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Resources utilization in maize (*Zea mays*)-based intercropping system under rainfed condition

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ABSTRACT

A field experiment was conducted during rainy (*kharif*) seasons of 2007 and 2008 at Rajasthan College of Agriculture, Udaipur to work out radiation and rain water-use efficiency under various maize (*Zea mays* L.)-based intercropping systems. The treatments consisting of sole maize, sole blackgram (*Vigna mungo* L.), sole greengram (*Vigna radiata* L.), sole soybean [*Glycine max* (L.), Merr.], maize + blackgram (2:2), maize + greengram (1:1) and maize + soybean (1:1). The results indicated that radiation-use efficiency of sole maize varied from 0.47 to 0.92 g/MJ, whereas, in intercropping system with blackgram, greengram and soybean, it varied from 0.55 to 1.03 g/MJ, 0.69 to 1.03 g/MJ and 0.79 to 1.32 g/MJ, respectively. The highest radiation-use efficiency of 1.32 g/MJ was recorded under maize + soybean (1:1) intercropping, followed by maize + greengram and maize +blackgram (1.03 g/MJ). The highest rain water-use efficiency was recorded under maize + blackgram (15.56 kg grain/ha/mm), followed by maize + soybean (14.08 kg grain/ha/mm) and maize + greengram (13.52 kg grain/ha/mm). The highest maize grain equivalent yield of 5.381 and 4.948 tonnes/ha was recorded under maize + blackgram (2:2) intercropping during 2007–2008, respectively which was significantly superior over sole maize by 21.1 and 12.4%.

Key words: Intercepted photosynthetically active radiation, Intercropping, Radiation-use efficiency, Rain water-use efficiency

Rajasthan ranks first in respect of maize (*Zea mays* L.) area, where in this crop occupies 10.50 lac ha area with production of 19.14 lac tones and productivity of 18.58 q/ha. (Government of Rajasthan 2010). In southern Rajasthan, maize and legumes are staple and supplementary crops, respectively and intercropping being more remunerative. It has been practised by the small- and medium-scale farmers. Blackgram, greengram, cowpea and pigeonpea are important legumes grown in intercropping. Cereal and legume intercropping is recognized as a common cropping system throughout tropical developing countries (Ofori and Stern 1987). Canopy structures and root systems of cereal crop are generally different from those of legume crops (Willey 1990). The formative rate is comparatively greater in cereal crops than in legume crops (Willey 1990). In cereal-legume intercropping, cereal crops form relatively higher canopy structures than the legume crops and the roots of the cereal crops grow to a greater depth than those of legume crops. This indicates that the component crops probably have differing spatial and temporal use of environmental resources such as radiation, water and nutrients (Willey 1990). Therefore, this cropping system may help improve productivity of low external input farming, which depends largely on natural resources such as rainfall and fertility.

Several studies have indicated that the risk to the small-scale farmers in multiple cropping is lower than in sole cropping. The mechanisms of the microclimate modification are, however, not scientifically clear. Therefore, this study has been initiated to clarify some of the micro climate modifications in maize-legume intercropping system, namely crop radiation interception and rain water use. The aim of this study is to assess the productivity of maize legume intercropping in region, considering crop radiation and rain water utilization.

MATERIALS AND METHODS

The field experiment was conducted during rainy (*kharif*) season of 2007 and 2008 at Instructional Farm, Rajasthan College of Agriculture, Udaipur (Rajasthan), situated at 24° 34’ N latitude, 73° 42’ E longitudes and altitude of 582.2 m above mean sea level. The mean annual rainfall of the centre was 600.8 mm, most of which (91.5%) is contributed by south west monsoon during June to September. The soil was clay loam in texture having 240.0 kg N, 20.5 kg P_2O_5/ha and 296.5 K_2O kg/ha with *p*H 8.2 and EC of 1.12 ds/m at 25°C. The

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experiment consisted of seven treatments, viz sole maize (*Zea mays* L.), sole blackgram (*Vigna mungo* L.), sole greengram (*Vigna radiata* L.), sole soybean [*Glycine max* (L.) Merr.], maize + blackgram (2:2), maize + greengram (1:1) and maize + soybean (1:1). The experiment was laid out in a randomized block design with four replications. The rows were oriented east-west. The crops were sown in the first week of July during 2007 and 2008. The rainfall during the crop season was 272.6 mm in 2007 and 559.7 mm in 2008. The 'Pratap Makka 5' maize, 'RBU 38' blackgram,'K 851' greengram and 'JS 335' soybean were used as test crop. All the sole crops were supplied with recommended dose of fertilizer, and in intercropping treatments, only the recommended rate of fertilizer was used for maize, ie 90 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha. Decagon ceptometer (Decagon Devices, Inc.; model LP 80, Pullman, WA) was used to measure incoming transmitted and reflected photosynthetically active radiation (PAR). Measurement of the photosynthetically active radiation was recorded at 45, 60 and 75 days after sowing at hourly interval from 11.00 to 14.00 hours daily. Total radiations were recorded with the help of Campbell's Automatic Weather Station installed near the experimental site. The incident photosynthetically active radiation was measured by facing the ceptometer (0.9 m) sky wards above the canopy. The transmitted photosynthetically active radiation (TPAR) was measured by placing the ceptometer on the ground across the rows. The intercepted photosynthetically active radiation (IPAR) was calculated by using formula

$$IPAR = PAR - TPAR$$

An inverted ceptometer located above the canopy measured reflected photosynthetically active radiation. Periodic samples of dry mater were taken. The light-use efficiency was calculated by using following formula.

APAR (Absorbed photosynthetically active radiation) was calculated as per equation proposed by Gallo and Daughtry (1986).

$$APAR = (IPAR + RPARs) – (TPAR + RPARc)$$

Where, IPAR is the incident PAR above the canopy, TPAR is the transmitted PAR through the crop canopy, RPARs and RPARc are reflected PAR from soil and crop surface, respectively. Hourly temperature and relative humidity at ground and 45 cm height were recorded with the help of automatic thermometer and humidity meter (Model CEM-DT-615) in different treatment. The selling price of maize, blackgram, greengram and soybean were ₹ 740, 3000, 2800 and 1650/q, respectively.

RESULTS AND DISCUSSION

Intercepted photo-synthetically active radiation

The intercepted photosynthetic active radiation (IPAR%) at different stages of the crop are presented in Table 1. Data show that intercrops intercepted more photosynthetic active radiation than the sole crops. The intercepted photosynthetic active radiation was the highest at 60 days after sowing in all treatments. The intercepted photosynthetic active radiation under maize + blackgram and maize + greengram was more than the sole maize and sole component crops at successive growth stages. However, sole soybean intercepted more photosynthetic active radiation as compared to maize + soybean and sole maize at 75 days after sowing.

At 45 days after sowing, maximum radiation interception was recorded in maize + blackgram intercropping (85.5%) as against 67.0% in sole maize and 81.5% in sole blackgram. Maize + blackgram intercepted more photosynthetically active radiation as compared to maize + greengram intercropping at each growth stages. The highest intercepted photosynthetically active radiation (91.5%) was recorded in maize + soybean intercropping at 60 days after sowing. After 60 days, radiation interception started to decrease in all treatments because of reduction of canopy vigour. Similar results were also observed by Gouranga (2005) in different intercropping systems.

Radiation-use efficiency

Radiation-use efficiency (RUE) at different growth stages of the crop are presented in Table 1. Two years mean data show that among cropping systems, the intercropping had

Table 1 Intercepted photo-synthetically active radiation, radiation-use efficiency and rain water-use efficiency in various maize-based intercropping (mean of two years)

Treatment	Intercepted photo-synthetically active radiation (%)				Radiation-use efficiency (g/MJ)				Rain water-use efficiency (kg grain/ha/mm)
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS	
Maize	37.5	67.0	82.2	79.3	0.47	0.87	0.92	0.89	13.17
Blackgram	49.7	81.5	84.9	63.9	0.63	0.55	0.50	0.39	11.80
Greengram	46.3	78.9	78.1	61.4	0.50	0.49	0.51	0.37	4.83
Soybean	51.2	80.5	89.1	89.9	0.67	0.88	0.92	0.83	10.71
Maize + blackgram (2:2)	53.9	85.5	90.5	79.0	0.55	1.02	1.03	0.88	15.56
Maize + greengram (1:1)	49.1	82.1	85.4	79.4	0.69	0.97	1.03	0.82	13.52
Maize + soybean (1:1)	55.6	85.3	91.5	88.8	0.79	1.23	1.32	1.21	14.08
CD (*P*=0.05)	5.00	8.96	6.55	6.96	0.03	0.05	0.06	0.05	0.95

higher radiation-use efficiency than sole maize cropping at successive growth stages. Data further show that radiation-use efficiency in sole maize varied from 0.47 to 0.92 g/MJ. Whereas in intercropping with blackgram, greengram and soybean, it varied from 0.55 to 1.03 g/MJ, 0.69 to1.03 g/MJ and 0.79 to 1.32 g/MJ, respectively. The highest radiation use efficiency of 1.32 g/MJ was recorded in maize + soybean (1:1) intercropping, followed by maize + greengram (1.03 g/MJ) and maize + blackgram (1.03 g/MJ). Sole soybean recorded higher radiation-use efficiency (from 0.67 to 0.92 g/MJ) as compared to sole maize, blackgram and greengram. The lowest radiation-use efficiency was recorded under sole greengram, followed by blackgram. Tsubo *el al.* (2003) also reported higher radiation-use efficiency in intercropping systems as compared to sole crop.

Rainwater-use efficiency

The yield of all the crops/crop combinations was converted into maize grain equivalent yield and rainwater-use efficiency in terms of maize grain equivalent yield produced/mm of rainwater received during crop growth period was computed. It was found that among different intercropping combinations, maximum rainwater-use efficiency was noted in maize + blackgram (15.56 kg grain/ha/mm), followed by maize + soybean (14.08 kg grain/ha/mm) and maize + greengram (13.52 kg grain/ha/mm). Among sole crops, maize recorded the highest rainwater-use efficiency (13.17 kg grain/ha/mm), followed by sole blackgram (11.80 kg grain/ha/mm). The lowest rainwater-use efficiency of 4.83 kg grain/ha/mm was recorded in sole greengram (Table 1). Gouranga (2005) also reported higher rainwater-use efficiency in intercropping systems as compared to sole crops.

Drymatter accumulation

Drymatter accumulation at 15 days intervals are presented in Table 2. Data show that intercropping systems produced significantly more dry matter as compared to sole crops during the entire growth period. The maximum dry matter observed at 75 days after sowing in sole maize, sole soybean and maize + soybean. However, blackgram, greengram and maize+blackgram and maize+greengram produced maximum dry matter accumulation at 60 days after sowing. Maize + soybean intercropping accumulated highest dry matter at each stage which was superior over rest of cropping systems.

Yield and maize grain equivalent yield

Maize and intercropping yield and maize grain equivalent yield are presented in Table 2. Data show that variation was observed in grain yield of intercrops due to intercropping system. The maize grain equivalent yield varied significantly due to different intercrops during both years. Grain yield of maize was significantly reduced by 17.3 and 12.6% during 2007 and 2008, respectively in maize + soybean intercropping as compared yield that obtained in sole maize.

Table 2 Dry matter accumulation (g/m^2), grain and maize grain equivalent yield under different intercropping systems

Treatment	Dry matter accumulation (g/m^2) (mean of two years)				Yield (tonnes/ha)				Maize grain equivalent yield (tonnes/ha)			
					Main crop		Intercrop		Intercrop			
	30 DAS	45 DAS	60 DAS	75 DAS	2007	2008	2007	2008	2007	2008	2007	2008
Maize	91.05	398.75	701.05	800.10	4.44	4.40			4.44	4.40		
Blackram	146.75	311.40	370.10	282.20			1.04	0.85	4.23	3.45	4.23	3.45
Greengram	110.25	275.10	341.05	274.75			0.47	0.34	1.78	1.31	1.78	1.31
Soybean	158.60	498.95	803.90	897.35			1.65	1.54	3.68	3.44	3.68	3.44
Maize + blackgram (2:2)	140.70	615.55	830.45	828.45	4.17	4.12	0.29	0.20	5.38	4.94	1.20	0.82
Maize + greengram (1:1)	152.10	555.85	757.50	705.40	4.23	3.84	0.13	0.08	4.74	4.16	0.50	0.32
Maize + soybean (1:1)	204.90	726.00	1101.25	1279.50	3.67	3.84	0.48	0.38	4.76	4.69	1.08	0.85
CD (*P*=0.05)	8.41	32.31	45.07	46.01	0.44	0.43			0.63	0.44	1.24	0.28

Table 3 Competitive relationship of various intercropping systems (mean of two years)

Treatment	LER	Aggressivity	RCC			MAI	ATER
			Ka	Kb	K		
Maize + blackgram (2:2)	1.21	0.68	15.14	0.355	5.41	6891.5	1.41
Maize + greengram (1:1)	1.17	0.65	13.51	0.365	5.11	6293.5	1.42
Maize + soybean (1:1)	1.12	0.58	5.85	0.375	2.13	3789	0.99

LER, Land equivalent ratio; RCC, relative crowding Coefficient; MAI, monetary advantage index; ATER, area time equivalent ratio

In 2008, maize grain yield was also significantly reduced in maize + greengram intercropping by 12.7% as compared sole maize. However, grain yield of maize recorded under maize + blackgram was at par with sole maize during both the years. With regards to intercropped, grain yield of intercrop was reduced as compared to their respective sole crop yield during both the years. The maximum grain yield of 1.653 and 1.545 tonnes/ha was recorded with sole soybean in 2007 and 2008, respectively. The highest grain equivalent yield of 5.381 and 4.948 tonnes/ha during 2007 and 2008, respectively was recorded in maize + blackgram (2:2) intercropping which was significantly superior over sole maize by 21.8 and 12.4%, respectively. The lowest maize grain equivalent yield of 1.785 and 1.314 tonnes/ha was recorded in sole greengram during 2007 and 2008, respectively. Among the sole intercrops, blackgram gave the highest maize grain equivalent yield (4.232 and 3.456 tonnes/ha in 2007 and 2008, respectively) during both the years which was significantly superior over other sole intercrops and intercrops in intercropping systems. Among the intercropping system, maximum grain equivalent yield of 1.204 tonnes/ha was recorded by blackgram under maize + blackgram (2:2) in 2007 which was at par with maize grain equivalent yield under maize + soybean but significantly superior over maize grain equivalent yield under maize + greengram. In 2008, maximum maize grain equivalent yield of intercrop was recorded under maize + soybean (0.85 tonnes/ha) which was significantly superior over maize grain equivalent yield of greengram under maize + greengram (5.11) (0.325 tonnes/ha) but at par with maize grain equivalent yield of blackgram under maize + blackgram (0.83 tonnes/ha).The results are in conformity with the findings of Padhi and Panigrahi (2006).

Competition index

Various competitive relationship of intercropping were computed and presented in Table 3. The mean land equivalent ratio in two years ranged from 1.12 to 1.21, indicating biological sustainability of intercropping over sole cropping. Maize + blackgram (2:2) recorded the highest land equivalent ratio (1.21), followed by maize + greengram (1.17), indicating that former system as a whole was more productive, giving 16.8% more yield. This indicates that paired row intercropping was more efficient in utilizing the natural resources than sole cropping of the component crops.

Aggressivity index

Maize + blackgram (2:2) recorded the highest aggressivity index (0.68), followed by both maize + greengram and maize + soybean (0.63 each) than other intercropping system (Table 3). The increase in number of rows of maize and blackgram in between increased the competition between plants and thereby resulted in the increase in dominance power of maize. (Verma *et al.* 2005) also recorded almost similar finding in sorghum + pigeonpea intercropping.

Relative crowding coefficient

Maize + blackgram recorded the highest relative crowding coefficient (5.41), followed by maize + greengram (5.11) and maize + soybean (2.13). In all intercropping system relative crowding coefficient value recorded more than one showing better utilization of land with intercropping than sole crops (Table 3).

Monetary advantage index

The maximum monetary advantage index of 6891.5 was

Table 4 Temperature (°C) and relative humidity (%) profile at 62 days after sowing in maize based intercropping system (2008)

	Temperature (°C)									
	11 AM		12 PM		1 PM		2 PM		3 PM	
Treatment	Ground	45 cm	Ground	45 cm	Ground	45 cm	Ground	45 cm	Ground	45 cm
Maize	30.2	27.1	32.9	32.4	33.4	33.6	32.7	32.6	34.0	34.4
Blackgarm	24.7	23.3	32.2	32.5	33.8	34.2	32.6	32.7	33.0	34.6
Greengram	25.2	24.5	32.5	32.4	33.5	33.9	33.6	34.0	33.8	34.0
Soybean	23.7	23.2	32.4	32.2	33.2	33.2	31.2	32.5	33.5	33.8
Maize+blackgram	20.5	19.2	30.2	30.8	32.1	32.4	31.5	32.0	32.5	33.2
Maize+greengram	21.1	20.5	31.2	31.6	32.5	32.8	33.5	34.0	32.9	33.8
Maize + soybean	21.1	20.1	32.8	32.9	34.2	34.0	33.0	33.4	34.9	35.2
Relative humidity (%)										
Maize	32.5	57.2	61.4	55.4	57.3	53.9	58.3	54.2	57.8	53.8
Blackgarm	66.6	53.3	66.0	56.0	58.4	52.0	60.1	58.5	58.5	51.2
Greengram	67.7	54.2	65.0	57.0	56.0	54.1	56.9	55.5	58.6	51.7
Soybean	66.0	63.5	64.5	58.7	57.8	53.8	60.7	53.3	60.0	55.2
Maize+blackgram	67.4	61.0	67.0	56.5	54.4	51.1	58.3	54.8	53.3	51.6
Maize+greengram	68.5	61.2	65.4	57.5	59.2	54.5	58.3	50.8	55.9	53.2
Maize +soybean	65.4	62.2	66.5	58.5	53.5	52.2	60.2	55.4	58.7	53.6

recorded with maize + blackgram intercropping, followed by maize + greengram (6293.5) and maize+ soybean (3789).

Area-time equivalent ratio

Maize + blackgram and maize + greengram recorded area time equivalent ratio value more than one indicating better land utilization efficiency than their sole crops (Table 3). Maize + soybean intercropping recorded area time equivalent ratio value less than one (0.99). This shows that soybean is not suitable for intercropping in maize under Udaipur conditions.

Temperature and relative humidity profile

Data (Table 4) show that at 11 AM, higher temperature and relative humidity were observed at ground level than at 45 cm height in all treatments. It was observed that sole maize recorded higher temperature at 11 AM than intercropping. However, the reverse trend was observed with respect to relative humidity. There were no much variations in temperature at ground level and 45 cm height, from noon to 3 PM. However, relative humidity was different at also heights from noon to 3 PM. The relative humidity was decreased at 45 cm height in all treatments as compared to that recorded at ground level.

All intercropping systems proved better for utilizing resources as compared to sole crops. The highest radiation use efficiency was recorded under maize + soybean (1:1) intercropping whereas maize + blackgram (2:2) intercropping recorded highest rain water-use efficiency and maize grain equivalent yield.

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