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Evaluation of different pigeonpea based intercropping systems in *Alfisols* for higher productivity

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Abstract
In rainfed and dry regions of southern Karnataka, sole cropping is not much remunerative in the current scenario of climate change to meet the pulses requirement of growing population. Hence, the field experiment was conducted at Zonal Agricultural Research Station, University of Agricultural Sciences, GKVK, Bengaluru during *Kharif*, 2021 to evaluate the most promising intercrops (sweet corn, baby corn, sorghum, vegetable soybean, field bean, quinoa and grain amaranth) in pigeonpea based cropping system and its effect on growth, yield and economics of pigeonpea where previously pigeonpea was cultivated as a sole crop. The experiment was laid out in RCBD with 15 treatments each replicated thrice. Higher pigeonpea seed and stalk yield (852 and 1678 kg ha^{-1}, respectively) were observed in pigeonpea + field bean (1:2) intercropping which was on par with vegetable soybean (1:2). The data revealed that higher seed yield was mainly attributed to higher plant height, leaf area, total dry matter production, no. of pods and pods weight per plant. However, planting of pigeonpea with sweet corn (1:2) as intercrop recorded higher pigeonpea equivalent yield (2724 kg ha^{-1}), net returns (Rs. 2, 96,750 ha^{-1}) and benefit: cost ratio (4.91) than rest of the treatments. Whereas, higher system indices like land equivalent ratio (1.43) and area time equivalent ratio (1.19) were recorded with pigeonpea + field bean (1:2) intercropping system.

Keywords: Intercropping, pigeonpea equivalent yield, land equivalent ratio

Introduction

India is primarily an agrarian country and about 52 % of agriculture is dependent on rainfall. Dryland agriculture occupies around 68 per cent of total net sown area and supports 40 per cent of human population of the country. Pulse based cropping systems are highly suited under rainfed conditions where they are grown in areas left after satisfying the needs for cereals / cash crops. India is the largest producer and consumer of pulses globally. The total pulse production has increased from 13.38 m t (2005-06) to 25.58 m t (2020-21) (Gaur, 2021) [2]. But yet this increase in pulse production is attributed only to rapid rise in Bengal gram production which is a predominant Rabi crop. Pigeonpea or red gram also known as tur, arhar (*Cajanus cajan* (L.) Millsp.) is the predominant *Kharif* pulse crop in rainfed / dryland agriculture, majorly in *Alfisols*. Approximately 10.6 per cent of the total geographical area of India is covered by red soil and around 44.2 per cent of the total area in Karnataka is red soils (Anon., 2007) [1] and hence there is a scope for increasing area and production of *Kharif* pulses. Pigeonpea has been found to be the most preferred component crop in rainfed production systems due to its deep penetration and lateral spread of root system. Pigeonpea being a drought resistant and less nutrient demanding, farmers are growing it under rainfed and poor soils which fails to exploit the yield potential of crop.

Demand for higher pulse production and changing climate make rainfed agriculture a challenging task in achieving sustainability. Owing to low yield and less economic returns, pigeonpea is grown as intercrop along with major cereal crops. But pigeonpea being a tall growing crop with initial slow growth and under wider spacing, provides ample scope for incorporation of less duration crops as intercrops. Further if the crops are of high value and climate smart, helps improve the system productivity as well as profitability. Therefore, there is a great advantage and scope to study the suitability of high value crops like sweet corn, baby corn, short duration crops like vegetable soybean, climate resilient and nutri rich super foods like quinoa and grain amaranth as intercrops in pigeonpea based intercropping.

Materials and Methods

The field experiment was carried out during *Kharif*, 2021 in red sandy loam soil at Zonal Agricultural Research Station, Gandhi Krishi Vignana Kendra, University of Agricultural Sciences, Bangalore. The site of experimentation comes under Eastern Dry Zone (Zone-V) of Karnataka with characteristic red soils and predominantly rainfed ecosystem. The initial soil pH was 6.4 with electrical conductivity of 0.16 dS m^{-1}. The organic carbon was 0.43 per cent. The soil was medium in available nitrogen (287.2 kg ha^{-1}), available phosphorous (36.5 kg ha^{-1}) and available potassium (255.7 kg ha^{-1}). The field experiment was laid out in RCBD replicated thrice with 15 treatments *viz*., T_1: Sole Pigeonpea; T_2: Sole Sweet corn; T_3: Sole Baby corn; T_4: Sole Sorghum; T_5: Sole Vegetable soybean; T_6: Sole Quinoa; T_7: Sole Grain amaranth; T_8: Sole Field bean; T_9: Pigeonpea + Sweet corn; T_{10}: Pigeonpea + Baby corn; T_{11}: Pigeonpea + Sorghum; T_{12}: Pigeonpea + Vegetable soybean; T_{13}: Pigeonpea + Quinoa; T_{14}: Pigeonpea + Grain amaranth; T_{15}: Pigeonpea + Field bean. Under intercropping, pigeonpea spacing followed was 120 cm x 15 cm with two rows of intercrops (1:2 ratio). The land was ploughed and made to fine seed bed. The recommended dose of fertilizers (NPK kg ha^{-1}) was given for the component crops as per requirements (Pigeonpea- 25:50:25, Sweet corn- 100:50:25, Baby corn- 150:75:40, Sorghum- 65:40:40, Vegetable soybean- 25: 62: 25, Quinoa- 40:20:20 kg, Grain amaranth- 60:40:40 in the form of urea, diammonium phosphate and muriate of potash as basal dose. In the intercropping system, the fertilizers were applied based on recommended full dose of the main crop and half recommended dose of the intercrops. Healthy and bold/ certified seeds of pigeonpea (BRG-5) and component crops were used for sowing. Need based weeding and plant protection measures were undertaken and required plant population was maintained by thinning and gap filling. The crops were harvested at their physiological maturity. Yield parameters and yield were recorded at harvest and the economics was worked out based on the cost of inputs, labour costs and price of output during the course of study Fischer's method of analysis of variance was used for analysis and interpretation of the data as outlined by Gomez and Gomez (1984) [3].

Results and Discussion

Growth parameters of pigeonpea

The data pertaining to growth attributes of pigeonpea as influenced by different intercrops are presented in Table 1.

Among the intercropping systems, pigeonpea + field bean recorded significantly higher values of growth contributing characters of pigeonpea *viz*., plant height (208.5 cm), total branches per plant (17.29), leaf area (5356.3 cm^2 $plant^{-1}$) and entire dry matter production (113.7 g $plant^{-1}$) (T_{15}) but was found at par with pigeonpea + vegetable soybean (T_{12}). Whereas significantly lower values noticed in pigeonpea + sweet corn (1:2) (T_9) intercropping system.

In the present investigation, significantly higher growth parameters of intercropped pigeonpea *i.e*., plant height, leaf area, number of branches and total dry matter production in treatment (T_{15}) might be owing to less competitive nature of pulse crops like field bean and vegetable soybean which can also act as nutrient replenishing crops compared to exhaustive cereal crops like sweet corn which grows taller than pigeonpea during its initial growth stage, thus produced shading effect and restricts the growth of the pigeonpea. The results also revealed that the relative growth was more in sole pigeonpea in all growth stages than in the intercropped pigeonpea. It may be due to competition for sunlight, space, nutrients and water by the component crops due to which resources were limiting for pigeonpea in intercropping system. The results are in accord with the findings of Sudharani *et al*. (2020) [9], and Rajashree *et al*. (2022) [7].

Yield parameters of pigeonpea

The yield attributes like no. of pods per plant (99.0), seed yield per plant (48.5 g), test weight (15.9 g), seed yield (852 kg ha^{-1}) and stalk yield (1678 kg ha^{-1}) were significantly higher in pigeonpea + field bean (1:2) intercropping system compared to pigeonpea + sweet corn (Table 2). Number of seeds pod^{-1} was not significantly influenced by different intercropping system which is a genetic character of the crop.

The appraisal of data indicates that sole pigeonpea recorded higher yield attributes and thereby higher yield compared to intercropping system. In intercropping, pigeonpea faced severe competition with vigorously growing crops like sweet corn and baby corn during its initial growth stage. Intercropped pigeonpea growth suffered as its above ground growth is inherently slow during initial stage, in addition competition for resources by cereal crops lead to further reduction in growth. Even after harvest of these exhaustive crops, pigeonpea failed to recover, thereby resulted in poor growth and development. Yield and yield attributing characters are positively correlated with growth and development of the crop, evidently resulted in less yield of the main crop. In pulse-based cropping systems, like vegetable soybean and field bean which are less competitive for nutrients, water, space and sunlight, did not remarkably influenced the yield parameters of pigeonpea. It could be also due to addition of nutrients by the nitrogen fixers in soil. The results are in line with findings of Vilas, 2018 [10] and Njira *et al*. (2021) [6].

Yield of pigeonpea

The data relating to yield of pigeonpea that differed significantly due to influence of different intercrops are depicted in Table 3.

Pigeonpea + field bean (1:2) (T_{15}) intercropping system produced significantly higher pigeonpea yield (852 kg ha^{-1}) compared to pigeonpea + sweet corn intercropping system (574 kg ha^{-1}). Whereas, harvest index of pigeonpea was not influenced by intercropping system. The reduction in seed yield of pigeonpea due to intercropping was 15 to 44 per cent as compared to the sole crop of pigeonpea. Whereas, higher stalk yield was also recorded at T_{15} (1678 kg ha^{-1}). It could be due to increased plant population pressure of main and intercrop together resulting in increased competition for nutrients, water, space and light which leads to decreased biomass and yield which was found maximum in exhaustive cereal crops. These results agree with the findings of Mallikarjun *et al*. (2018) [5] and Shivakumar *et al*. (2021) [8].

Economics of pigeonpea based cropping system

The data relating to yield of pigeonpea that differed significantly due to influence of different intercrops are depicted in Table 4.

Among different intercropping, the highest net returns of ₹ 2,96,750 ha^{-1} were obtained under T_9: pigeonpea + sweet corn (1:2) with benefit cost ratio of 4.91 followed by treatment T_{12}: pigeonpea + vegetable soybean (1:2) which incurred the net return of ₹ 1,24,050 ha^{-1} and benefit cost ratio of 3.91. It may be due to higher combined yield of both pigeonpea and sweet corn along with higher market price of the high value crops like sweet corn and vegetable soybean. Even though pigeonpea faced competition from these crops for growth resources additional income was obtained from different intercrops, thereby increased the system productivity. These results were supported by Kumar *et al*. (2017) [4] and Yadav *et al*., 2021 [11].

It could be concluded from the results of the experiment that when two crops were grown under intercropping, their yields were generally reduced in intercropping system as compared to their sole crop yields. But the combined yield may be higher than either of the sole crops. It is possible that the reduction in yield of component crops grown together could be minimized by selecting compatible crop species having different growth habits *viz*., high value crops like sweet corn, baby corn and climate resilient crops like quinoa and grain amaranth. Hence, intercropping of sweet corn / baby corn with pigeonpea in 1:2 row proportion was found to be the most profitable pigeonpea based intercropping system near to urban areas which fetch higher returns whereas field bean and new crops like vegetable soybean (1:2), which are harvested for their pods and are less competitive with the main crop (Pigeonpea), can be followed under both rainfed and protected irrigation.

Table 1: Growth parameters of pigeonpea as influenced by different intercrops in pigeonpea based cropping system

Treatments	Plant height (cm)	Total number of branches plant^{-1}	Total leaf area (cm^2 plant^{-1})	Total dry matter accumulation (g plant^{-1})
T_1: Sole pigeonpea	210.2	17.94	5787.9	117.6
T_9: Pigeonpea + sweet corn (1:2)	173.6	13.28	2735.6	73.5
T_{10}: Pigeonpea + baby corn (1:2)	186.3	13.60	2946.6	79.7
T_{11}: Pigeonpea + sorghum (1:2)	190.9	14.38	3478.8	87.5
T_{12}: Pigeonpea + veg. soybean (1:2)	205.4	16.85	4959.4	110.5
T_{13}: Pigeonpea + quinoa (1:2)	193.4	15.10	4397.9	103.7
T_{14}: Pigeonpea + G. amaranth (1:2)	198.4	15.67	3863.4	107.6
T_{15}: Pigeonpea + field bean (1:2)	208.5	17.29	5356.3	113.7
F test	*	*	*	*
S.Em. ±	3.7	0.29	77.66	1.8
C.D. at 5%	11.1	0.87	235.57	5.5

Table 2: Yield attributes and yield of pigeonpea as influenced by different intercrops in pigeonpea based intercropping system

Treatments	No of pods plant^{-1}	No of seeds pod^{-1}	Seed yield (g plant^{-1})	Test weight (g)
T_1: Sole pigeonpea	104.7	4.6	52.3	16.3
T_9: Pigeonpea + sweet corn (1:2)	62.3	3.5	24.7	14.8
T_{10}: Pigeonpea + baby corn (1:2)	70.5	3.9	29.3	14.9
T_{11}: Pigeonpea + sorghum (1:2)	74.7	3.7	30.0	15.3
T_{12}: Pigeonpea + veg. soybean (1:2)	96.3	4.0	44.7	15.8
T_{13}: Pigeonpea + quinoa (1:2)	89.6	3.8	41.9	15.2
T_{14}: Pigeonpea + G. amaranth (1:2)	90.0	3.9	43.0	15.3
T_{15}: Pigeonpea + field bean (1:2)	99.0	4.0	48.5	15.9
F test	*	NS	*	*
S.Em. ±	3.5	0.2	1.73	0.29
C.D. at 5%	10.5	-	5.26	0.88

Table 3: Yield of pigeonpea based intercropping systems

Treatments	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Harvest index
T_1: Sole pigeonpea	1012	2227	0.31
T_9: Pigeonpea + sweet corn (1:2)	574	1033	0.36
T_{10}: Pigeonpea + baby corn (1:2)	605	1120	0.35
T_{11}: Pigeonpea + sorghum (1:2)	642	1193	0.35
T_{12}: Pigeonpea + veg. soybean (1:2)	798	1565	0.34
T_{13}: Pigeonpea + quinoa (1:2)	735	1440	0.34
T_{14}: Pigeonpea + G. amaranth (1:2)	765	1439	0.35
T_{15}: Pigeonpea + field bean (1:2)	852	1678	0.34
F test	*	*	-
S.Em. ±	22.83	37.82	-
C.D. at 5%	69.27	114.7	-

Table 4: Economic analysis of pigeonpea based intercropping systems

Treatments	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
T_1: Sole pigeonpea	35995	58899	22905	1.64
T_9: Pigeonpea + sweet corn (1:2)	75907	372657	296750	4.91
T_{10}: Pigeonpea + baby corn (1:2)	74026	168500	94474	2.28
T_{11}: Pigeonpea + sorghum (1:2)	41029	101848	60819	2.48
T_{12}: Pigeonpea + veg. soybean (1:2)	42593	166643	124050	3.91
T_{13}: Pigeonpea + quinoa (1:2)	42247	103337	61091	2.45
T_{14}: Pigeonpea + G. amaranth (1:2)	42507	75366	32859	1.77
T_{15}: Pigeonpea + field bean (1:2)	41249	110680	69431	2.68
F test	-	-	-	-
S.Em. ±	-	-	-	-
C.D. at 5%	-	-	-	-

Conclusion

In summary, the study investigated the growth parameters, yield attributes, and economic viability of pigeonpea under different intercropping systems. Pigeonpea intercropped with field bean exhibited superior growth characteristics, while sweet corn intercropping resulted in lower growth parameters. Despite facing competition from vigorous crops like sweet corn, pigeonpea intercropped with vegetable soybean or field bean showed promising results in terms of yield attributes. However, the sole pigeonpea consistently outperformed intercropped scenarios in terms of yield. Economic analysis revealed that intercropping with sweet corn generated the highest net returns, followed by vegetable soybean intercropping. Nonetheless, combining pigeonpea with high-value crops like sweet corn proved to be profitable, highlighting the potential for optimizing intercropping systems for enhanced productivity and economic gains. Overall, the findings underscore the importance of selecting compatible crop species and row proportions to maximize the benefits of intercropping, especially in pigeonpea-based cropping systems.

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