INTERCROPPING ON RAINFED RED SOILS OF THE DECCAN PLATEAU, INDIA

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Mutual competitive effects of several crops suited to the region were tested to develop a successful intercropping system. Highest total yields were obtained when sorghum (*Sorghum bicolor* (L.) Moench.) was grown at the highest population tested (220,000 plants/ha) and intercropped with sorghum or with pigeon pea (*Cajanus cajan* (L.) Millsp.). Reducing the population of sorghum to better accommodate intercrops reduced yield for which the intercrops did not compensate. Manipulating planting pattern to reduce mutual competition had little effect on total yield. In the 2 yr, 1974 and 1975, yields of sorghum grown at high populations (at least 220,000 plants/ha) generally surpassed yields from plots of sorghum intercropped with pigeon pea. Nevertheless, monetary, nutritional, and risk considerations favor the intercropping system.

On a évalué les effets compétitifs de plusieurs cultures adaptées à la région dans le but de mettre au point un système efficace de cultures intercalaires. La combinaison de sorgho (*Sorghum bicolor* (L.) Moench.) à densité de semis la plus élevée (220,000 plants/ha) cultivée avec du sorgho ou du pois cajan (*Cajanus cajan* (L.) Millsp.) a donné les plus forts rendements totaux. La réduction de la densité du sorgho pour mieux accommoder les cultures intercalaires s'est traduite par une baisse de rendement que n'ont pu compenser celles-ci. Les modifications du régime de semis visant à réduire la compétition des plants ont peu influé sur le rendement total. En l'espace de 2 ans (1974 et 1975), le rendement du sorgho cultivé à forte densité (au moins 220,000 plants/ha) a généralement surpassé celui des parcelles de sorgho cultivées avec du pois cajan. Toutefois, les considérations monétaires et alimentaires, ainsi que le facteur risque, justifient ce système cultural.

Intercropping and mixed cropping are traditional practices of subsistence farmers in many subtropical and tropical countries. Intercropping is the growing of two or more different crops together in separate rows. In mixed cropping, the crops are grown simultaneously in the same area with no row arrangement. An important reason for these cropping practices is to minimize risks by using, in the mixture, a "stable component," a crop that is not subject to complete loss due to drought or pests. The proportions of the crops are often determined by the dietary preferences of the farmer and his family.

Scientific interest in intercropping has developed recently as a means of making use of the entire growing season, and maximizing the utilization of environmental resources, thereby increasing total production from a unit area of land. Interest in mixed cropping has existed among forage workers for many years (Donald 1963). The rationale in growing crops together is that two or more crops with diverse growth habits or durations of growth, or both, may be able to exploit plant nutrients and moisture in different soil layers and intercept light more effectively than a single crop (Donald 1963; Loomis et al. 1971; Trenbath 1974).

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Large areas of the tropics and subtropics have a growing season that is too long to be effectively utilized by a single crop but too short for successful double cropping, i.e. two crops that follow in time. Andrews (1972a,b) in Nigeria and K. Vijayalakshmi (Dryland Project, Amberpet, Hyderabad, India, personal communication) near Hyderabad, India, working in areas with growing seasons of 180–200 days, found that this period could be used most effectively by intercropping. This gave higher returns per hectare than double or single cropping. Similar advantages from intercropping have been reported by Kassam and Stockinger (1973), Enyi (1973), Alexander and Genter (1962), and Pendleton et al. (1963).

In successful crop combinations, the sum of the intercrop competition should be less than the sum of the intracrop competition of the component crops when grown alone. Gain originates because either individual plants yield more or higher total plant population densities are possible, or both (Andrews and Kassam 1975). In combinations of crops with similar maturities, intercrop competition should be minimal in space whereas in combinations of crops with different maturities, excessive intercrop competition should be avoided in space or time (Andrews and Kassam 1975).

In an attempt to minimize intercrop competition, Andrews (1972a, 1974) compared sorghum varieties for intercropping and found that dwarf types were most suitable. Tarhalkar and Rao (1975) tested a number of crop combinations, ideotypes, and planting patterns and found several successful crop combinations. They also found that dwarf, erect types of sorghum, castor, and pigeon pea were most suitable for intercropping and that pairing the rows (for example see Fig. 4) of one of the component crops did not reduce its yield, while the other crop benefitted from the wider inter-row space. Evans (1960), on the other hand, found no difference in intercrop competition and consequently no advantage in growing crops in adjacent rows as opposed to mixing the crops in the same row.

The objective of our study was to develop a successful intercropping system (1) by studying the mutual competitive effects of various crops and selecting the most promising combination and (2) when using that combination, by attempting to further reduce intercrop competition and increase productivity by studying various planting patterns and population densities of the component crops.

MATERIALS AND METHODS

The experiments were conducted in 1974 and 1975 on a rainfed red soil of the Deccan Plateau near Hyderabad, India. Red soils are formed from granitic rock. They are highly variable in depth and show a well developed profile character with the percentage of clay increasing markedly from the top soil to the subsurface soils. The clay generally forms a compacted layer, at a depth of 10–15 cm, that cannot be penetrated by fibrous roots. Red soils are low in nitrogen, phosphorus, and humus but high in potassium. Fertilizer was broadcast over the experimental area at 80 kg N and 80 kg P_2O_5/ha each year before tillage. The plots were seeded at the onset of the monsoon rains. In 1974, total rainfall between 21 May and 6 Nov. was 669 mm, with one dry period during which plants exhibited stress symptoms. In 1975, rainfall for the same period was 1,079 mm, with good distribution during the growing season.

The plots were harvested as the various crops reached maturity. Grain yield data were subjected to an analysis of variance and discussion of significance is based on the 5% level of probability using Tukey's procedure.

Usually no clear distinction is made between main crops and intercrops although the more stable or higher yielding crop is often considered the main crop, while the lower yielding, less important crop is considered an intercrop. In this paper, however, a distinction is made for convenience of presentation.

Experiment I

In 1974, a 3 × 3 × 10 split-plot design of three planting patterns (whole plot; Fig. 1), three main crops (subplots), and nine intercrops (sub-

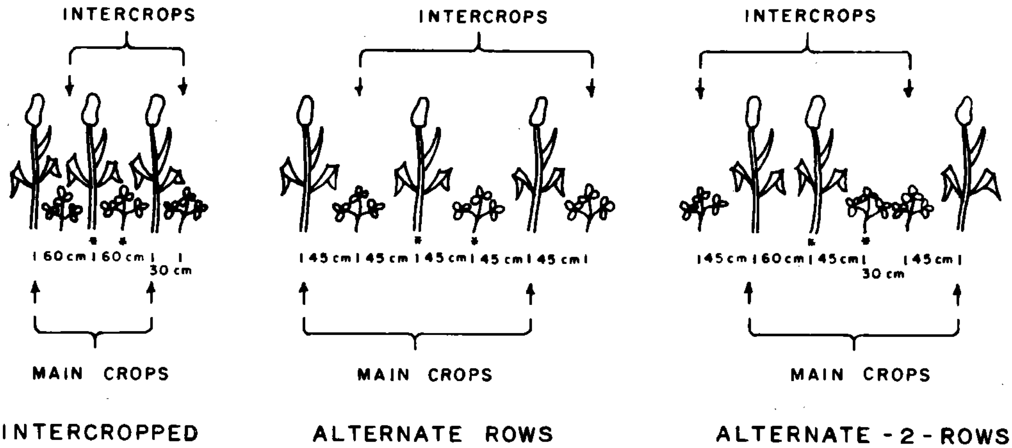

Fig. 1. Planting patterns used in experiment I. When sorghum, castor, and pigeon pea were treated as intercrops, the inter-row space was kept constant at 60 cm in the 'alternate rows' and 'alternate-2-rows' planting patterns (* = rows harvested).

subplots, 8 m long; Table 1) was replicated four times (the 10th treatment of the split plot was the main crop grown without an intercrop, i.e., check). When sorghum, pigeon pea, and castor were grown as intercrops in "alternate rows" or "alternate-2-rows" with the main crops, the distance between the rows was kept at 60 cm. Intrarow spacing between plants was kept constant and was: pigeon pea, 30 cm; sorghum and castor, 15 cm; cowpea, soybean, and dolichos, 10 cm; pearl and finger millet, solid seeding (ca. 2 cm between plants). One row of the main crop and one row of the intercrop were harvested from the center of the plots so that in all cases there were two border rows (Fig. 1). Single rows spaced 4 m apart (i.e., without inter-row competition) of the nine crops, replicated four times and with the intrarow plant spacings listed above, were grown adjacent to the plots. Yields from 8-m sections of the single rows were compared to yields of the same species from the same length of row from within the plots. This comparison provided a measure of inter-row competition, which is of paramount importance in intercropping. An assumption was made that intrarow competition was constant for all planting patterns and combinations.

Experiment II

In 1975, two crops were used, sorghum cv. CSH 5 and pigeon pea, cv. Hy2. A 5 × 3 × 3 split-plot design was used, with five planting patterns as the whole plots and combinations of three intercrop treatments (none, sorghum, and

Table 1. Crops used in experiment 1. All were used as intercrops; the first three were also used as main crops

Crop		Cultivar	Approximate duration to maturity (days)
Sorghum	*Sorghum bicolor* (L.) Moench.	CSH 5	100
Pigeon pea	*Cajanus cajan* (L.) Millsp.	Hy3A	180
Castor	*Ricinus communis* L.	157 B	160
Pearl millet	*Pennisetum americanum* (L.) Schum.	HB 3	90
Cowpea	*Vigna unguiculata* (L.) Walp	C 152	80
Hyacinth bean	*Lablab purpureus* L.	Co 8	90
Finger millet	*Eleusine coracana* (L.) Gaertn.	PR 202	120
Soybean	*Glycine max* (L.) Merr.	Sy 2	85
Black gram	*Vigna mungo* (L.) Hepper	T 9	80

pigeon pea) and three density levels (55,000, 110,000, and 220,000 plants/ha) as the subplots. The intercrop–density combination, sorghum grown at 55,000 plants/ha and intercropped with sorghum, was excluded. An additional treatment, pigeon pea grown alone, was included but the data were omitted from the analysis of variance. The whole plots were 3.4 m wide and the subplots were 8 m long. Two rows of pigeon pea and either two or three rows of sorghum were harvested leaving at least two border rows on either side of each plot. Intrarow spacing of intercropped sorghum was kept constant at 15 cm. Intrarow spacing of intercropped pigeon pea was adjusted to maintain a constant population density of 37,000 plants/ha. Height to lowest branches was measured and number of fruit-bearing branches was counted on pigeon pea.

RESULTS AND DISCUSSION

Experiment I

In the intercropped planting pattern, a second crop was squeezed between the rows of a full stand. Consequently, the cumulative competitive effect exerted on an individual row by the intercrop and the main crop is more severe than in the other two planting patterns (Fig. 2). Even in alternate and alternate-2-row planting patterns, main crops exerted a marked effect on themselves (checks in Fig. 2). This effect was more noticeable for pigeon pea and castor than for sorghum. The former two crops possess considerable elasticity, and in single rows, without competition from adjacent rows, they have the ability to produce numerous fruit-bearing branches.

Short-duration pulses (cowpea, soybean, and black gram) escaped excessive competitive effect from long-duration main crops (castor and pigeon pea). However, their potential yield is low, so their contribution to total yield in an intercropping system was limited (Fig. 3). A severe infestation of pod borer destroyed the grain of hyacinth bean (known locally as dolichos), but its competitive effect on main crops could still be measured. Growth of pearl millet was suppressed markedly by sorghum while finger millet grew poorly with pigeon pea. Sorghum exerted a smaller competitive effect on pigeon pea and vice versa than either crop exerted on itself (Fig. 2).

Sorghum generally yielded more in the intercropped than in the other planting patterns (Fig. 3). This yield difference was probably due to a difference in population density, which was confounded with planting patterns and was 50% higher in the intercropped than in the other plots. The population density effect was not noticeable in pigeon pea and castor. Intercropped sorghum tended to have a greater depressing effect than pigeon pea on yields of main crop sorghum. Yields of pigeon pea and castor were not as markedly affected by planting patterns as were yields of sorghum.

Highest yields were obtained from main crop sorghum intercropped with sorghum or pigeon pea (Fig. 3).

Experiment II

Yields of main crop sorghum increased significantly with increasing population densities, while planting patterns had no significant effect (Fig. 4 and Table 2). Intercrops depressed the yield of main crop sorghum but the differences were not significant. Yields of intercropped pigeon pea were significantly lower than yields of intercropped sorghum. Yields of intercropped pigeon pea, in most cases, decreased significantly with each increase in population density of main crop sorghum.

Planting patterns had, in some instances, a significant effect on pigeon pea, with highest yields obtained from plots planted with 60-cm inter-row spacing. Wider inter-row space provided by pairing rows of sorghum (Fig. 4) had no significant effect on yields of intercropped pigeon pea. Yields of pigeon pea tended to be lower at 135-cm spacing than at the narrower row spacings. However, the differences were not significant across all the sorghum planting patterns and population densities. For pigeon pea, height to first branches increased and number of fruit-bearing branches decreased with increasing populations of sorghum. Planting pattern had no effect on these two variables.

Planting pattern had a significant effect on yields of intercropped sorghum, which again was probably due to population density. The intrarow plant distance of intercropped sorghum was kept constant; consequently, the population density varied with the different row widths used in the various planting patterns. Highest total yields were obtained with sorghum grown at 220,000 plants/ha and intercropped with sorghum. This yield was significantly higher than from plots of sorghum grown at the same population and intercropped with pigeon pea.

In intercropping, production by one of the component crops is generally suppressed, but the reduction is offset by the other crop (Anthony and Willimot 1957; Evans 1960; Grimes 1963; Enyi 1973; Dalal 1974). The advantage from the combination may be due to either increased total yield or monetary value. A number of aspects which

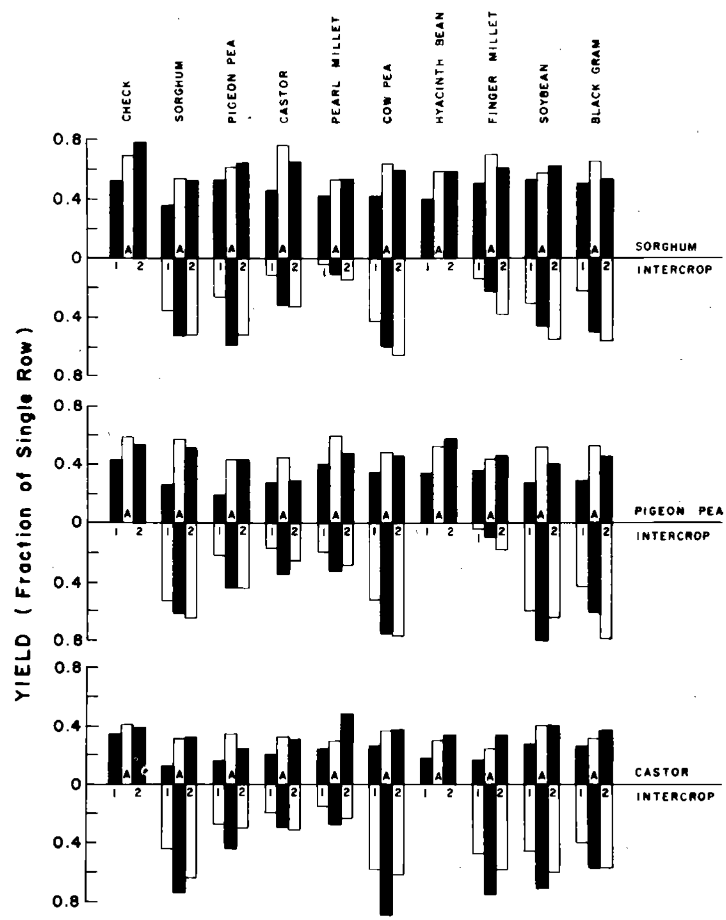

Fig. 2. Effect of inter-row competition on relative grain yield of three main crops, sorghum, pigeon pea, and castor, and check (monoculture), and nine intercrops intercropped in three planting patterns (1 = intercropped, A = alternate rows, and 2 = alternate-2-rows). Yields from an 8-m length of a row grown in a stand are expressed as a fraction of yield from an 8-m length grown without inter-row competition.

affect productivity of an intercropping system have been studied. Kassam and Stockinges (1973) and Dalal (1975) examined nutrient requirements and uptake.

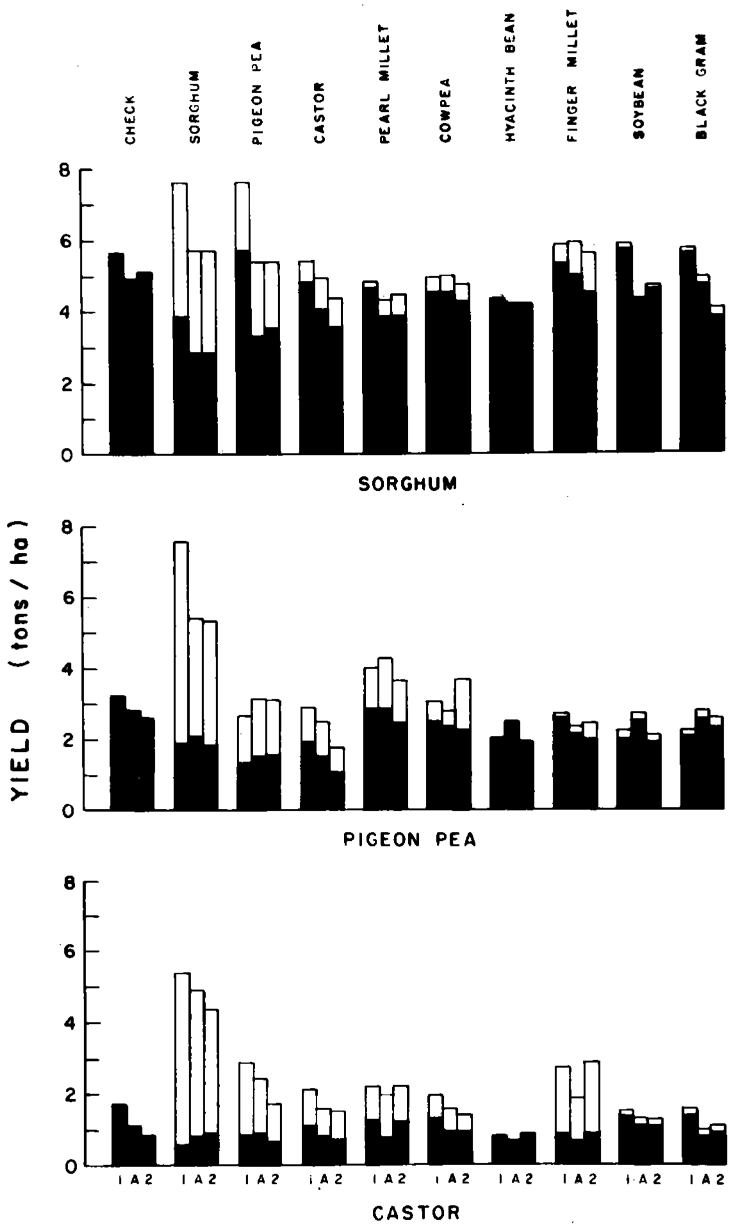

Fig. 3. Grain yield (t/ha) of three main crops, sorghum, pigeon pea, and castor (solid bar), and check (monoculture), and nine intercrops (open bar) intercropped in three planting patterns (1 = intercropped, A = alternate rows and 2 = alternate-2-rows). Standard errors are 0.101 for main crop, 0.061 for intercrop, and 0.119 for total.

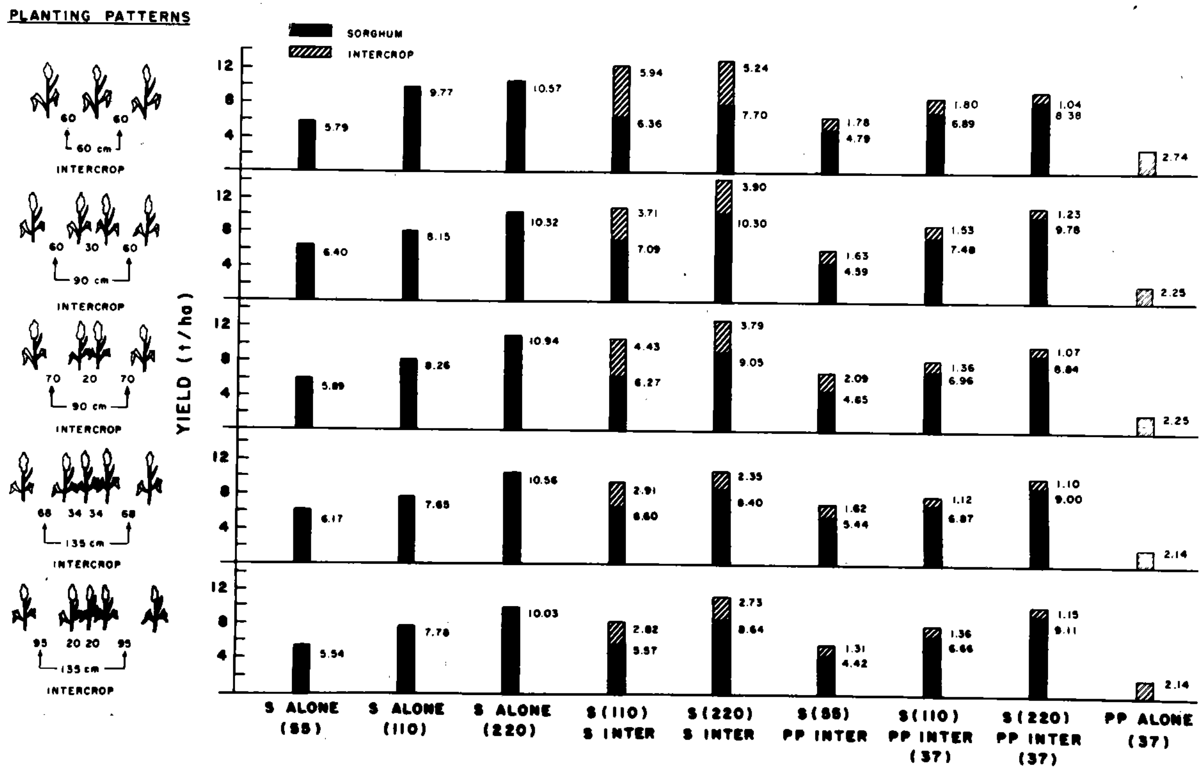

Fig. 4. Grain yields (t/ha) of pigeon pea (PP) and sorghum (S) grown in five planting patterns, as sole crops and in intercropping combinations. The population density of sorghum was varied (55,000 (55), 110,000 (110), and 220,000 (220) plants/ha), while the plant population density of pigeon pea was kept constant at 37,000 plants/ha. Intrarow spacing of intercropped sorghum was kept constant at 15 cm. Degrees of freedom and mean squares are presented in Table 2.

Table 2. Degrees of freedom and mean squares for experiment II

Source	Main crop df	Main crop Mean square	Intercrop df	Intercrop Mean square	Total df	Total Mean square
Reps	3	0.54	3	0.13	3	0.62
Pattern	4	3.00	4	7.19	4	9.57
Error (a)	12	1.66	12	0.09	12	1.71
Intercrop	2	36.32	1	125.82	2	19.28
Density	2	152.82	2	2.28	2	138.25
Intercrop × density	3	0.43	1	0.01	3	1.36
Pattern × intercrop	8	1.51	4	4.86	8	3.20
Pattern × density	8	1.32	8	0.27	8	2.07
Error (b)	117	1.04	64	0.20	117	1.20

Andrews (1972a,b) compared sorghum cultivars of various durations and growth types, while Tarhalkar and Rao (1975) studied planting patterns in an attempt to reduce competition between the crops. No studies on the effects on yield of various population densities of the component crops have heretofore been reported. Results from experiment II, in which the population density of one of the crops was varied, indicate the importance of this variable. Further studies in which population densities of both the component crops are varied are desirable.

In the 2 yr of trials, higher yields were obtained with a single crop of sorghum grown at a high population density (viz. sorghum intercropped with sorghum) than with a sorghum–pigeon pea combination. The difference was significant only in 1975, while in 1974 the difference in yield was very small. The market value of pigeon pea is higher than that of sorghum; consequently the two-crop combination is often more profitable than either crop grown alone. Furthermore, pigeon pea, a legume, has a good lysine content, but is low in methionine, while sorghum has a good methionine content, but is low in lysine; thus, the two crops supplement each other in a human diet.

In 1974 and 1975, the amount and distribution of rainfall were favorable for sorghum. In years with serious gaps in the distribution of rain or with amounts insufficient for sorghum growth, an intercropping system of sorghum and pigeon pea may yield more than a single crop of sorghum. Pigeon pea, unlike sorghum, has a deep root system, can draw on moisture from the subsoil, and is consequently considered a crop that never fails. In favorable years, it branches and is capable of yielding up to 3,000 kg/ha although this is still considerably lower than the potential of a cereal such as sorghum.

In most years, highest yields can be achieved with sorghum grown alone at a high plant population density (i.e. higher than the generally recommended population density of 150,000 plants/ha). Nevertheless monetary, nutritional, and risk considerations favor intercropping sorghum with pigeon pea while still maintaining a high population density of sorghum. Various inter-row spacings and planting patterns had little effect on yield; consequently, within limits, they can be adjusted to suit cultural operations.

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