Indian Journal of Agronomy **57** (4): 343–348 (December 2012)

Research Paper

Effect of anti-transpirant and nutrient management on pearlmillet (*Pennisetum glaucum*)-pigeonpea (*Cajanus cajan*) intercropping system under rainfed conditions

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Received :February 2012; Revised accepted: October 2012

ABSTRACT

A field experiment was conducted during rainy (*kharif*) seasons of 2009 and 2010 to study the effect of cropping systems, transpiration suppressants and nutrient management on productivity of pearlmillet (*Pennisetum glaucum* L.)– pigeonpea [*Cajanus cajan* (L.) Millsp] intercropping system under rainfed conditions on a sandy loam soil at New Delhi. All the growth parameters of pearlmillet and pigeonpea (plant height, total number of tillers of pearlmillet, leaf area index and crop growth rate) were significantly influenced due to cropping systems. The grain yield of pearlmillet declined by 8.6% in intercropping system as compared to sole stand. Similarly, intercropped stand of pigeonpea recorded its lower productivity (0.61 t/ha) when compared to its sole stand (1.52 t/ha). Intercropping system recorded higher pearlmillet equivalent yield and net returns as compared to sole stand. Protein content in grain and nutrient (N and P) concentration in grain and stover remained unaffected due to cropping systems and transpiration suppressants. Significant improvement in all the growth and yield attributes and yield under transpiration suppressants with the spray of PMA (320 ppm) and cycocel (200 ppm) over the control in limited moisture conditions. Cycocel was found less effective than PMA. Application of 50 kg N + 17.2 kg P/ha gave on an average highest grain yield of pearlmillet (3.35 t/ha), pigeonpea (1.21 t/ha), pearlmillet equivalent yield (4.45 t/ha) and net returns (₹36.6×10^3) over other treatments. Protein content in grain enhanced by 7.3% and N and P concentration increased by 7.4 and 9.2% in grain, and 40.9 and 51.1% in stover of pearlmillet with the application of 50 kg N + 17.2 kg P/ha over control, respectively. The maximum protein content in grain (20.40%) and N (3.26 and 1.38%) and P (0.44 and 0.14%) concentration in grain and stover, respectively was noticed with the application of 50 kg N + 17.2 kg P/ha as compared to other fertility levels.

Key words : Intercropping, Nutrient management, Pearlmillet, Pigeonpea, Transpiration suppressants

Pearlmillet is a major cereal crop in the arid and semi-arid regions of India. Today, it is getting more attention due to increasing evidence of less seasonal rainfall, terminal heat, frequent occurrence of extreme weather events coupled with scanty water resources (Singh *et al.*, 2010). It occupies a distinct position in the agricultural economy of the country. Pigeonpea ranks second after chickpea in both acreage (3.58 mha) and production (2.74 mt) among the pulses in India with average productivity of 765 kg/ha (Jat and Ahlawat, 2009), which is predominantly grown on marginal lands and is usually intercropped with cereals under rainfed conditions.It would be justifiable to accept that intercropping system will attract increasing attention to overcome ecological constraints. Expectations remain high that legumes have considerable potential to contribute to soil fertility and substantial yield increase in rainfed farming system.Therefore, any plan for increasing pulse production in the country should be based on an efficient approach for improved productivity of these crops under rainfed conditions rather than only the use of high inputs.

Soil moisture is the major content in dryland agriculture. Water loss from crop plants can be reduced either by reducing the loss of water with the help of an antitranspirants such as PMA (stomata closing type) or suppressing the overall growth of the plants by using a growth retardant such as cycocel. No inputs are available on the effects of these chemicals on the pearlmillet/pigeonpea intercropping system. Adequate N and P fertilization is essential for successful pearlmillet/pigeonpea intercropping system (2:1 ratio). However, limited information is available on the role of biofertilizers in this intercropping system. Therefore, an experiment was con-

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ducted to study the productivity of pearlmillet and pigeonpea cropping system as influenced by an antitranspirants PMA, a growth retardant cycocel and N, P management practices under rainfed conditions.

MATERIALS AND METHODS

The experiment was conducted during *kharif* season (June - December) of 2009 and 2010. During 2009, the rainfall was erratic with an annual precipitation of 490 mm as compared to the normal rainfall of around 650 mm. Further, the distribution was also uneven with a drought like situation in the early part of the season leading to desiccation of tender plants requiring gap filling to maintain optimum plant population. In 2010, the rainfall was above normal (850 mm). The unfavourable climate and weather conditions adversely affected the growth and development of pearlmillet and pigeonpea in 2009. Free from such adverse climatic conditions in 2010, the performance of pearlmillet and pigeonpea was better.

The soil was sandy loam in texture with pH 7.8, organic C 0.3%, available N 135.85 kg/ha, available P 10.4 kg/ha and available K 187.9 kg/ha. The soil moisture content at field capacity and permanent wilting point was 18.8 and 6.5%, respectively with bulk density 1.50 Mg/m^3 of 0-30 cm layer. The experiment was laid out in split plot design with nine combinations from three cropping system *viz*.pearlmillet sole, pigeonpea sole and paired row of pearlmillet + one row of pigeonpea, three transpiration suppressants *viz*.control, cycocel (200 ppm) and PMA (320 ppm) in the main plots and four fertility levels *viz.*Control, 25 kg N + 8.6 kg P/ha, 50 kg N + 17.2 kg P/ha, 25 kg N + 8.6 kg P/ha + *Azotobacter* + PSB) in the sub plots were replicated thrice. The pearlmillet and pigeonpea was sown at 50 cm row spacing in sole cropping while paired row of pearlmillet + one row of pigeonpea (30/70 cm) in 2: 1 ratio. Varieties used Pusa composite 383of pearlmillet and Pusa 991 of pigeonpea. Crops were sown in mid fortnight of July and grown as per recommended package of practices. Pearlmillet matured in second fortnight of October, while pigeonpea matured in the first fortnight of December in both the years of experimentation. Fertilizer was drilled in bands 8–10 cm below the surface. Transpiration suppressants application was depend upon rainfall pattern and moisture availability to the crops. Pearlmillet and pigeonpea seed was inoculated with biofertilizers (*Azotobacter* and PSB) two hours before sowing (@ 20 g/kg seed). While, *Rhizobium* culture was used only for pigeonpea crop (@ 20 g/kg seed) and it was also used as seed inoculant before sowing of the crops. Total volume of solution of transpiration suppressants applied was 800 litre/ha.

The area of leaves of five plants was measured with the help of leaf area meter (Model LICOR 3000, USA). Leaf area index (LAI) and crop growth rate(CGR) were calculated by using the following formula:

LAI=Total leaf area/plant (cm^2)/Ground area occupied/plant (cm^2)

CGR=W2–W1/T2–T1 g/plant/day

Where, W1 and W2 are the dry weights recorded at time T1 and T2, respectively. T1 and T2 are time in days.

Nitrogen concentration in grain and stalk was estimated by modified Kjeldha's method (Jackson, 1958). Phosphorus content in the plant samples was determined by Vanado-molybdo-phosphoric yellow colour method (Jackson, 1958). The protein content was determined by multiplying the seed nitrogen content by a factor 6.25.

RESULTS AND DISCUSSION

Growth attributes and yield of pearlmillet

All the growth parameters of pearlmillet (plant height, total number of tillers, leaf area index and crop growth rate) were significantly influenced due to cropping systems (Table 1). The plant height and number of tillers/m row length of pearlmillet more at maturity stage; on an average 9.62 cm and 1.9 respectively in sole stand of pearlmillet than intercropping system. Intercropping system decreased leaf area index by 6.5 and 11.1% over sole cropping of pearlmillet at 60 DAS and at maturity stage, respectively. The crop growth rate of sole stand increased 12.22% during 30–60 DAS over intercropping system. The grain yield of pearlmillet was lower by 8.6% in intercropping system as compared to sole stand (Table 3). This might be due to presence of competition between main crop and the intercrop for growth resources such as nutrients, moisture and solar radiation because of exhaustive nature of pearlmillet (Moriri *et al.*, 2010). Cropping system did not influence significantly of crop growth rate at 0-30 DAS and 60 DAS-maturity stage as well as days to 50% flowering of pearlmillet during both the years of experimentation (Table 1). The results of present investigation are in close conformity with the findings of Dass and Sudhishri (2010).

On an average transpiration suppressants had significant effect on growth attributing parameters (plant height and leaf area index at maturity) and yield of pearlmillet over control (Table 1), which may be attributed primarily due to varying rainfall pattern and dry spell in 2009 and 2010. Maximum plant height (178.2 cm), tillers/m-row length (22.7), and yield (3.08 t/ha) was recorded with the spray of PMA (320 ppm) over control (Table 1 and 3). Cycocel was found less effective than PMA. Favourable effect of transpiration suppressants on the crop in 2009 attributed to the role of transpiration supplement in reducing the effect of dry spell on the crop (Chitokdar *et al*.

Table 1. Effect of cropping systems, transpiration suppressants and fertility levels on growth attributes of pearlmillet (mean of two years)

Treatment	Plant height at maturity (cm)	Tillers/m row length (at maturity)	Leaf area index		Crop growth rate (g/tiller/day)			Days to 50% flowering
			60 DAS	At maturity	0-30 DAS	30-60 DAS	60 DAS-maturity	
Cropping systems								
Pearlmillet sole	180.62	23.00	4.92	1.33	0.42	1.01	0.37	46.15
Pearlmillet+ pigeonpea	171.00	21.10	4.62	1.20	0.41	0.90	0.34	44.60
SEm±	2.30	0.50	0.07	0.04	0.01	0.03	0.02	0.80
CD (P=0.05)	7.20	1.60	0.23	0.11	NS	0.10	NS	NS
Transpiration suppressants								
Control	171.45	21.20	4.64	1.17	-	0.89	0.32	45.05
Cycocel (200 ppm)	177.65	22.31	4.78	1.30	-	0.95	0.37	45.80
PMA (320 ppm)	178.20	22.71	4.82	1.30	-	0.98	0.35	45.30
SEm±	2.49	0.60	0.08	0.04		0.035	0.025	1.14
CD (P=0.05)	7.14	1.75	0.24	0.11		0.1	NS	3.28
Fertility levels								
Control	166.20	19.20	4.30	1.09	0.34	0.86	0.32	41.80
25 kg N + 8.6 kg P/ha	173.85	21.45	4.73	1.25	0.41	0.91	0.35	45.10
50 kg N + 17.2 kg P/ha	183.55	24.40	5.12	1.40	0.47	1.03	0.38	48.75
25 kg N + 8.6 kg P/ha + BF	179.45	23.20	4.90	1.30	0.44	0.99	0.35	45.95
SEm±	2.49	0.60	0.08	0.04	0.01	0.03	0.02	1.14
CD (P=0.05)	7.14	1.75	0.24	0.11	0.03	0.10	NS	3.28

PMA: Phenyl Mercuric Acetate; BF: Bio-fertilizers (*Azotobacter* and PSB)

2005).

Application of fertilizer, irrespective of its source significantly enhanced growth attributes and yield of pearlmillet over unfertilized crop (Table 1). Application of 50 kg N + 17.2 kg P/ha through fertilizer enhanced mean plant height, total number of tillers and crop growth rate during 30-60 DAS of pearlmillet by 17.3 cm, 5.2 tillers/m row length and 0.17 (g/tiller/day) over control, respectively (Table 1). 50 kg N + 17.2 kg P/ha increased the leaf area index by 19.0 and 28.5% over control, at 60 DAS and at maturity stage of pearlmillet, respectively. This might be due to presence of competition between sole and intercropped pearlmillet for growth resources such as nutrients, moisture and solar radiation. The maximum grain yield of pearlmillet was recorded with 50 kg N + 17.2 kg P/ha (3.35 t/ha), while the minimum was with control (2.55 t/ha). Further, 50 kg N + 17.2 kg P/ha gave significantly higher pearlmillet grain yield by 24.7% over control. The favourable improvement in yield attributes could be due to favourable influence of nitrogen and phosphorous nutrition on growth parameters, finally leading to greater nutrient uptake, efficient partitioning of metabolites and adequate accumulation and translocation of photosynthates. The observations of the present study are in line with the findings of Ghosh *et al.* (2009) and Singh *et al.* (2010).

Growth attributes and yield of pigeonpea

The performance of pigeonpea was affected in intercropping with pearlmillet when compared with its sole stand (Table 2). The magnitude of increase was 6.5, 11.1 and 4.1% for plant height, dry weight at maturity and leaf area index at 90 DAS over intercropping system. Intercropped pigeonpea, on an average, decreased the crop growth rate by 26.1 and 11.5% during 30-60 DAS and 60-90 DAS as compared to its sole stand. The cumulative effect of reduction in plant height, dry weight, leaf area index and crop growth rate in intercropped pigeonpea lower the productivity (0.61 t/ha) when compared to its sole cropping (1.52 t/ha) (Table 3). This could be attributed due to the plating pattern, which creates dissimilar conditions for plant growth and development of pigeonpea in intercropping systems than its sole cropping. The results are in close agreement with Moriri *et al*.,(2010).

Transpiration suppressants brought a significant improvement on an average in the growth attributes of pigeonpea, *viz*., plant height and dry weight. The maximum plant height (160.9 cm), dry weight (67.4 g/plant) and Yield (1.08 t/ha) was recorded in PMA followed by cycocel (160.65 cm, 66.7 g/tiller and 1.06 t/ha) spray and the minimum with control (154.05 cm, 63.8 g/tiller and 1.04t/ha), respectively (Table 2 and 3). However, transpiration suppressants could not affect leaf area index and crop growth rate significantly during 2010. Anti-transpirants enhanced the nutrient and moisture supply, which created conducive environment for plant growth and development. The results are in close agreement with

Table 2. Effect of cropping systems, transpiration suppressants and fertility levels on growth attributes of pigeonpea (mean of two years)

Treatment	Plant height at maturity (cm)	Tillers/m row length (at maturity)	Leaf area index		Crop growth rate (g/tiller/day)		
			90 DAS	At maturity	30-60 DAS	60-90 DAS	90 DAS-maturity
Cropping systems							
Pearlmillet sole	164.10	69.40	2.30	2.13	0.29	0.58	0.67
Pearlmillet+ pigeonpea	152.95	62.60	2.21	2.07	0.23	0.52	0.62
SEm ±	2.16	1.00	0.03	0.03	0.01	0.02	0.02
CD (P=0.05)	6.81	3.13	0.09	NS	0.03	0.05	NS
Transpiration suppressants							
Control	154.05	63.80	2.22	2.08	0.25	0.54	0.63
Cycocel (200 ppm)	160.65	66.75	2.27	2.10	0.26	0.55	0.65
PMA (320 ppm)	160.90	67.40	2.27	2.12	0.27	0.56	0.66
SEm±	2.25	1.22	0.03	0.02	0.01	0.02	0.03
CD (P=0.05)	6.76	3.74	NS	NS	NS	NS	NS
Fertility levels							
Control	149.90	61.20	2.10	1.95	0.18	0.51	0.64
25 kg N + 8.6 kg P/ha	157.30	65.85	2.26	2.12	0.25	0.55	0.65
50 kg N + 17.2 kg P/ha	165.85	69.75	2.35	2.19	0.30	0.58	0.66
25 kg N + 8.6 kg P/ha + BF	161.05	67.25	2.31	2.15	0.29	0.56	0.64
SEm±	1.92	1.30	0.03	0.03	0.01	0.03	0.03
CD (P=0.05)	5.50	3.74	0.09	0.07	0.03	0.08	0.09

PMA: Phenyl Mercuric Acetate; BF: Bio-fertilizers (*Azotobacter* and PSB)

those of Ghosh *et al.* (2009) and Moriri *et al.* (2010).

Fertility levels increased growth attributes and yield of pigeonpea as compared to control. The maximum plant height (165.85 cm), dry weight (69.75 g/plant), leaf area index (2.35 at 90 DAS and 2.19 at maturity) and crop growth rate (0.3 g/tiller/day during 30-60 DAS) was recorded with the application of 50 kg N + 17.2 kg P/ha followed by 25 kg N + 8.6 kg P/ha + *Azotobacter* + PSB, and while the minimum was with control. The maximum grain and stalk yield was obtained with the application of 50 kg N + 17.2 kg P/ha (1.20 and 4.38 t/ha) followed by 25 kg N + 8.6 kg P + *Azotobacter* + PSB (1.14 and 4.19 t/ha), which was 37.9 and 31.5, and 3103 and 25.8% higher over control, respectively (Table 2 and 3). Adequate amounts of N and P fertilization facilitate better growth and development, which ultimately increased the yield. *Azotobacter* facilitate the atmospheric N_2 fixation while, PSB increased the P uptake due to solubilization of native phosphorous (Tetarwal and Rana, 2006).

Pearlmillet equivalent yield and net returns

Pearlmillet intercropped with pigeonpea recorded significantly higher pearlmillet equivalent yield (PEY) as compared to either of sole cropping. It was due to almost similar yield of pearlmillet to that of its sole stand, and additional yield of pigeonpea as a bonus in intercropping system (Ghosh *et al.*,2009). Intercropping system on an average increased net returns by 53.9 and 21.9% over sole stand of pearlmillet and pigeonpea, respectively (Table 3). Pearlmillet + pigeonpea intercropping system gave higher net returns as compared to either of sole stand due to more combined yield with nearly similar cost of cultivation.

PMA (320 ppm), being at par with cycocel (200 ppm) recorded the maximum pearlmillet equivalent yield (PEY) being higher than control. It might be due to significant increases in grain yield of pearlmillet in aforesaid treatment over control which resulted in higher pearlmillet equivalent yield. Cycocel (200 ppm) spray fetched the highest net returns ₹ 32.30×10^3 over other treatment.This was due to the increased yield with low cost in these treatments (Tetarwal and Rana, 2006).

The PEY on an average increased by 35.67, 14.60, 4.46% with the application of 50 kg N + 17.2 kg P/ha over control, 25 kg N + 8.6 kg P/ha and 25 kg N + 8.6 kg P/ha + *Azotobacter* + PSB.This might be due to increase in economic yield of both the component crops in intercropping system with N and P application over no fertilizer application. Application of 50 kg N + 17.2 kg P/hato the crops fetched the highest net returns (₹36.64×10^3) over other fertility levels (Table 3). Significant increase in yield with 50 kg N + 17.2 kg P/ha over control resulting in higher net returns. Similar results were also reported by Tetarwal and Rana (2006).

Protein and nutrient content

Protein content in grain and nutrient (N and P) concentration in grain and stover remained unaffected by cropping systems and transpiration suppressants in both the

Table 3. Effect of cropping systems, transpiration suppressants and fertility levels on yield of pearlmillet and pigeonpea (mean of two years)

Treatment	Pearlmillet					Pigeonpea				
	1,000-grain weight (g)	Grain yield (t/ha)	Stover yield (t/ha)	H.I. (%)	1,000-grain weight (g)	Grain yield (t/ha)	Stalk yield (t/ha)	H.I. (%)	PEY (t/ha)	Net returns (×10^3₹/ha)
Cropping systems										
Pearlmillet sole	7.53	3.14	8.04	28.05	-	-	-	-	3.14	25.09
Pigeonpea sole	-	-	-	-	64.33	1.52	5.58	21.40	4.15	31.67
Pearlmillet + pigeonpea	7.36	2.89	7.23	28.55	63.95	0.61	2.25	23.10	4.57	38.62
SEm ±	0.13	0.05	0.19	0.37	0.47	0.02	0.07	0.62	0.11	-
CD (P =0.05)	NS	0.13	0.58	NS	NS	0.05	0.22	NS	0.35	-
Transpiration suppressants										
Control	7.29	2.92	7.28	28.40	63.82	1.04	3.81	22.60	3.81	31.73
Cycocel (200 ppm)	7.47	3.04	7.78	28.00	64.23	1.06	3.95	22.05	3.98	32.3
PMA (320 ppm)	7.56	3.08	7.84	28.35	64.35	1.08	3.98	22.10	4.04	31.36
SEm ±	0.16	0.05	0.21	0.45	0.57	0.01	0.08	0.75	0.11	-
CD (P =0.05)	NS	0.14	NS	NS	NS	0.03	0.23	NS	NS	-
Fertility levels										
Control	7.23	2.55	6.64	27.97	63.89	0.87	3.33	21.95	3.28	25.19
25 kg N + 8.6 kg P/ha	7.40	2.95	7.49	28.81	64.02	1.04	3.75	22.50	3.80	30.31
50 kg N + 17.2 kg P/ha	7.62	3.35	8.35	28.63	64.42	1.20	4.38	21.75	4.45	36.64
25 kg N + 8.6 kg P/ha + BF	7.53	3.18	8.08	28.22	64.20	1.14	4.19	22.75	4.26	35.05
SEm ±	0.16	0.04	0.18	0.34	0.66	0.02	0.13	0.68	0.07	-
CD (P =0.05)	NS	0.13	0.57	NS	NS	0.07	0.39	NS	0.22	-

PMA: Phenyl Mercuric Acetate; BF: Bio-fertilizers (*Azotobacter* and PSB)

*PEY = Pearlmillet equivalent yield, and net returns based on 2010 minimum support price (MSP). H.I. represents harvest index.

Table 4. Effect of cropping systems, transpiration suppressants and fertility levels on protein and nutrient content of pearlmillet and pigeonpea (mean of two years)

Treatment	Pearlmillet					Pigeonpea				
	Protein content (%)	N content (%)		P content (%)		Protein content (%)	N content (%)		P content (%)	
		Grain	Stover	Grain	Stover		Grain	Stalk	Grain	Stalk
Cropping systems										
Pearlmillet sole	11.4	1.85	0.58	0.35	0.19	-	-	-	-	-
Pegionpea sole						19.4	3.11	1.29	0.39	0.12
Pearlmillet + pigeonpea	11.3	1.83	0.56	0.35	0.19	19.2	3.08	1.28	0.39	0.12
SEm±	0.10	0.02	0.01	0.01	0.01	0.09	0.02	0.01	0.01	0.01
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Transpiration suppressants										
Control	11.3	1.83	0.56	0.35	0.19	19.2	3.07	1.28	0.39	0.12
Cycocel (200 ppm)	11.4	1.84	0.58	0.35	0.19	19.3	3.10	1.29	0.40	0.12
PMA (320 ppm)	11.4	1.84	0.59	0.35	0.19	19.4	3.12	1.29	0.39	0.13
SEm±	0.12	0.02	0.02	0.01	0.01	0.09	0.02	0.01	0.01	0.01
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fertility levels										
Control	10.9	1.75	0.45	0.27	0.16	17.5	2.80	1.19	0.34	0.11
25 kg N + 8.6 kg P/ha	11.5	1.85	0.58	0.34	0.18	19.6	3.14	1.29	0.36	0.12
50 kg N + 17.2 kg P/ha	11.7	1.89	0.65	0.40	0.22	20.4	3.26	1.38	0.44	0.14
25 kg N + 8.6 kg P/ha + BF	11.5	1.86	0.60	0.36	0.20	19.8	3.18	1.31	0.42	0.13
SEm±	0.15	0.02	0.02	0.004	0.004	0.18	0.03	0.004	0.013	0.003
CD (P=0.05)	0.44	0.07	0.06	0.012	0.013	0.53	0.09	0.09	0.01	0.01

years of experimentation (Table 4).

Significant variations in protein content in grain and nutrient (N and P) concentration in grain and stover were observed due to N and P fertilization (Table 4). Application of 50 kg N + 17.2 kg P/ha recorded the higher protein content in grain of pearlmillet (11.74%), and N (1.89 and 0.65%) and P (0.40 and 0.22%) concentration in grain and stover, respectively over control.

The maximum protein content in grain of pigeonpea (20.40%), and N (3.26 and 1.38%) and P (0.44 and 0.14%) concentration in grain and stover, respectively was noticed with the application of 50 kg N + 17.2 kg P/ha as compared to other fertility levels. Inclusion of biofertilizers with 25 kg N + 8.6 kg P/ha improved the quality and nutrient content of pigeonpea over only 25 kg N + 8.6 kg P/ha. The improvement in quality and nutrient content could be attributed to higher N and P concentration in grain where crops were sown with N and P-fertilizers (Singh *et al*., 2010). P being responsible for synthesis of DNA and RNA and as an ingredient of phospho-proteins plays a central role in synthesis of proteins. Improvement in protein content in grain due to N and P fertilization has also been reported by Parihar *et al.* (2009) and Morir*iet al.* (2010).

Thus based on two years results of the present investigation clearly demonstrate that pearlmillet + pigeonpea intercropping system in 2:1 (30/70 cm) row ratio practiced to achieve high yield as well as profitability than their sole crop at 50 cm row spacing under rainfed sandy loam soils. Use of transpiration suppressants (PMA and cycocel) was found useful in year of low rainfall and dry spells. Application of 50 kg N + 17.2 kg P/ha was found more productive over other fertility levels.

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