

Influence of Support System on Country Bean Production during summer season

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Abstract

Country bean (*Lablab purpureus* L.) is a valuable leguminous vegetable crop with nutritional and economic significance in tropical and subtropical regions. The present study was to evaluate the performance of three photo-insensitive country bean genotypes, namely Sikribi Sheem-1 (V1), Sikribi Sheem-2 (V2) and SB003 (V3), which were grown under three different support systems called horizontal trellis (S1), vertical trellis (staking, S2) and sloped trellis (A-shaped trellis, S3). The results showed that internode length varied significantly among treatments, with Sikribi Sheem-1 under vertical trellis (17.57 cm) exhibiting the greatest length, indicating increased canopy spread and photosynthetic efficiency. However, other vegetative features showed insignificant variation. Flowering occurred earliest in Sikribi Sheem-1 under an A-shaped frame (40.00 days) and latest under a horizontal trellis (45.67 days). Genotype support interaction significantly influenced pod number per plant and pod yield. The highest values were recorded in Sikribi Sheem-1 under vertical trellis (288.83 pods per plant and 1.34 kg per plant), whereas SB003 under staking and A-shaped frame produced the longest pods (9.93 and 9.80 cm) and highest dry matter (22.30%). Pearson correlation analysis revealed strong positive correlations among pod yield, number of pods per plant, number of branches per plant, and pod morphology, highlighting the critical factors for high productivity. Then, Principal Component Analysis (PCA) split growth, physiological, and yield-contributing traits into distinct groups, explaining 62.8% of total variation, whereas heatmap clustering illustrated co-association patterns among traits and treatments. These findings demonstrate that Sikribi Sheem-1 with vertical trellis or staking is the most effective combination for optimizing plant architecture, enhancing assimilate partitioning, improving canopy efficiency, and providing an effective, low-cost strategy to maximize yield and pod quality of climbing country bean under summer cultivation.

Introduction

The popular name of country bean (*Lablab purpureus* L. Sweet) is lablab bean or dolichos bean. We Bengalis called it "Sheem". It belongs to the family Fabaceae and to the subfamily Papilionoideae (Naeem et al., 2023). Green pods and seeds are excellent sources of protein. Among other legume vegetables in Bangladesh and worldwide, country bean ranked first (Suborna et al., 2024). It is a self-pollinating crop, and its chromosome numbers are $2n = 20, 22$, and 24 . It has numerous synonyms, including Dolichos bean, hyacinth bean, lablab bean, Indian bean, faba bean, and labia bean (Nisha et al., 2021). Due to its photosensitivity, it is cultivated during the winter season in Bangladesh (Shibli et al., 2021). It is the third-most widely grown vegetable in Bangladesh's central and southwest regions, after taro and eggplant. In Bangladesh, green pods are primarily available during the winter season (Rahman et al., 2022). As a nutritious crop, they are equally essential in the summer season. Researchers made an effort and succeeded in developing photo-insensitive country bean genotypes that will meet consumer demand during the summer season (Kumar, 2023). There are specific photo- and thermo-insensitive country bean varieties best suited for summer, developed by the Olericulture division of Bangladesh Agricultural Research Institute. To develop suitable country bean varieties for monsoon cultivation, the BRAC Agricultural Research & Development Center (BARDC) launched a summer country bean

development project in 2002. So far, five lines of summer country beans have been established: Borsha, Usha, Broad purple fruit, Broad green fruit, and Maya (Rakibuzzaman et al., 2024; Pathy et al., 2025). These lines are becoming increasingly popular in Bangladesh's commercial agricultural areas due to their resistance to heat and viruses. These seasonal constraints also led to the development of photo-insensitive country bean genotypes named Sikribi Sheem-1 and Sikribi Sheem-2 (Emon et al., 2025). Country beans are common annual and perennial leguminous vegetables in Bangladesh and worldwide, with traits such as twining, creeping, or bushy growth. In Bangladesh, dried seeds are favored as a pulse, whereas green pods are still consumed as vegetables (Punniyamoorthy et al., 2025). The crop plays a significant role in atmospheric nitrogen fixation, contributing to soil fertility and sustainable agriculture. In addition, it has potential medicinal value and may be utilized in the pharmaceutical and nutraceutical industries. Country bean contains about 20–28% protein, including essential amino acids. It is a versatile crop with twining, creeping, or bushy growth habits and is widely cultivated as both an annual and a perennial vegetable in Bangladesh and worldwide (Khan et al., 2018; Shahrajabian et al., 2022). Vine begins to lodge when it reaches a length of more than 30 cm. For this reason, researchers recommend setting out support from early on (Savita, 2023). Branch growth and yield are decreased considerably in the absence of support. That is why bamboos are used as a support, such as bamboo matcha (trellis) and plant branches (Basak et al., 2021). To be considered a sound plant support system, it must meet the following criteria. It should be robust enough to withstand the plant's weight until harvest and be able to utilize as much light, space, and moisture as possible. Crop yields can be increased several times when prefabricated plant supports, such as trellises and stakes, are used. For more precise information, further research on these genotypes with different support systems, such as trellis, staking, slop trellis, ring trellis, etc., should be conducted (Ghislain et al., 2019; Ferraro-Fanning, A., 2023). There is insufficient information to understand the impact of varying support structures on the increase in country bean yield. To increase bean production per unit area, the support system may need to be standardized. Based on the above perspective, the present study was designed to assess the growth, yield, and physiological traits of summer country bean genotypes and to examine the influence of different support systems on these traits.

Materials and Methods

Experimental Site and Duration

The research work was conducted at the experimental field of the Department of Horticulture, Faculty of Agriculture, Sylhet Agricultural University (SAU), Sylhet-3100, Sylhet, Bangladesh, which is under the Agro-ecological Zone – 20: Northern and Eastern piedmont Plain (Tsuda, 2012). The experiment was conducted from April to October, 2023. The soil was loamy, well-drained, with a pH of 6.5–6.8 (FAO & UNDP, 2001), 1.2% organic matter, and nutrient content determined by standard soil analysis methods (Hossain, 2009). The site is located in the North-Eastern part of Bangladesh, lying between 23°57' to 25°13' North latitude and 90°56' to 92°21' East latitude (Rahman et al., 2020).

Plant Materials and Treatments

The three country bean genotypes used in the experiment were Sikribi Sheem-1, Sikribi Sheem-2, and SB003. The planting material, country bean seeds, was collected from the Department of Horticulture lab of Sylhet Agricultural University. Three support systems were evaluated: (i) horizontal trellis (Net), (ii) vertical trellis/staking (Bamboo head), and (iii) A-shaped frame (sloped trellis). The experiment was laid out in a two-factorial Randomized Complete Block Design (RCBD) with three replications. Twenty-seven plots were made for the experiment with an area of 23 m × 8m (184 m²). The unit plot size was 2m × 2m, and each plot was used as a bed. A double row and four pits characterized each bed. The plant-to-plant distance was 1 m, and the row-to-row distance was 1m (Fig. 1). A 50 cm drain was laid out between the beds within each block to drain out the excess water. A 50 cm × 50 cm × 50 cm pit was dug 10 days prior to seed sowing. Cow dung, MoP, TSP and Zn were applied in the pit seven days prior to seeding. The pit was arranged 10 cm above the soil surface to facilitate adequate drainage. On April 15, 2023, the four seeds of Sikribi Sheem-1, Sikribi Sheem-2, and SB003 of each genotype were directly sown in each pit. To encourage healthy seed germination, watering was performed shortly after sowing. In each pit, only healthy plants were permitted to develop after the seedlings were established. So, each plot carried four plants.

Data collection and Statistical Analysis

Vine length (cm), terminal leaflet length and breadth (cm), petiole length (cm), and internode length (cm) were measured at 30–45 DAS using a measuring tape. Data collection involved obtaining SPAD readings from a SPAD meter at three distinct sites on a single leaf, then recording the average value for each plant. Days to first flowering and days to first harvest were recorded from sowing until the appearance of the first flower and first mature pod, respectively. Number of pods per plant, individual pod weight (g), pod yield per plant (kg), pod length and breadth (cm) were recorded at physiological maturity. Fiber contents (%) and dry matter content were also measured. Data were analyzed using R software (v4.4.3), and LSD was used to correct mean differences and variations at the 1% and 5% levels of significance for interpretation of the results. The analysis was done using a computer. The nutritional attribute parameters were analyzed using simple statistical measures and discussed based on the estimated results. Tables were prepared using Microsoft Excel.

Estimation of physiological attributes

Fiber contents (%)

To determine the dry matter content of all three genotypes, fresh pods were taken randomly from each plot. Then 50 g pods were weighed and sliced into small pieces with a sharp knife for proper drying. They were placed in a paper envelope, dried in an electric oven at 72°C, and kept until a constant dry weight

was attained (3 days). The pod's dry weight was estimated after proper drying. Then it was converted to percent dry matter. The formula given below-

$$\text{Fiber content (\%)} = \frac{\text{Dried fibre weight of pods}}{\text{Fresh weight of pods}} \times 100$$

Dry matter content (%)

To determine the dry matter content of all three genotypes, fresh pods were taken randomly from each plot. Then 50 g pods were weighed and sliced into small pieces with a sharp knife for proper drying. They were placed in a paper envelope, dried in an electric oven at 72°C, and kept until a constant dry weight was attained (3 days). The pod's dry weight was estimated after proper drying. Then it was converted to percent dry matter. The formula given below-

$$\text{Dry matter (\%)} = \frac{\text{Dry weight of pods}}{\text{Fresh weight of pods}} \times 100$$

Results

Effect of Different Support Systems on Morpho-Physiological Characteristics of Country Bean

Most morphological and physiological results did not show significant differences, but there were significant differences between the genotype and support system (Table 1). Comparatively, genotype SB003 achieved the greatest height (293.33 cm) when supported by a horizontal trellis, compared to 239.00 cm with a vertical trellis or staking. The comparatively shortest terminal leaflet length (11.95 cm) was observed in Sikribi Sheem-1 when supported by a horizontal trellis, and the longest (13.73 cm) was noted in SB003 carried by an A-shaped frame (sloped trellis). Even though terminal leaflet breadth did not show substantial differences, comparatively broadest leaflets (14.06 cm) were found in SB003 with an A-shaped frame. In contrast, the narrowest (11.33 cm) was observed in Sikribi Sheem-2, which used a horizontal trellis. Petiole length did not exhibit significant variation, varying from 8.37 cm in Sikribi Sheem-1 to 11.99 cm in Sikribi Sheem-2, both cultivated within an A-shaped frame. Internode length displayed significant differences, with the longest internodes observed in SB003 grown on a horizontal trellis (17.79 cm) and Sikribi Sheem-1 utilizing a vertical trellis (17.57 cm). The number of branches per plant did not show significant variation. Comparatively, Sikribi Sheem-1 with vertical trellis produced the highest number (11.42), SB003 with the same support had the lowest (6.50). The comparatively highest SPAD value (46.55) was obtained from Sikribi Sheem-2 under a horizontal trellis, while Sikribi Sheem-1 under the A-shaped frame showed the lowest (39.71).

Table 1

Effect of different support system on morphological and physiological characteristics of country bean

Variety	Vine length (Cm)	Terminal leaflet length (cm)	Terminal leaflet breadth (cm)	Petiole length (cm)	Internode length (cm)	Branch per plant	SPAD Value at 45 DAS
V1S1	244.30	11.95	12.15	8.83	13.18bc	11.00	39.93
V1S2	264.33	12.31	12.59	8.76	17.57a	11.42	40.65
V1S3	250.42	12.05	11.92	8.37	14.89abc	9.58	39.71
V2S1	253.00	12.42	11.33	10.60	12.54c	8.43	46.55
V2S2	255.33	12.92	11.87	11.61	13.45bc	8.20	44.06
V2S3	275.00	12.23	10.92	11.99	14.83abc	7.17	43.80
V3S1	293.33	12.23	11.46	8.80	17.79a	8.93	42.18
V3S2	239.00	12.30	11.59	8.55	16.75ab	6.50	41.92
V3S3	247.00	13.73	14.06	9.33	16.14abc	9.17	40.01
CV (%)	8.52	6.62	8.79	10.16	8.5	20.46	1.42
P value	0.05	0.23	0.05	0.5	< 0.01	0.3	0.31

V1 = Sikribi Sheem-1, V2 = Sikribi Sheem-2, V3 = SB003; S1 = Horizontal Trellis, S2 = Vertical Trellis (Staking) and S3 = A-shaped frame (Sloped Trellis).

Effect of Different Support Systems on Yield Characteristics of Country Bean

The reproductive and yield attributes of country bean were significantly influenced by the interaction effects across genotype and support system (Table 2). There was a notable difference in time to flowering between Sikribi Sheem-1 under a horizontal trellis (45.67 days) and the same genotype supported by an A-shaped frame (sloped trellis) (40.00 days). There was a minor variation in harvesting time: Sikribi Sheem-1 with an A-shaped frame had the earliest harvesting time (75.33 DAS). In comparison, the latest harvesting (77.00 DAS) occurred in Sikribi Sheem-2 with a horizontal trellis, Sikribi Sheem-2 with an A-shaped frame, and SB003 with an A-shaped frame. On a vertical trellis, Sikribi Sheem-1 produced the highest pod count (288.83 pods per plant), whereas on staking, SB003 produced the fewest (148.67 pods per plant). In the genotype–support interaction, individual pod weight did not differ significantly; however, the heaviest pods (5.21 g) were recorded in SB003 with an A-shaped frame, and the lightest (3.50 g) in Sikribi Sheem-2 under a horizontal trellis. Pod yield per plant showed a statistically significant variation. Sikribi Sheem-1 grown on a vertical trellis attained the highest yield (1.34 kg per

plant), indicating that appropriate support structure and genotype selection can significantly influence productivity in country bean.

Table 2
Effect of different support system on yield characteristics of country bean

Variety	Days to flower	Days to harvest	No. of pods/plant	Individual pod weight (g)	Pod Yield/Plant (kg)	Pod yield (t/ha)
V1S1	45.67	76.67	246.17b	4.75	1.10ab	10.86ab
V1S2	42.00	76.00	288.83a	4.62	1.34a	13.14a
V1S3	40.00	75.33	230.00bc	4.61	1.05bc	10.37bc
V2S1	42.67	77.00	162.33d	3.50	0.56e	5.53e
V2S2	42.67	76.33	152.00d	3.77	0.57e	5.63e
V2S3	43.67	77.00	179.33cd	3.68	0.65e	6.42e
V3S1	43.00	76.00	168.33d	4.95	0.83cd	8.20cd
V3S2	43.33	76.00	148.67d	5.08	0.75de	7.41de
V3S3	42.67	77.00	175.42d	5.21	0.91bc	8.99bc
CV (%)	8.00	7.27	12.97	15.85	4.9	6.5
P value	0.52	1.00	0.03	0.98	< 0.05	< 0.05
V1 = Sikribi Sheem-1, V2 = Sikribi Sheem-2, V3 = SB003; S1 = Horizontal Trellis, S2 = Vertical Trellis (Staking) and S3 = A-shaped frame (Sloped Trellis)						

Effect of Different Support Systems on fruits Characteristics of Country Bean

The interaction between variety and support system significantly affected pod length, but pod breadth, fiber content, and dry matter percentage remained statistically unaffected across treatments (Table 3). A highly significant difference was observed for pod length, with SB003 producing the longest pods under both staking and vertical trellis (9.93 cm) and the A-shaped frame (9.80 cm); by contrast, other combinations yielded comparatively shorter pods. Despite this, the pod breadth was not significantly affected by the interaction, ranging from 2.29 cm in Sikribi Sheem-2, utilizing a horizontal trellis, to 2.85 cm in Sikribi Sheem-1 with the same support. In addition, the fiber content of green pods showed no significant variation, with a slight range from 0.40% in Sikribi Sheem-1 with an A-shaped frame to 1.07% in Sikribi Sheem-2 with a horizontal trellis. The dry matter content also remained statistically similar across treatments, ranging from 9.43% to 22.30%, with the highest recorded in SB003, supported by an A-shaped frame, and the lowest in Sikribi Sheem-1 under a horizontal trellis.

Table 3

Effect of different support system on fruit and fruit physiological characteristics of country bean

Variety	Pod length (cm)	Pod breadth (cm)	Fibre of green pod (%)	Dry matter of pod (%)
V1S1	9.41ab	2.85	0.65	9.43
V1S2	8.87abc	2.73	0.52	9.90
V1S3	9.27ab	2.78	0.40	9.63
V2S1	7.30d	2.29	1.07	11.07
V2S2	8.03cd	2.56	1.06	10.72
V2S3	7.69cd	2.34	0.94	10.89
V3S1	8.44bcd	2.38	1.03	12.30
V3S2	9.93a	2.49	0.95	10.85
V3S3	9.80a	2.48	0.90	10.04
CV (%)	4.98	2.36	13.25	5.3
P value	< 0.01	0.12	0.73	0.42
V1 = Sikribi Sheem-1, V2 = Sikribi Sheem-2, V3 = SB003; S1 = Horizontal Trellis, S2 = Vertical Trellis (Staking) and S3 = A-shaped frame (Sloped Trellis)				

The Traits Association

The correlation coefficients for morpho-physiological and yield traits of lablab bean across different genotypes and support systems were presented in Fig. 2. They represent the relationships among different morpho-physiological and yield-contributing traits of lablab bean across different genotypes and support systems. The Correlation coefficients ranged from – 0.82 to 0.92, indicating a wide range of relationships among the attributes considered. A very strong and highly significant positive correlation ($r = 0.92^{***}$) was observed between the number of pods per plant (NPP) and pod yield per plant (PYP), followed by pod length (POL) and individual pod weight (IPW), with $r = 0.90^{***}$. Similarly, Branch per plant (BPP), Terminal leaflet length (TLL), individual pod weight (IPW) and SPAD showed positive associations with pod breadth (PB), Terminal leaflet breadth (TLB), internode length (IL), and petiole length (PEL), indicating that yield development is strictly connected with pod morphological characters. In contrast, phenological traits such as days to flowering (DTF) and days to harvest (DTH) showed weak, non-significant correlations with most physiological and yield parameters, suggesting that flowering time had limited direct influence on yield. However, negative and significant relationships were noted between SPAD value and pod yield per plant (PYP) and individual pod weight (IPW) ($r = -0.82^{**}$), as well as between SPAD and pod length (POL, $r = -0.85$) and also between SPAD and pod breadth ($r = -0.75^{**}$), indicating that extreme vegetative progress or late maturity may defeat chlorophyll buildup or photosynthetic productivity.

A principal component analysis (PCA) biplot showed the correlation circle for growth, physiological, and yield-related traits of *Lablab purpureus* under different support systems during the summer season. The first two principal components (PC1 and PC2) accounted for 46.7% and 16.1% of the total variation, respectively (Fig. 3). They clearly separated the traits into individual groups based on their relationships. Traits located close together indicate strong positive correlations, whereas those located on opposite sides represent negative relationships. Traits such as SPAD, petiole length (PEL), dry matter (DM), and fiber (FB) were strongly and positively correlated with PC1, indicating their significant contribution to overall plant performance and photosynthetic capacity. Conversely, yield-contributing parameters such as number of pods per plant (NPP), pod breadth (PB), pod yield per plant (PYP), and branch per plant (BPP) were situated on the opposite side of the circle, showing strong intercorrelations among themselves but contrasting with phenological traits. This indicates that higher yield performance is primarily driven by pod morphology and branching traits rather than by early phenological development. Growth attributes including internode length (IL), terminal leaf breadth (TLB), and terminal leaf length (TLL) contributed moderately to PC2, indicating their variability across variety. Meanwhile, days to flowering (DTF) and days to harvest (DTH) were located near the center, indicating weak association with the principal components and minimal influence on trait variance.

Clustered heatmap illustrating the standardized distribution of growth, physiological, and yield-related traits of *Lablab purpureus* as influenced by different support systems during the summer season (Fig. 4). The hierarchical dendrograms display similar patterns among both traits (columns) and treatments (rows). Green shades indicate positive correlations, while negative correlations are indicated by red shades, with color intensity proportional to the magnitude of deviation from the mean (scale bar at right). Different clusters were formed among traits, with parameters such as individual weight (IPW), number of pods per plant (NPP), pod yield per plant (PYP), and number of branches per plant (BPP) showing strong association, reflecting their strong influence on yield performance. In contrast, physiological traits like SPAD value, vine length (VL), and phenological traits (days to flowering (DTF) and days to harvest (DTH)) clustered together, suggesting that various responses of growth and yield components under varying support conditions.

Discussions

Overall, the present findings highlight the critical role of improved genotype support system interactions in maximizing canopy structure, photosynthetic efficiency, and yield stability in summer-grown *Lablab purpureus*. Responsive genotypes such as Sikribi Sheem-1, when integrated with vertical and A-shaped trellises, enhanced canopy light interception, assimilate translocation, and pod development, leading to superior yield performance without compromising pod quality. The integrative use of correlation, PCA, and heatmap analyses revealed that pod morphology, branching ability, and dry matter accumulation are the principal traits of yield, while phenological adaptability plays a relatively minor role. These findings form a foundation for developing genotype-specific strategies to enhance the productivity and sustainability of *Lablab purpureus* in tropical summers. Significant variation was observed among *Lablab purpureus* genotypes and support systems for most growth- and yield-related traits, indicating

strong genotype × environment interactions under summer conditions (Digrado et al., 2023; Janauskaite, 2025). Trellis structure and genotype adaptability jointly influenced canopy architecture, light interception, and assimilate partitioning, which are critical for optimizing production. Vine length showed moderate variability, with horizontal trellises promoting maximum growth. Lateral canopy expansion improved light penetration and photosynthetic efficiency, enhancing apical dominance and internode elongation (Wang et al., 2023). Morphological traits, including terminal leaflet dimensions and petiole length, varied across supports, indicating structural stability (Barua, 2014). Larger leaflets of SB003 under A-shaped trellises exhibited improved photosynthetic activity (Donati and Flanagan, 2016). Vertical supports increased internode length and branching, enhancing assimilate accumulation; Sikribi Sheem-1 performed best under vertical trellises (Akter et al., 2018; Emon et al., 2025). Phenological traits were influenced by trellis structure. A-shaped trellises accelerated flowering and maturity, likely due to favorable microclimatic conditions, whereas horizontal trellises delayed flowering due to shading and reduced aeration (Yu et al., 2022). Yield traits were strongly affected by genotype–support interactions. Vertical trellises enhanced pod number and yield, reflecting improved light exposure, flower retention, and assimilate partitioning (Clark et al., 2017). Pod length varied significantly, whereas pod breadth, fibre content, and dry matter were largely genotype-dependent (Huang and Hong, 2025).

Correlation analysis revealed strong positive relationships among pod number, pod yield, pod length, and individual pod weight, indicating that pod morphology and number are key yield determinants (Subarna et al., 2024). Branching and leaf traits also positively correlated with pod traits, highlighting the role of vigorous vegetative growth in yield formation. Phenological traits had limited influence on yield under high-temperature conditions (Khatun et al., 2022). A strong negative correlation between SPAD values and yield traits ($r = -0.82^{**}$) suggested that excessive vegetative growth may limit reproductive efficiency (Tariq et al., 2017; Moniruzzaman et al., 2020). PCA explained 62.8% of total variation, separating traits into physiological, morphological, and yield-related clusters (Subla et al., 2024). SPAD, petiole length, fibre content, and dry matter loaded positively on PC1, while yield traits loaded negatively, indicating inverse relationships. Growth traits contributed moderately to PC2, whereas DTF and DTH had minimal contribution (Khalid et al., 2023). Heatmap analysis supported these patterns, showing clustering of yield traits and separate grouping of phenological and physiological traits, reflecting trellis-induced microclimatic effects (Saha and Biswas, 2020; Islam et al., 2024). Overall, optimized genotype support combinations enhanced canopy structure, photosynthetic efficiency, and yield stability. Sikribi Sheem-1, grown on vertical or A-shaped trellises, exhibited superior light interception, assimilate translocation, and pod development. Pod morphology, branching, and dry matter accumulation were primary yield determinants, while phenological adaptability played a minor role. These findings provide a basis for genotype-specific strategies to improve the productivity and sustainability of *Lablab purpureus* in tropical summer conditions.

Conclusion

Among several country bean genotypes, this study assessed how various support systems affect morpho-physiological and yield-related traits, with support systems primarily affecting pod morphology.

Among these genotypes, Sikribi Sheem-1 consistently produced the highest number of pods per plant and overall yield under vertical trellis, indicating strong adaptability and better reproductive efficacy. However, SB003 showed the highest individual pod weight and yield under a sloped trellis, highlighting genotype-specific responses to support systems. Pearson correlation analysis revealed strong positive correlations among the number of pods per plant, the number of branches per plant, and yield, while PCA and heatmap analyses further demonstrated the clustering and interdependence of growth, physiology, and yield characters between genotypes and support systems. These findings confirm that pod morphology, branching capacity and dry matter accumulation are the key functional determinants of overall productivity, whereas phenological traits have a limited effect. However, V1-Sikribi Sheem-1 grown under S2-vertical trellis or staking displayed the most promising combination among the treated genotypes during the summer season.

Declarations

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Author contributions

M.S.I. and B.D. formulated research ideas, goals and guided all the phases of methodology. M.S.I. and R.K. designed methods, R.K., B.D.P., M.P. and A.A.K., conducted field and lab experiments, analyzed data and wrote manuscript. A.A.K. review and editing the manuscript.

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Data availability

All data generated or analyzed during this study are included in this manuscript.

Ethics approval and consent to participate

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Consent for publications

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Clinical trial

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Competing interests

The authors declare no competing interests.

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Figures



Figure 1

Pictorial view of research field

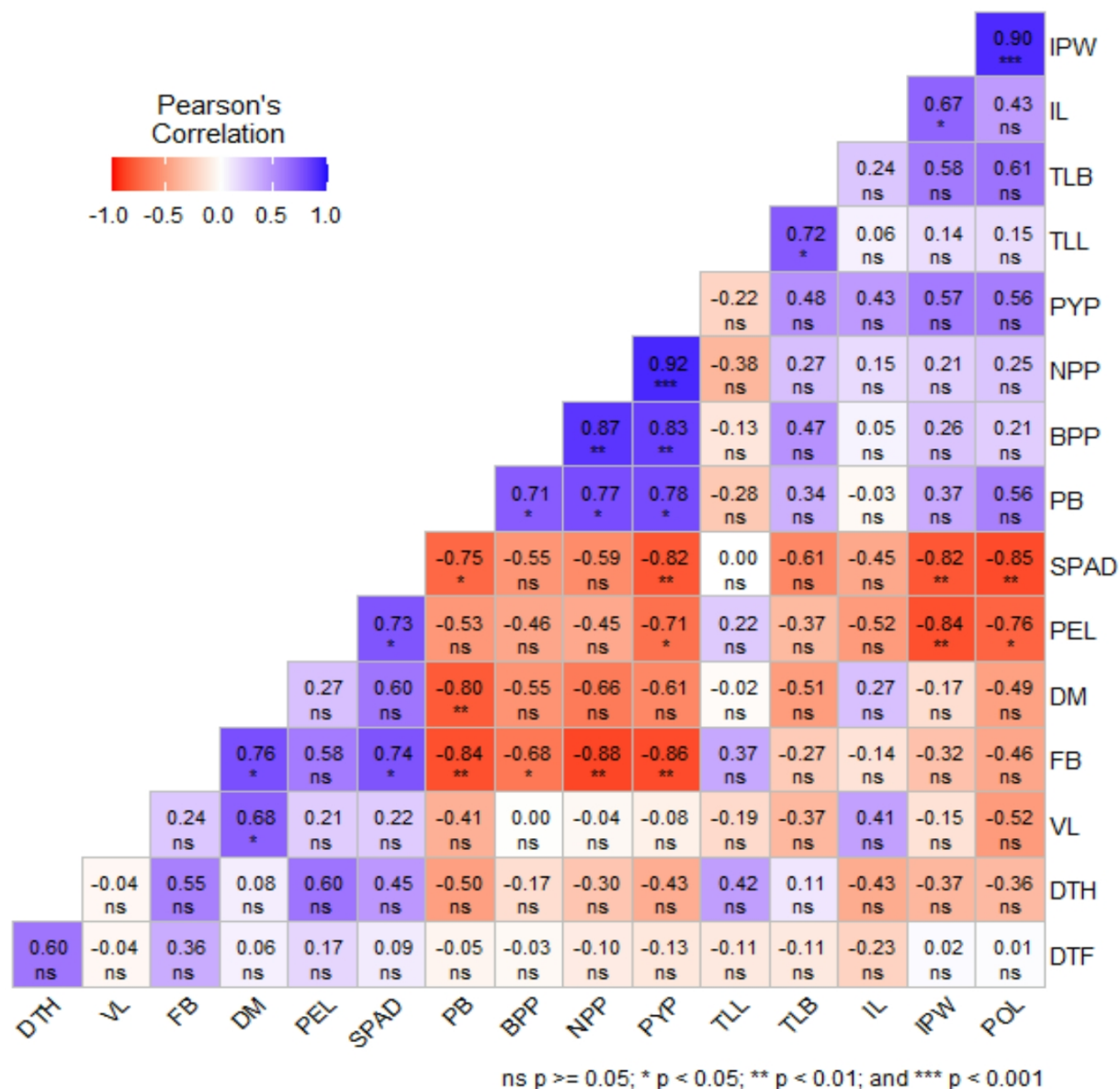


Figure 2

Correlation co-efficient of morpho-physiological and yield traits of country among among different variety and support systems. Here, DTF (Days to flower), DTH (Days to harvest), NPP (No. of pods/plant), PYP (Pod Yield/Plant), VL (Vine length), TLL (Terminal leaflet length), TLB (Terminal leaflet breadth), PL (Petiole length), IL (Internode length), BPP (Branch per plant), POL (Pod length), IPW (Individual pod weight), PB (Pod breadth), FB (Fibre %), DM (Dry matter %) and SPAD

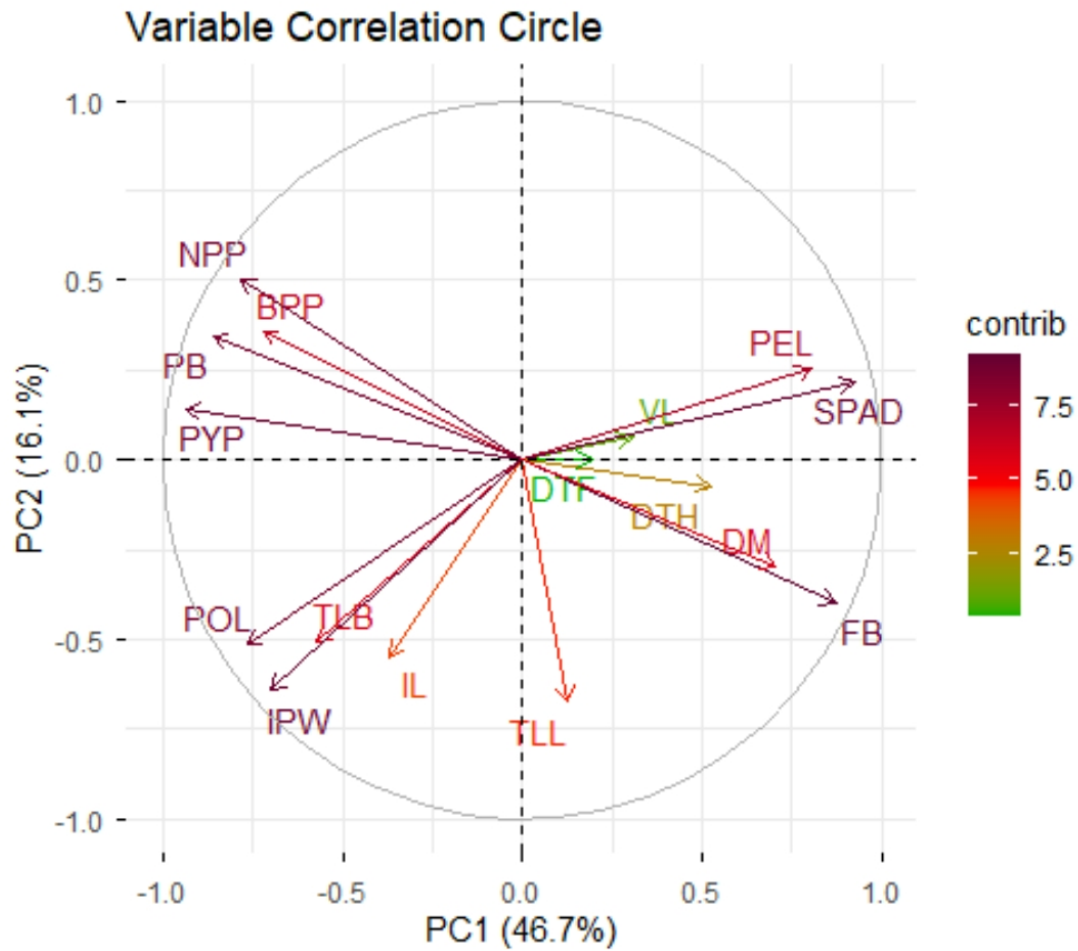


Figure 3

PCA for morpho-physiological and yield traits of country bean among different variety and support systems. Here, DTF (Days to flower), DTH (Days to harvest), NPP (No. of pods/plant), PYP (Pod Yield/Plant), VL (Vine length), TLL (Terminal leaflet length), TLB (Terminal leaflet breadth), PL (Petiole length), IL (Internode length), BPP (Branch per plant), POL (Pod length), IPW (Individual pod weight), PB (Pod breadth), FB (Fibre %), DM (Dry matter %) and SPAD.

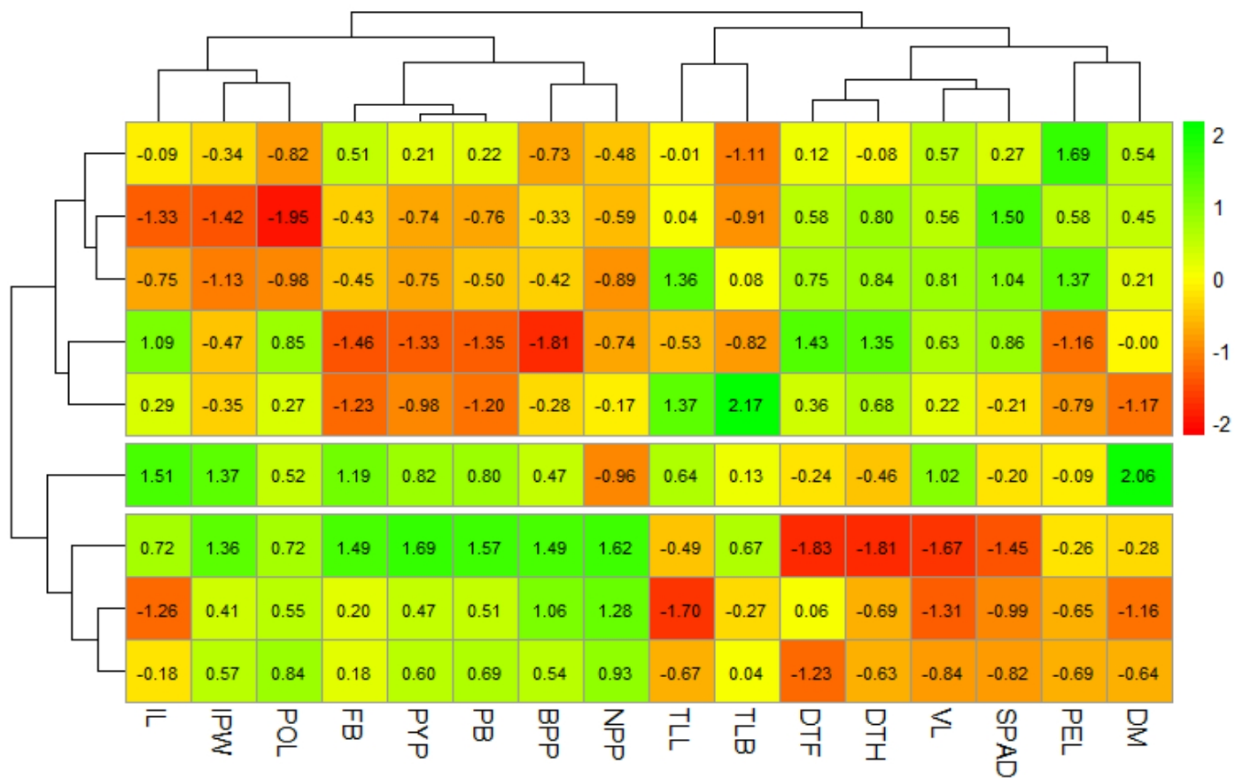


Figure 4

Heatmap for morpho-physiological and yield traits of country bean among different variety and support systems. Here, DTF (Days to flower), DTH (Days to harvest), NPP (No. of pods/plant), PYP (Pod Yield/Plant), VL (Vine length), TLL (Terminal leaflet length), TLB (Terminal leaflet breadth), PL (Petiole length), IL (Internode length), BPP (Branch per plant), POL (Pod length), IPW (Individual pod weight), PB (Pod breadth), FB (Fibre %), DM (Dry matter %) and SPAD