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Growth, yield, yield indices and system productivity of Pigeonpea as influenced by pigeonpea-based intercropping system in eastern dry zone of Karnataka

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Abstract
A field experiment was conducted during *Kharif*, 2020 at 'K' Block, Zonal Agricultural Research Station, University of Agricultural Sciences, Gandhi Krishi Vigyan Kendra, Bengaluru and studied the growth attributes, yield attributes, yield and yield indices of pigeonpea as influenced by pigeonpea-based intercropping system in Eastern Dry Zone of Karnataka. The experiment had 15 treatments which were replicated thrice in Randomised Complete Block Design. Treatments consisted of sole crops pigeonpea and sole crop of intercrops tried (field bean, vegetable soybean and chia) and intercrops in different row proportions of (1:2, 1:3 and 1:4). The results revealed that, among the different planting geometries. Sole paired row pigeonpea at 120/60 cm spacing recorded significantly higher plant height (151.7 cm), number of primary (9.92) and secondary branches (6.5) at harvest. Among planting geometry and intercropping systems, higher number of pods (137.3), pod yield (107.9 g plant^{-1}), seed yield (42.5 g plant^{-1}), stalk yield (225.6 g plant^{-1}), shelling percentage (69.7%) and test weight (12.1 g) was observed in paired row (120/60 cm × 30 cm) of sole pigeonpea. Among different planting geometry and intercropping system, higher seed yield, stalk yield and harvest index (1813 kg ha^{-1}, 4218 kg ha^{-1} and 0.307, respectively) was observed in paired row (120/60 cm × 30 cm) of sole pigeonpea compared to other treatments.

Keywords: Pigeonpea, planting geometry, paired row, growth, yield, pigeonpea equivalent yield

Introduction
Pigeonpea (*Cajanus cajan* (L.) Millsp.) Popularly known as 'Tur or Arhar' and It is the most important *kharif* pulse crop of India. It is rich in protein, calcium, manganese, crude fibre, trace elements and minerals (Saxena *et al.*, 2010) [22]. It is the economical and easily accessible source of protein to majority of the population, compared to animal source, which is costly, heavy on environment and not relished by all. For being healthy, we need about 65 g/person/day of pulses as recommended by National Institute of Nutrition, Hyderabad (Ali, 2013). Presently, in India, per capita availability of pulses has been reduced to less than 40 g/person/day (Mittal, 2006) [18]. It is estimated that projected pulses demand to be 42.5 m t by 2021 and 57.7 m t by 2026. We are living in nutrition conscious era, but our pulse production does not match with requirement. Order of the day is intensified pulses production to be self- sufficient and combat wide spread protein and mineral malnutrition in near future.

Intercropping is one of the alternative ensuring food security and enhancing yield stability (Raseduzzaman and Jensen, 2016) [21]. It can secure food supply by providing for almost 15 -20 percent additional yield. Intercropping is said to increase productivity per unit area of land (Iqbal *et al.*, 2019) [11] and intensify the production of crops (Idoko *et al*., 2018) [10]. Promoting pulses in dryland areas with pulse main crop is one of the option for increasing pulse production. On the other hand pulse /nutri rich crops like chia which are climate smart crops which also need the Arid climate/drier areas for expressing their full potential, these crops can be grown as intercrops on priority basis can solve the problem of sustainability and profitability of dryland production system. Pigeonpea is the most commonly grown *kharif* pulse crop especially in black soil areas.

Pigeonpea is the prominent pulse crop of dryland. Keeping pigeonpea as main crop, choosing the component crops with similar or superior nutritional quality in terms of protein and minerals, short duration and tolerant / resistant to drought with better market price will be a great option. In this regard, vegetable soybean having short duration (65-70 days) which complete its life cycle in the initial slow growth phase of main crop, pigeonpea and very hardy / climate smart, highly nutritious / super food crop like chia seems to be promising as component crops.

Planting geometry or arrangement of crop in rows to provide most suitable condition for plant to express its full potential plays an important role in crop production. Alteration of planting geometry is essential in intercropping system depending on the kind of crops involved. Paired row system with less or no variation in main crop plant population, offers a great scope for inclusion of compatible crop for increasing the total system productivity. In such system, as the large space will be left between the two paired rows of main crop (tall growing), it prevents shading by main crop and allow sufficient solar radiation for the component (short growing) crop which improves growth and development of companion crop (Anon., 1972 and Ali., 1990) [4, 1]. Aimed at intensive pulse production towards mitigating protein and mineral malnutrition with the above options possible.

Materials and Methods

A field experiment was conducted during *Kharif*, 2020 at 'K' Block, Zonal Agricultural Research Station, University of Agricultural Sciences, Gandhi Krishi Vigyan Kendra, Bengaluru to study the growth attributes, yield attributes, yield and yield indices of pigeonpea as influenced by pigeonpea-based intercropping system in Eastern Dry Zone of Karnataka. The experiment consisted of 15 treatments which were replicated thrice in Randomised Complete Block Design. Treatments had combinations of planting geometry and sole as well as intercropping. Details of the treatments is as follows, T_1: Normal row (120 cm x 30 cm) Pigeonpea (Sole crop), T_2: Normal row (120 cm x 30 cm) Pigeonpea + Field bean (1:2), T_3: Normal row (120 x 30 cm) Pigeonpea + Vegetable soybean (1:3), T_4: Normal row (120 x 30 cm) Pigeonpea + Chia (1:2), T_5: Paired row (120/60 x 30 cm) Pigeonpea (Sole crop), T_6: Paired row (120/60 x 30 cm) Pigeonpea + Field bean (1:2), T_7: Paired row (120/60 x 30 cm) Pigeonpea + Vegetable Soybean (1:3), T_8: Paired row (120/60 cm x 30 cm) Pigeonpea + Chia (1:2), T_9: Paired row (150/60 x 45 cm) Pigeonpea (Sole crop), T_{10}: Paired row (150/60 x 45 cm) Pigeonpea + Field bean (1:3), T_{11}: Paired row (150/60 x 45 cm) Pigeonpea + Vegetable Soybean (1:4), T_{12}: Paired row (150/60 x 45 cm) Pigeonpea + Chia (1:3), T_{13}: Field bean (Sole crop - 45 x 15 cm), T_{14}: Vegetable Soybean (Sole crop - 30 x 10 cm) and T_{15}: Chia (Sole crop - 45x 15 cm).

The soil of experimental site belonged to the order *Alfisols* and had a texture of red sandy loam. Electrical conductivity of the soil was 0.12 dS $m^{-1}$and pH was acidic (5.03). There was 0.46 percent organic carbon content. The soil had moderate levels of available nitrogen (312.5 kg ha^{-1}), phosphorus (28.5 kg ha^{-1}) and potassium (295.0 kg ha^{-1}).

The land was ploughed with a tractor-drawn disc plough after the harvest of previous crop, harrowed twice in order to break up any clods and create loose, friable soil. Stubbles, roots and weeds were removed from the experimental area. FYM @ 7.5 t ha^{-1} was applied at the time of harrowing for uniform mixing with soil at 2-3 weeks before sowing of the crop. Later, rotovator was passed to bring the soil to fine tilth. Pigeonpea variety (BRG-4), vegetable soybean (Karune), field bean (HA-4) and Chia (GKVK chia-1) recommended by UASB were used. Pigeonpea crop sown in normal row/ paired row based on the treatments. The component crops were sown at prescribed spacing fieldbean (45 cm x 15 cm), vegetable soybean (30 cm x 10 cm) and chia (45 cm x 15 cm) as sole and as intercrops in between the pigeonpea at different row proportion as per the treatments using their recommended seed rate 15 kg/ha, 30 kg/ha, 62.5 kg/ha and 2 kg/ha, respectively for sole and as per requirement under intercropping during first fortnight of July, 2020.

RDF was applied for the sole pigeonpea (25: 50: 25 kg/ha NPK), field bean (25:50:25 kg/ha NPK) Soybean (25:62:25 kg/ha NPK) and chia (100:50:50 kg/ha NPK) using urea, di-ammonium phosphate and muriate of potash fertilizers. In the intercropping system, the nutrientsat recommended full dose to main crop and the half of recommended dose to component crops were applied at the time of sowing as basal dosage as per UASB package of practice.

Two manual hand weeding's to keep the plot weed free at 20 DAS followed by second-hand weeding at 40DAS and this was followed by intercultural operation and earthing up.

Pigeonpea equivalent yield (PEY)

The pigeonpea equivalent yield of intercropping system was calculated by taking into account the seed yield and the prevailing market price of the crops. Finally, Pigeonpea equivalent yield was calculated using the below mentioned formula

$$\text{Pigeonpea equivalent yield (PEY) (q ha}^{-1}) = \frac{\text{Yield of Fieldbean/Soybean/Chia (q ha}^{-1}) \times \text{Price of Fieldbean/Soybean/Chia (Rs. q}^{-1})}{\text{Price of Pigeonpea (Rs. q}^{-1})} + \text{Yield of Pigeonpea (q ha}^{-1})$$

Land Equivalent Ratio (LER)

It is defined as the relative land area under sole crops that is required to produce the yields obtained in intercropping at the same level of management (Willey, 1979). It is calculated as follows.

$$\text{Land Equivalent Ratio (LER)} = \frac{\text{Yield of pigeonpea in intercropping system}}{\text{Yield of pigeonpea in sole cropping}} + \frac{\text{Yield of intercrop (fieldbean/soybean/chia) in intercropping system}}{\text{Yield of fieldbean/soybean/chia in sole cropping}}$$

Area Time Equivalent Ratio (ATER)

The limitation in the use of LER is the emphasis on the land area without consideration of time the field is dedicated to production. To correct this deficiency, the LER was modified by Hiebsch and Macollam (1980) [9] to include the duration of time of crop present on the land from planting to harvest. This method is known as the area time equivalent ratio (ATER). ATER was calculated according to formula given by Hiebsch and Macollam (1980) [9].

$$\text{Area Time Equivalent Ratio (ATER)} = \frac{(RYc \times tc) + (RYp \times tp)}{T}$$

Where,

RY = Relative yield of species c and p

$$RY = \text{Relative yield of species c and p} = \frac{\text{Yield of intercrop per hectare}}{\text{Yield of monocrop per hectare}}$$

tc = duration (days) of species c and p
T = duration (days) of the intercropping system

The experimental data gathered on the growth parameters and yield parameters were subjected to Fisher's method of Analysis of Variance (ANOVA) as outlined by Panse and Sukhatme (1954) [20]. For comparison between the treatment means, an appropriate value of critical difference (CD) was worked out wherever F- test was significant. All the data were analysed and the results are presented and discussed at a probability level of 5 percent.

Results and Discussion

Effect of planting geometry and intercropping system on plant height (cm)

The data pertaining to plant height of redgram as affected by different planting geometry and intercropping system of pigeonpea is shown in Table 1. Different planting geometry and intercropping systems did not show significant difference on plant height at 45 DAS. Numerically the higher plant height of pigeonpea (51.5 cm) was observed in paired row (120/60 cm × 30 cm) of sole pigeonpea and it was lower (44.9 cm) in normal row (120 cm × 30 cm) of pigeonpea + chia (1:2).

Among different planting geometry, sole paired row pigeonpea at 120/60 cm spacing recorded significantly higher plant height (125.5, 147.8 and 151.7 cm, respectively) at 90, 135 DAS and at harvest, which was on par with paired row (120/60 cm × 30 cm) of pigeon pea + vegetable soybean (121.5, 145.0 and 147.2 cm, respectively) at 90, 135 DAS and at harvest, whereas lower plant height (99.5, 125.9 and 128.7 cm, respectively) at 90, 135 DAS and at harvest was observed in pigeonpea + chia at (1:2) intercropping under normal row planting.

The increase in plant height up to 45 DAS is very slow because of initial slow growth rate of pigeonpea there after plant height increased linearly at 90 and 135 DAS as this is grand growth period. Two rows of pigeonpea which were close together led to increase the plant height in search of sunlight. The higher plant height was found with 120/60 cm × 30 cm paired row planting of pigeonpea as the plant population of pigeonpea were little higher than sole cropping at 120 cm x 30 cm. The treatments recorded higher plant height as there was no competition for resources with intercrops like water, nutrient, sunlight *etc.*, Pigeonpea intercropped with soybean (1:3) with 120/60 cm × 30 cm paired planting may be due to no much competition between these two crops for sunlight and nutrients. As both fix their own nitrogen and extract soil moisture from different depths. The results are in conformity with findings of Shanmugam (2008) [23].

Effect of planting geometry and intercropping system on number of primary and secondary branches plant^{-1}

The data of number of primary branches plant^{-1} recorded at 45, 90, 135 DAS and at harvest as influenced by different planting geometry and intercropping is graphically represented in Fig. 1. Number of branches increased progressively with the age of the crop. The number of primary branches plant^{-1} differed significantly at 90 and 135 DAS and at harvest except at 45 DAS with intercrops and row proportions of pigeonpea.

At 45 DAS, there is no significant difference found with respect to number of primary branches per plant. The higher number of primary branches per plant recorded in treatment with paired row (120/60 cm × 30 cm) of sole pigeonpea (3.80) which was on par with paired row (120/60 cm × 30 cm) of pigeonpea + vegetable soybean (3.46) and lower number of primary branches per plant was recorded in the treatment with normal row (120 cm × 30 cm) of pigeonpea + chia (1:2) (2.60).

Significantly higher number of primary branches per plant at 90, 135 DAS and at harvest was recorded as (5.80, 8.67 and 9.92, respectively) in paired row (120/60 cm × 30 cm) of sole pigeonpea and while the treatment T_7 (5.6, 8.47 and 9.57, respectively) was statistically on par with it. and lower number of primary branches per plant (4.00, 6.27 and 7.42, respectively) in normal row (120 cm × 30 cm) of pigeonpea + chia (1:2).

The number of secondary branches per plant at different stages of growth as influenced by planting geometry and intercropping is presented in Fig. 1. Up to 60 DAS there was no development of secondary branches because of slow growth of pigeonpea during initial growth stages.

Significantly higher number of secondary branches per plant was recorded with the planting geometry of paired row (120/60 cm × 30 cm) of sole pigeonpea (4.5, 5.6 and 6.5, respectively) and lower number of secondary branches per plant was recorded in normal row (120 cm × 30 cm) of pigeonpea + chia (2.4, 2.7 and 3.5, respectively) at 90, 135 DAS and at harvest.

The results of the research indicated that the number of primary branches per plant and number of secondary branches per plant were higher in paired row (120/60 cm × 30 cm) sole pigeonpea, when compared to intercropped pigeonpea. This is because of less competition between the plants for light, nutrients, space and moisture in paired row (120/60 cm × 30 cm) sole pigeonpea than in the intercropped pigeonpea. These results were in accordance with the findings of Gamit (2014) [7].

Effect of planting geometry and intercropping system on leaf area (cm^2 plant^{-1})

The observations pertaining to leaf area (cm^2 plant^{-1}) of redgram as affected by different planting geometry and intercropping system of pigeonpea are shown in Table 2. Lower Leaf area (cm^2 plant^{-1}) was recorded at 45 DAS and It increased with age of the crop and was maximum at 135 DAS. There after due to senescence of foliage the leaf area showed declining trends towards maturity.

Leaf area per plant at 45, 90 and 130 days after sowing has expressed marked difference due to different planting geometry and intercropping system. Significantly higher leaf area (283.9, 2150.7 and 1875.8 cm2 plant-1, respectively) was observed in paired row (120/60 cm × 30 cm) of sole pigeonpea and lower leaf area (146.3, 1038.3 and 1009.2 cm2 plant-1, respectively) was observed in normal row (120 cm × 30 cm) of pigeonpea + chia (1:2).

Leaf area is the basic requirement of higher biomass and yield, as it is the total area available for photosynthesis and energy production. The highest leaf area in paired row planting with 120/60 cm × 30 cm is recorded without intercropping owing to competition free environment. The next best treatment with respect to leaf area is intercropping with 2 rows of field bean followed by soybean with 3 rows. The treatment with chia as intercrop recorded lower pigeonpea leaf area as the chia grew taller and competed for light as well as other resources like water and nutrients, vigorously. The results are in confirmity with findings of (Jasbir Singh and Thenua, 2014) [12].

Effect of planting geometry and intercropping system on yield attributes of pigeonpea

Yield parameters *viz.* number of pods per plant, number of seeds per pod, pod yield per plant (g), seed yield per plant (g), stalk yield per plant (g), shelling percentage (%), 100 seed weight (g), seed yield per hectare (kg ha^{-1}), stalk yield per hectare (kg ha^{-1})

and harvest index were significantly influenced by different planting geometry and intercropping system. (Table 3 and 4).

Among different planting geometry and intercropping system, significantly higher number of pods (137.3), pod yield (107.9 g $plant^{-1}$), seed yield (42.5 g $plant^{-1}$), stalk yield (225.6 g $plant^{-1}$), shelling percentage (69.7%) and test weight (12.1 g) was observed in paired row (120/60 cm × 30 cm) of sole pigeonpea. Followed by T_6 (125.4, 102.3 g $plant^{-1}$, 40.5 g $plant^{-1}$, 2251.4 g $plant^{-1}$, 64% and 10.9 g, respectively). Whereas, lower number of pods (88.0), pod yield (50.7 g $plant^{-1}$), seed yield (28.6 g $plant^{-1}$), stalk yield (123.1 g $plant^{-1}$), shelling percentage (55.1%) and test weight (9.3 g), was observed in normal row (120 cm × 30 cm) of pigeonpea + chia (1:2).

The data on number of seed pod^{-1} has shown non-significant difference due to different planting geometry and intercropping. Higher number of seeds (4.1) was observed in paired row (120/60 cm × 30 cm) of sole pigeonpea, whereas numerically lower number of seeds (3.8) was observed in normal row (120 cm × 30 cm) of pigeonpea + chia (1:2).

The yield components like No of Pods $plant^{-1}$, No of seeds pod^{-1}, Pod yield (g $plant^{-1}$), Seed yield (g $plant^{-1}$), Stalk yield (g $plant^{-1}$) Shelling percentage (%), Test weight (g) per plant were higher in the treatment 120/60 cm × 30 cm paired row planting with soybean as intercrop might be due better vegetative growth reflected in terms of growth indices like leaf area index, crop growth rate, absolute growth rate and Net assimilation rate as influenced by the planting geometry which accommodated slightly more plant population than normal spacing coupled with sufficient scope for better utilization of resources with the intercrop. The intercrop soybean's growth habit does not interfered with light interception and no competition for water and nutrients as their critical stage were different. The vegetable soybean completed its life cycle before grand growth stage of pigeonpea. Better weed suppression and residual nutrients by soybean is an added advantage for the growth and yield of pigeonpea. The similar results were recorded by Kasbe *et al.* (2010) [13] and Narendra *et al.* (2013) [19] with respect to main crop yield.

Among different planting geometry and intercropping system, significantly higher seed yield, stalk yield and harvest index (1813 kg ha^{-1}, 4218 kg ha^{-1} and 0.307, respectively) was observed in paired row (120/60 cm × 30 cm) of sole pigeonpea. Which was on par with T_6 (1770 kg ha^{-1}, 4026 kg ha^{-1} and 0.305, respectively). Whereas, lower seed yield, stalk yield and harvest index (768 kg ha^{-1}, 2597 kg ha^{-1} and 0.228, respectively) was observed in normal row (120 cm × 30 cm) of pigeonpea + chia (1:2).

The higher pigeonpea crop yield is due to competition free environment for pigeonpea under sole cropping. Further, the pigeonpea yield was higher under paired row could be indicating that the micro climate suitable for pigeonpea is found under paired row than existing normal row planting geometry. Further, intercropping with field bean and vegetable soybean which recorded on par yield as compared with sole pigeonpea demonstrated that these low growing, short duration pulses does not interfere much with growth of pigeonpea and it has near similar sole crop conditions. The overall production from the system, it is much more productive than the sole crop. This clearly illustrate that field bean and vegetable soybean are better option as component crops under intercropping system was also reported by by Yamuna (2013) [27], Kavya *et al.* (2022) [14] and Kumar *et al.* (2017) [15].

Effect of planting geometry and intercropping system on yield indices of pigeonpea

The observations pertaining to yield indices of pigeonpea as affected by different planting geometry and intercropping system of pigeonpea are shown in Table 5.

Pigeonpea equivalent yield (PEY)

Yield advantages occurs when environmental resources such as water, light, and nutrients were efficiently used by intercrops which could be converted into crop biomass (Ghanbari *et al.*, 2010; Dwivedi *et al.*, 2015) [8, 5].

Paired row pigeonpea with vegetable soybean at 120/60 cm spacing recorded significantly higher pigeonpea equivalent yield (1843 kg ha^{-1}) and was being on par with paired row pigeonpea with field bean at 120/60 cm spacing (1842 kg ha^{-1}) and Lower PEY was recorded in normal row pigeonpea + field bean 1:2 row proportion (1363 kg ha^{-1}).

Intercropping improves the radiation interception through more complete ground cover. Light intercepted was more efficient in intercropping compared to sole cropping. The higher pigeonpea equivalent yield in the system was recorded with intercropping of vegetable soybean under paired row planting 120/60 cm × 30 cm due to optimum utilisation of resources to put forth the greater biomass. However, the PEY was high in quinoa crop in spite of low biomass by quinoa may be attributed to higher price of quinoa compared to prices of other intercrops. Similar results were found by Shrivastava *et al.*, 2000 [24] and Kasbe *et al.* (2010) [13] in soybean, Narendra *et al.* (2013) [19] in blackgram, Kumar and Rana (2007) [15] in greengram.

Land equivalent ratio (LER)

Land equivalent ratio, the common index used to measure intercropping land productivity (Alla *et al.*,2014), may be used to verify the effectiveness of intercrops in utilizing environmental resources (Iqbal *et al.*, 2019) [11].

The land equivalent ratio was worked out for different treatments as influenced by different planting geometry and intercropping. All the intercrop treatments recorded higher LER as compared to pure stands of crops. The maximum LER of (1.69) was observed in paired row pigeonpea with vegetable soybean at 150/60 cm spacing, which was on par with paired row pigeonpea + field bean 1:3 ratios (1.62). Among different planting geometry and intercropping system of pigeonpea based intercropping systems least LER was observed with normal row pigeonpea + chia 1:2 row proportion (1.13).

The higher LER recorded with wider paired rows and intercrops like vegetable soybean could be due to better crop growth facilitated by wider spacing and accommodation of more intercrop in the system. i.e. more of intra specific competition and inter specific facilitation in the cropping system. The similar results were also recorded with paired row planting and grain soybean by Kasbe *et al.* (2010) [13] and Turkhede *et al.* (2014) [25] and by Narendra *et al.* (2013) [19], in green gram.

Area time equivalent ratio (ATER)

The data pertaining to ATER indicated that, inclusion of intercrops under different planting geometry and intercropping system of pigeonpea recorded higher ATER values over pure stand crops. Among them, paired row pigeonpea with vegetable soybean at 150/60 cm spacing recorded significantly higher ATER value (1.29) and followed by paired row pigeonpea + field bean 1:3 ratios (1.24), Among different planting geometry and intercropping system of pigeonpea least ATER was observed with normal row pigeonpea + chia 1:2 row proportion (1.00).

The higher ATER recorded with wide row spacing with vegetable soybean might be due shorter crop duration of component crop and better resource utilization under wider spacing facilitated better crop growth and yield in the inter cropping system. The similar results were also reported by Marer (2005) [17] in maize pigeonpea intercropping system.

Table 1: Plant height (cm) of pigeonpea at different growth stages as influenced by planting geometry and intercrops in pigeonpea based cropping system

Treatments	45 DAS	90 DAS	135 DAS	At harvest
T_1: NR (120 cm × 30 cm) Pigeonpea (Sole crop)	47.0	109.5	136.8	138.4
T_2: NR (120 cm × 30 cm) Pigeonpea + Field bean (1:2)	46.7	106.4	130.3	132.1
T_3: NR (120 cm × 30 cm) Pigeonpea + Vegetable soybean (1:3)	46.9	107.1	133.3	135.3
T_4: NR (120 cm × 30 cm) Pigeonpea + Chia (1:2)	44.9	99.5	125.9	128.7
T_5: PR (120/60 cm × 30 cm) Pigeonpea (Sole crop)	51.5	125.5	147.8	151.7
T_6: PR (120/60 cm × 30 cm) Pigeonpea + Field bean (1:2)	49.1	118.8	142.6	144.5
T_7: PR (120/60 cm × 30 cm) Pigeonpea + Vegetable Soybean (1:3)	50.1	121.5	145.0	147.2
T_8: PR (120/60 cm × 30 cm) Pigeonpea + Chia (1:2)	47.0	102.1	128.0	130.6
T_9: PR (150/60 cm × 45 cm) Pigeonpea (Sole crop)	48.2	117.7	140.3	143.3
T_{10}: PR (150/60 cm × 45 cm) Pigeonpea + Field bean (1:3)	46.9	113.9	137.0	139.2
T_{11}: PR (150/60 cm × 45 cm) Pigeonpea + Vegetable Soybean (1:4)	47.3	116.5	139.4	140.3
T_{12}: PR (150/60 cm × 45 cm) Pigeonpea + Chia (1:3)	45.7	101.7	129.8	134.5
S.Em.±	1.8	3.9	4.5	4.5
CD (5%)	-	11.3	13.2	13.3

Note: DAS: Days After Sowing, NR: Normal row, PR: Paired row

Table 2: Leaf area (cm^2 $plant^{-1}$) of pigeonpea at different growth stages as influenced by planting geometry and intercrops in pigeonpea based cropping system

Treatments	45 DAS	90 DAS	135 DAS
T_1: NR (120 cm × 30 cm) Pigeonpea (Sole crop)	182.6	1374.7	1215.0
T_2: NR (120 cm × 30 cm) Pigeonpea + Field bean (1:2)	187.9	1439.1	1216.9
T_3: NR (120 cm × 30 cm) Pigeonpea + Vegetable soybean (1:3)	212.7	1534.4	1233.3
T_4: NR (120 cm × 30 cm) Pigeonpea + Chia (1:2)	146.3	1038.3	1009.2
T_5: PR (120/60 cm × 30 cm) Pigeonpea (Sole crop)	283.9	2150.7	1875.8
T_6: PR (120/60 cm × 30 cm) Pigeonpea + Field bean (1:2)	265.3	1810.0	1643.8
T_7: PR (120/60 cm × 30 cm) Pigeonpea + Vegetable Soybean (1:3)	232.4	1672.8	1530.2
T_8: PR (120/60 cm × 30 cm) Pigeonpea + Chia (1:2)	189.8	1092.0	1210.3
T_9: PR (150/60 cm × 45 cm) Pigeonpea (Sole crop)	241.0	1592.3	1527.1
T_{10}: PR (150/60 cm × 45 cm) Pigeonpea + Field bean (1:3)	215.3	1552.2	1472.9
T_{11}: PR (150/60 cm × 45 cm) Pigeonpea + Vegetable Soybean (1:4)	204.9	1563.1	1339.3
T_{12}: PR (150/60 cm × 45 cm) Pigeonpea + Chia (1:3)	149.7	1040.0	1079.3
S.Em.±	9.61	49.93	46.66
CD (5%)	28.18	146.44	136.85

Note: DAS: Days After Sowing, NR: Normal row, PR: Paired row

Table 3: Yield attributes of pigeonpea as influenced by planting geometry and intercrops in pigeonpea based intercropping system

Treatments	No of pods $plant^{-1}$	No of seeds pod^{-1}	Pod yield (g $plant^{-1}$)	Seed yield (g $plant^{-1}$)	Stalk yield (g $plant^{-1}$)	Shelling percentage (%)	Test weight (g)
T_1: NR (120 cm × 30 cm) Pigeonpea (Sole crop)	94.5	3.9	68.2	30.6	149.0	58.5	10.2
T_2: NR (120 cm × 30 cm) Pigeonpea + Field bean (1:2)	98.1	3.9	74.0	30.7	162.3	66.8	10.4
T_3: NR (120 cm × 30 cm) Pigeonpea + Vegetable soybean (1:3)	102.0	3.9	78.8	32.0	168.4	64.6	10.7
T_4: NR (120 cm × 30 cm) Pigeonpea + Chia (1:2)	88.0	3.8	50.7	28.6	123.1	55.1	9.3
T_5: PR (120/60 cm × 30 cm) Pigeonpea (Sole crop)	137.3	4.1	107.9	42.5	225.6	69.7	12.1
T_6: PR (120/60 cm × 30 cm) Pigeonpea + Field bean (1:2)	125.4	4.0	102.3	40.5	221.4	64.0	10.9
T_7: PR (120/60 cm × 30 cm) Pigeonpea + Vegetable Soybean (1:3)	116.5	4.0	95.4	38.6	202.7	66.5	11.3
T_8: PR (120/60 cm × 30 cm) Pigeonpea + Chia (1:2)	94.0	3.8	61.5	30.4	148.5	60.3	9.5
T_9: PR (150/60 cm × 45 cm) Pigeonpea (Sole crop)	115.0	4.0	94.7	35.1	198.2	64.7	10.8
T_{10}: PR (150/60 cm × 45 cm) Pigeonpea + Field bean (1:3)	105.5	3.9	92.7	34.9	188.9	61.3	10.7
T_{11}: PR (150/60 cm × 45 cm) Pigeonpea + Vegetable Soybean (1:4)	103.1	3.9	82.6	32.4	176.3	61.9	10.8
T_{12}: PR (150/60 cm × 45 cm) Pigeonpea + Chia (1:3)	90.0	3.8	57.6	30.2	136.4	57.7	8.8
S.Em.±	3.48	0.09	6.62	1.17	5.99	2.17	0.36
CD (5%)	10.21	-	19.40	3.43	17.58	6.37	1.06

Note: NR: Normal row**,** PR: Paired row

Table 4: Seed yield, stalk yield and harvest index of pigeonpea as influenced by planting geometry and intercrops in pigeonpea based cropping system

Treatments	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Harvest index
T_1: NR (120 cm × 30 cm) Pigeonpea (Sole crop)	1264	2954	0.300
T_2: NR (120 cm × 30 cm) Pigeonpea + Field bean (1:2)	1293	3054	0.297
T_3: NR (120 cm × 30 cm) Pigeonpea + Vegetable soybean (1:3)	1312	3218	0.292
T_4: NR (120 cm × 30 cm) Pigeonpea + Chia (1:2)	768	2597	0.228
T_5: PR (120/60 cm × 30 cm) Pigeonpea (Sole crop)	1813	4218	0.307
T_6: PR (120/60 cm × 30 cm) Pigeonpea + Field bean (1:2)	1770	4026	0.305
T_7: PR (120/60 cm × 30 cm) Pigeonpea + Vegetable Soybean (1:3)	1699	3981	0.298
T_8: PR (120/60 cm × 30 cm) Pigeonpea + Chia (1:2)	1099	2868	0.277
T_9: PR (150/60 cm × 45 cm) Pigeonpea (Sole crop)	1548	3615	0.300
T_{10}: PR (150/60 cm × 45 cm) Pigeonpea + Field bean (1:3)	1479	3460	0.299
T_{11}: PR (150/60 cm × 45 cm) Pigeonpea + Vegetable Soybean (1:4)	1455	3341	0.285
T_{12}: PR (150/60 cm × 45 cm) Pigeonpea + Chia (1:3)	937	2705	0.257
S.Em.±	46.24	104.28	0.01
CD (5%)	135.63	305.85	0.03

Note: NR: Normal row, PR: Paired row

Table 5: Pigeonpea Equivalent Yield (PEY), Land Equivalent Ratio (LER) and Area Time Equivalent Ratio (ATER) as influenced by planting geometry and intercrops in pigeonpea based cropping system

Treatment	Yield (kg ha^{-1})		PEY (kg ha^{-1})	LER	ATER
	a	b			
T_1: NR (120 cm × 30 cm) Pigeonpea (Sole crop)	1264	-	1264	-	-
T_2: NR (120 cm × 30 cm) Pigeonpea + Field bean (1:2)	1293	210	1363	1.46	1.21
T_3: NR (120 cm × 30 cm) Pigeonpea + Vegetable soybean (1:3)	1312	389	1441	1.54	1.22
T_4: NR (120 cm × 30 cm) Pigeonpea + Chia (1:2)	768	282	1483	1.13	1.00
T_5: PR (120/60 cm × 30 cm) Pigeonpea (Sole crop)	1813	-	1813	-	-
T_6: PR (120/60 cm × 30 cm) Pigeonpea + Field bean (1:2)	1770	216	1842	1.43	1.17
T_7: PR (120/60 cm × 30 cm) Pigeonpea + Vegetable Soybean (1:3)	1699	432	1843	1.50	1.18
T_8: PR (120/60 cm × 30 cm) Pigeonpea + Chia (1:2)	1099	293	1833	1.14	1.07
T_9: PR (150/60 cm × 45 cm) Pigeonpea (Sole crop)	1548	-	1547	-	-
T_{10}: PR (150/60 cm × 45 cm) Pigeonpea + Field bean (1:3)	1479	316	1584	1.62	1.24
T_{11}: PR (150/60 cm × 45 cm) Pigeonpea + Vegetable Soybean (1:4)	1455	585	1650	1.69	1.29
T_{12}: PR (150/60 cm × 45 cm) Pigeonpea + Chia (1:3)	937	332	1769	1.21	1.13
T_{13}: Field bean (Sole crop- 45 cm × 15 cm)	-	479	1423	-	-
T_{14}: Vegetable soybean (Sole crop - 30 cm × 10 cm)	-	775	1522	-	-
T_{15}: Chia (Sole crop - 45 cm × 15 cm)	-	548	2636	-	-
S.Em.±	93.80	NA	59.299	NA	NA
CD (5%)	275.10	-	171.782	-	-

Note: NR: Normal row, PR: Paired row, a: Yield of pigeonpea, b: Yield of intercrops

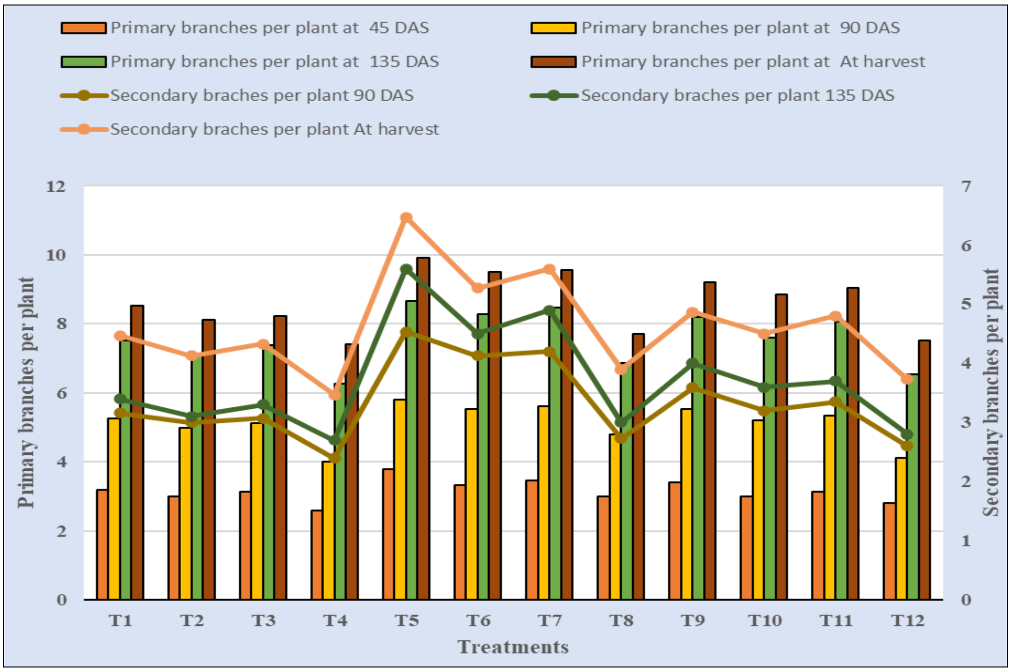

Fig 1: Number of primary branches plant^{-1} and Number of secondary branches plant^{-1} of pigeonpea at different growth stages as influenced by planting geometry and intercrops in pigeonpea based cropping system

Conclusion

In conclusion, the study evaluated the impact of different planting geometries and intercropping systems on various growth parameters and yield attributes of pigeonpea. While planting geometries and intercropping did not significantly affect plant height at early stages, differences emerged later in the growth cycle. Paired row planting of pigeonpea exhibited superior growth in terms of plant height, number of primary and secondary branches, and leaf area, indicating reduced competition for resources compared to intercropped systems. Yield attributes such as pod and seed yield, as well as harvest index, were significantly influenced by planting geometry and intercropping, with paired row pigeonpea showing higher yields compared to intercropped systems. Additionally, yield indices such as pigeonpea equivalent yield, land equivalent ratio, and area time equivalent ratio highlighted the benefits of paired row planting, particularly when combined with compatible intercrops like vegetable soybean. These findings underscore the importance of optimizing planting arrangements and intercropping strategies to maximize pigeonpea yield and overall productivity.

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