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Performance of soybean intercropped under different seed sources of *Pongamia pinnata* agroforestry system

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ABSTRACT: Eleven seed sources of *Pongamia pinnata* were selected from three provenances from Maharashtra, Tamil Nadu and Karnataka to identify suitable seed sources for inclusion in agroforestry condition and study their effect on soybean productivity. Growth attributes viz., height (5.05 m), diameter at breast height (11.86 cm), crown area (4.98 m^2/tree) and number of branches (38.16) were maximum in Pongamia source RAK-89 followed by MTP-II. Maximum leaf dry weight (3.59 g/plant) was found in sole soybean when compared to other Pongamia sources based agroforestry systems. Leaf dry weight was maximum (2.18 & 2.53 g/plant) in MTP-II + soybean and lowest in RAK-90 + soybean (0.44 & 0.74 g/plant). Maximum stem dry weight of soybean was recorded in RAK-89 + soybean (2.85 & 3.06 g/plant); whereas the treatment MTP-III + soybean (0.10 & 0.26g/plant) had the lowest stem dry weight at 1.5 and 3 m distances from tree base respectively. In soybean as intercrop, the pod dry weight increased significantly in all the Pongamia sources at harvest from 1.5 and 3 m distance from Pongamia row. Seed yield of soybean was maximum in DPS-4+soybean (D_1-1.5m and D_2-3m; 721.8 and 725.8 kg ha^{-1}) followed by RAK-89 + soybean (D_1-1.5m and D_2-3m; 674.0 and 678.5 kg ha^{-1}). The yield reduction was to the extent of 58% in MTP-III + soybean as compared to the sole soybean.

Key words: Harvest index, interaction, LTR, sole crop and soybean

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1. INTRODUCTION

Pongamia pinnata belongs to the family Papilionaceace and is a medium sized evergreen tree with a spreading crown and a short bole. It is one of the few nitrogen fixing trees producing seeds containing 30-40% oil. Natural distribution is along coasts and riverbanks in lands and native to the Asian subcontinent. It is also cultivated along roadsides, canal banks and open farm lands. It is a preferred species for controlling soil erosion and binding sand dunes because of its dense network of lateral roots. Its root, bark, leaves, sap, and flowers have medicinal properties and traditionally used as a medicinal plants.

The seeds are largely exploited for extraction of non-edible oil commercially known as 'Karanja oil', which is well known for its medicinal properties. Pongamia seeds consist of 95% kernel and are reported to contain about 27-40% oil. The yield of oil is reported to be about 24 to 26.5 per cent, if mechanical expellers are used for the recovery of oil from the kernels. There are numerous reports that document favorable and harmful effects of trees on agricultural crops grown under their shade. The changes are more pronounced with increase in tree size and stand density (Harsh and Tewari, 1993). Trees modify surrounding environment including soil depending on species and planting arrangement and these modification in environment cause changes in crop production (Chauhan, 2000). Present investigation, therefore was planned to study the performance of soybean under different Pongamia seed sources.

2. MATERIALS AND METHODS

The experiment was carried out during *kharif* season of 2013-14 in "I" block, agroforestry experimental field, Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad, located at 15^0 26' N latitude, a longitude of 75^0 0' E and altitude of 678 m above mean sea level. It is situated in transitional tract, representing Northern transitional agro climatic zone (zone 8) of Karnataka.

During the year 2013 mean maximum temperature recorded was 30.4 ^{0}C and was similar to the mean value of previous eight years (30.5 ^{0}C). The mean minimum temperature was observed exactly the same as that of average value and was 18.4 ^{0}C. The highest mean maximum temperature was recorded in April (36.9 ^{0}C) and the lowest mean minimum temperature was recorded in December (12.7 ^{0}C). During the year 2013 total of 740.4 mm rainfall was recorded in 63 rainy days as against average value of 892 mm in 65 rainy days. Major proportion of the rainfall was received during the months of May, July and September. Relative humidity was higher (82, 89, 85 & 81%) during June, July, August and September months and a similar trend was observed during previous eight years data. In an ongoing agroforestry experiment, 11 seed sources of *Pongamia pinnata* were planted during the year 2006 at 6 m × 4 m spacing. Pongamia seed sources *viz.,* seven sources from Maharashtra (RAK-103, RAK-106, RAK-11, RAK-90, RAK-22, RAK-05 and RAK-89), three seed sources from Tamil Nadu (MTP-I, MTP-II and MTP-III) and one seed source from Karnataka (DPS-4). Soybean (JS-335) intercrop was grown in between the *Pongamia pinnata* seed source alleys (6 m alley). Soybean yield and yield attributing characters were recorded at the time of harvest (2nd week of September, 2013). Data obtained were analyzed for comparing the treatment means.

3. RESULTS AND DISCUSSION

Growth performance of different Pongamia sources *viz.,* RAK-103, RAK-106, RAK-11, RAK-90, RAK-22, RAK-05, RAK-89, MTP-I, MTP-II, MTP-III and DPS-4 was measured on the basis of quantitative characters under agroforestry system.

Among the 11 Pongamia sources studied, RAK-89 source attained maximum height of 5.05 m and RAK-22 the minimum 3.47 m. RAK-89 and MTP-II were found most suitable sources with respect to height. Similarly with respect to diameter at breast height (dbh) RAK-89 source has recorded the highest dbh (11.86 cm) followed by MTP-II (11.61 cm) and the least was recorded by DPS-4 (8.26 cm). RAK-89 was found most suitable to the experimental site as compared to all other seed sources (Table 1).

RAK-89 Pongamia source has grown very well in terms of height and dbh when compared to all other Pongamia sources, which may be due to high potential and wider adaptability of this Pongamia source in zone 8. There were significant differences among Pongamia sources with respect to crown area. Higher average crown area was observed in RAK-89 (4.98 m^2 $tree^{-1}$) than in other Pongamia sources. The crown area which forms photosynthetic structure helped in higher dry matter productivity. The higher value of growth attributes viz., height and dbh in RAK-89 Pongamia source may be attributed to higher crown area (Table 1). The increased crown area in RAK-89 Pongamia sources may be due to absorption of higher amount of solar radiation resulting in increased production of photosynthesis. Increased distribution of these photosynthates into main stem ultimately resulted in measured height, dbh and number of branches and crown area. Difference in yield components and ultimately the yield of the intercrop (Soybean) is attributed to the differences in dry matter production and its partitioning at different growth stages. Therefore, dry mater accumulation at each growth stage and its portioning to reproductive organs during preflowering to maturity period has more importance in determining the productivity.

Table 1. Tree growth of *Pongamia pinnata* seed sources as influenced by different components in agroforestry system

Seed source/Agroforestry system	Height (m)	DBH (cm)	Crown area (m^2 $tree^{-1}$)	No. of branches ($tree^{-1}$)
T_1 - RAK-103 +FC	3.67	10.51	4.66	31.16
T_2 - RAK-106 + FC	3.84	9.78	4.50	28.36
T_3 - RAK-11 + FC	4.66	9.79	4.30	16.80
T_4 - RAK-90 + FC	3.76	8.30	3.86	13.96
T_5 - RAK-22 + FC	3.47	9.64	4.86	20.20
T_6 - RAK-05 + FC	4.04	7.59	4.30	24.13
T_7 - RAK-89 + FC	5.05	11.86	4.98	38.16
T_8 - MTP-I + FC	4.49	8.86	3.89	21.60
T_9 - MTP-II + FC	4.84	11.61	4.74	12.26
T_{10} - MTP-III + FC	3.98	9.44	4.14	20.63
T_{11} - DPS-4 + FC	3.93	8.26	4.27	21.33
Mean	4.16	9.60	4.41	22.60
SE(m) ±	0.138	0.511	0.308	0.494
CD 5%	0.410	1.519	NS	1.469

FC - Field crop

Soybean at 1.5 m distance from tree base suffered due to non availability of soil moisture, solar energy and nutrients during early stages and thus failed to build up adequate plant structure which resulted in lower dry matter production during crop growth. Both Pongamia source and distance from Pongamia tree had significant effect on dry matter production of soybean intercrop. The extent of reduction in dry matter production under RAK-90 and MTP-III Pongamia source was to the tune of 61.4 % for soybean intercrop as compared to the sole crop (Table 2).

Table 2. Influence of seed sources of *Pongamia pinnata* under agroforestry system on growth characters of soybean

Seed source/Agroforestry system	Leaf dry weight ($g\ plant^{-1}$)		Stem dry weight ($g\ plant^{-1}$)		Pod dry weight ($g\ plant^{-1}$)		Total dry weight ($g\ plant^{-1}$)	
	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2
T_1 - RAK-103 +Soybean	1.93	2.16	2.05	2.18	11.39	12.64	15.38	16.98
T_2-RAK-106 +Soybean	1.62	1.92	0.61	0.77	10.88	11.88	13.11	14.58
T_3 - RAK-11 +Soybean	1.64	2.06	0.68	0.85	9.80	10.80	12.12	13.72
T_4-RAK-90 +Soybean	0.44	0.74	0.35	0.44	6.69	7.56	7.48	8.75
T_5-RAK-22 +Soybean	1.43	1.85	1.03	1.14	9.30	10.24	11.76	13.24
T_6 - RAK-05 +Soybean	2.03	2.25	1.23	1.35	8.41	9.73	11.68	13.34
T_7 - RAK-89 +Soybean	2.62	3.07	2.85	3.06	10.54	11.56	16.02	17.69
T_8 - MTP-I +Soybean	1.27	1.74	0.17	0.33	7.41	8.27	8.86	10.35
T_9-MTP-II +Soybean	2.18	2.53	2.52	2.68	10.22	11.29	14.93	16.51
T_{10} - MTP-III +Soybean	1.38	1.74	0.10	0.26	7.62	8.79	9.11	10.79
T_{11} - DPS-4 +Soybean	1.66	2.07	1.55	1.75	12.86	13.60	16.08	17.43
T_{12} - Soybean (Sole)	3.59	3.59	3.68	3.68	14.78	14.78	21.06	21.06
Mean	1.73	2.06	1.40	1.54	9.99	10.93	13.13	14.53
For comparing means	SE(m) ±	CD (0.05)	SE(m) ±	CD (0.05)	SE(m) ±	CD (0.05)	SE(m) ±	CD (0.05)
Seed source / AF system (SAF)	0.021	0.060	0.016	0.047	0.082	0.234	0.087	0.249
Distance (D)	0.009	0.024	0.007	0.019	0.033	0.096	0.036	0.102
Interaction (SAF × D)	0.030	0.085	0.023	0.066	0.116	0.331	0.123	0.352

D_1 = 1.5 m distance from Pongamia alleys; D_2 = 3.0 m distance from Pongamia alleys

The number of pods was maximum in the treatment DPS-4 + soybean (32.50 and 34.82) followed by RAK-89 + soybean (28.26 and 32.13) and it was minimum in MTP-III + soybean (4.58 and 7.02) at 1.5 m and 3 m from the base of the tree, respectively. Seed weight of soybean was significantly influenced by the Pongamia sources and distances from Pongamia alleys. The seed weight was significantly higher in the treatment DPS-4 + soybean (8.59 g) and RAK-89 + soybean (7.76 g) at 1.5 and 3 m distance, respectively, than others. The data on 100 seed weight in soybean was significantly influenced by the different sources and distances from base of tree. The treatment DPS-4 + soybean recorded significantly increased hundred seed weight (10.58 and 10.87 g) followed by the treatment RAK-89 + soybean (9.46 and 9.68 g) at 1.5 and 3 m distance from tree base (Table 3).

Reduction of hundred seed weight was highest in MTP-III + soybean (1.81 and 1.91 g) followed by RAK-05 + soybean (2.19 and 2.74 g) at both the distances from tree base. Among the distances, minimum hundred seed

Table 3. Influence of seed sources of *Pongamia pinnata* under agroforestry system on yield characters of soybean

Seed source/Agroforestry system	Pods (No. $plant^{-1}$)		Seed weight ($g\ plant^{-1}$)		100 seed weight (g)	
	D_1	D_2	D_1	D_2	D_1	D_2
T_1 - RAK-103 +Soybean	17.68	20.66	3.62	3.92	5.43	5.85
T_2 - RAK-106 +Soybean	22.54	24.37	5.23	5.78	7.43	7.86
T_3 - RAK-11 +Soybean	7.97	10.14	2.06	3.57	2.84	3.07
T_4 - RAK-90 +Soybean	24.27	26.72	6.40	6.87	8.52	8.84
T_5 - RAK-22 +Soybean	19.43	22.95	4.53	4.88	6.51	6.87
T_6 - RAK-05 +Soybean	7.33	10.43	1.84	2.60	2.19	2.74
T_7 - RAK-89 +Soybean	28.26	32.13	7.49	7.76	9.46	9.68
T_8 - MTP-I +Soybean	14.34	17.37	3.51	3.96	4.45	4.81
T_9 - MTP-II +Soybean	11.51	14.47	2.85	3.19	3.46	3.85
T_{10} - MTP-III +Soybean	4.58	7.02	1.64	2.24	1.81	1.91
T_{11} - DPS-4 +Soybean	32.50	34.82	8.59	5.24	10.58	10.87
T_{12} - Soybean (Sole)	51.29	51.29	9.29	9.29	12.51	12.51
Mean	20.14	22.70	4.75	4.94	6.26	6.57
For comparing means	SE(m) ±	CD (0.05)	SE(m) ±	CD (0.05)	SE(m) ±	CD (0.05)
Seed source / AF system (SAF)	0.426	1.217	0.345	0.985	0.084	0.239
Distance (D)	0.174	0.497	0.141	NS	0.034	0.098
Interaction (SAF × D)	0.603	NS	0.488	1.393	0.118	NS

D_1 = 1.5 m distance from Pongamia alleys; D_2 = 3.0 m distance from Pongamia alleys weight was noticed at 1.5 m distance from the tree base whereas; at 3 m distance maximum hundred seed weight was observed. This may due to the low LTR (Light Transmission Ratio) values and extensive type of canopy with dense branching habit under the Pongamia sources RAK-90 and MTP-III, which inhibited the light intensity to pass through the canopy of Pongamia beneath the tree, and adverse effect of these factors was reflected in the reduction of leaf dry matter, stem dry matter. Low LTR was observed in closer distance from Pongamia rows as crown shading was higher around trees. Its effect was revealed in yield components as well as haulm yield.

These growth parameters were affected mainly due to lack of soil moisture, solar radiation and nutrient availability (Korwar, 1992, Jaswal *et al*., 1993, Iang *et al*., 1995, Chauhan *et al*., 1990). Patre and Sahu (1986) also reported the adverse effect of low light intensity on growth and dry matter production.

Yield is the ultimate manifestation of morphological, physiological, biochemical processes and growth parameters and is considered to result from trapping and the conversion of solar energy. The highest seed yield was obtained in sole soybean (1230 kg ha^{-1}) followed by the crop under Pongamia source DPS-4 + soybean (721.8 and 725.8 kg ha^{-1}) at two distances from tree base. The lowest yield was recorded under Pongamia source MTP-III + soybean (509.5 kg ha^{-1}) agroforestry system. Among agroforestry system Pongamia source DPS-4 + soybean was superior followed by RAK-89 + soybean. This may be due to canopy structure and less branching habit of Pongamia crowns, which in turn recorded high light transmission ratio values, which attributed to increased number of pods per plant, seed weight and 100 seed weight which in turn on total dry matter accumulation (Table 4).

Among the distances, soybean growing at 3m distance from Pongamia recorded significantly higher seed yield (665 kg ha^{-1}) compared to 1.5 m distance (664 kg ha^{-1}). Significantly lower soil moisture at 1.5 m distance at pod filling stage of soybean was observed due to competition for moisture by the surfacial root system of the tree, as most of lateral root spread of Pongamia is confined to 1.5 m distance from the tree base and in turn was attributed to lower yield by the intercrop. Competition for moisture, nutrient and light in agroforestry system is a common phenomenon, which can affect the system adversely (Ong *et al*., 1991 and Rao *et al*., 1999). Similarly reduction in the yield of field crops grown with perennial components were reported by Chandrashekaraiah (1986), Sunderlin (1992) and Roder *et al*., (1995). There was a maximum reduction in seed yield in the close proximity of the tree base. Further, the yield improved in a linear fashion with an

Table 4. Influence of seed sources of *Pongamia pinnata* under agroforestry system on seed yield and harvest index in soybean

Seed source/Agroforestry system	Seed yield (kg ha^{-1})		Haulm yield (kg ha^{-1})		Harvest index (%)	
	D_1	D_2	D_1	D_2	D_1	D_2
T_1 - RAK-103 +Soybean	608.5	612.5	526.3	530.0	0.536	0.536
T_2 - RAK-106 +Soybean	619.5	623.5	481.6	486.0	0.563	0.562
T_3 - RAK-11 +Soybean	575.6	579.5	454.3	458.6	0.559	0.558
T_4 - RAK-90 +Soybean	669.0	673.0	493.0	497.0	0.576	0.575
T_5 - RAK-22 +Soybean	614.0	618.0	476.3	480.3	0.563	0.563
T_6 - RAK-05 +Soybean	564.0	535.5	481.6	485.6	0.539	0.524
T_7 - RAK-89 +Soybean	674.0	678.5	580.6	584.6	0.537	0.537
T_8 - MTP-I +Soybean	597.5	601.5	416.0	420.6	0.590	0.588
T_9 - MTP-II +Soybean	592.0	596.0	498.3	503.3	0.543	0.542
T_{10} - MTP-III +Soybean	509.5	513.5	361.3	366.6	0.585	0.583
T_{11} - DPS-4 +Soybean	721.8	725.8	542.3	547.3	0.571	0.570
T_{12} - Soybean (Sole)	1230.0	1230.0	949.6	949.6	0.564	0.564
Mean	664.7	665.6	521.8	525.8	0.561	0.559
For comparing means	SE(m) ±	CD (0.05)	SE(m) ±	CD (0.05)	SE(m) ±	CD (0.05)
Seed source / AF system (SAF)	32.963	NS	25.854	73.835	0.0007	0.0022
Distance (D)	13.457	NS	10.555	NS	0.003	NS
Interaction (SAF × D)	45.617	NS	36.563	NS	0.007	NS

D_1 = 1.5 m distance from Pongamia alleys; D_2 = 3.0 m distance from Pongamia alleys increase in distance from the tree base. More negative effect in close vicinity of trees can be ascribed to more competition for soil moisture, nutrients and light. Reductions in yield of wheat below the tree crown due to resource competition were also reported by Puri and Bangarwa (1992) and Dhillon *et al.* (1998).

Hundred seed weight was lowest when soybean was grown with MTP-III Pongamia source in both the distances (0-1.5 m and 1.5-3 m distances; 1.81 and 1.91 g) followed by RAK-05 (2.19 and 2.74 g) compared to sole soybean. A positive correlation with seed yield and other components has been reported by several workers *viz.*, Potdar *et al.* (1977), Sidhu and Bains (1980), Vericumber (1993), Venakat Rao *et al.*, (2006a) and Kushal and Verma (2003) who opined that the growth and yield of crop was influenced negatively below the tree crown, while it increased with increase in distance from the tree trunk. Soil moisture, nutrients and temperature were reduced considerably at 1 and 2 m distances from the tree base.

Among Pongamia source based agroforestry system, the seed yield was maximum in DPS-4 + soybean followed by RAK-89 + soybean, RAK-90 + soybean and RAK-22 + soybean. The main reasons for decreased yield of soybean under Pongamia sources were due to severe competition for moisture, light and nutrients by Pongamia component. The detrimental effect of agroforestry system on physiology and yield of intercrops was mainly because of the exposure of crops to low light intensity. The shading effect was more conspicuous during vegetative stage compared to reproductive stage due to growth of the intercrops. Similarly, reduction in yields of maize, sorghum, safflower and groundnut adjoining tree lines were reported by Chandarashekaraiah (1986), Itnal (1987) and Nadagoud (1990).

The extent of reduction in seed yield under different Pongamia sources was in the order of MTP-III > RAK-05 > RAK-11 > MTP-II > MTP-I > RAK-103 > RAK-22 > RAK-106 > RAK-90 >RAK-89 > DPS-4. Significant lower seed yield of soybean was recorded at 1.5 m distance from Pongamia row as compared to 3 m distances. The extent of reduction in pod yield was 11.2 % at 1.5 m distance from Pongamia row as compared to 3 m distance, which may be due to lower soil moisture and low light transmission ratio (46.7 to 62.9 %) as compared to 1.5 -3.0 m (54.2 to 66.2 %) from Pongamia row. This may also be due to shade effect of trees, and also adverse effect of these factors was reflected in the reduction of dry matter production of soybean under Pongamia row. Similarly, reduction in yields of maize, sorghum, sunflower and groundnut adjoining tree lines were reported by Chandrasekharaiah (1986), Itnal (1987), Bhat (1988), Nadagoud (1990), Anon. (1990), Anon. (1996) and Venkat Rao *et al.*, (2006b). Low light intensity and soil moisture also had adverse effect on intercrop growth resulting in reduction of soybean yields nearer the tree line. Yield reduction decreased with increase in distance from Pongamia row. The stress resulting from competition throughout the crop growth resulted in primitive closure of stomata to reduce transpiration loss. In addition it also decreased carbon dioxide diffusion into the leaves thereby affecting photosynthesis, transpiration rate, partitioning of biomass from vegetative parts of economic parts and increased stomatal and mesophyll resistance in crop plants (Nygren and Killomaki, 1993).

The interaction effects of Pongamia sources and distances were non-significant. Seed yield decreased nearer to Pongamia row in all sources except in sole soybean treatment, but they did not differ significantly within distances among Pongamia sources. The probable reasons for differences in soil moisture content and light transmission ratio at various distances are tree crown size and root spread which in turn affected the total dry matter production, pod weight and number of pods per plant; which was similar to observations made by Nadagoud (1990) and Venkat Rao *et al.*, (2006a).

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