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Research Communication

Effect of nutrient-and moisture-management practices on crop productivity, water-use efficiency and energy dynamics in rainfed maize (*Zea mays*) + soybean (*Glycine max*) intercropping system

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ABSTRACT

A field experiment was conducted during the rainy season of 2012 at New Delhi, to study the effect of cropping systems, nutrient-and moisture-management practices on productivity and water-use efficiency (WUE) of maize (*Zea mays* L.) + soybean [*Glycine max* (L.) Merr.] intercropping system under rainfed conditions. Treatment comprised 2 cropping systems (maize sole and paired row planting maize + soybean) and 2 moisture-management practices (control and Kaolin 6% + organic mulch) in main plots, and 4 nutrient levels, viz. control, 50% recommended dose of fertilizer (RDF) + 50% recommended dose of nitrogen (RDN) through FYM, 50% RDF + 50% RDN through vermicompost and 100% RDF in sub–plots of split–plot design. However, maize-equivalent yield (3.47 t/ha) was the highest under paired row planting maize + soybean. The 100% RDF registered significantly higher grain yield (2.99 t/ha) of maize over control (2.03 t/ha) and 50% RDF+ 50% RDN through FYM (2.74 t/ha), 50% RDF+ 50% RDN through vermicompost (2.85 t/ha). Paired-row planted maize + soybean also registered more consumptive use (CU) of water (331.7 mm) than sole maize (324.6 mm). Moisture-conservation practices showed considerable variation in CU. Maximum water-use efficiency (WUE) was recorded with Kaolin 6% + organic mulch. Fertility levels also influenced the CU with highest value with100% RDF (330 mm) followed by 50% RDF + 50% RDN through vermicompost (329.1 mm). Significantly higher WUE was observed under paired row planted maize + soybean (10.9 kg/ha–mm). Cropping systems altered the soil-moisture extraction pattern in all the 3 layers (0–15, 15–30 and 30–45 cm). Energy output, energy input and energy-use efficiency was higher in paired-row planted maize + soybean, Kaolin 6% + organic mulch and 100% RDF than their respective counterparts.

Key words : Energetics, Intercropping, Maize, Soybean, Maize-equivalent yield, Paired row planting, Water-use efficiency

In India, maize and soybean are the 2 major crops grown under rainfed eco-systems during rainy (*kharif*) season, but the productivity of these crops under rainfed areas need to be improved using appropriate nutrient-and moisture-management practices. With its average yield around 2.5 t/ha, maize ranks first among cereals. Currently, it is cultivated over 8.67 million ha with 21.6 million tonnes production, having an average productivity of 2,435 kg/ha. On the other hand, soybean is cultivated over 9.95 million ha with 12.57 million tonnes production, having an average productivity of 1,264 kg/ha.

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Soybean is considered as an ideal crop for intercropping with maize owing to its comparative tolerance for shade and drought, efficient light utilization and less competitiveness for soil moisture. Paired-row technique is simple way of exploiting land resources to harness the maximum yield advantage in intercropping system. Sole cropping of maize under limited irrigated condition is not viable due to delayed monsoons accompanied with prolonged intermittent dry spell (Choudhary and Suri, 2014). Nutrient management plays key role in sustaining the productivity of this system. The cereal + legume intercropping system has still not been understood adequately as compared to sole cropping in terms of system efficiency, more so regarding the concept of nutrient management where both crops have different growth habits and input requirements. Soybean is an energy rich crop and hence the requirement of major nutrients including secondary and micronutrients is high for soybean (Suri and Choudhary, 2013). In order to boost the productivity of rainfed maize and soybean, various studies have been carried out on nutrient-and moisture-management separately but limited work has been done on nutrient and moisture management in maize + soybean as intercrops under rainfed conditions. Therefore, a field experiment was conducted to study the effect of nutrient-and moisture-management practices on productivity, water-use efficiency, moisture-extraction pattern and energy dynamics in maize + soybean intercropping system.

The field experimentation was carried out during the rainy season (*kharif*) 2012 at the research farm of Indian Agricultural Research Institute, New Delhi (28°40' N and 77°12' E, 229 m above mean sea-level). The climate of above experimental farm is sub-tropical semi-arid with mean annual evaporation of 850 mm, and average annual rainfall of 650 mm, 80% of which is received through ‘South–West Monsoons’ during July–September, and the rest is received during the ‘Western Disturbances’ from December to February. The rainfall received during the crop-growing period from July to October was 416 mm. The experimental soil was sandy loam, having pH 8.2, low in organic C (0.3%) and available nitrogen (145 kg/ha), medium in available P (11.4 kg/ha) and available K (186.70 kg/ha). The treatment comprised of 2 cropping systems (maize sole and paired row planting maize + soybean) and 2 moisture-management practices (control and Kaolin 6 % + organic mulch) in main plots, and 4 nutrient levels [control, 50% recommended dose of fertilizer (RDF) + 50% recommended dose of nitrogen through FYM, 50% RDF + 50% RDN through vermicompost and 100% RDF] in sub-plots replicated thrice in split-plot design. The statistical analysis was done (Gomez and Gomez 1984). The 100% RDF for rainfed maize was NPK @ 80:40:40 kg/ha, while no NPK was added to soybean intercrop. Half N dose in 100% RDF treatment was applied through urea at time of sowing and full P and K dose as basal as per treatments through diammonium phosphate and murate of potash, respectively. The FYM and vermicompost were applied as per treatments 15 days before crop sowing. Remaining N was applied at 45 days after sowing (DAS) as top-dressing. ‘PEHM 2’ and ‘PS 1347’ varieties of maize and soybean, respectively, were used in experiment. Crop sowing was done on 11 July 2012. Maize seeds were sown @ 25 kg/ha by *kera* (dropping the seeds in furrows behind the plough). Spacing between rows in sole maize was kept at 60 cm. While in between rows of paired-row planted maize spacing is 45/90 cm. Harvesting of maize and soybean crops was done as soon as the grain matured using sickles after leaving border area from all the corners of each plot. The crop yields were expressed as maize-equivalent yield (MEY).

Soil-moisture extraction was worked out from 3 different layers, viz. 0–15, 15–30 and 30–45 cm separately during the growing seasons. The total soil-moisture depleted (SMD) from root zone (0–45 cm) was estimated by summing up the depletion from each layer. Gravimetric method was used for soil moisture study. The energy input referred to the both renewable and non-renewable energy. Renewable energy included manual, animal/bullock, seed, manure etc. whereas non-renewable energy encompassed chemical fertilizer, tractor, diesel, electricity, machinery etc. Total physical output referred to both grain and byproduct. For estimation of energy input and output (expressed in MJ/ha) for each items of input and agronomic practices equivalent were utilized as suggested by Mittal and Dhawan (1988):

Energy-use efficiency = Energy output (MJ/ha)/energy input (MJ/ha)

Net energy (MJ/ha) = Energy output (MJ/ha)–energy input (MJ/ha)

There was significant difference in yield of maize as influenced by cropping system. Paired row planted maize gave less yield than to normal planting because only 4 lines of maize in paired row planting while 6 rows in case of sole maize (Table 1). Moisture-conservation practices resulted in marked improvement in grain yield of maize, kaolin 6% + organic mulch having maximum numerical value in respect of grain yields. Different fertility levels also influenced the grain yield of maize. The highest grain yield was recorded with 100% RDF, followed by 50% RDF + 50% RDN through vermicompost which was at par with 50% RDF + 50% RDN through FYM and lowest in control. Soybean seed yield was significantly influenced due to moisture-conservation practices. Moisture conservation practices brought about a marked improvement in grain yield of soybean, kaolin 6% + organic mulch having maximum numerical value in respect of grain yield of soybean. The results confirm the findings of Suri and Choudhary (2013). The highest grain yield was recorded with 50% RDF + 50% RDN through vermicompost followed by RDF 50% through FYM and lowest in control. The results are in accordance with the findings of Suri *et al*. (2006) and Kumar and Rana (2007).

The maize + soybean inter-cropping system showed measurable improvements in maize-equivalent yield (MEY) over sole maize (Table 1). Maize intercropped with soybean recorded significantly higher MEY than sole maize. The higher MEY in intercropping treatment was owing to almost similar yield of maize to that of its sole stand, and an additional yield of soybean as a bonus in inter-cropping system. The results are in accordance with findings of Kumar and Rana (2007). Different moisture-management practices showed remarkable improvement in MEY. Kaolin 6% recorded the maximum MEY. This might be attributed to the availability of more moisture saving in kaolin 6% spray + organic mulch for longer time for proper growth and development of crops. The application of 100% RDF enhanced the MEY over the control. This might be owing to increase in economic yield of both the component crops with nutrient application (Suri and Choudhary, 2012, 2013).

Paired-row planted maize + soybean recorded more consumptive use (CU) of water than sole maize. Moisture-conserving practices exhibited considerable CU variation. The maximum CU was recorded with kaolin 6% + organic mulch (Table 2). Fertility levels also considerably influenced the CU of water. The highest CU of water was recorded with100% RDF, closely followed by 50% RDF + 50% RDN through vermicompost, and 50% RDF + 50% RDN through FYM lowest with the control. Cropping systems markedly improved in water–use efficiency (WUE) of the crop in terms of MEY. Significantly higher WUE was observed under paired row planted maize + soybean compared to sole maize. Maize + soybean cropping system recorded higher WUE than sole maize. This might be due to the fact that grain yield of both crops were relatively higher than sole maize (Choudhary *et al.,* 2006). Rate of moisture use was higher in maize + soybean intercropping system than sole maize. It could be attributed to the fact that both the crops absorb more moisture for dry-matter production than sole maize which resulted in higher rate of moisture use in maize + soybean intercropping system than sole maize. The highest WUE was observed under kaolin 6% + organic mulch (9.23 kg/ha-mm) over the control. This might be attributed to the availability of more moisture through Kaolin 6% + organic mulch for longer time for proper growth, development and metabolic activity of the crops. These results confirm the findings of Ahlawat and Gangaiah (2010). Fertility levels showed marked variation in WUE in terms of MEY (Choudhary *et al*., 2006). Statistically higher WUE was recorded with 100% RDF closely followed by 50% RDF + 50% RDN through vermicompost and 50% RDF + 50% RDN through FYM, and minimum under the control. Highest WUE, CU and rate of moisture use were recorded at 100% RDF. This might be due to proportionately greater increase in maize yield owing to readily available NPK at initial maize growth (Choudhary *et al*., 2013).

Cropping systems also altered the soil-moisture extraction pattern in all 3 layers (0–15, 15–30, 30–45 cm) (Table 2). In 0–15 cm layer, maximum soil-moisture extraction was recorded with maize paired row planting maize + soybean, while in respect of 2 layers, viz. 15–30 and 30–45 cm, sole maize caused higher soil-moisture-extraction compared to maize paired raw planting maize + soybean (Choudhary *et al*., 2013). Crop extracted substantial soil moisture from top layer (0–15 cm) than 15–30 and 30–45 cm soil depths in both the systems with lowest in 30–45 cm soil profile. Moisture depletion from deeper layers by maize + soybean intercropping might be due to soil mois-

Table 1. Yield of maize and soybean as influenced by cropping systems, moisture-conservation practices and fertility levels

Treatment	Maize yield (t/ha)			Soybean yield (t/ha)	
	Grain	Stover	Biological	Seed	Biological
Cropping systems					
Maize sole	2.82	5.00	7.82	–	–
Maize PRP (45/90) + soybean	2.49	4.46	6.94	–	–
SEm±	0.02	0.040	0.045	–	–
CD (P=0.05)	0.07	0.14	0.16	–	–
Moisture conservation practices				–	–
Control	2.57	4.56	7.13	0.41	1.28
Organic mulch + 6% kaolin spray	2.74	4.90	7.64	0.45	1.43
SEm±	0.02	0.040	0.045	0.01	0.02
CD (P=0.05)	0.07	0.14	0.16	0.04	0.14
Fertility levels					
Control	2.03	3.84	5.87	0.39	1.25
50% RDF + 50% RDN through FYM	2.74	4.87	7.61	0.44	1.37
50% RDF + 50% RDN through VC	2.85	5.06	7.91	0.46	1.41
100% RDF	2.99	5.15	8.13	0.43	1.39
SEm±	0.02	0.064	0.056	0.01	0.03
CD (P=0.05)	0.05	0.19	0.16	0.03	0.09

RDF, Recommended dose of fertilizer; RDN, recommended dose of nitrogen; VC, vermicompost; PRP, paired row planting ture stress in upper 0–15 cm soil profile compelling roots to go deeper for moisture (Kumar and Rana, 2007). Fertility levels slightly influenced the soil-moisture extraction pattern. In 0–15 cm layer, the maximum soil-moisture extraction was recorded in the control. In the rest of the layers (15–30, 30–45 cm), there was higher soil-moisture extraction in 100% RDF; 50% RDF + 50% RDN through vermicompost over the control. These results are in close agreement with those of Ahlawat and Gangaiah (2010).

Cropping systems significantly influenced the energy-use efficiency (EUE) of maize and soybean (Table 3). The grain yield of maize was significantly influenced due to nutrient and moisture-management practices (Prusty *et al*., 1985). Energy output, energy input and EUE was more in paired-row planted maize + soybean over sole maize. Kaolin 6% + organic mulch recorded the maximum energy

Table 2. Effect of cropping systems, nutrient and moisture-management practices on consumptive use of water, water-use efficiency and moisture-extraction pattern of maize and soybean intercropping system

Treatment	System productivity (MEY) (t/ha)	Consumptive use (mm)	Water-use efficiency (kg/ha–mm)	Moisture-extraction pattern (%)		
				0–15 cm	15–30 cm	30–45 cm
Cropping systems						
Maize sole	2.82	324.6	6.88	53.1	24.5	22.4
Maize PRP (45/90) + soybean	3.30	331.7	10.86	52.5	25.5	22.2
SEm±	0.01	0.18	0.06	0.07	0.01	0.01
CD (P=0.05)	0.06	0.63	0.22	0.26	0.02	0.02
Moisture conservation practices						
Control	2.95	327.3	8.51	53.1	24.5	22.4
Organic mulch + 6% kaolin spray	3.17	327.0	9.23	52.5	25.5	22.2
SEm±	0.01	0.18	0.06	0.07	0.01	0.01
CD (P=0.05)	0.06	0.63	0.22	NS	0.02	0.02
Fertility levels						
Control	2.39	326.2	7.12	53.0	24.8	22.1
50% RDF + 50% RDN through VC	3.16	327.6	8.90	52.9	24.8	22.3
50% RDF + 50% RDN through FYM	3.28	329.1	9.59	52.9	24.8	22.3
100% RDF	3.40	329.7	9.86	52.6	25.6	22.3
SEm±	0.01	0.16	0.10	0.11	0.01	0.01
CD (P=0.05)	0.05	0.46	0.30	0.31	0.03	0.03

RDF, Recommended dose of fertilizer; RDN, recommended dose of nitrogen; VC, vermicompost; PRP, paired row planting.

Table 3. Effect of cropping systems, moisture management practices and fertility levels on energy-use efficiency of maize and soybean intercropping system

Treatment	Energy indices		
	Energy output ($\times 10^3$ MJ/ha)	Energy input ($\times 10^3$ MJ/ha)	Energy use efficiency
Cropping systems			
Maize sole	64.8	9.7	6.68
Maize PRP (45/90) + soybean	86.9	10.7	8.12
Moisture conservation practices			
Control	73.3	9.9	7.36
Organic mulch + 6% kaolin spray	78.34	10.5	7.44
Fertility levels			
Control	69.8	9.2	7.53
50 % RDF + 50 % RDN through FYM	74.2	9.7	7.60
50 % RDF + 50 % RDN through VC	78.7	11.2	6.98
100% RDF	80.7	10.7	7.50

RDF, Recommended dose of fertilizer; RDN, recommended dose of nitrogen; VC, vermicompost; PRP, paired row planting output, energy input and EUE over sole maize. Fertility levels significantly affected the energy output, energy input and EUE. The Maximum energy output, energy input and EUE were recorded with application of 100% RDF followed by 50% RDF + 50% RDN through FYM (Prusty *et al*., 1985).

Overall, paired-raw planted maize + soybean intercropping systems led to superior maize-equivalent (MEY) yield, water consumptive use, WUE, energy output, energy input and energy-use efficiency over the sole maize. Among the moisture-conservation practices, Kaolin 6% + organic mulch again realized higher MEY, consumptive use of water and WUE both under sole and intercropping system. Among fertility levels, MEY, consumptive use of water, WUE, and energy relations was superior with 100% RDF over other fertility levels.

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