



Performance of four intercropping systems under variable monsoon onset conditions in rainfed semi-arid region of Rajasthan

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ABSTRACT

To provide a contingency cropping plan for the rainfed areas of hot semi-arid region of south-eastern Rajasthan a four seasons (2003 to 2007) *kharif* field experiment evaluated four intercropping systems *viz.* sorghum [*Sorghum bicolor* (L.) Monech] + pigeon pea [*Cajanus cajan* (L.) Millsp] (1:1), pigeon pea + black gram (*Vigna mungo* L.) (1:2), castor (*Ricinus communis* L.) + green gram [*Vigna radiata* (L.) Wilczek] (1:2) and soybean [*Glycine max* (L.) Merr.] + pigeon pea (4:1) under three dates of sowing, *viz.* first (normal) and third week of July, and first week of August. Four years mean pigeon pea grain equivalent data showed that sorghum + pigeon pea is the most remunerative cropping system under normal monsoon conditions but the crop yields sharply decline with the delayed onset of monsoon. The two week delayed planting of castor + green gram system did not show any yield reduction while four weeks delayed planting reduced yield by 16% only as against corresponding yield reduction by 9 and 54%, 25 and 46% and 28 and 57% for sorghum + pigeon pea, pigeon pea + black gram and soybean + pigeon pea intercropping systems respectively. Results indicated that if the monsoon onset is delayed by two weeks either castor + green gram or sorghum + pigeon pea should be the preferred cropping systems, whereas under four week delayed onset of monsoon situation only castor + green gram intercropping system has potential to maintain acceptable yield levels.

Key words: Aberrant monsoon, Delayed planting, Intercropping, Livelihood security, Rainfed, Subsistence farming, Water use efficiency.

One of the major concern in crop planning is uncertainties associated with monsoon behavior in rainfed semi-arid regions. There is need to understand common aberrations in monsoon behavior and develop contingency cropping plans accordingly to minimize the economic losses and ensure a minimum level of production under adverse circumstances. Delayed onset of monsoon for few days to several weeks is common in rainfed region of south-eastern Rajasthan which often leads to partial or complete failure of crops (Ali *et al.*, 2004 and Singh *et al.*, 2004). The normal date of monsoon onset in south-eastern Rajasthan is 2 July (Ali *et al.*, 2007). During preceding 20 years (1989 to 2008) the region has recorded normal onset of monsoon only for 9 years while for remaining years it was delayed by 1 to 5 weeks. In spite of Chambal canal network in the region, about 44% area continues to be under rain fed agriculture where crop yields are generally low and unstable. With average annual rainfall of 750 mm and good soil water retention capacity (>30 cm/m profile) the medium deep black soils of the region offer excellent

scope of intercropping to maximize production by efficient utilization of resources (Prasad *et al.*, 1997).

Earlier studies on sorghum, pigeon pea, castor and soybean based intercropping systems showed that these intercropping systems were more productive and remunerative when compared with sole cropping of component crops and therefore can provide biological insurance against total crop failure in the region (Prasad *et al.*, 1997 and Porwal *et al.*, 2006). Intercrop row combinations were standardized for south-eastern Rajasthan in a series of independent investigations. These studies suggested that sorghum + pigeon pea with (1:1), castor + green gram (1:2), pigeon pea + black gram (1:2) and soybean + pigeon pea (4:1) rows were the optimum row combinations with the land equivalent ratio (LER) values of 1.83, 1.76, 1.6 and 1.26 (Verma and Prasad, 1988; Prasad and Verma, 1986; Verma *et al.*, 1986 and Prasad *et al.*, 1997). However, these studies were staggered over different growing seasons and simultaneous performance of recommended intercropping systems under variable monsoon situations had not been investigated earlier. Especially the information on promising intercropping systems under delayed

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monsoon conditions has been lacking which is required for contingency crop planning. Hence, this study was conducted to identify suitable intercropping system for delayed onset of monsoon situations.

MATERIALS AND METHODS

A field experiment was conducted at Central Soil and Water Conservation Research and Training Institutes, Research Centre at Kota for four growing seasons from 2003 to 2007. The soil of the experimental site is clay loam, having pH 7.7, organic carbon 0.48% and available N, P and K of 265.5, 12.5 and 399 kg/ha. The soil has available moisture storage capacity of 15.6 cm/m depth. The study was laid out in split plot design replicated thrice with 3 dates of sowing. (first and third week of July and first week of August) as main plot and four intercropping systems (sorghum + pigeon pea in 1:1 rows, pigeon pea + black gram in 1:2 rows, castor + green gram in 1:2 rows and soybean + pigeon pea in 4:1 rows) as sub-plot treatments. Distance between the two rows was kept as 30 cm in all the systems. Sorghum hybrid 'CSH-9', pigeon pea 'Local' (duration 240 days), soybean 'JS-335', black gram 'Type-9', green gram 'Type-44' and castor hybrid 'GCH-4' were used in the study. The net sub-plot size was 6 m X 5 m. A fertilizer dose of 50-17.6-25, 20-17.6-25 and 80-17.6-25 were applied to sorghum + pigeon pea; pigeon pea + black gram / soybean and castor + green gram intercropping systems respectively. Full dose of fertilizer was applied as basal except in castor + green gram and sorghum + pigeon pea where half N was used for top dressing 35 to 40 days after sowing along castor or sorghum rows. The crops were raised under rainfed conditions with recommended package of practices. One picking in green gram

and four pickings in castor were done. The crops were harvested at maturity (Table 1). Pigeon pea grain equivalent yield (PGE) was calculated on the basis of support price of respective year of produce and input cost was also taken as actual of each year. The crop water use has been computed using following equation:

$$WU_t = Ra_t - Ru_t - \Delta Sw_t$$

where WU_t denotes the water use during the period t , Ra_t the rainfall, Ru_t the runoff and ΔSw_t the change in water content up to 90 cm soil depth. The seasonal water use for cropping periods was computed for four intercropping systems for four growing seasons. The total seasonal rainfall received from June to September were 459, 523, 540 and 792 mm in 30, 25, 24 and 32 rainy days during 2003, 2004, 2005 and 2006 respectively. However, effective rainfall for different planting dates varied as cropping period reduced for delayed planting dates (Table 1). Although onset of monsoon was delayed by 2 and 4 weeks in 2004 and 2006 the pre-monsoon rains provided adequate moisture for crop planting at normal (D1) and two weeks delayed (D2) dates (Fig. 1). The crops were not irrigated during either mid-season dry spells or early withdrawal of monsoon.

RESULTS AND DISCUSSION

Weekly rainfall pattern

Rainfall pattern varied widely during four years of experimental period (Fig.1) and was a major factor governing the overall crop performance. The total seasonal rainfall was normal only during 2006, whereas it was deficit by about 12% during 2004, and about 30% during 2003 and 2005. Also the withdrawal of monsoon rains occurred 4 weeks earlier during 2004 and 2006. Although total sea-

Table 1. Cropping period and monsoon behavior during experimental period.

Year	Monsoon onset date	Planting date treatment	Rainfall during cropping period (mm)	Planting dates	Harvesting dates					
					Sorghum	Pigeonpea	Black gram	Castor	Green gram	Soybean
2003-04	2 July 2003	D1	387	04.07.03	16.10.03	23.03.04	01.10.03	28.02.04	17.09.03	13.10.03
		D2	282	18.07.03	20.10.03	23.03.04	03.10.03	28.02.04	01.10.03	13.10.03
		D3	217	01.08.03	14.11.03	23.03.04	22.10.03	28.02.04	Failed	22.10.03
2004-05	4 July 2004	D1	455	09.07.04	13.10.04	21.03.05	22.09.04	28.02.05	22.09.04	18.10.04
		D2	428	19.07.04	25.10.04	21.03.05	01.10.04	28.02.05	01.10.04	23.10.04
		D3	366	04.08.04	03.11.04	21.03.05	01.10.04	28.02.05	11.10.04	27.10.04
2005-06	2 July 2005	D1	390	09.07.05	21.10.05	27.03.06	22.09.05	27.03.06	22.09.05	15.10.05
		D2	294	20.07.05	29.10.05	27.03.06	03.10.05	27.03.06	03.10.05	17.10.05
		D3	182	03.08.05	29.10.05	27.03.06	15.10.05	27.03.06	15.10.05	22.10.05
2006-07	21 July 2006	D1	676	05.07.06	20.10.06	19.02.07	29.09.06	19.02.07	28.09.06	11.10.06
		D2	590	25.07.06	29.10.06	19.02.07	10.10.06	19.02.07	10.10.06	17.10.06
		D3	483	02.08.06	04.11.06	29.03.07	17.10.06	27.03.07	17.10.06	17.10.06

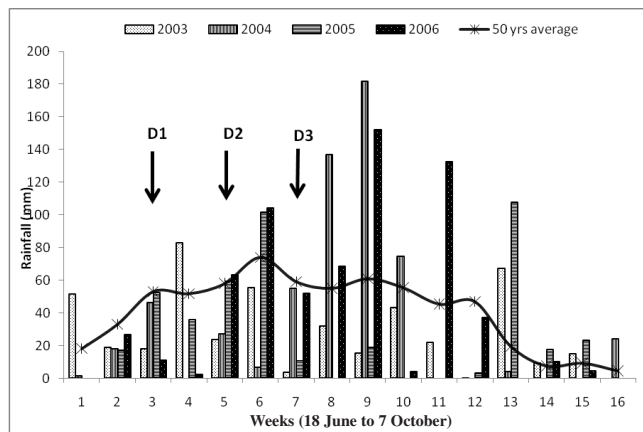


Fig. 1. Cumulative monsoon season rainfall during four years of experimental period. D1, D2 and D3 are normal, two and four week delayed planting dates.

sonal rainfall was similar in 2003 and 2005, its distribution pattern differed substantially. In contrast to the well distributed rainfall in 2003, there was prolonged mid-season dry spell between 6 and 12 week having only 32.3 mm rainfall during 6 week, which is about 90% less than normal amount for this period in 2005. Rainfall received during cropping period progressively decreased with the delayed sowing dates (Table 1).

Grain yield

Crop performance was closely linked with the rainfall pattern over four years period (Fig.2). In spite of considerable difference in total rainfall during 2003 and 2004, crop yields were similar which can be attributed to timely onset and good mid season rainfall during these two years. During 2006 in spite of highest total rainfall, crop yields reduced by about 22% when compared with 2003 due to late onset and early withdrawal of monsoon rains. Crop yield most severely suffered during 2005 due to prolonged mid season drought which reduced average grain yield by about 64%.

Among the four intercropping systems, sorghum + pigeon pea produced highest grain yield consistently during all the four years for normal and 2 weeks delayed sowing. However, under 4 weeks delayed sowing condition, castor + green gram performed better than all other cropping systems. Averaged over four years, yield reduction in castor + green gram due to 2 and 4 weeks delayed sowing was 1.4 and 17.6% as against 12% and 58% in sorghum + pigeon pea, 14% and 45% in pigeon pea + black gram and 23% and 54% in soybean + pigeon pea cropping systems. The robust performance of castor + green gram against delayed sowing is due to shorter growing period of green gram (65 to 70 days) when compared with other intercrop and better drought resistance of castor as compared pi-

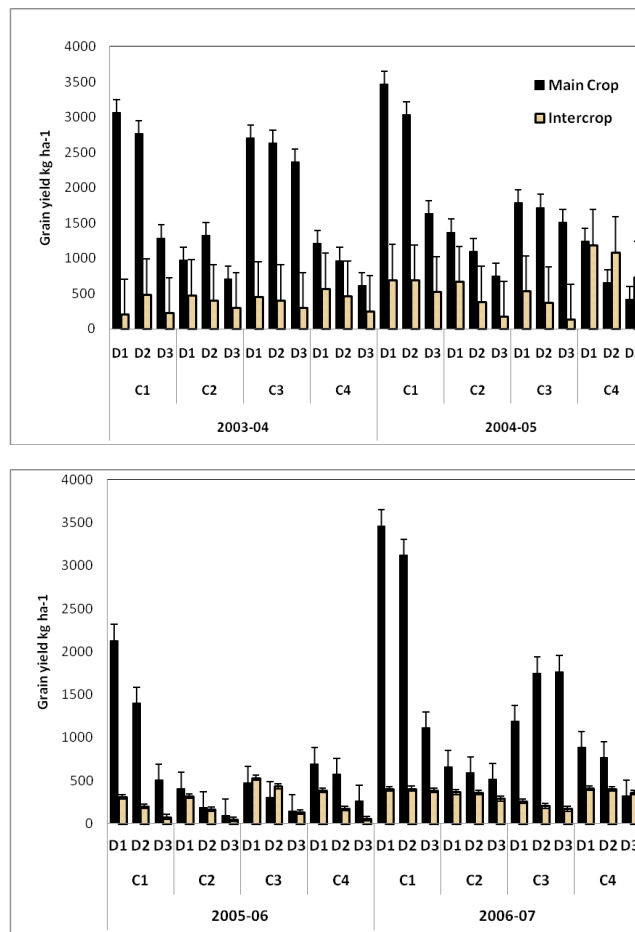


Fig. 2. Crop yields of four intercropping systems C1, sorghum + p. pea; C2, p. pea + black gram; C3, castor + green gram; C4, soybean + p. pea; during four growing seasons in response to three planting dates: D1, Normal (July first week); D2, 2 weeks delayed (July third week); D3, 4 week delayed (August first week).

geon pea. Although castor + green gram is better suited intercropping systems for delayed monsoon conditions, it showed greater sensitivity to mid-season dry spells than that of other cropping systems. Under the prolonged mid-season dry spells in 2005, grain yields of castor and green gram suffered more severely than other crops and sorghum + pigeon pea and soybean + pigeon pea performed better than castor + green gram on all sowing dates. Padmavathi and Raghuvaiiah (2004) also reported castor sensitivity to drought while it maintains good productivity levels as an intercrop. Castor grain yield also suffered during heavy mid-season rains in 2006 which favored excessive vegetative growth of castor followed by partial lodging.

To facilitate comparison of economic productivity of cropping systems, the pigeon pea grain equivalent yields (PGEY) were calculated considering prevailing support prices of the grains. Analysis of variance for Pigeon pea

grain equivalent yield data was conducted for each year independently as well as 4 years pooled data. Effect of planting date and cropping system, and their interactions were highly significant for all the four years. Pooled analysis confirmed significant variations among the years on cropping system and planting date interaction. Four year mean data (Table 2) showed that castor + green gram produced substantially higher economic yield on all sowing dates than that of all other systems whereas pigeon pea + black gram was the lowest performing system during all four years and for all the three sowing dates. In this study a long duration pigeon pea variety 'Local' was used which is a farmers' preference owing to its superior fodder and grain quality and relatively better performance under water stress conditions owing to its indeterminate flowering characteristics. However, performance of pigeon pea was inferior to shorter duration crop of castor due frost and pest susceptibility and severe moisture stress conditions for pigeon pea. There is need and scope for evaluating

shorter duration pigeon pea varieties under intercropping combinations. Black gram has broader leaves than green gram and therefore excessive vegetative growth during early growth stages tend to adversely effect flowing due to self shading. Soybean + pigeon pea gave better pigeon pea grain equivalent yield (PGEY) than sorghum during relatively normal monsoon conditions whereas sorghum performed better during delayed onset (2006) and prolonged mid-season dry spells (2005).

Sowing dates had marked effect on PGEY in all these cropping systems except castor + green gram. Four years mean data show that there was no loss of yield in castor + green gram when sowing was delayed by 2 weeks and only 16% PGEY yield reduction was recorded under 4 weeks delayed sowing. Corresponding yield reductions under 2 and 4 weeks delayed sowing were 9% and 54%, 25% and 46% and 28 and 57% for sorghum + pigeon pea, pigeon pea + black gram and soybean + pigeon pea intercropping systems. Similar trend was recorded during all

Table 2. Effect of planting dates on pigeon pea grain equivalent yield(kg/ha) under four intercropping systems

Intercropping systems	Date of Sowing			Mean
	First Week of July (D1)	Third Week of July (D2)	First week of August (D3)	
2003-2004				
Sorghum+ Pigeon pea (1:1)	1,426	1,734	804	1,321
Pigeon pea+ Black gram (1:2)	1,965	1,520	1,110	1,531
Castor+ Green gram(1:2)	2,619	2,514	2,187	2,440
Soybean+ Pigeon pea(4:1)	1,547	1,216	744	1,169
CD (P=0.05)	Planting date: 88 kg, Cropping system: 118 kg, Interaction:197kg			
2004-2005				
Sorghum+ Pigeon pea (1:1)	2,416	2,154	1,391	1,987
Pigeon pea+ Black gram (1:2)	2,396	1,671	1,098	1,721
Castor+ Green gram(1:2)	2,397	2,156	1,693	2,082
Soybean+ Pigeon pea(4:1)	2,370	1,720	1,149	1,746
CD (P=0.05)	Planting date: 38 kg, Cropping system: 53 kg, Interaction: 88 kg			
2005-2006				
Sorghum+ Pigeon pea (1:1)	1,323	866	320	836
Pigeon pea+ Black gram (1:2)	810	396	168	458
Castor+ Green gram(1:2)	1,065	782	294	714
Soybean+ Pigeon pea(4:1)	963	650	275	629
CD (P=0.05)	Planting date: 43 kg, Cropping system: 31 kg, Interaction: 63 kg			
2006-2007				
Sorghum+ Pigeon pea (1:1)	2,145	2,025	1,011	1,727
Pigeon pea+ Black gram (1:2)	1,202	1,117	950	1,090
Castor+ Green gram(1:2)	1,593	2,088	2,061	1,914
Soybean+ Pigeon pea(4:1)	1,496	1,109	725	1,110
CD (P=0.05)	Planting date: 42 kg, Cropping system: 24 kg, Interaction: 55 kg			
Four years average				
Sorghum+ Pigeon pea (1:1)	1,827	1,695	882	1,468
Pigeon pea+ Black gram (1:2)	1,593	1,176	832	1,200
Castor+ Green gram(1:2)	1,918	1,885	1,559	1,787
Soybean+ Pigeon pea(4:1)	1,594	1,174	723	1,164
CD (P=0.05)	Planting date: 28 kg, Cropping system:37 kg, Interaction:57kg			

Respective year support prices of crops were used for Pigeonpea grain equivalent yield conversion

the years except 2005 when there was sharp yield reduction due to mid-season dry spells.

Crop water use

The water use by the different cropping systems did not differ significantly while it reduced progressively with delayed planting due to reduced rainfall received during cropping period (Table 3). The water use efficiency (WUE) of four intercropping systems varied significantly and followed grain yield and PGEY patterns. The WUE for grain productivity was highest for sorghum + pigeon pea for normal and two week delayed planting. Under four week delayed planting castor + green gram was most efficient system. The WUE for PGEY compared the economic productivity of water under four intercropping systems. Across planting dates, castor + green gram remained most efficient system to provide highest economic productivity of water. Under four weeks delayed planting situations the WUE for PGEY of castor + green gram was about twice to other three systems.

Economics

In spite of some variation in the input cost of cropping

systems the net returns from four cropping systems followed similar trends as observed for PGEY. With the net returns ranging from about ₹9,000 to 25,900/ha under favourable monsoon situations castor + green gram was most remunerative cropping systems whereas soybean + Pigeonpea gave the lowest net return for all sowing dates (Table 4). Average reduction for 2 and 4 weeks delayed sowing was 2.7 and 33% in castor + green gram. For all other cropping systems 4 weeks delay in sowing resulted in negligible to negative net returns. For normal sowing date sorghum + pigeon pea and soybean + pigeon pea gave average net return marginally lower to castor + green gram system but it fell sharply by 2 week delayed sowing. With 11% reduction in net returns sorghum + pigeon pea emerged as a better choice over soybean + pigeon pea system which gave about 45% net returns under 2 weeks delayed sowing conditions.

Castor + green gram intercropping ensures acceptable yield levels and net income under delayed onset of monsoon up to 4 weeks. Sorghum + pigeon pea is also a better intercropping options than soybean + pigeon pea system during early monsoon withdrawal or mid-season dry spells situations. Pigeon pea + black gram did not perform

Table 3. Water use and water use efficiency(WUE) of four intercropping systems

Year	Cropping systems	Water use (cm)				WUE for PGEY (kg/ha cm ⁻¹)			
		D1*	D2	D3	Mean	D1	D2	D3	Mean
2003-04	Sorghum + pigeonpea	47.8	37.5	31.7	39.0	24	36	20	27
	Pigeonpea + black gram	47.5	36.5	31.4	38.5	30	47	31	36
	Castor + green gram	47.3	37.0	29.0	37.8	56	69	76	67
	Soybean + pigeonpea	47.6	37.1	30.7	38.5	41	43	31	38
	Mean	47.6	37.0	30.7	38.4	38	48	40	42
CD (P=0.05) for WUE: Planting date: 2.1, Cropping system: 1.6 and Interaction: 2.7									
2004-05	Sorghum + pigeonpea	41.0	41.6	33.1	38.6	45	41	32	40
	Pigeonpea + black gram	42.8	41.1	32.1	38.7	46	35	28	37
	Castor + green gram	41.6	42.1	33.5	39.0	55	48	48	50
	Soybean + pigeonpea	42.4	41.7	33.5	39.2	61	44	36	47
	Mean	41.9	41.6	33.0	38.9	52	42	36	43
CD (P=0.05)for WUE: Planting date: 0.6, Cropping system: 0.9 and Interaction: 1.7									
2005-06	Sorghum + pigeonpea	33.2	34.8	16.5	28.2	40	25	19	28
	Pigeonpea + black gram	34.0	34.8	16.7	28.5	28	13	11	17
	Castor + green gram	35.1	33.6	14.9	27.9	31	24	20	25
	Soybean + pigeonpea	34.5	34.3	15.7	28.2	26	17	16	20
	Mean	34.2	34.4	16.0	28.2	31	20	17	23
CD (P=0.05) for WUE: Planting date: 1.0, Cropping system: 0.7 and Interaction: 1.2									
2006-07	Sorghum + pigeonpea	53.7	52.7	35.6	47.4	41	38	27	35
	Pigeonpea + black gram	52.7	52.7	34.9	46.8	25	24	29	26
	Castor + green gram	51.2	51.3	32.4	45.0	25	33	52	37
	Soybean + pigeonpea	53.8	54.5	34.9	47.7	29	20	19	23
	Mean	52.9	52.8	34.5	46.7	30	29	32	30
CD (P=0.05) for WUE: Planting date: 1.5, Cropping system: 0.5 and Interaction: 0.8									

*Planting dates: D1= Normal (July 1st week), D2= 2 weeks delayed (July 3rd week), D3= 4 week delayed (August 1st week)
WUE, Water use efficiency; and PGEY, Pigeonpea equivalent yield.

Table 4. Net return (₹/ha) under intercropping systems.

Intercropping systems	Date of Sowing			
	First Week of July (D1)	Third Week of July (D2)	First week of August (D3)	Mean cost of cultivation
2003-2004				
Sorghum+ Pigeon pea (1:1)	12,520	16,713	4,065	6,873
Pigeon pea+ Black gram (1:2)	20,107	14,059	8,483	6,617
Castor+ Green gram(1:2)	25,927	24,499	20,056	9,691
Soybean+ Pigeon pea(4:1)	14,129	9,632	3,208	6,910
CD (P=0.05)	Planting date: ₹1,192, Cropping system: ₹1,609, Interaction: ₹2,678			
2004-2005				
Sorghum+ Pigeon pea (1:1)	26,821	23,178	12,572	6,767
Pigeon pea+ Black gram (1:2)	26,580	16,493	8,529	6,733
Castor+ Green gram(1:2)	23,522	20,172	13,741	9,796
Soybean+ Pigeon pea(4:1)	25,343	16,308	8,366	7,609
CD (P=0.05)	Planting date: ₹533, Cropping system: ₹736, Interaction: ₹1220			
2005-2006				
Sorghum+ Pigeon pea (1:1)	11,108	4,706	-2,933	7,418
Pigeon pea+ Black gram (1:2)	4,502	-1,288	-4,485	6,842
Castor+ Green gram(1:2)	5,643	1,690	-5,141	9,267
Soybean+ Pigeon pea(4:1)	5,061	683	-4,566	8,421
CD (P=0.05)	Planting date: ₹606, Cropping system: ₹433, Interaction: ₹880			
2006-2007				
Sorghum+ Pigeon pea (1:1)	16,884	15,197	904	13,360
Pigeon pea+ Black gram (1:2)	5,778	4,589	2,234	11,170
Castor+ Green gram(1:2)	8,991	15,980	15,590	13,470
Soybean+ Pigeon pea(4:1)	7,833	2,381	-3,032	13,260
CD (P=0.05)	Planting date: ₹587, Cropping system: ₹341, Interaction: ₹770			
Overall				
Sorghum+ Pigeon pea (1:1)	16,833	14,948	3,652	8,605
Pigeon pea+ Black gram (1:2)	14,242	8,463	3,690	7,841
Castor+ Green gram(1:2)	16,020	15,585	11,061	10,556
Soybean+ Pigeon pea(4:1)	13,091	7,251	994	9,050
CD (P=0.05)	Planting date: ₹387, Cropping system: ₹458, Interaction: ₹784			

satisfactorily due to frost and pest damages and water stress during later growth stages of long duration pigeon pea variety tested in this experiment.

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