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Climate Resilient Practices on Performance and Economics of Transplanted Pigeonpea and Sunflower Intercropping in *Vertisol* of Northern Karnataka

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Abstract: A field experiment was conducted during *Kharif* 2019 to evaluate transplanted pigeonpea and sunflower intercropping system at different dates of sowing and fertilizers. Treatment combinations consists of two sowing time and eight intercropping system replicated thrice. Pigeonpea transplanted in second fortnight of July recorded significantly higher grain yield, equivalent yields of pigeonpea (PEY) and sunflower (SEY), over second fortnight of August. However, higher sunflower seed yield and oil content was in second fortnight of August sowing. Among intercropping systems, sole pigeonpea and sunflower recorded significantly higher seed yield (2254 and 1781 kg ha^{-1}) over sole drilled pigeonpea as well as intercropping systems. Transplanted pigeonpea + sunflower (1:2) with RDF for both crops recorded superior pigeonpea grain yield (1936 kg ha^{-1}), PEY (2914 kg ha^{-1}), SEY (3816 kg ha^{-1}), gross returns (Rs. 157680 ha^{-1}) and net returns (Rs. 108880 ha^{-1}). Drilled pigeonpea + sunflower (1:1) considered as farmers practice recorded significantly greater sunflower seed yield (1382 kg ha^{-1}), oil content (37.7 %) and B: C (3.49) over rest of the combinations. Transplanted pigeonpea was superior over drilled sown pigeonpea.

Keywords: Intercropping, Pigeonpea establishment, Sowing time

Among pulses, pigeonpea [*Cajanus Cajan* (L) Millsp.] holds first place in Karnataka both in area (1.48 m ha) and production (0.94 m t) with a productivity of 647 kg ha^{-1} (Anonymous 2018). Among major production constraints, erratic and scanty rainfall that resulted in lower soil moisture and reducing pigeonpea productivity in *Vertisol* of N-Karnataka. Sunflower (*Helianthus annuus* L.) crop in Karnataka shares 52% of the area and 40% of the production in the country. Amongst factors responsible for yield improvement in both the crops, optimum fertilizers application and timely sowing were of prime important. Wider yield gap can be minimized by the use of adequate and balanced fertilization (Naik et al 2016, Umesh et al 2020). Crop nutrient removal far exceeds than the addition through fertilizers and manures. Application of nutrient requirement of pigeonpea and urdbean intercropping through 100% fertilizer and vermicompost enhances productivity (Pal and Singh 2015). In annual intercropping systems, climate resilient practices with conservation approach was most important to improve the farm productivity (Bitew and Abera 2018). Balanced application of major nutrients can increase sunflower growth and yield substantially. Long duration pigeonpea can adjust to a wider range of population and spacing. It is cultivated on marginal lands in mono/mixed cropping system without or suboptimal fertilizers under rainfed conditions. Delayed sowing shortens the time for growing period, hastens maturity and ultimately reduces the yield. Early sowing may encourage the vegetative growth which may make the crop prone to different insect pests and diseases. Thus, the need for timely planting through alternate feasible means such as transplanting. Farmers adopted different row proportions in pigeonpea based intercropping rather than the recommended optimum. Transplanting of seedlings and seed hand dibbling in pigeonpea is recently adopted techniques in the region. The transplanting of pigeonpea would be one of the better agronomic practices to avoid delayed sowing and also maintain desired plant population (Priyanka et al 2013, Praharaj et al 2015). Raising pigeonpea seedlings well in advance and transplanting in the field on receipt of good rains would help in reaping the benefits of early sowing. Keeping these facts, the present investigation was carried out with an objective to evaluate feasibility of pigeonpea and sunflower intercropping in a changed sowing window and fertilizers supply in *Vertisol* of N Karnataka.

MATERIAL AND METHODS

A field experiment was conducted during *Kharif* 2019 at Main Agricultural Research Station, Raichur. The soils of the site were medium black having 7.74 soil reaction, 0.6 % organic carbon and 0.21 dS m^{-1}EC. The available N, P_2O_5 and K_2O before initiation of experiment were 293.3, 39.7 and 365.9 kg ha^{-1}. The experiment was carried out in split plot design replicated thrice. Main plots were sowing both the

crops in July second fortnight and August second fortnight, sub-plot treatments were transplanted pigeonpea + sunflower (1:1) with RDF for main crop, transplanted pigeonpea + sunflower (1:1) with RDF for both the crops, transplanted pigeonpea + sunflower (1:2) with RDF for main crop, transplanted pigeonpea + sunflower (1:2) with RDF for both the crops, drilled sown pigeonpea + sunflower (1:1) sole sunflower, sole transplanted pigeonpea, sole drilled sown pigeonpea (Table 1). Fertilizers were applied for pigeonpea @ 25-50 kg N-P_2O_5 and sunflower @ 90-90-60 kg N-P_2O_5-K_2O ha^{-1}. Under intercropping system, the fertilizers were applied according to the component crops population in each treatment. The entire quantities of fertilizers were applied to pigeonpea at basal. For sunflower half of recommended N and entire dose of P and K were applied at basal and remaining N was top dressed at 30 DAS. Foliar application of 19:19:19 @ 1% and Pulse magic @ 10 g/l was done at flowering stage. Pigeonpea variety BSMR-736 and sunflower hybrid RSFH-1887 were selected for the trial.

Pigeonpea seeds were sown on first week of June and July in polythene bags (8" x 5") having 3/4th of soil and 20 g of vermicompost for establishing seedlings to match sowing time as per treatment. Polythene bags were watered regularly. After one month, the seedlings were transplanted in the main field at 1.2 m x 0.6 m. For drill sown treatment seeds were sown at 1.2 m x 0.6 m spacing on the day of transplanting. In main field, 30 days old pigeonpea seedlings were transplanted after removing the polythene cover without disturbing the soil at the root zone. Sunflower under intercropping was sown exactly at the center of pigeonpea rows in 1:1, whereas two rows of sunflower at 60 cm apart in 1:2 row proportion. Rest of the production practices for both the crops was followed as per the regional recommendation by the University. Irrigation was provided during long dry spells to avoid stress. Pigeonpea and sunflower equivalent yields were calculated based on market price and yield levels as per the standard procedure (Umesh et al 2002). The cost includes expenditure on seeds, fertilizers, weed management and plant protection chemicals. At maturity, the crop was harvested and plot wise yields were recorded. The data recorded at different stages of crop was subjected to statistical analysis at 5 % probability.

RESULTS AND DISCUSSION

Pigeonpea grain yield: Pigeonpea transplanted in July recorded 35.3 per cent higher grain yield (2130 kg^{-1} ha) over August transplanting (Table 1). Sole transplanted pigeonpea was recorded significantly higher grain yield (2253 kg ha^{-1}) over rest of the intercropped treatments and drilled pigeonpea. Application of fertilizers to both the crops in

Table 1. Effect of sowing time and row proportions on seed yield, protein content, oil content and equivalent yields of pigeonpea (PEY) and sunflower under (SEY) intercropping system

Treatment	Pigeonpea			Sunflower		
	Grain yield (kg ha^{-1})	Protein content (%)	PEY (kg ha^{-1})	Seed yield (kg ha^{-1})	Oil content (%)	SEY (kg ha^{-1})
Sowing time						
July	2130	21.4	2570	1124	36.1	3354
August	1574	20.5	2122	1300	38.3	2778
C.D. (P=0.05)	305	0.6	180	186	2.1	82
Row proportions and fertilizers						
Transplanted pigeonpea + sunflower (1:1) RDF for main crop	1819	20.9	2453	831	36.8	3213
Transplanted pigeonpea + sunflower (1:1) RDF for both crops	1926	21.3	2635	929	37.0	3451
Transplanted pigeonpea + sunflower (1:2) RDF for main crop	1778	20.7	2592	1066	36.0	3394
Transplanted pigeonpea + sunflower (1:2) RDF for both crops	1936	21.0	2914	1280	36.5	3816
Drill sown pigeonpea + sunflower (1:1)	1593	20.0	2648	1382	37.7	3468
Sole sunflower	-	-	1360	1781	39.1	1781
Sole transplanted pigeonpea	2252	22.2	2252	-	-	2949
Sole drill sown pigeonpea	1659	20.4	1659	-	-	2457
C.D. (p=0.05)	170	0.4	173	101	1.3	267
Interaction	I×S S×I	I×S S×I	I×S S×I	I×S S×I	I×S S×I	I×S S×I
S.Em. ±	123 89	0.3 0.2	98 91	70 52	0.8 0.6	35 122
C.D. (p=0.05)	NS NS	277 275	277 275	NS NS	NS NS	383 360

transplanted pigeonpea + sunflower (1:2) recorded significantly greater grain yield (1937 kg ha^{-1}) over drilled pigeonpea + sunflower (1593 kg ha^{-1}). Combined effect of sunflower intercropped with different row proportions and RDF along with time of transplanting found non-significant. Yield advantage in the early sown crop was mainly due to increased growth, yield attributes and physiological characters. It also favored by climatic conditions, temperature during growth, development and maturity stages. Efficient utilization of nutrients and moisture as well as greater light interception had resulted in higher growth and yield attributes. Similar results on yield advantage in sown crops were reported in early studies (Reddy et al 2012, Yu 2014, Uprikar 2017). Channabasavanna et al (2015) reported that the growth and yield benefits in early sown pigeonpea due to long growing period consequently accumulated greater dry matter enhanced leaf area and phenological potential. Intercropping has reduced the yields of both pigeonpea and sunflower. Sole transplanted pigeonpea recorded higher seed and dry matter yield over intercrop with sunflower and was mainly attributed to enhanced growth in terms of plant height, primary branches, LAI and TDMP and yield parameters *viz*., pods per plant, seed yield per plant, seeds per plant and 100 seed weight. Impact of intercropping on growth and yield was reported by Pal et al (2016).

Sunflower seed yield: The sunflower has photoperiod benefit in terms of improved yield (15.66%) either by sowing or transplanting in second fortnight of August (1300 kg ha^{-1}) over second fortnight of July (Table 1). Sole sunflower out yielded (1781 kg ha^{-1}) over rest of the intercropped combinations. Drilled pigeonpea + sunflower (1:1) considered as farmer practice has recorded greater sunflower seed yield (1382 kg ha^{-1}) over sunflower as intercrop with transplanted pigeonpea (1:1) with RDF for main crop (831 kg ha^{-1}). Intercropping systems reduced the sunflower yield 22.4-55.3% owing to population difference and was compensated by contribution from pigeonpea indicated in terms of equivalent yield. Combined effect of sowing time and intercropping with row proportions and fertilizers application has no significant effect on sunflower seed yield. An uninterrupted availability of various resources *viz*., solar interception, soil moisture and nutrients for sole crop might have helped the crop to utilize the resources to a great extent resulting in enhanced values of varied growth parameters and yield attributes (Umesh et al 2017, Suresh et al 2019). Ahmed *et al.,* (2015) reported that sunflower yield was significantly influenced by date of sowing. The productivity of sunflower was mainly determined by the weather and soil moisture throughout its life cycle and the imposed cultural practices. Delayed sowing increased the yields. The timely sown (May) crop experienced moisture stress during early stage of the crop which adversely affected its growth and yield attributes. However, well distributed rainfall and adequate moisture in late sown might be responsible for enhanced sunflower yield. Additionally, sunflower is a thermo insensitive and it adjust to the late sowing but most important factor is moisture availability for their luxuriant crop growth and yield (Kaleem et al 2011, Demir 2019). Sole sunflower gave higher yields than intercropped has a result of higher plant population (Sandeep Kumar et al 2019). Row proportion of sunflower and pigeonpea had significant effect on seed and stalk yield of sunflower. The higher seed and stalk yield of sunflower was recorded under 2:1 row proportion than 1:1 row proportion.

Seed protein content: Crops sown in second fortnight of July recorded significantly higher protein content (21.36 %) than second fortnight of August (20.50 %) (Table 1). Greater accumulation of nutrients in seed and better crop performance might be responsible for enhanced protein content. Sole transplanted pigeonpea recorded higher protein (22.2%) content than intercropped as well as drilled pigeonpea. Application of fertilizers to both the crops in transplanted pigeonpea + sunflower (1:1) also recorded greater protein content (21.32 %) over rest of the treatment combinations. Drilled pigeonpea + sunflower (1:1) and sole drilled pigeonpea was on par to each other but recorded lower than the sole transplanted and intercropped pigeonpea. Combined effect of time of sowing and intercropping system with different row proportion and fertilizer application on protein content was found non-significant. Vishwanatha (2009) reported higher protein content with sole pigeonpea than intercrops. In intercropping supply of balanced nutrients to the crop especially phosphorous may be due to the biochemical role of phosphorous in protein synthesis (Udikeri, 2013). Protein content in seed is a function of N concentration, therefore, higher concentration of N in seed under the superior treatments seems to be the only reason for attaining higher protein content in pigeonpea (Kumar and Paslawar, 2017).

Sunflower seed oil content: Sunflower seed oil content was significantly greater in second fortnight of August sown (38.3%) over July (36.1%) (Table 1). Intercropping combinations reduced the oil content over sole sunflower (39.1 %). Combined effect of time and row proportions and fertilizers application was non-significant in oil content and was mainly due to enhanced vegetative growth and development in August sown than July. Late-sown plants increases the seed oil might be due to the fact that the temperature increases during seed development (Allam et al

2003). Application of RDF to both the crops recorded higher oil content and might be due to lower fatty acid synthesis through the pentose phosphate pathway in seeds without fertilizer application to intercrop owing to increased competition and non-availability of required quantity of nutrients but the treatment which received RDF had better synthesis of fatty acid owing to optimum nutrient availability (Vishwanatha, 2009).

Equivalent yields: Pigeonpea transplanted in second fortnight of July recorded 21.1% higher PEY (2570 kg ha^{-1}) over August (Table 1). Further, was greater in sole transplanted pigeonpea (2252 kg ha^{-1}) than drilled pigeonpea and sunflower alone and also improved by application of fertilizers to both the crops in transplanted pigeonpea + sunflower (1:2) (2914 kg ha^{-1}). Application of RDF to main crop in transplanted pigeonpea + sunflower (1:1) recorded significantly lower PEY (2453 kg ha^{-1}). Prevalence of favorable climatic weather and resources availability has resulted higher yield of both main and intercrop yield with early sowing than delayed sowing (Ravindra 2019). Murali et al (2014) also showed increased PEY with transplanting 4-5 weeks old pigeonpea seedlings than drilled sown pigeonpea as sole crop. It might be due to efficient utilization of natural resources and additional yields of component crops and their better performance in transplanted pigeonpea with higher market prices which intern resulted in higher PEY and net returns. Praharaj et al (2015) reported significantly higher PEY over direct sown in pigeonpea and soybean intercropping and sole cropping. Intercropping system had a significant influence in obtaining higher PEY over either of sole cropping except unfertilized control. This was due to higher seed yields of component crops owing to optimum nutrient availability (RDF to both the crops) coupled with higher price of both the crops contributed to higher PEY (Poornima 2009). Sunflower equivalent yield was 20.7% greater in crops sown in second fortnight of July (3354 kg ha^{-1}) over August sown (Table 1). It might be due to better sunflower productivity under timely sowing than delay sowing coupled with higher market price. Intercropped treatments recorded significantly greater SEY than the sole. Further, it also enhanced by application of RDF to both the crops in transplanted pigeonpea + sunflower (1:2). It was significantly reduced under sole sunflower (1781 kg ha^{-1}). The interaction effect between sowing time, intercropping system, row proportions and fertilizers application have significant effect on the SEY. The pigeonpea and sunflower 1:2 row proportion was recorded higher SEY as compared to other row proportions.

Economic returns: Crops sown/transplanted in second fortnight of July recorded higher gross returns (Rs. 136769 ha^{-1}), net returns (Rs. 94421 ha^{-1}) and B: C ratio (3.2) over August sown crops (Table 2). Sole transplanted pigeonpea recorded significantly higher gross returns (Rs. 123860) and net returns (Rs. 83560 ha^{-1}) over drilled pigeonpea and sunflower. Application of RDF for both crops in transplanted pigeonpea + sunflower (1:2) higher gross returns (Rs.157680 ha^{-1}) and net returns (Rs.108880 ha^{-1}) over 1:1 row proportions and RDF to main crop. The drilled pigeonpea

Table 2. Economic returns of pigeonpea and sunflower intercropping system sown in different months and row proportions

Treatments	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
Sowing /transplanting time				
July	42339	136769	94421	3.20
August	39811	114163	74361	2.85
S.Em. ±	-	1596	1539	0.04
C.D. @ 5 %	-	10454	10079	0.28
Row proportions				
Transplanted pigeonpea + sunflower (1:1) RDF for main crop	43850	133285	89435	3.11
Transplanted pigeonpea + sunflower (1:1) RDF for both crops	48800	143090	94290	2.99
Transplanted pigeonpea + sunflower (1:2) RDF for main crop	43850	140430	96580	3.28
Transplanted pigeonpea + sunflower (1:2) RDF for both crops	48800	157680	108880	3.30
Drill sown pigeonpea + sunflower (1:1)	44000	142895	98895	3.49
Sole sunflower	26500	71240	44740	2.69
Sole transplanted pigeonpea	40300	123860	83560	3.07
Sole drill sown pigeonpea	32500	91245	58745	2.72
C.D. @ 5 %	-	8616	7126	0.23

Market price of Pigeonpea: Rs. 55/kg, Sunflower price: Rs. 42/kg

+ sunflower (1:1) considered as farmers practice recorded higher BC ratio (3.49) over transplanted pigeonpea + sunflower in (1:1) and 1:2. Higher grain yield which results in higher gross return. Similar results were also reported by Uprikar (2017). Higher net returns realized from intercropping was due to complementarity between component crops which produced higher yield. Higher returns from drilled pigeonpea + sunflower (1:1) were due to additional cost incurred towards nursery raising and transplanting in transplanting method. Superior performance in transplanted pigeonpea treatments might be due to efficient utilization of natural resources and additional yields of component crops and their better performance in transplanted pigeonpea with higher market prices which intern resulted in higher pigeonpea equivalent yield and net returns. Similarly higher remunerative returns were observed in intercropping system over sole cropping by Vishwanatha et al (2012). Sole transplanted pigeonpea recorded higher BC ratio over sole sunflower (2.69) and drilled sown pigeonpea (2.72) (Table 2). Dibbled pigeonpea and sunflower intercropping recorded higher BC ratio was due to higher cost of cultivation in transplanting method than of dibbling method. Similar results were reported by Priyanka et al (2013) and Ramanjaneyalu et al. (2016).

CONCLUSION

The pigeonpea either direct sown or transplanted was superior in terms of yield and economic returns. The second fortnight August was benefitted to sunflower. Drill sown pigeonpea and sunflower combination in 1:1 had greater yield advantage over sole drilled pigeonpea. Yield and economic benefit were greater in second fortnight of July sown crop as compared second fortnight of August sown crop. Higher net return was realized in transplanted pigeonpea and sunflower intercropping system with 1:2 row proportion and application of RDF based on both the crops. Transplanted pigeonpea has the greater productive potential than drill sown pigeonpea.

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