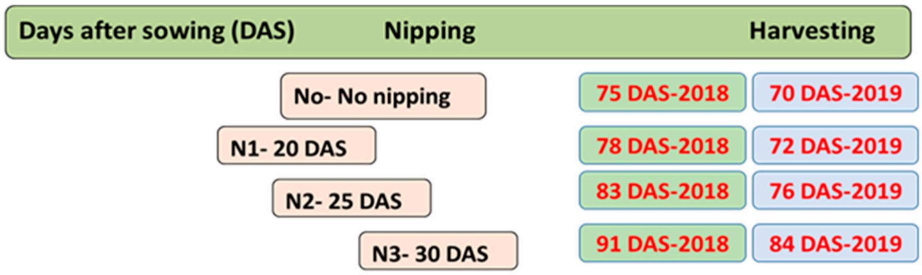

Figure 1. Schematic diagram of the details of nipping and harvesting of blackgram.

The experimental site is located at a latitude of 8°30′ to 10°40′ N, a longitude of 78°24′ to 79°4′ E, and an altitude of 122 m above mean sea level. During the cropping period of 2018 and 2019, a total rainfall of 210 mm and 138 mm was respectively received over 12 and 11 rainy days. The mean maximum and minimum temperatures for the year 2018 were recorded at 36.4 °C and 24.4 °C, while for the year 2019, they were 36.3 °C and 24.8 °C. The soil status of the experimental field was with the soil order *alfisol*, soil texture was sandy clay loam, soil pH—5.82, organic carbon content—0.44 (%), available soil nutrient content was 184.2, 19.6, and 160.3 N, P, and K kg.ha^{-1}, respectively.

Blackgram VBN6, VBN8, and ADT5 cultivars were selected for the study. The special features of these cultivars are given in Table 1.

Table 1. Special features of blackgram cultivars used for these experiments.

Particulars	VBN6	VBN8	ADT5
Parentage	Vamban 1 × *Vigna mungo* sub sp. *silvestris*	Vamban 3 × VBG 04-008	Pure line selection from Kanpur, Utter Pradesh
Duration (days)	65–70	65–70	65–70
Yield (kg.ha^{-1})	890	988	1323
100 grains weight (grams)	3.8–4.0	4.5–5.5	3.6
Special features	Resistant to mungbean yellow mosaic diseases and synchronized pod maturity	Resistant to mungbean yellow mosaic virus (MYMV), moderately resistant to powdery mildew diseases, and leaf crinkle	After 65 days, the second set of flowering starts. Moderately resistant to mungbean yellow mosaic diseases.

The above blackgram cultivars are high yielding, short duration, and familiar among the farmers of south India.

Seeds were treated with bio-fertilizer (600 g each of *rhizobial* culture CRM 6 and *phosphobacteria*) and were sown with a spacing of 30 cm × 10 cm. To control weeds, a pre-emergence application of pendimethalin 30 EC + imazethapyr 2 EC—(ready mix) herbicide @ 1 kg.a.i. ha^{-1} at 3rd DAS was performed followed by one hand weeding at 30 DAS. Nutrients were applied as follows: RDF of 25:50:25 kg NPK ha^{-1} was applied before the sowing of blackgram seeds as basal, and TNAU Pulses Wonder at a rate of 5 kg ha^{-1} was applied through the foliar spray at the peak flowering stage. In the years 2018 and 2019, the channel method of irrigation was practiced, and the application of 140 and 232 mm of irrigation water, respectively, excluding rain water was made through beds at different growth stages, namely sowing, 3 DAS, 25 DAS, at flowering, pod formation, and maturity stages. Observations on growth and yield parameters, namely plant height, leaf area index (LAI), days to 50% flowering, number of pods per plant, 100 grain weight, and seed yield were recorded at the maturity stage. The costs involved in the application of organic, major, and micro nutrients along with plant growth regulators were worked out using the current market price of inputs and blackgram seed. The cost of cultivation refers to the expenses incurred from field preparation to harvest, expressed as US dollars (USD) per hectare. Gross return was calculated by computing the crop yield per hectare and determining the total income based on the prevailing minimum market rate, which, at the time of the study was

USD 0.85 per kg of blackgram. Net return was then calculated by subtracting the cost of cultivation from the gross return for each treatment. Net return = Gross return (USD.ha^{-1})—Cost of cultivation (USD.ha^{-1}). Finally, the B:C ratio was worked out using the formula, B:C ratio = Gross return (USD.ha^{-1})/Total cost of cultivation (USD.ha^{-1}). The post-harvest soil samples were collected and analysed for their nutrients. Standard procedures were used for the determination of available N [28] P [29] and K (kg.ha^{-1}) content [30].

Statistical Analysis

The experimental data were pooled, and the mean data for two years were subjected to statistical analysis as per the standard methods [31]. Critical difference (CD) was used to test the significant differences between the means at a probability level of P = 0.05 using the analysis of variance (ANOVA). To assess the significance of differences among the means, a standard ANOVA was conducted. The ANOVA was used to determine the impact of various independent variables on the dependent variables. In this study, the variables under scrutiny as independent were the different cultivars, N management, and nipping practices i.e., the treatments imposed. The dependent variables were the growth and yield parameters of blackgram. The specific ANOVA test carried out was a one-way ANOVA due to the evaluation of the impact of one factor or treatment on the dependent variables. The analysis was carried out using TNAU AGRES Statistical software v 7.01.

3. Results

The results of pooled data from the two years, 2018 and 2019, revealed that a significant increase was observed on growth, yield attributes, and yield of blackgram in different blackgram cultivars, graded levels of NPK, and nipping of all the treatments over the control. A pooled mean of two years was used for the analysis since the year effect was not significant for the traits. Among the three cultivars, VBN8 recorded higher plant height (49.52 cm), LAI of 0.72 and 1.11 on 45 and 60 DAS respectively, number of branches (4.08), days to 50% flowering (39.81 DAS), number of pods per plant (47.75), and a seed yield of 882 kg.ha^{-1}. The lowest plant height, number of branches and pods per plant, and seed yield were observed in VBN6 (Tables 2 and 3).

Table 2. Impact of nitrogen levels and nipping schedule on the growth of blackgram cultivars under irrigated conditions (two years pooled mean).

Treatments	Plant Height (cm)	Leaf Area Index (LAI)		Number of Branches /Plant	Days to 50% Flowering (DAS)
		45 DAS	60 DAS		
Blackgram cultivars					
V_1—VBN6	43.12 ^{b}	0.59	0.87	2.98 ^{c}	35.49 ^{c}
V_2—VBN8	49.52 ^{a}	0.72	1.11	4.08 ^{a}	39.81 ^{b}
V_3—ADT5	45.10 ^{b}	0.61	1.08	3.44 ^{b}	42.86 ^{a}
Standard Error (SE)	0.92	0.04	0.06	0.04	1.46
Critical difference (CD) (P = 0.05)	2.57	NS	NS	0.12	2.82
B. Fertilizer NPK (kg.ha^{-1})					
F_1—100% N (25:50:25)	42.88 ^{c}	0.63 ^{b}	0.94 ^{b}	3.35 ^{b}	36.50
F_2—125% N (31.25: 50:25)	46.31 ^{b}	0.71 ^{a}	1.06 ^{a}	4.17 ^{a}	37.24
F_3—150% N (37.5: 50:25)	50.85 ^{a}	0.73 ^{a}	1.17 ^{a}	4.16 ^{a}	40.59
SE	1.00	0.03	0.08	0.07	1.77
CD (P = 0.05)	2.83	0.19	0.21	0.24	NS
C. Nipping					
N_0—No Nipping	50.18 ^{a}	0.58 ^{b}	0.75 ^{c}	2.94 ^{d}	35.82 ^{c}
N_1—Nipping on 20 DAS	46.84 ^{b}	0.68 ^{a}	1.03 ^{b}	3.48 ^{c}	41.62 ^{b}
N_2—Nipping on 25 DAS	45.07 ^{b}	0.70 ^{a}	1.16 ^{a}	4.08 ^{a}	45.65 ^{a}
N_3—Nipping on 30 DAS	42.56 ^{c}	0.75 ^{a}	1.18 ^{a}	3.76 ^{b}	49.25 ^{a}
SE	0.91	0.04	0.05	0.07	1.24
CD (P = 0.05)	2.52	0.11	0.12	0.22	3.63

Table 2. *Cont.*

Treatments	Plant Height (cm)	Leaf Area Index (LAI)		Number of Branches /Plant	Days to 50% Flowering (DAS)
		45 DAS	60 DAS		
Interaction					
V × F:SE	1.25	0.48	0.53	0.12	1.43
CD (P = 0.05)	NS	NS	NS	NS	NS
V × N:SE	1.68	0.45	0.52	0.13	1.39
CD (P = 0.05)	NS	0.14	0.16	NS	NS
F × V: SE	1.59	0.46	0.53	0.14	1.35
CD (P = 0.05)	NS	NS	NS	NS	NS
N × V:SE	1.73	0.47	0.55	0.13	1.64
CD (P = 0.05)	NS	NS	NS	NS	NS
V × F × N:SE	1.34	0.48	0.57	0.24	1.42
CD (P = 0.05)	NS	NS	NS	NS	NS

SE: Standard Error; CD: Critical difference; NS: Non significance. Different alphabetical letters indicate the significant difference between the treatments

Table 3. Yield parameters and seed yield of blackgram cultivars as influenced by nitrogen levels and nipping schedule (two years pooled mean).

Treatments	Number of Pods/Plant	Number of Seeds/Pod	100 Seed Weight (g)	Seed Yield (kg.ha^{-1})
Blackgram cultivars				
V_1—VBN6	37.12 ^{c}	6.10	4.17	781 ^{c}
V_2—VBN8	47.75 ^{a}	6.16	4.91	882 ^{a}
V_3—ADT5	43.31 ^{b}	6.12	4.95	814 ^{b}
SE	1.10	0.07	0.11	5.53
CD (P = 0.05)	3.12	NS	NS	21
B. Fertilizer NPK (kg.ha^{-1})				
F_1—100% N (25:50:25)	42.25	6.12	4.56	845 ^{b}
F_2—125% N (31.25: 50:25)	46.80	6.12	4.71	894 ^{a}
F_3—150% N (37.5: 50:25)	38.25	6.14	4.72	738 ^{c}
SE	1.36	0.04	0.17	14
CD (P = 0.05)	NS	NS	NS	41
C. Nipping				
N_0—No Nipping	38.33 ^{c}	6.08	4.55	774 ^{b}
N_1—Nipping on 20 DAS	42.81 ^{b}	6.13	4.71	796 ^{b}
N_2—Nipping on 25 DAS	48.14 ^{a}	6.15	4.72	902 ^{a}
N_3—Nipping on 30 DAS	39.50 ^{c}	6.10	4.74	831 ^{b}
SE	1.22	0.04	0.18	20
CD (P = 0.05)	3.28	NS	NS	62
Interaction				
V × F: SE	0.26	0.07	0.27	15.30
CD (P = 0.05)	NS	NS	NS	NS
V × N: SE	0.31	0.08	0.26	21.64
CD (P = 0.05)	NS	NS	NS	62.80
F × V: SE	0.23	0.05	0.25	23.37
CD (P = 0.05)	NS	NS	NS	NS
N × V: SE	0.22	0.05	0.26	24.43
CD (P = 0.05)	NS	NS	NS	NS
V × F × N: SE	0.30	0.08	0.28	41.28
CD (P = 0.05)	NS	NS	NS	NS

SE: Standard Error; CD: Critical difference; NS: Non significance. Different alphabetical letters indicate the significant difference between the treatments.

With respect to three levels of N application, the treatment, which received applications of 125% N and 100% P and K (31.25:50:25 kg NPK ha^{-1}) (F_2) recorded a greater number of branches/plant (4.17), number of pods per plant (46.80), and a seed yield of 894 kg.ha^{-1}.

However, the plant height was higher (50.85 cm) and LAI was 0.73 and 1.17 on 45 and 60 DAS, respectively, in applications of 150% N and 100% P and K (F_3), and the lowest plant height was registered with the application of 100% NPK (F_1) (Tables 2 and 3).

3.1. Effect of Nipping

Nipping has a direct impact on the growth and branching of blackgram. Between nipping and no nipping treatments, no nipped plants recorded significantly more plant height. Nipping at 25 DAS registered a significantly higher number of branches and reduced plant height. Among the three different nipping timings along with no nipping, nipping at 25 DAS registered a greater number of branches (4.08), more pods per plant (48.14), and a seed yield of 902 kg.ha^{-1}. The days to 50% flowering were significantly higher 49.25 DAS from nipping at 30 DAS followed by 45.65 DAS from nipping at 25 DAS (Tables 2 and 3). The maximum height was recorded as 50.18 cm in no nipping treatment, and a plant height of 46.84 cm was observed from nipping at 20 DAS. The highest LAI of 0.75 and 1.18 on 45 and 60 DAS, respectively, was noticed when nipping was performed at 30 DAS followed by 0.70 and 1.16 at 45 and 60 DAS, respectively, when nipping was performed at 25 DAS. There was no significant effect of blackgram cultivars, NPK, and nipping on 100 grain weight and number of pods in blackgram. A significant interaction effect was observed on a seed yield of 857 kg.ha^{-1} between blackgram cultivars and nipping timings.

3.2. Economics

The economic analysis for each treatment was conducted to assess the financial viability of the recommended practice, as detailed in Table 4. Gross returns were determined by multiplying the average seed yield of blackgram over two years (2018 and 2019) collected from the local market price of blackgram seeds. Additionally, the cost of cultivation was calculated based on the average values over the two-year period of the experiments. For treatments involving nipping, the average wages for nipping work were factored in at USD 35.90 per hectare, considering USD 3.0 per worker. The result shows that the highest gross return (USD 748.15 ha^{-1}), net return (USD 300.50 ha^{-1}) and a B:C ratio (2.49) was obtained in the cultivation of blackgram cv. VBN8. A gross return of USD 745.70 ha^{-1}, a net return of USD 425.66 ha^{-1}, and a B:C ratio of 2.33 were recorded with the application of 125% of N and 100% P and K, and the lowest B:C ratio (2.04) was registered for the application of 150% of N and 100% P and K. The highest gross return was USD 753.74 ha^{-1}, net return USD 434.27 ha^{-1}, and B:C ratio 2.36 with nipping at 25 DAS, indicating its greater economic feasibility compared with no nipping.

Table 4. Economic analysis of blackgram cultivars influenced by nitrogen levels and nipping schedule (two years pooled mean).

Treatments	Gross Return (USD.ha^{-1})	Cost of Cultivation (USD.ha^{-1})	Net Return (USD.ha^{-1})	Benefit Cost Ratio
A. Blackgram cultivars				
V_1—VBN6	651.82	294.17	357.64	2.22
V_2—VBN8	748.15	300.50	447.64	2.49
V_3—ADT5	703.13	329.96	373.17	2.13
B. Fertilizer NPK (kg.ha^{-1})				
F_1—100% N (25:50:25)	703.31	316.46	386.86	2.23
F_2—125% N (31.25:50:25)	745.70	320.04	425.66	2.33
F_3—150% N (37.5:50:25)	656.06	321.77	334.28	2.04
C. Nipping				
N_0—No Nipping	666.34	290.57	375.78	2.29
N_1—Nipping on 20 DAS	710.43	328.83	381.60	2.16
N_2—Nipping on 25 DAS	753.74	319.48	434.27	2.36
N_4—Nipping on 30 DAS	669.78	322.81	346.98	2.08

3.3. NPK Uptake

A significant impact was observed on nutrient uptake and post-harvest soil available NPK in different blackgram cultivars, graded levels of N, and nipping treatments over the control. Among the three cultivars, VBN8 (V_2) recorded higher NPK uptakes of 26.17, 5.63, and 15.42 kg.ha^{-1}, respectively, which was on par with VBN6 (V_1). The lowest NPK uptake was registered in blackgram cv. ADT5. Impact of three levels of N fertilizer doses significantly influence on NPK uptake in blackgram. Applications of 150% RDF of N and 100% P and K (F_3) registered higher N, P, and K uptakes of 28.16, 5.38, and 16.65 kg.ha^{-1}, respectively, which were on par with applications of 125% N and 100% P and K (F_2) (Table 5). The lowest NPK uptake was recorded with the application of 100% RDF of NPK (F_1).

Table 5. Influence of nitrogen levels and nipping schedule on NPK uptake and availability in various blackgram cultivars (two years pooled mean).

Treatments	Nutrient Uptake (kg.ha^{-1})			Post-Harvest Soil Available Nutrients (kg.ha^{-1})		
	N	P	K	N	P	K
A. Blackgram cultivars						
V_1—VBN6	25.06 [a]	5.40 [a]	14.57 [a]	188.58 [a]	27.90	176.42 [a]
V_2—VBN8	26.17 [a]	5.63 [a]	15.42 [a]	187.40 [b]	28.02	175.18 [b]
V_3—ADT5	22.70 [c]	5.09 [b]	13.19 [b]	190.24 [a]	28.11	177.73 [a]
SE	0.71	0.09	0.40	1.33	0.49	1.02
CD (P = 0.05)	1.53	0.27	1.14	2.70	NS	2.07
B. Fertilizer NPK (kg.ha^{-1})						
F_1—100% N (25:50:25)	20.71 [b]	4.41 [b]	11.12 [b]	187.29	25.40 [b]	175.21 [b]
F_2—125% N (31.25: 50:25)	26.25 [a]	5.12 [a]	15.52 [a]	188.75	28.26 [a]	177.66 [a]
F_3—150% N (37.5: 50:25)	28.16 [a]	5.38 [a]	16.65 [a]	190.82	29.91 [a]	179.31 [a]
SE	1.21	0.23	1.13	1.75	0.96	1.55
CD (P = 0.05)	2.42	0.54	2.77	NS	2.01	3.10
C.Nipping						
N_0—No Nipping	22.25 [c]	4.85 [b]	12.62 [b]	191.53 [a]	28.31 [a]	176.38
N_1—Nipping on 20 DAS	26.25 [b]	5.62 [a]	16.02 [a]	188.72 [a]	28.31 [a]	175.93
N_2—Nipping on 25 DAS	28.16 [a]	5.88 [a]	17.03 [a]	189.03 [a]	29.08 [a]	177.36
N_4—Nipping on 30 DAS	26.45 [a]	5.68 [a]	15.74 [a]	186.96 [b]	27.26 [b]	177.37
SE	0.77	0.17	1.19	1.54	0.82	1.25
CD (P = 0.05)	1.89	0.38	2.41	2.97	1.74	NS
Interaction						
V × F:SE	0.93	0.34	0.56	0.91	0.84	0.85
CD (P = 0.05)	NS	NS	NS	NS	NS	NS
CV (%)	8.55	8.79	7.88	7.16	6.95	7.16

SE: Standard Error; CD: Critical difference; NS: Non-significance. Different alphabetical letters indicate the significant difference between the treatments.

A significant effect was observed when the nipping of terminal shoots was carried out in three different time intervals in blackgram. Nipping at 25 DAS registered significantly higher NPK uptakes of 28.16, 5.88, and 17.03 kg.ha^{-1}, respectively. The lowest NPK uptake was registered in no nipping of blackgram (Table 5). No significant interaction effect was observed between the treatments.

3.4. Post-Harvest Soil Available NPK

Among the three cultivars studied, the cultivar ADT5 (V_3) exhibited significantly highest post-harvest soil available N at 190.24 kg.ha^{-1}, and soil available K at 177.73 kg.ha^{-1}, as indicated in Table 5. In contrast, the cultivar VBN8 (V_2) of blackgram showed a significantly lower post-harvest available N at 187.40 kg.ha^{-1}. No significant differences were observed among the blackgram cultivars in terms of post-harvest available P levels in the soil.

Among the graded levels of N, the application of 150% RDF of N and 100% RDF of P and K (F_3) resulted in significantly higher quantities of post-harvest soil available P at

29.91 kg.ha^{-1} and available K at 179.31 kg.ha^{-1}. This was comparable to the plot where 125% RDF of N and 100% RDF of P and K were applied (F_2). However, there was no significant effect observed on post-harvest available N among the different levels of N application. The lowest post-harvest levels of NPK were recorded in plots where 100% RDF of NPK (F_1) was applied.

Among the three nipping timings with no nipping treatments, a higher post-harvest soil available N was registered at 191.53 kg ha^{-1} in no nipping treatment, which was on par with nipping at 25 DAS. However, the post-harvest soil available P was higher at 29.08 kg.ha^{-1} in nipping at 25 DAS (N_2) and no significant effect of K was recorded due to different nipping timings. The lowest post-harvest soil available N and P were registered with nipping at 30 DAS (N_3). No significant interaction effect was observed between the treatments.

4. Discussion

4.1. Effect of Nipping on Plant Growth Characteristics and Seed Yield

Nipping and graded levels of nutrients resulted in higher plant growth characteristics and seed yield. In cowpea (*Vigna unguicalata* L.), the practice of nipping tendrils resulted in significantly reduced plant height, increased dry weight, and a higher number of branches, ultimately leading to enhanced seed productivity [32]. Similarly, in *Vicia faba*, nipping the top portion during the early flowering and pod filling stages led to greater seed yield and increased total pods per plant. Nipping at the pod development stage also resulted in more leaf area, earlier podding, and reduced pod shedding.

In chickpea (*Cicer arietinum* L.), various nipping timings (30, 40, 60, and 75 days after emergence) were studied. It was found that pinching at 30 days after emergence resulted in the highest number of branches per plant, which was statistically comparable to nipping at 45 days after emergence. Additionally, pinching at 30 days after emergence led to a higher number of pods per plant and maximum yield [33]. Plants subjected to no nipping treatments exhibited greater plant height due to uninterrupted growth of the main shoot, unlike nipped plants. However, nipped plants showed a higher number of branches. Nipping promotes profuse branching and a broader canopy, requiring more space for proper interception of solar radiation [34]. This branching enhancement is attributed to the effect of nipping on apical buds, resulting in the production of more secondary branches and the cessation of vertical growth due to redirected growth regulators, especially auxins, towards potential and tertiary shoot buds, which remain dormant under normal conditions [35–37].

Nipping is also recognized as an effective technique for increasing flower production while reducing foliage production [38]. The increase in the number of branches with nipping may be attributed to the removal of the apical portion of the main shoot, leading to more secondary branches as carbohydrates are redirected towards lateral auxiliary buds below the nipped portion [39]. Nipping also stimulates dormant lateral shoots, contributing to a greater number of secondary branches. The inhibition of axillary bud growth in chickpea (*Cicer arietinum* L.) plants by indole-3-acetic acid generated in the apical portion is counteracted by nipping, leading to increased lateral branching [40–42].

Although the days to flower initiation were not significantly different between nipping treatments, the nipping treatment required more days to reach 50% flowering and resulted in higher dry matter per plant at harvest compared to no nipped plants. This delay in flowering in nipped plants may be attributed to the temporary hindrance of meristematic cell multiplication in the growing tip due to nipping. These findings are consistent with those reported by [43] in sesame (*Sesamum indicum* L.), [44,45] in okra (*Abelmoschus esculentus* L.), and [46] in fenugreek (*Trigonellafoenum graecum* L.).

4.2. Effect of Nipping on Yield for Different Varieties

Based on the results, it appears that among the different cultivars studied, the combination of blackgram cv. VBN8, applying 125% of the RDF of N and 100% of P and K, and nipping at 25 DAS had a significant positive impact on enhancing blackgram productivity. The differences in seed yield and yield parameters observed between varieties in the present study may be attributed to their differences in growth habits and genetic yielding ability. Similar varietal differences in chickpea with respect to plant growth and seed yield parameters were reported in earlier studies [47,48], as well as in cowpea (*Vigna unguicalata* L.) [32].

It is an established fact that grain quality characteristics vary among cultivars of different crop species due to genetic and environmental factors. The differences in seed quality traits noted between chickpea (*Cicer arietinum* L.) cultivars may be attributed to varietal variations in seed development and accumulation of reserved food material. This showed the importance of selecting the appropriate cultivar and optimizing agronomic practices to enhance crop productivity and seed quality [49,50].

While few of the earlier studies examine rainfed conditions, focusing on irrigated conditions is critical for regions where irrigation is prevalent [32,47,48]. This aspect is particularly relevant for maximising yield potential in areas where water is available for irrigation. The novelty of this study lies in its integrated approach to examining multiple agronomic practices on a specific and economically important crop under controlled irrigated conditions, providing practical, cultivar-specific, and environmentally conscious recommendations for improving blackgram productivity. By combining practices like nipping and N management, the study provides a comprehensive analysis that encompasses plant physiology, agronomy, and potentially even soil science. This holistic approach can lead to more robust agricultural recommendations in the forthcoming years.

4.3. Effect of Nitrogen on Growth and Yield of Blackgram

The highest plant height, LAI, yield attributes, and yield of blackgram were recorded with applications of 125% RDF of N and 100% P and K among the graded levels of nutrients. With each successive increase in N levels from 25 kg N ha^{-1} to 37.5 kg N ha^{-1}, plant height significantly increased. This increase in plant height may be attributed to better vegetative growth due to the application of N, aligning with the findings [51]. Sufficient application of N manifests plant growth in terms of plant height and the number of branches per plant, ultimately increasing the seed and stalk yield of the plant. The application of a higher dose of N showed a greater number of pods per plant and seed yield over a lower dose of N. This may be because the increase in N levels up to the highest rate of N may be ascribed to the overall improvement in plant vigour and production of sufficient photosynthates owing to greater availability of nutrients, resulting in better manifestation of yield attributes [52,53].

The increase in yield parameters of blackgram with higher doses of N might be due to the favourable function of N to enlarge and multiply the cells with thinner cell walls, promoting vegetative growth and encouraging the formation of good quality foliage by producing more carbohydrates. The basic fact that N is a major constituent of the cell helps in cell division and cell elongation, ultimately increasing plant growth [54]. In addition, more accumulation of nitrogenous substances and their translocation to reproductive organs, as well as efficient seed filling by better translocation of photosynthates on the application of N dose, might contribute to the observed effects [55].

4.4. Economics

Economic analysis showed the significant effect of the treatments on profitability. A higher B:C ratio indicates better economic feasibility of the applied treatments. In this case, nipping at 25 DAS resulted in a B:C ratio of 1:2.36, indicating that for every USD invested in this treatment, a return of USD 2.36 was obtained. This suggests that the economic feasibility of this treatment is higher compared to no nipping treatments. Enhanced nutrient availability in a balanced manner by the integration of major nutrients and micronutrient mixture foliar spray with nipping resulted in an improvement of yield attributing characters and seed yield. This ultimately led to increased gross return and net return [10,56,57].

4.5. Nitrogen, Phosphorus, and Potassium (NPK) Uptake

N, P, and K uptake was also significantly influenced by the treatments. A balanced supply of nutrients in adequate amounts and available forms is crucial for successful crop production. Effective fertilizer management involves adding the right amount of nutrients at the right time and through appropriate methods to minimize nutrient losses [58]. This approach enhances crop productivity and preserves soil fertility by efficiently utilizing nutrients, as emphasized by an earlier study [59]. This approach enhances crop productivity and preserves soil fertility by efficiently utilizing nutrients [60]. N and P play a critical role in chlorophyll formation, plant metabolism, biological N fixation, and the synthesis of RNA and DNA. Additionally, the impact on N and P uptake at higher doses of application likely influences the growth, development, and yield of blackgram [24].

4.6. Post-Harvest Soil Nutrient Availability

Legume N fixation commences with the formation of nodules, wherein a common soil bacterium, *rhizobium*, invades the root and establishes root nodules. Biological N fixation converts inert N into biologically useful NH_3, thereby reducing the necessity for N fertilization in pulses, although their P requirement remains high. Nonetheless, the supplementation of P fertilizers and microbial inoculants in pulses is essential to address this need [60–62]. It is imperative to achieve a breakthrough in promoting P fertilizer utilization in legumes among farmers. The application of an optimum dose of 60 to 70 kg P_2O_5 per hectare is essential for higher chickpea production in acid *alfisols* of the western Himalayas [60]. Few studies reported that the combined application of *rhizobium* + *phosphorus-solubilizing bacteria* (PSB) + N + P or the inoculation of *rhizobium* and PSB alone or in combination resulted in higher net returns over control, attributed to the reduced cost of biofertilizers [63,64].

5. Conclusions

The results from the experiments showed that nipping in blackgram as a strategic cultivation technique resulted in improving plant architecture, optimizing growth conditions, and ultimately increasing yield. It involves the removal of the apical bud to encourage lateral branching and enhance the plant's productive capacity, which has resulted in significant enhancements in the productivity of blackgram, and NPK uptake was observed with blackgram cv. VBN8, when subjected to the application of 125% RDF of N and 100% P and K, along with nipping at 25 DAS. This combination resulted in higher plant height (49.52 cm), an increased number of branches (4.17), a higher number of pods per plant (46.80), and greater seed yield (894 kg.ha^{-1}) with a B:C ratio of 2.33. Additionally, nipping at 25 DAS exhibited a 14% increase in profitability compared to no nipping treatments, registering notable improvements in various parameters such as number of branches (4.08), pods per plant (48.14), and seed yield (902 kg.ha^{-1}) with a B:C ratio of 2.36. Nipping at 25 DAS lead to an increase in photosynthetic area, resulting in a higher photosynthetic rate, better assimilation, and accumulation of more photosynthates. This, in turn, is evident in better seed development and yield of blackgram. In a nutshell, blackgram cv. VBN8, the application of 125% RDF of N and 100% P and K and nipping at 25 DAS were found to be significant in enhancing the productivity of blackgram, and hence this practice needs to be recommended to the pulse growing farmers.

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