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Effect of transpiration suppressants and nutrients under rainfed conditions: An integral view on crop productivity and biological indices in millet/pulses intercropping system

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Under rainfed condition (650 mm/annum) of India drought of unpredictable intensity and duration is a prevailing feature. Appropriate intercropping combinations and management practices for sustaining crop productivity in such situations needs to be worked out, where monoculture is prevailing. Objectives were to examine the effect of transpiration suppressants and nutrients on sustaining productivity, profitability of pearlmillet/pigeonpea intercropping for realizing maximum nutrients and moisture use efficiency in moisture scarce conditions. Though there was a reduction in yield of component crops under intercropping greatly so for pigeon pea, higher Pearlmillet Equivalent Yield (PEY), land equivalent ratio (LER) value, economics (net returns and B:C ratio) was achieved higher in pearlmillet/pigeonpea intercropping system as compared to their sole cropping. Nutrients and apparent rain water use efficiency (ARUE) was also higher in same cropping system. The yield response of the transpiration suppressants was observed only in limited soil moisture conditions (2009). However, with respect to yield advantage indices, the effect of transpiration suppressants was comparable to control. Over the period of time, 50 kg N + 17.2 kg P ha^{-1} recorded higher crop performance ratio, ARUE, agronomic and physiological efficiency of N and P over other fertility treatments.

Key words: Apparent rainfall use efficiency, *Cajanus cajan*, biological indices, nutrients use efficiency, *Pennisetum glaucum*, transpiration suppressants.

INTRODUCTION

Pearlmillet [*Pennisetum glaucum* (L.)] 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

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extreme weather events coupled with scanty water resources (Singh et al., 2010). Annual rainfall and its monthly distribution are highly variable in this zone (Painuli et al., 2002). Studies in rainfed sub tropical agro climatic zones of India indicated depleted soil fertility, poor microbial activity and low organic matter content resulting in the reduced soil volume exploited by the plant for essential nutrients and water (Jakhar et al., 2006). Therefore, efficient soil management and profitable production systems are needed for this non irrigated region to improve the economic condition of the farmers. In grey areas of the country, the best alternative to increase the production of cereals, millets and pulses is the adoption of location-specific intercropping systems. Pearlmillet and pigeonpea intercropping has been the most important for dryland areas with limited water availability on marginal and sub-marginal lands in north-west, west and central parts of India (Singh et al., 2010). Careful selection of crops having different growth habit can reduce the mutual competition to a considerable extent (Moriri et al., 2010). Pigeonpea [*Cajanus cajan* (L.) Millsp.] is deep rooted and slow growing in early growth, more rapidly growing crops like pearlmillet may be conveniently intercropped in the hope of utilizing the natural resources more efficiently (Ghosh et al., 2006). To stabilize crop production and to provide insurance against aberrant weather situations in rainfed agriculture, intercropping of millets with pulses such as pigeonpea could be a viable risk minimizing agronomic means of sustainable venture. Use of transpiration suppressants like cycocel (growth retardant) and phenyl mercuric acetate (PMA, stomata closing type); reduce transpiration losses from plants and effectively increases productivity and water use by crops under rainfed conditions (Gaballah and Moursy, 2004). It is necessary to consider nutrient competition in an intercropping system that involves crops of different maturity, such as a pearlmillet with pigeonpea, whose peak demand for resources do not coincide (Tobita et al., 1996).

Understanding is needed of when and which component crop is suffering from which nutrient deficiency to establish strategies for fertilizer use. The cereal components is usually taller and has a faster growing or more extensive root system (Lehmann et al., 1998), and has a high demand for soil N (Carr et al., 2004). However, an effectively nodulated legume component is able to fix N_2 from the atmosphere (Jensen, 1996), leading to a potentially non-competitive association with respect to N nutrition at least. However, with the changing scenario of crop improvement in pearlmillet and pigeonpea intercropping, there is a need to relook and investigate low cost technology. In this paper, we have attempted to examine the effect of transpiration suppressants and nutrients on sustaining productivity of pearlmillet/pigeonpea intercropping for realizing maximum yield and profit in moisture scarce conditions.

MATERIALS AND METHODS

Experimental site

The field experiment was conducted at the Indian Agricultural Research Institute (IARI), New Delhi, situated at latitude of 28° 4” N longitude of 77° 12” E and altitude of 228.6 m for two consecutive years (2009 to 2010). The soil of the experimental site was sandy loam in texture having pH 7.8, organic carbon 0.3% and EC 0.38 dS m^{-1}. Soils at 0 to 15 cm depth are low in alkaline permanganate N (61.72 mg/kg of soil) (Subbiah and Asija, 1956), available P (4.72 mg/kg of soil) (Olsen et al., 1954) and medium in available K (ammonium acetate K 85.4 mg/kg of soil) [Flame photometer method (Hanway and Heidel, 1952)]. The moisture at 0.03 and 0.15 M pa tensions were 18.8 and 6.5% [pressure plate apparatus (Richards and Weaver, 1943)] and bulk density was 1.50 Mg m^{-3} (0 to 15 cm). The region has a semi-arid tropical climate and receives an annual rainfall of 850 mm, (>90% from July to September).

Experimental and crop culture

The experiment was laid out in split plot design with nine combinations including three cropping system (C1- pearlmillet sole, C2- pigeonpea sole, C3- paired row of pearlmillet + one row of pigeonpea) and three transpiration suppressants [T0- control, T1- cycocel (200 ppm), T2-PMA (320 ppm)] in the main plots, that were each split for four fertility levels (F0- Control, F1- 25 kg N + 8.6 kg P ha^{-1}, F2- 50 kg N + 17.2 kg P ha^{-1}, F3- 25 kg N + 8.6 kg P ha^{-1} + *Azotobacter* + PSB) in sub plot and replicated thrice. Pearlmillet (variety Pusa-383) and short duration pigeonpea (variety Pusa-991), both as sole and intercrops were sown in the third week of July. Two to three seeds of pigeonpea were sown $hill^{-1}$ at a row spacing of 50 cm and the seedlings were thinned to one plant $hill^{-1}$ one week after emergence for achieving a plant density of 100 × 10^3 ha^{-1} and plant-to-plant spacing of 20 cm. For pearlmillet, row-to row spacing of 50 cm and plant-to-plant spacing of 10 cm were maintained to get a plant density of 200 × 10^3 ha^{-1}. In intercropping, one row of pigeonpea was sown after every two rows of pearlmillet (1:2) at a distance of 30 cm. This way, pigeonpea to pigeonpea row distance in intercropping was 100 cm. A plant population of 200 × 10^3 ha^{-1} for intercropped pearlmillet and 50 × 10^3 ha^{-1} for intercropped pigeonpea was maintained. Transpiration suppressants was applied at 55 days after sowing (DAS) in 2009 and at 70 DAS in 2010. PMA (320 ppm) and cycocel (200 ppm) were applied at 256 and 160 g ha^{-1}, respectively, and total volume of solution was maintained at 800 L/ha.

Fertilizer was drilled in bands 8 to 10 cm below the surface. Pearlmillet seeds were inoculated with biofertilizers [*Azotobacter* and phosphate solubilizing-bacteria (PSB)]; while, pigeonpea seeds were inoculated with PSB and Rhizobium culture 2 h before sowing at 20 g/kg seed. Pearlmillet was harvested manually at 88 and 91 DAS while pigeonpea was harvested at 145 and 147 DAS in 2009 and 2010, respectively. The crop was harvested manually by sickle at ground level and threshed with an electrically operated multi crop thresher.

Yield advantage indices

The yields of sole and intercrop pigeonpea was converted to pearlmillet equivalent yield (PEY) on financial basis and expressed as PEY = yield of pigeonpea × unit price of pigeonpea/unit price of pearlmillet. However, PEY does not indicate the net gain obtained from a cropping system and also does not explain the land use pattern of the cropping systems. Land equivalent ratio (LER) is the relative land area under sole crops that is required to produce the yields achieved in intercropping. LER value greater than unity reflects the extra advantage of intercropping system over sole cropping system; It was calculated by using following formula:

LER = Yab/Yaa + Yba/Ybb

Where, Yaa is yield of component a as sole crop, Ybb is yield of component b as sole crop, Yab is yield of component a as intercrop grown in combination with component b and Yba is yield of component b as intercrop grown in combination with component a. Crop performance ratio (CPR) was calculated by using the formula:

CPR = Qia/Pia × Qsa + Qib/Pib × Qsb

Where Q ia and ib is productivity per unit area in the intercrop of a and b, Qsa and Qsb is productivity per unit area in the sole crops of a and b, Pia and Pib is proportion of the intercrop area sown with the species a and b.

Apparent rain water use efficiency

Apparent rain water use efficiency (ARUE) of crop was worked out from the seasonal rainfall of water as illustrated by using the following formula:

WUE (kgha^{-1}mm^{-1}) = Grain yield (kg ha^{-1})/Rainfall (mm)

Nutrients use efficiency

The estimated values of agronomic efficiency (AE), physiological efficiency (PE) and harvest index (HI) of applied N and P were computed using the following expressions as suggested by Fageria and Baligar (2003) and Dobermann (2005):

AE = (YN - YAc)/Na
PE = (YN - YAc)/(UN - UAc)
HI = GUN/UN

Where YN is grain yield (kg ha^{-1}) in N applied plots, YAc is grain yield (kg ha^{-1}) in absolute control, Na is nutrient (N/P) applied (kg ha^{-1}), UN is total nutrient (N/P) uptake (kg ha^{-1}), UAc is total nutrient (N/P) uptake (kg ha^{-1}) in absolute control and GUN is total nutrient (N/P) uptake (kg ha^{-1}) in grain.

Production efficiency

Farmers are concerned mostly with total profit and the marginal benefit: cost ratio from investment in labour and inputs (Ghosh et al., 2006). The yield and economic performance of intercropping was assessed to determine whether pearlmillet yield and additional pigeonpea yield were sufficient for practising intercropping system. For comparing the economical value of systems, the grain yields were converted into gross return and/or net return.

Economics

Economics of different treatment was worked out by taking into account the cost of inputs and income obtained from output (grain and stover yield). Net returns (Rs ha^{-1}) calculated by using formula = gross returns - cost of cultivation. Benefit: cost ratio was calculated by used formula = gross returns/cost of cultivation. Minimum support price (fixed by government of India) of pearlmillet in 2009 and 2010 = Rs 8400 and Rs 8800 t^{-1}, respectively, minimum support price of pigeonpea in 2009 and 2010 = Rs 23000 and Rs 28000 t^{-1}, respectively. The cost of cycocel = Rs 5,122 L^{-1} and cost of PMA = Rs 10,588 kg^{-1}, `140/man-day, price of stalk/stover = `1500 t^{-1}, cost of nitrogen = `11.54 kg$^{-1}$ N, cost of phosphorus (P) = `49.35 kg^{-1}, cost of biofertilizers = `10 packet$^{-1}$, cost of cycocel = `5122 L^{-1}, cost of PMA = `9588 kg^{-1} was used for economic analysis.

Rainfall

The total rainfall received during rainy seasons (June to December) was 493 mm in 2009 and 776 mm in 2010 (Figure 1a and b). The year 2009 received low rainfall during a part of the pearlmillet and pigeonpea growing seasons. In comparison to the long term average, the rainfall received during growing season was not only low but also erratic. Most of the precipitation occurred during July to August.

Data analysis

Data obtained from pearlmillet and pigeonpea crops for consecutive two years were pooled and statistically analyzed using the F-test as per the procedure given by Gomez and Gomez (1984). LSD at P = 0.05 were used to determine the significance between treatment means.

RESULTS

Yield

There was 8.3% reduction in grain yields of intercrop pearlmillet and 149% of intercrop pigeonpea over the corresponding sole crops (Table 1). Transpiration suppressants compared with no suppressants significantly (*$P < 0.05$) increased grain yield of sole and intercrop pearlmillet and pigeonpea in 2009 but not 2010. Application of 50 kg N + 17.2 kg P ha^{-1} on an average gave significantly higher pearlmillet and pigeonpea grain yield by 31, 25 and 16 and 38, 31 and 19% over control, 25 kg N + 8.6 kg P ha^{-1}, 25 kg N + 8.6 kg P ha^{-1} + BF, respectively.

Biological indices

The yield advantage in terms of pearlmillet equivalent yield (PEY) was greater in pearlmillet/pigeonpea intercropping system than their respective sole cropping (Table 1). The yield response to transpiration suppressants was higher in 2009. PMA spray recorded the highest PEY and control showed the lowest. On an average, 45 and 10% more yield advantages in terms of PEY was received from intercropping over sole pearlmillet and sole pigeonpea, respectively. Transpiration suppressants also gave 6% more PEY over control. Higher LER values in intercropping system that is, 1.31 and 1.35 in respective years of 2009 and 2010 clearly indicated 31 and 35% advantage over sole cropping. Transpiration suppressants increased the LER values on an average of 3% over control (Table 1). The

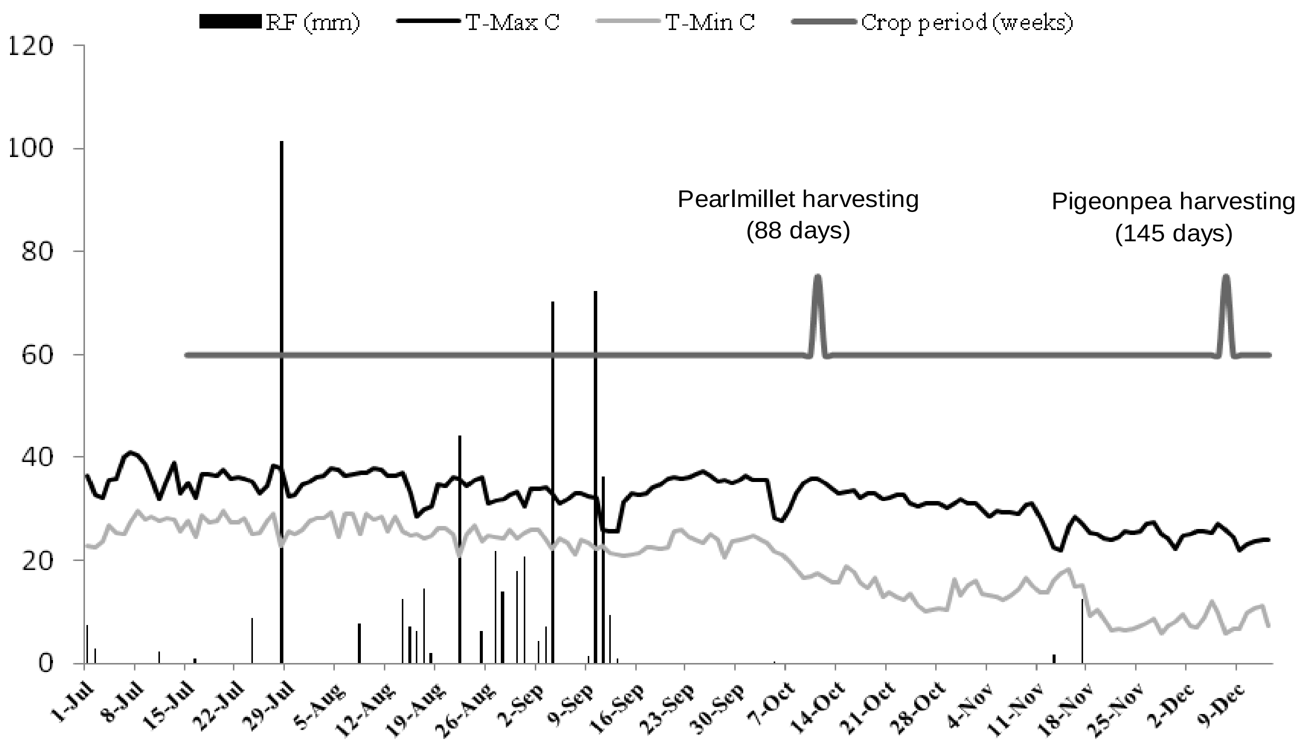

Figure 1a. Meteorological parameters and crop duration during cropping season of 2009.

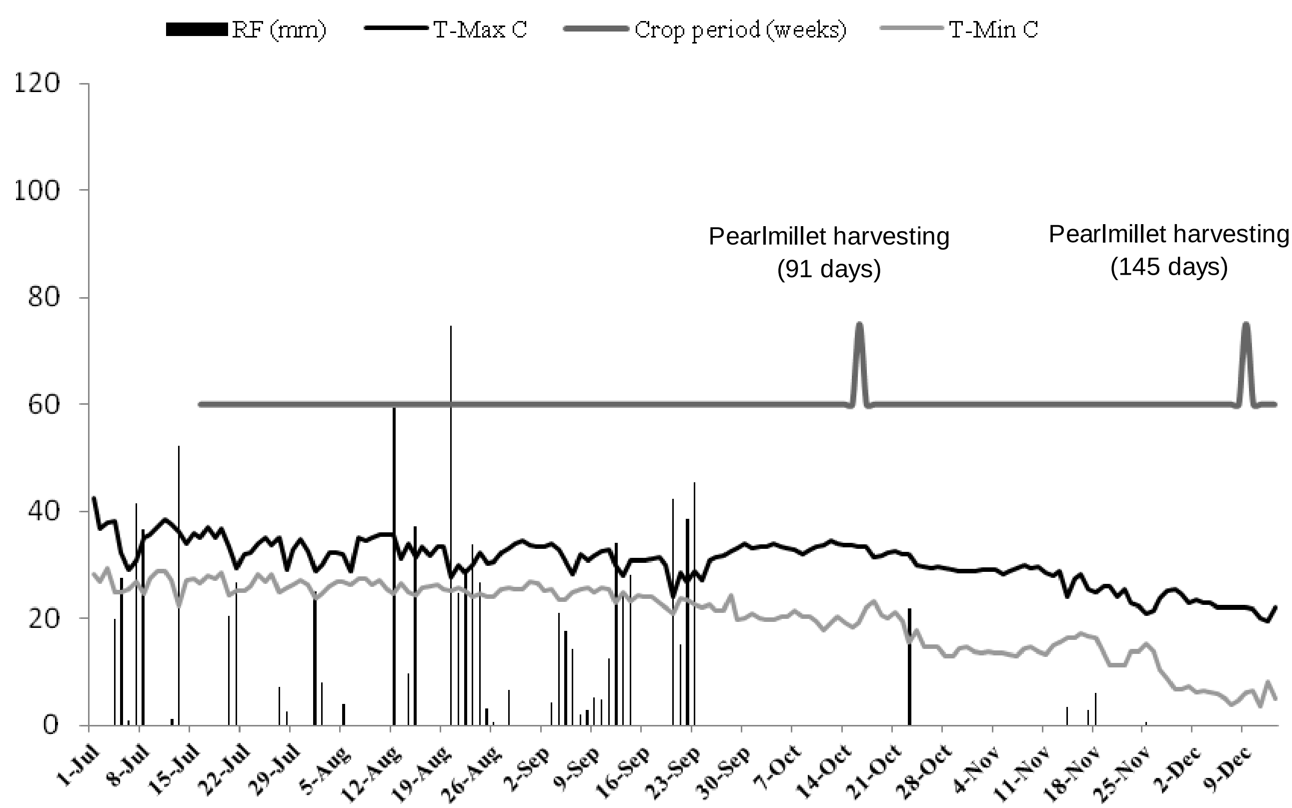

Figure 1b. Meteorological parameters and crop duration during cropping season of 2010.

Table 1. Effect of cropping systems transpiration suppressants and fertility levels on yields, PEY and LER of sole pearlmillet, sole pigeonpea and intercropping system.

Treatments	Grain yield of pearlmillet (t/ha)		Grain yield of pigeonpea (t/ha)		Pearlmillet equivalent yield (PEY) (t/ha)		Land equivalent ratio (LER)	
	2009	2010	2009	2010	2009	2010	2009	2010
Cropping systems								
Sole pearlmillet	2.93	3.34	-	-	2.93	3.34	1.00	1.00
Sole pigeonpea	-	-	1.50	1.54	4.09	4.20	1.00	1.00
Pearlmillet + pigeonpea	2.74	3.04	0.57	0.65	4.31	4.82	1.31	1.35
L.S.D. (P = 0.05)	0.15	0.11	0.03	0.06	0.16	0.54	0.11	0.32
Transpiration suppressants								
Control	2.69	3.14	1.01	1.07	3.62	3.99	1.09	1.10
Cycocel	2.89	3.19	1.04	1.09	3.81	4.15	1.10	1.11
PMA	2.93	3.24	1.05	1.12	3.89	4.19	1.12	1.14
L.S.D. (P = 0.05)	0.19	NS	0.03	NS	0.16	NS	NS	NS
Fertility levels								
Control	2.37	2.73	0.85	0.90	3.16	3.39	1.07	1.10
25 kg N + 8.6 kg P/ha	2.86	3.05	1.00	1.08	3.63	3.96	1.11	1.11
50 kg N + 17.2 kg P/ha	3.13	3.57	1.17	1.24	4.22	4.68	1.12	1.15
25 kg N + 8.6 kg P/ha + BF	2.96	3.41	1.12	1.16	4.10	4.41	1.12	1.12
L.S.D. (P = 0.05)	0.17	0.09	0.04	0.10	0.15	0.28	NS	NS

* NS, BF and PMA represent non significant, biofertilizers (Azotobacter and phosphate solubilizing bacteria) and phenyl mercuric acetate, respectively. Yields of sole and intercrop pigeonpea were converted to pearlmillet equivalent yield (yield of pigeonpea × unit price of pigeonpea/unit price of pearlmillet). Thus, PEY in intercropping is yield of intercrop pearlmillet + PEY of intercrop pigeonpea.

higher value of CPR in cropping system was recorded in PMA spray (1.76) over control (1.66) (Figure 2a). While in 2010, the effect of transpiration suppressants did not show any significant variation. 50 kg N + 17.2 kg P ha^{-1} significantly increased the PEY being on par with 25 kg N + 8.6 kg P ha^{-1} + *Azotobacter* + PSB as compared with other fertility levels (Table 1). The significantly higher LER and CPR were recorded under same treatment during both the year of experimentation.

Apparent rain water use-efficiency

Over the period of time, intercropping system was recorded significantly at 18 and 127% higher apparent rain water use-efficiency (ARUE) over sole pearlmillet and sole pigeonpea (Figure 3a). The minimum ARUE was recorded under sole cropping of pigeonpea (4.64 kg ha^{-1} - mm). Among transpiration suppressants, higher ARUE was recorded in PMA spray (8.23 kg ha^{-1} - mm) over control (7.94 kg ha^{-1} - mm) (Figure 3b). The maximum ARUE was observed with the application of 50 kg N + 17.2 kg P ha^{-1}, followed by 25 kg N + 8.6 kg Pha^{-1} + *Azotobacter* + PSB (Figure 3c). The minimum ARUE was recorded with control during both the year of experimentation.

Nutrients use indices

The pearlmillet/pigeonpea intercropping system significantly increased AEN and AEP than either of the sole cropping. Significantly, higher PEN (18.38 kg $grainkg^{-1}$ N uptake) and PEP (1.09 kg grain kg^{-1} P uptake) was recorded with pearlmillet/pigeonpea intercropping system as compared to sole cropping of pearlmillet and pigeonpea (Table 2). Sole pearlmillet recorded significantly higher NHI as compared to sole cropping of pigeonpea and pearlmillet and pigeonpea intercropping system. The effect of transpiration suppressants on agronomic efficiency, physiological efficiency and harvest index of N and P was found to be non significant (Table 2). The highest AE and PE of N and P was recorded with the application of 25 kg N + 8.6 kg P ha^{-1} + *Azotobacter* + PSB over other fertility levels (Table 2). There was no significant effect of N and P fertilization on NHI of pearlmillet and pigeonpea crops.

Economics

On an average, intercropping system gave maximum net returns of 38.62 × 10^3 ` ha^{-1}, which was about 54% higher than sole pearlmillet and 22% higher than sole pigeonpea

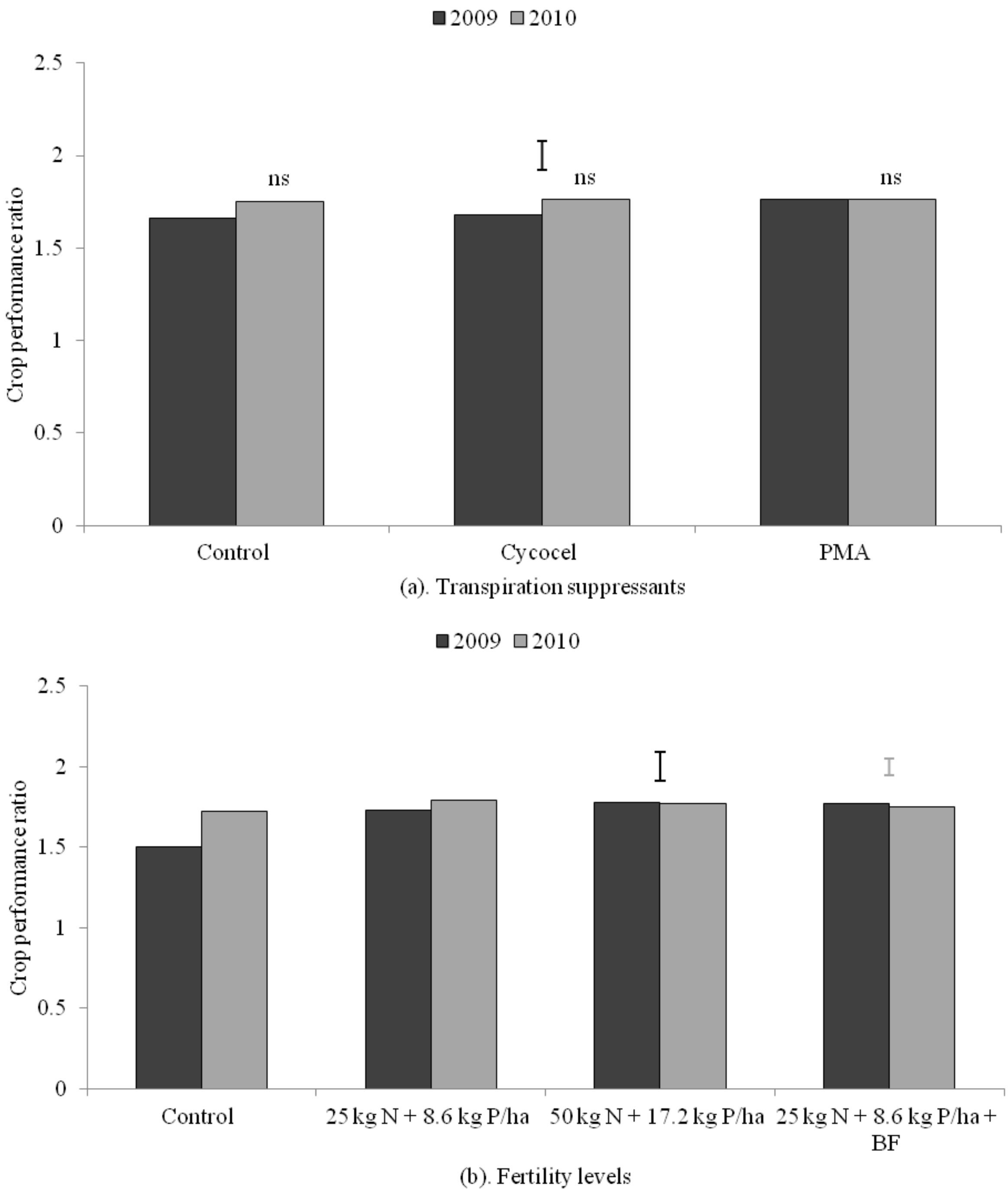

Figure 2. Crop performance ratio under different transpiration suppressants (a) and fertility levels in pearlmillet/pigeonpea intercropping system (b). Vertical bar and ns represents L.S.D. (P = 0.05) and non significant, respectively.

(Table 3). This system also provided significantly higher ` per ` invested (3.23) than that of the other two systems (Table 3). Higher crop profitability was recorded under intercropping system over sole pearlmillet and sole pigeonpea. The effect of transpiration suppressants was not significant on net return and benefit: cost ratio. Cycocel gave the highest crop profitability of other treatments. Application of 50 kg N + 17.2 kg P ha^{-1} through fertilizer enhanced mean net returns by `11.32 × 10^3 ha^{-1} over control. Further, application of 25 kg N + 8.6 kg P ha^{-1} + BF enhanced net returns by Rs 9.63 × 10^3 ha^{-1} over control (Table 3). Inclusion of biofertilizers

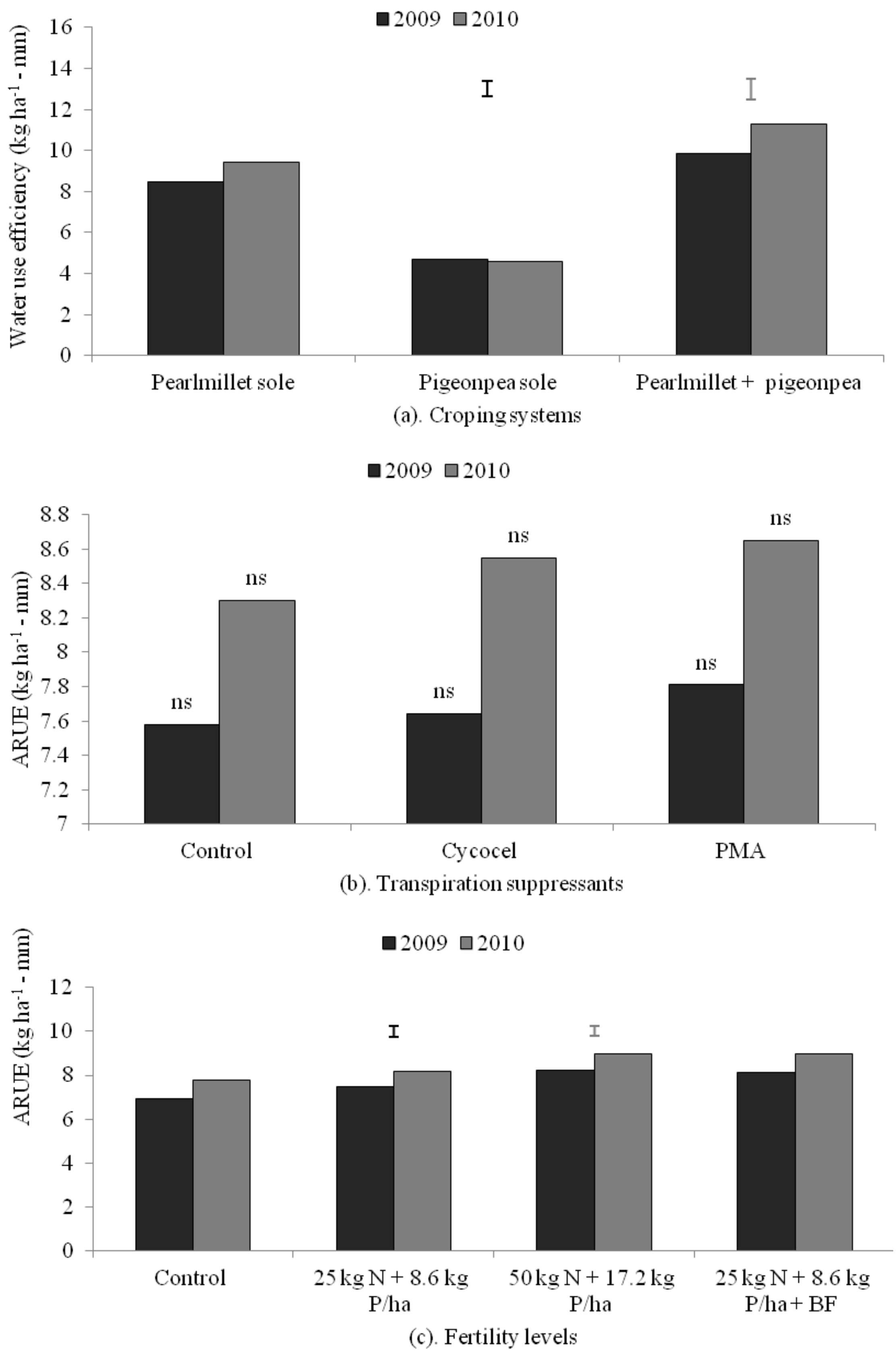

Figure 3. The apparent rain -use-efficiency (kg ha^{-1}-mm) of pearlmillet and pigeonpea crops under different cropping systems (a) and transpiration suppressants (b) and fertility levels in 2009 and 2010 (c). The ns and vertical bar represents non significant and L. S. D. (P = 0.05), respectively.

Table 2. Effect of cropping systems, transpiration suppressants and fertility levels on agronomic efficiency, physiological efficiency and harvest index of N and P (pooled data of two years).

Treatment	Nitrogen			Phosphorus		
	AEN (kg grain /kg N applied)	PEN (kg grain /kg N uptake)	NHI (%)	AEP (kg grain /kg P applied)	PEP (kg grain /kg P uptake)	PHI (%)
Cropping systems						
Pearlmillet sole	14.86	15.15	54.93	0.58	0.64	37.57
Pigeonpea sole	7.165	7.66	38.61	0.21	0.47	45.61
Pearlmillet + pigeonpea	27.73	18.38	50.87	1.03	1.09	46.41
L.S.D. (P = 0.05)	3.88	3.66	2.57	0.20	0.75	2.86
Transpiration suppressants						
Control	16.72	14.27	47.94	0.63	0.80	43.40
Cycocel	16.42	12.93	48.10	0.57	0.68	43.20
PMA	16.61	13.81	48.37	0.62	0.71	43.01
L.S.D. (P = 0.05)	NS	NS	NS	NS	NS	NS
Fertility levels						
Control	0.00	0.00	48.93	0.00	0.00	45.62
25 kg N + 8.6 kg P/ha	16.89	15.12	48.66	0.64	0.98	42.55
50 kg N + 17.2 kg P/ha	18.21	19.18	47.12	0.66	0.96	42.18
25 kg N + 8.6 kg P/ha + BF	31.25	20.61	47.84	1.13	0.99	42.44
L.S.D. (P = 0.05)	2.96	2.47	NS	0.14	0.21	1.95

* NS, BF and PMA represent non significant, biofertilizers (*Azotobacter* and phosphate solubilizing bacteria) and phenyl mercuric acetate, respectively. AEN and AEP; PEN and PEP and NHI and PHI representing agronomic efficiency of N and P, physiological efficiency of N and P and harvest index of N and P, respectively.

Table 3. Effect of cropping systems, transpiration suppressants and fertility levels on economics and crop profitability (pooled data of two years).

Treatment	Economics				Crop profitability (Rs/ha/day)
	Cost of cultivation ($\times 10^3$ Rs/ha)	Gross returns ($\times 10^3$ Rs/ha)	Net returns ($\times 10^3$ Rs/ha)	B:C ratio	
Cropping systems					
Pearlmillet sole	13.99	39.08	25.09	1.79	269.74
Pigeonpea sole	15.42	47.09	31.67	2.06	221.46
Pearlmillet + pigeonpea	16.18	54.80	38.62	2.39	270.09
Transpiration suppressants					
Control	13.76	45.49	31.73	2.31	253.24
Cycocel	14.43	47.33	32.30	2.15	257.82
PMA	16.30	48.16	31.36	1.87	250.23
Fertility levels					
Control	14.32	39.51	25.19	1.76	201.16
25 kg N + 8.6 kg P/ha	15.22	45.53	30.31	1.99	241.62
50 kg N + 17.2 kg P/ha	15.98	52.62	36.64	2.29	292.38
25 kg N + 8.6 kg P/ha +BF	15.27	50.32	35.05	2.30	279.90

(*Azotobacter* + PSB) with 25 kg N + 8.6 kg P/ha enhanced the net returns by `4.41 × 10^3 ha^{-1} over only 25 kg N + 8.6 kg P ha^{-1}. Application of 50 kg N + 17.2 kg P ha^{-1} increased the mean net returns and B:C ratio by 49.34 and 36.58, 21.66 and 17.15 and 5.18 and 2.18% over control, 25 kg N + 8.6 kg P ha^{-1} and 25 kg N + 8.6 kg

P ha^{-1} + BF, respectively.

The highest and 45% more crop profitability was also found in same treatments over control. These findings are in line with those of Ghosh et al. (2006).

DISCUSSION

Soil water deficits that frequently occur during crop growth because of erratic monsoon and non-uniform distribution of rain reduce yield in traditional production systems (Gupta and Rajput, 2001). In 2009, the crops faced initial water stress due to delayed onset of monsoon and at later stages, frequency and severity of water deficit increased from September to December. Though, adequate precipitation occurred in July to September (Figure 1a and b). The rainfall during growing season (July to December) in 2009 was 493 mm against 776 mm in 2010 (Figure 1a and b). Therefore, yield of crops in 2009 was generally low compared to 2010. The higher profile soil water content in 2009 was related to less extraction of soil water owing to low biomass production. Our results clearly indicated that under uneven and deficit rainfall situation, pearlmillet/pigeonpea intercropping is superior to conventional pearlmillet or pigeonpea monoculture production in the semi-arid region of India, and minimizes the risk of failure of monoculture (pearlmillet/pigeonpea) and provides maximum profit. The pearlmillet/pigeonpea intercropping system maintained comparatively lower water storage than sole cropping suggesting higher soil water extraction. Thus, higher profit in the intercropping system may be attributed to more extraction of soil water, high yield and high market price of pigeonpea as a bonus in intercropping system.

The duration of a crop in an intercropping system plays a useful role in achieving yield advantage. Higher yield advantage can be expected when the maturity period of the component crops are different (Nambiar et al., 1983). In pearlmillet/pigeonpea intercropping system, associated crops had different maturity periods and hence competition was less. Figure 2 show that pearlmillet was harvested when the associated pigeonpea attained its grand growth period (85-90 DAS) and competition with associated pigeonpea was not considerable. Pearlmillet being a fast growing crop, utilized resources, particularly the soil water due to rainfall received during June to August (Figure 1) early in the season. Pigeonpea utilized resources later in the season and being a deep-rooted crop; it continued to grow by extracting residual soil moisture from deeper soil layers. Crop complementarities or supplementarities determine the magnitude of competition.

In the present study, though there was a reduction in yield of intercrops, but, higher PEY and LER value in intercropping system indicated a definite advantage compared to monoculture yields apparently because of crop complementarities. Our results indicated that use of transpiration suppressants was advantageous in rainfed India during drought situations to increase yield significantly. Myaka et al. (2006) also emphasised the significantly higher yield in intercropping under non-irrigated environment than sole cropping. Tetarwal and Rana (2006) reported that yield from transpiration suppressants spray in pearlmillet were greater than control in limited moisture condition. CPR is defined as the productivity of an intercrop per unit area of ground area compared with that expected from sole crops sown in the same proportions. A value of CPR greater than unity implies an intercrop advantage and a value less than unity implies the intercrop disadvantages.

In our study, there were significant differences among the treatments. The higher value of CPR was recorded in PMA over other transpiration suppressants treatment. In all treatments, it was higher than unity in pearlmillet/pigeonpea intercropping system, showing intercrop advantage. This indicates that in order to improve the mixture productivity of the intercropping system, efforts should be geared towards improving the productivity of the dominated components as sole cropping. These findings are in line with those of Ghosh et al. (2006). Among N and P fertilization, highest value of PEY, LER and CPR was recorded in pearlmillet/pigeonpea intercropping system with the application of 50 kg N + 17.2 kg P/ha followed by 25 kg N + 8.6 kg P/ha + *Azotobacter* + PSB than other fertility levels. In all fertility treatments, CPR were higher than unity in pearlmillet/pigeonpea intercropping system than sole cropping, showings intercrop advantage. This indicates that in order to improve the mixture productivity of the intercropping system, efforts should be geared towards improving the productivity of the dominated components as sole cropping. These findings are in line with those of Padhi et al. (2010).

The ARUE of intercropping system was higher over sole pearlmillet and pigeonpea. The grain yields of both crops were proportionately higher under intercropping than the amount of water used for biomass production. Pearlmillet intercropped with pigeonpea utilized more water for evapotranspiration and metabolic activities. But, in intercropping system, both the intercrops drew more moisture for dry matter production than sole pigeonpea which resulted in higher rate of moisture use in intercropping system than sole pigeonpea. These findings are in accordance with Kachhadiya et al. (2009) and Yi et al. (2010). The maximum and minimum AE and PE of N and P were recorded with pearlmillet/pigeonpea intercropping system than that of their sole cropping. It was due to more uptake of N in intercropping system and lesser uptake in either of sole crop that is, pearlmillet or pigeonpea, which resulted into more yield per unit of N uptake. Transpiration suppressants did not significantly affect the AE and PE of N and P. It might be due to almost same amount of N uptake among all the transpiration suppressant treatments. N and P fertilization had significant effect on AE and PE of N and P of pearlmillet and pigeonpea crops. Application of 25 kg N + 8.6 kg P ha^{-1} + BF (*Azotobacter* + PSB) recorded significantly higher AE and PE of N and P in pearlmillet and pigeonpea crops over other fertility levels. This was due to additional N_2 fixation by biofertilizers which ultimately made more N available to the plant for uptake and thus there were more AEN and PEN. These findings are in accordance with Myaka et al. (2006) and Singh et al. (2010).

Pearlmillet sole cropping significantly recorded higher NHI followed by intercropping system and the minimum under sole cropping of pigeonpea, while higher PHI was recorded under intercropping system. It might be due to the maximum N and P content and their uptake under pearlmillet sole cropping as compared to sole cropping of pigeonpea. Transpiration suppressants and N and P fertilizations had no-significant effect on NHI of pearlmillet and pigeonpea crops. Pearlmillet/pigeonpea intercropping system gave higher net returns and B:C ratio as compared to either of sole cropping due to more combined yield with nearly similar cost of cultivation (Kachhadiya et al., 2009). Cycocel spray gave higher net returns and net returns per rupee invested than other treatment in limited moisture conditions. This was due to the increased yield with low cost in these treatments. These findings are in accordance with Rana et al. (2009). The maximum net returns was recorded with application of 50 kg N + 17.2 kg P ha^{-1} followed by 25 kg N + 8.6 kg P ha^{-1} + *Azotobacter* + PSB, while B:C ratio was more under 25 kg N + 8.6 kg P ha^{-1} + *Azotobacter* + PSB than other treatment. Higher net returns with combined N and P fertilization were due to higher grain yield. These findings are in accordance with Ghosh et al. (2006).

Conclusion

Based on two year results, it is concluded that consistently higher productivity and profitability from pearlmillet/pigeonpea intercropping could be obtained. The risk of low yields or crop failure associated with the prevailing traditional monoculture production system, under drought of unpredictable intensity and duration could be reduced, especially when transpiration suppressants is used under moisture stress conditions. Use of transpiration suppressants (PMA and cycocel) was found useful in year of low rainfall and dry spells; while, there is no need of transpiration suppressant spray in good rainfall condition to realize optimum yield of pearlmillet/pigeonpea intercropping system. Application of 50 kg N + 17.2 kg P ha^{-1} was found to be more productive over other fertilizer doses.

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