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Research Paper

Identifying a viable agro-technique to improve productivity of medium-duration pigeonpea (*Cajanus cajan*) in north-eastern hills zones of India

BIMAN DE[1], PARTHA DAS[2], D.P. AWASTHI[3], BUDHACHANDRA THANGJAM[4], BANANI DAS[5] AND SUJOY HAZARI[6]

All India Coordinated Research Project on Pigeonpea, Research Farm, College of Agriculture, Tripura, Lembucherra, West Tripura 799 210

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ABSTRACT

An experiment was conducted during the rainy (*kharif*) season of 2018 and 2019 at research farm of College of Agriculture Tripura, Lembucherra, West Tripura, to identify a viable agro-technique for improving productivity of medium-duration pigeonpea [*Cajanus cajan* (L.) Millsp]. Treatments comprised all possible combination of no nipping (N_0), nipping @ 45 days after sowing (DAS) (N_{45}), nipping @ 60 DAS (N_{60}) and nipping @ 90 DAS (N_{90}) with row-to-row spacing @ 45 cm (S_{45}), 60 cm (S_{60}), 75 cm (S_{75}) and 90 cm (S_{90}). The results showed that, early nipping (45 to 60 DAS) and wider spacing (75 to 90 cm) was very much effective for good crop canopy and productivity (leaf area index of 5.36), which can be addressed as a solution to the marginal pigeonpea farmers of Tripura for better growth (20.53 nos. of primary branches), yield (1.15 t/ha) and economic returns (37.89 × 10^3 ₹/ha).

Key words: Canopy, Economics, Nipping, NEH, Pigeonpea, Spacing, Harvest index

Pulses are second to cereals in importance for human and animal dietary needs. Deep-rooting characteristics, ability to fix atmospheric nitrogen and huge leaf fall make pulses an important component in cropping systems (Yadav *et al*., 2015; Sekhon *et al.,* 2018). In north-eastern hills (NEH) region, rice (*Oryza sativa* L.) is the dominant crops in valley areas and pulses are mainly grown rainfed on marginal lands with low or no inputs (Bhadana *et al.,* 2013). The NEH region has ample scope for pulse production; and farmers are growing them for better economic returns (Praharaj and Singh, 2019). In hilly areas, most farmers are growing pigeonpea [*Cajanus cajan* (L.) Millsp] as sole or intercrop. Pigeonpea when grown during the rainy season as a sole crop, with less fertile soil, results in poor yield. Modification of few agro-techniques can play a significant role to enhance the productivity and profitability through efficient utilization of land, moisture, and solar energy (Kumar *et al.,* 2016; Rajput and Bhadouriya, 2019). Nipping, i.e. removing apical buds which helps increase the apical dominance, has been found to increase the number of branches with better source-sink relationship, thereby, enhancing the yield (Dhaka *et al.,* 2020). Again, increase in row spacing results more in branches/plant with higher biomass production, harvest index and seed yield (Ibrahimi *et al.,* 2017). With these facts, an investigation was carried out to identify the viable agro-technique (nipping and spacing) to improve productivity of medium-duration pigeonpea in NEH zone.

MATERIALS AND METHODS

An experiment was conducted during the rainy (*kharif)* seasons of 2018 and 2019 at the research farm of College of Agriculture, Tripura, Lembucherra (23°90' N, 91°31' E, 52 m above mean sea-level). The soil of experimental farm was sandy loam, having *p*H 5.5, organic carbon 0.47%, nitrogen 260 kg N/ha, phosphorus 8.3 kg P_2O_5/ha and potash 176 kg K_2O/ha. Climate is subtropical with high rainfall and humidity with a prolonged winter (Fig. 1). The bulk density of soil was 1.36 mg/m^3 and pore space was 34.9%.

The design was factorial randomized block, having the treatments of nipping and spacing. The treatments were replicated thrice with all possible combination of no nipping (N_0), nipping @ 45 days after sowing (DAS) (N_{45}), nipping @ 60 DAS (N_{60}) and nipping @ 90 DAS (N_{90})

[1]**Corresponding author's Email:** d2_biman@yahoo.co.in
[1]Scientist (Agronomy), [2]Assistant Professor and Scientist (Plant Breeding), [3]Assistant Professor and Scientist (Plant Pathology), [4]Assistant Professor and Scientist (Entomology), AICRP on Pigeonpea, [5]Assistant Professor (Agricultural Economics), College of Agriculture, Lembucherra, Tripura 799 210; [6]Assistant Professor (Agricultural Economics), Faculty of Management and Commerce, The Institute of Chartered Financial Analysts of India University, Tripura 799 210

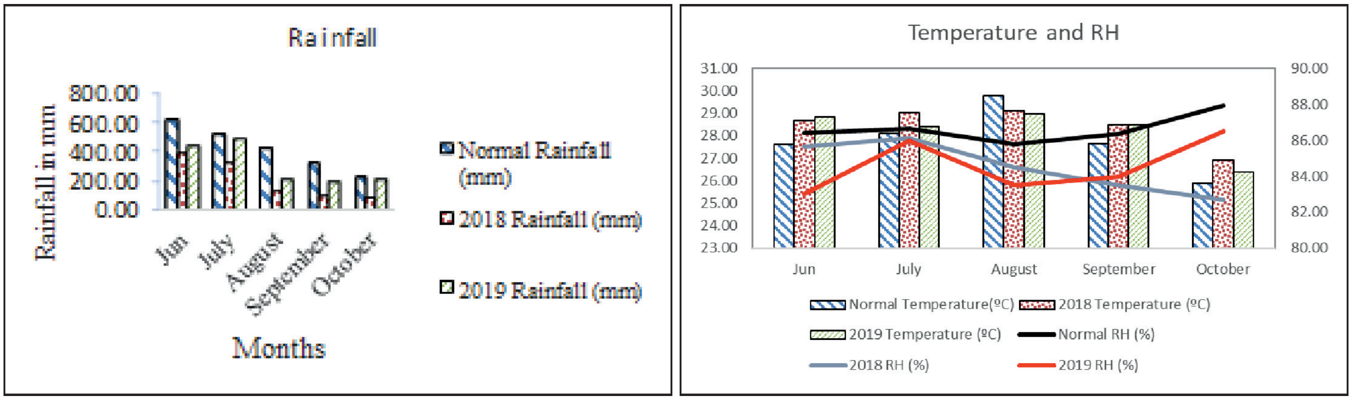

Fig. 1. Weather during the rainy season of 2018 and 2019 seasons compared to the normal

with row-to-row spacing @ 45 cm (S_{45}), 60 cm (S_{60}), 75 cm (S_{75}) and 90 cm (S_{90}). The plant-to-plant distance was 30 cm for all the spacing treatments. To keep a minimum 6 rows, plots of size 5.4 m and 4 m row length were maintained with recommended package of practices, with FYM @ 5 t/ha and recommended dose of fertilizer (RDF) @ 20, 60 and 40 kg N, P and K/ha respectively. The pigeonpea variety used was 'PAU 881'. Seed treatments were done with *Rhizobium* and phosphate-solubilizing bacteria (PSB) @ 500 g each/ha. Sowing was done on 8 and 13 June in 2018 and 2019, respectively, maintaining proper spacing as mentioned in the treatments. Plant-protection chemicals were applied as per recommendations and intercultural operations were done at 30 and 50 days after sowing (DAS). As per treatment intervals, nipping (top ¼th portion) were done with secateurs. Randomly selected 10 plants/treatment were tagged/used for data recording towards growth and yield-attributing parameters at regular intervals of 30, 60, 90, 120 DAS till harvesting. Leaf-area index was also measured using leaf-area meter. The first picking was done at 113 DAS and successive on 121 and 135. Before net plot yield collection, number of plant stand were taken and converted to per cent plant population.

Total cost of cultivation of ₹ 28.02 × 10^3/ha (no nipping) and ₹ 28.93 × 10^3/ha (nipping) occurring in production of pigeonpea was calculated excluding the cost of fertilizers and manures. Price of the produce was taken as per the minimum support price (MSP) of ₹ 5,800/q or 100 kg for pigeonpea. On the basis of that, benefit: cost ratio was calculated (Rana *et al*., 2014). The total duration of the crop from sowing to harvesting was 135 days to express returns per day. Data were analysed with statistical package (Indostat services, Hyderabad). Pearson correlation and Duncan multiple range tests (DMRT) were done using SPSS Inc Version 16.

RESULTS AND DISCUSSION

Plant population

The highest plant populations were recorded in N_0 (90.1%) followed by N_{60} (86.9%) (Table 1). Among vari-

Table 1. Outcome of nipping and spacing in crop stand and growth for medium-duration pigeonpea (pooled data of 2 years)

Treatment	Plant population (%)	Plant height (cm)	Primary branches (nos.)	Leaf-area index 30 DAS	60 DAS	90 DAS	120 DAS	At harvesting
Nipping levels (days after sowing)								
N_0	90.12^a	269.04^a	13.66^b	0.117^b	1.43^c	3.41^{bc}	4.10^{bc}	0.33^b
N_{45}	83.86^{ab}	260.34^a	20.53^a	0.128^a	1.80^a	4.12^a	5.36^a	0.75^a
N_{60}	86.89^{ab}	249.61^a	12.68^b	0.113^b	1.38^c	3.36^c	3.94^c	0.33^b
N_{75}	82.19^b	252.61^a	12.48^b	0.117^b	1.56^b	3.64^b	4.45^b	0.70^a
Spacing levels (cm × cm)								
$S_{45 \times 30}$	84.82^a	257.45^a	12.6^b	0.115^b	1.42^b	3.43^b	4.09^b	0.33^b
$S_{60 \times 30}$	85.88^a	260.97^a	15.76^{ab}	0.117^b	1.56^a	3.64^{ab}	4.74^a	0.58^a
$S_{75 \times 30}$	85.52^a	261.83^a	16.12^a	0.119^b	1.60^a	3.72^a	4.60^a	0.53^a
$S_{90 \times 30}$	86.84^a	251.34^a	14.88^{ab}	0.124^a	1.58^a	3.74^a	4.42^{ab}	0.67^a

DAS, Days after sowing

Means followed by same letters (a,b,c) in a column are not different at 0.05 probability level

No nipping (N_0); nipping @ 45 DAS (N_{45}); nipping @ 60 DAS (N_{60}); nipping @ 90 DAS (N_{90}) with row-to-row spacing @ 45 cm (S_{45}); 60 cm (S_{60}); 75 cm (S_{75}); 90 cm (S_{90}). The plant-to-plant spacing was 30 cm for all the spacing treatments ous spacings S_{90} (86.8%) achieved the highest plant population but no significant differences were not seen in both factors A (nipping) and factor B (spacing). Varatharajan *et al.* (2019a) reported insignificant difference among population levels but differed significantly with primary branches as in the case of nipping @45 DAS (N_{45}) at spacing of 75 cm (S_{75}). Cubic curve fitting of plant population to primary branches (Fig. 2b) clearly showed that, primary branches increased with population stand but decreased with the further increase in plant population after achieving a critical point which might be due to the fact that after that point population crowding affected the number of primary branches (Kumar *et al.,* 2021, 2022).

Plant growth parameters

Plant height was the highest in N_0 (269 cm) followed by N_{45} (260.3 cm) and N_{75} (252.6 cm). Spacing S_{75} (261.8 cm) achieved the highest plant height followed by spacing S_{60} without any significant differences (Table 1). Plant height gradually increased up to the age of 120 DAS and thereafter, it decreased which may be due to genetic reasons (Varatharajan *et al.,* 2019b). Primary branches (Table 1) in nipping treatments showed significant differences, the highest number of branches were recorded in N_{45} (20.53) followed by N_0 (13.66), but non-significant differences were observed in case of spacing treatments, highest being at S_{60} (15.76). Cubic curve fitting of primary branches to seed yield (Fig. 2a) inferred that at the initial stages there was decline in yield with increase in primary branches in most of the treatment combinations, but with further increase in branches, a rapid increase in seed yield was seen. Initial reduction in yield might be due to crowding effect in close spacing combinations which was opposite with wider combinations (Badiyala *et al*., 2012). Significant values

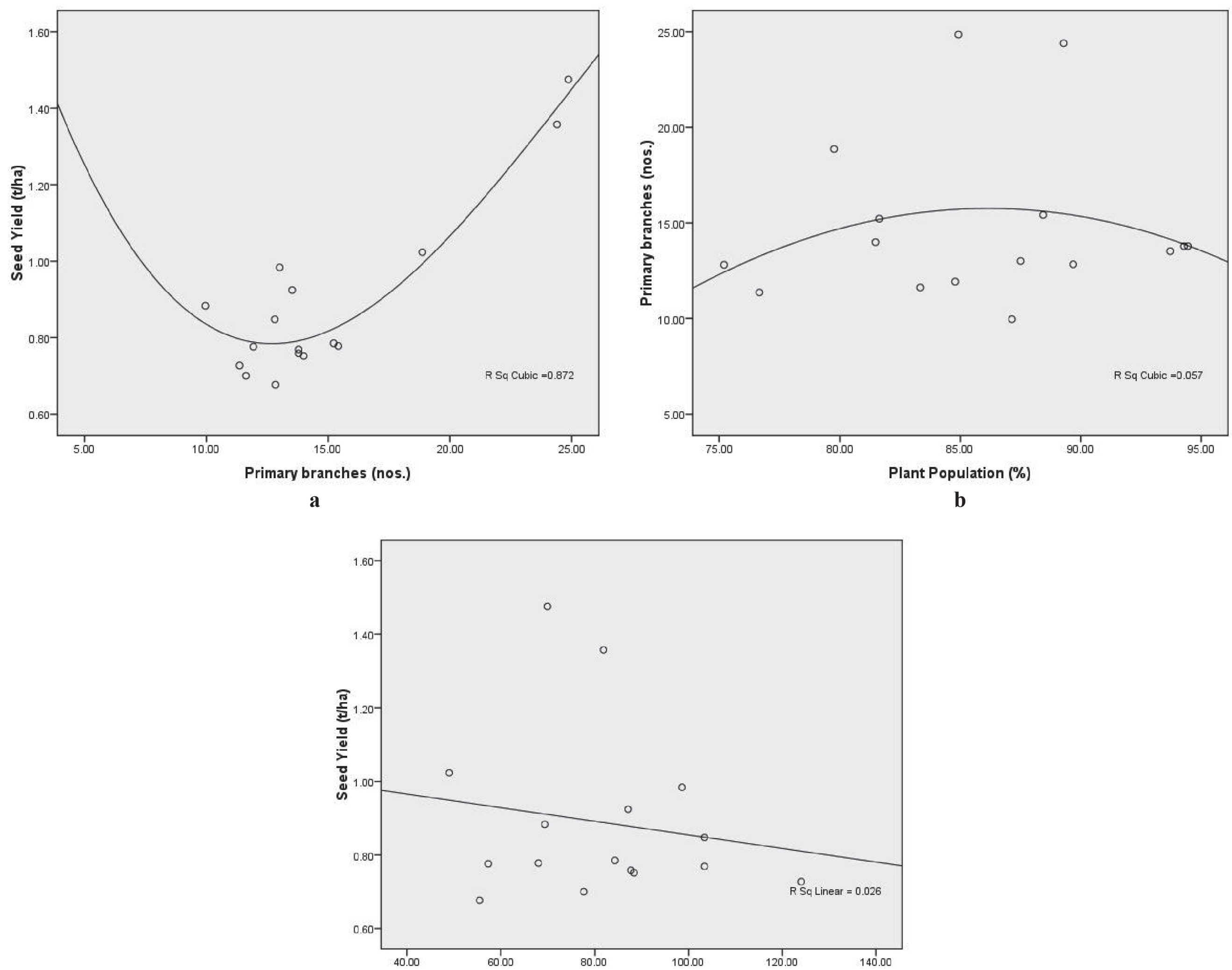

Fig. 2. a. Cubic curve fitting of plant population (%) to primary branches (no.), b. Cubic curve fitting of primary branches (no.) to seed yield (t/ha) and c. Linear curve fitting of number of pods (no.) to seed yield (t/ha).

were observed for leaf-area index (LAI) at all the intervals, i.e. 30, 60, 90, 120 and 135 (at harvesting) DAS for both nipping and spacing, the highest being at N_{45} at all the intervals. In case of spacings, the highest LAI differed at different days (Table 1). The highest LAI was measured in 120 DAS for N_{45} treatments (5.36) showed significantly higher leaf-area index than the other treatments, but in case of spacing, multiple range test depicts that, the treatments S_{60} (4.74) and S_{75} (4.60) were at par but significantly higher than the other spacing treatments, which might be due to the fact that early nipping at wider row spacing induced more branches with more ground area coverage than late nipping with reduced spacing (Kumar *et al*., 2020; Gupta *et al*., 2022).

Yield attributes and yield

Pod yield/plant showed insignificant difference among the nipping treatments, while significant differences were observed in spacing treatments (Table 2). The highest pod yield/plant was achieved in N_{45} (26.30 g) and S_{90} (28.45 g) under nipping and spacing, respectively, which under multiple range tests differed from others for nipping but was at par in case of spacing with S_{75} (24.16 g). The possible reason might be due to diversion of energy at late nipping and crowding effect of close spacing (Kumar *et al.,* 2020, 2021). Number of pods/plant for both nipping and spacing treatments were significantly different among them individually and the highest was recorded in N_{60} (91.31) and S_{75} (93.84) treatments. Multiple range tests (Table 2) show at par results between S_{75} (93.84) and S_{90} (90.74) treatments. Linear curve fitting of number of pods to seed yield (Fig. 2c) depicted that, with the rise in pod number there was a sharp decline in seed yield which may be due to poor grain formation at the successive pickings, and thus both of them are independent to each other (Sharma *et al.,* 2003, Singh *et al.,* 2020). Pod yield, an important yield-attributing character, showed non-significant differences among them for both nipping and spacing treatments (Table 2), but multiple range tests showed that N_{45} (1.49 t/ha) was found superior and different among the nipping treatments, whereas 1.37 t/ha was achieved in S_{75} and S_{90} spacing treatments, being at par and different from others in case of spacing (Kumar *et al.,* 2020). Cubic curve fitting of pod yield to seed yield (Fig. 3a) indicated that, at initial stage with the rise in pod yield, there was a slow (lag) increase in seed yield which may be because of poor pod to seed formation at both initial and successive pickings due to late nipping at the crucial time, diverted the energy from healthy pod formation to branch initiation. Seed index, is also a superior yield-attributing parameter, showed non-significantly different for both the cases. Pooled data revealed that, N_{45} (8.40 g) and S_{90} (8.48 g) showed the highest values for both nipping and spacing respectively (Sharma *et al.,* 2003).

Seed yield which also decides the economics (Table 2), upon which the viability of a particular agro-technique depends for further dissemination and adoption to the farmer, was the maximum in N_{45} (1.15 t/ha) nipping treatments from pooled data. Multiple range tests also showed that N_{45} (1.15 t/ha) was insignificantly different from at par treatments of N_0 (0.75 t/ha), N_{60} (0.83 t/ha) and N_{75} (0.82 t/ha). In case of spacing, S_{75} treatments (1.02 t/ha) yielded the best, being non-significantly different from the other spacing treatments (Ibrahimi *et al.,* 2017). Though stover yield is the by-product of the pigeonpea cultivation, it has its own importance as a good fuel. Significantly higher

Table 2. Outcome of nipping and spacing in seed yield-imputing characters for medium-duration pigeonpea (pooled data of 2 years)

Treatment	Pod yield/plant (g)	Pods /plant (nos.)	Pod yield (t/ha)	Seed index (g)	Stover yield (t/ha)	Seed yield (t/ha)	Harvest index
Nipping levels (days after sowing)							
N_0	14.86^{b}	84.19^{ab}	1.02^{b}	8.35^{a}	7.11^{a}	0.75^{b}	0.096^{b}
N_{45}	26.30^{a}	72.29^{b}	1.49^{a}	8.40^{a}	7.84^{a}	1.15^{a}	0.128^{a}
N_{60}	19.84^{b}	91.31^{a}	1.30^{ab}	8.32^{a}	8.10^{a}	0.83^{b}	0.093^{b}
N_{75}	19.06^{b}	78.58^{ab}	1.20^{ab}	8.18^{a}	7.69^{a}	0.82^{b}	0.096^{b}
Spacing levels (cm × cm)							
$S_{45 \times 30}$	10.43^{c}	69.70^{b}	0.99^{a}	8.07^{b}	7.75^{a}	0.73^{b}	0.89^{b}
$S_{60 \times 30}$	17.02^{b}	72.09^{b}	1.26^{a}	8.36^{ab}	7.56^{a}	0.88^{ab}	0.103^{ab}
$S_{75 \times 30}$	24.16^{a}	93.84^{a}	1.37^{a}	8.35^{ab}	7.91^{a}	1.02^{a}	0.113^{a}
$S_{90 \times 30}$	28.45^{a}	90.74^{a}	1.37^{a}	8.48^{a}	7.52^{a}	0.93^{ab}	0.108^{ab}

DAS, Days after sowing

Means followed by same letters (a,b,c) in a column are not different at 0.05 probability level

No nipping (N_0); nipping @ 45 DAS (N_{45}); nipping @ 60 DAS (N_{60}); nipping @ 90 DAS (N_{90}) with row-to-row spacing @ 45 cm (S_{45}); 60 cm (S_{60}); 75 cm (S_{75}); 90 cm (S_{90}). The plant-to-plant spacing was 30 cm for all the spacing treatments.

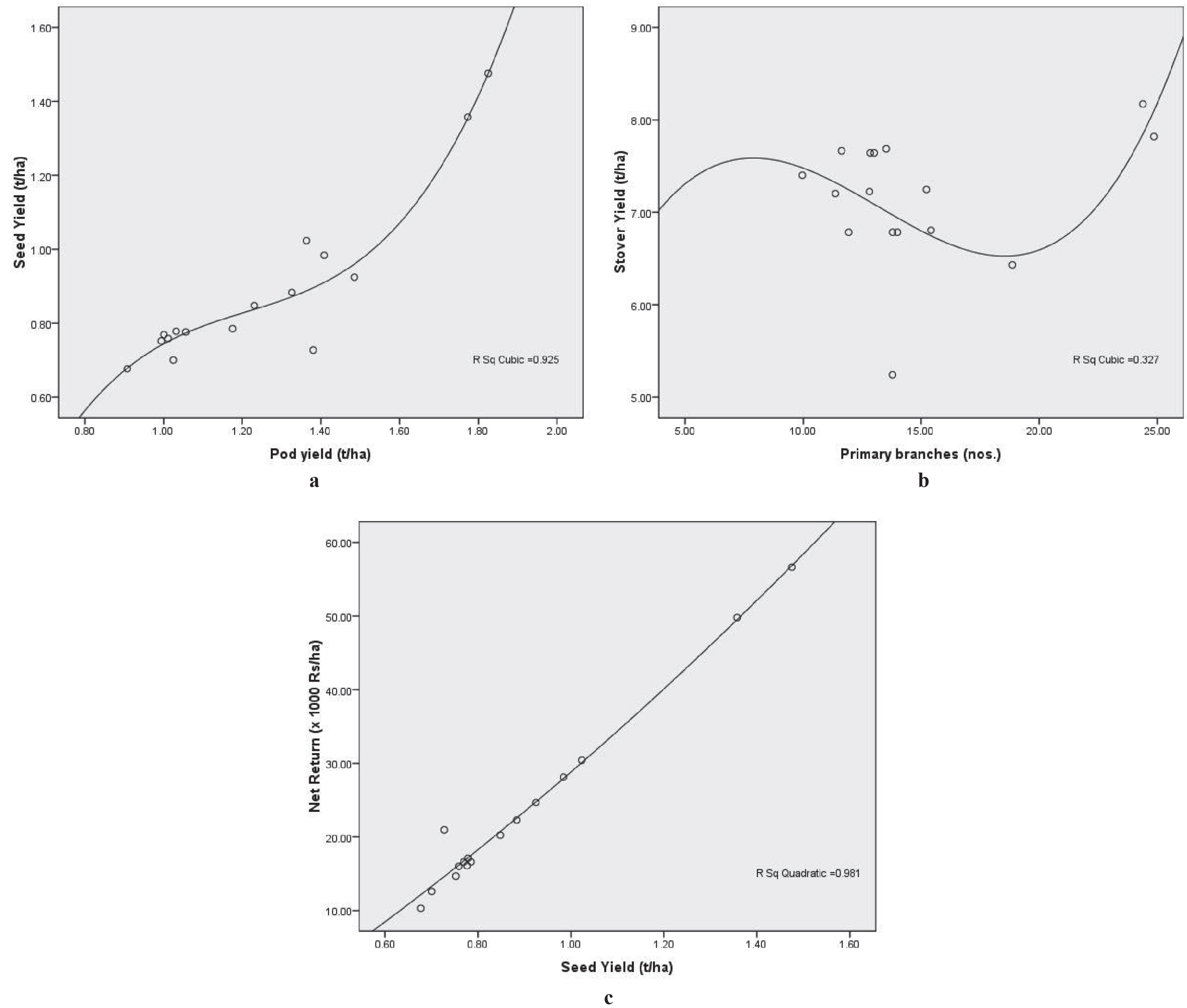

Fig. 3. a. Cubic carve fitting of primary branches (nos.) to seed yield (t/ha), b. Cubic carve fitting of primary branches (nos.) to stover yield (t/ha) and c. Exponential curve fitting of net return (× 10^3 ₹/ha) to seed yield (t/ha)

yield was recorded in both the cases, with the highest being at N_{60} (8.10 t/ha) and S_{75} (7.91 t/ha) treatments respectively (Table 2). Cubic curve fitting of primary branches to stover yield (Fig. 3b) revealed that, at the initial stages there was decline in yield with increase in primary branches in many combinations. However, with the further increase in branches there was improvement in yield, which might be owing to senescence and dropping of the matured branches at lower portion in early nipping and close spacing combinations and the reverse combinations recovered the stover yield. The results confirm the findings of Sharma *et al.,* (2003). Higher harvest index was noted in N_{45} (0.128) and S_{75} (0.113) treatments. Multiple range tests also confirm that the respective cases are insignificantly different from others for harvest index.

Economics

The net returns, benefit: cost and returns per day on the basis pooled data showed the same trend as seed yield which were also non-significantly different from the other treatments of nipping and spacing respectively. The highest net return was in N_{45} (₹37.89 × 10^3/ha) and S_{75} (₹30.39 × 10^3/ha) treatments. Similarly, the highest benefit: cost also showed similar trend, i.e. N_{45} (2.31) and S_{75} (2.06), followed by N_{60} (1.73) and S_{90} (1.95), treatments (Table 3). Returns per day for the whole period starting from sowing till harvesting exhibited same trend like the other economic parameters (Varatharajan *et al.,* 2019b). Exponential curve fitting of net returns to seed yield (Fig. 3c) displayed that, net returns increased with the increase in seed yield which might be owing to the direct effect of the improved

Table 3. Economics of nipping and spacing to improve productivity for medium-duration pigeonpea (pooled data of 2 years).

Treatment	Net returns (×10³ ₹/ha)	Benefit: cost ratio	Returns/day (₹/ha)
Nipping levels (days after sowing)			
N_0	15.58ᵇ	1.56ᵇ	115.41ᵇ
N_{45}	37.89ᵃ	2.31ᵃ	280.66ᵃ
N_{60}	21.02ᵇ	1.73ᵇ	155.73ᵇ
N_{75}	18.81ᵇ	1.65ᵇ	139.35ᵇ
Spacing levels (cm × cm)			
$S_{45 \times 30}$	13.43ᵇ	1.47ᵇ	99.46ᵇ
$S_{60 \times 30}$	22.21ᵃᵇ	1.77ᵃᵇ	164.51ᵃᵇ
$S_{75 \times 30}$	30.39ᵃ	2.06ᵃ	225.17ᵃ
$S_{90 \times 30}$	27.27ᵃᵇ	1.95ᵃᵇ	202.00ᵃᵇ

DAS, Days after sowing
Means followed by same letters (a,b,c) in a column are not different at 0.05 probability level
No nipping (N_0); nipping @ 45 DAS (N_{45}); nipping @ 60 DAS (N_{60}); nipping @ 90 DAS (N_{90}) with row-to-row spacing @ 45 cm (S_{45}); 60 cm (S_{60}); 75 cm (S_{75}); 90 cm (S_{90}). The plant-to-plant spacing was 30 cm for all the spacing treatments

productivity of most of the treatment combinations that ultimately pushed the net returns in an ascending manner.

Pearson correlation among different parameters

Correlation among the growth, yield and economic parameters showed that, primary branches had significantly positive correlation with pod yield, seed yield and net returns. Again, positive correlation of pod yield was found with stover yield, seed yield and net returns (Table 4). A highly positive correlation was also observed between seed yield and net return. However, the plant population and number of pods/plant showed negative to poorly positive correlation between the other parameters. The study drew few recommendations that early nipping was very effective for branching, pod and yield formation. Wider spacing is very much effective for good crop canopy and productivity (Rajpoot *et al.,* 2021). Late nipping and closer spacing negatively effects the overall production of pigeonpea.

Thus, early nipping (45 to 60 DAS) and wider spacing of (75 to 90 cm) can be recommended as an effective agro-technique to the marginal pigeonpea farmers of Tripura for better growth, yield and economic returns.

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Table 4. Pearson correlation among the growth, yield and economic parameters to improve productivity for medium-duration pigeonpea (based on pooled of 2 years)

	Plant Population (%)	Primary branches (no.)	Pods/ plant (no.)	Pod yield (t/ha)	Stover yield (t/ha)	Seed yield (t/ha)	Net returns (×10³ ₹/ha)
Plant Population (%)	1	.057	-.145	-.082	-.107	.003	.003
Primary branches (no.)		1	-.249	.687**	.252	.865**	.865**
Pods/plant (no.)			1	.079	.023	-.079	-.079
Pod yield (t/ha)				1	.536*	.934**	.934**
Stover yield (t/ha)					1	.434	.434
Seed yield (t/ha)						1	.990**
Net returns (×10³ ₹/ha)							1

**P=0.01 (2-tailed); *P=0.05 (2-tailed).

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