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System productivity and profitability of sugarcane (*Saccharum* spp. hybrid complex) + grain amaranth (*Amaranthus hypochondriacus*) intercropping system

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ABSTRACT

Field experiments were conducted during 2003-04 and 2004-05 at Lucknow, to study performance of sugarcane (*Saccharum* spp. hybrid complex) + grain amaranth (*Amaranthus hypochondriacus* L.) intercropping at various planting geometries (sugarcane sole at 90 cm row spacing, amaranth sole at 45 cm row spacing, sugarcane + amaranth in 1:1 row ratio and sugarcane paired (45:135 cm) + amaranth 2 rows in 135 cm spacing in 2:2 row ratio) and nutrient levels (50% of the recommended dose of fertilizer-(RDF), 75% RDF, 100% RDF, 125% RDF, 150% RDF for the system. Significantly higher number of tillers (318.9 thousand/ha), plant height (324.9 cm), number of millable canes (120.9 thousand/ha), cane length (248.2 cm) and the cane yield (75.7 t/ha) were recorded in sugarcane planted in paired rows of 45:135 cm accommodating 2 rows of grain amaranth intercrop (2:2). The cane equivalent yield (94.6 t/ha), sugar yield (8.77 t/ha) and sugar equivalent yield (11.04 t/ha) were also the highest with this treatment which was, however, on par with sugarcane (90 cm) + amaranth (one row) system. Nourishing the crop with high doses of fertilizer (150% RDF) significantly increased the cane yield (89.2 t/ha) as well as cane equivalent yield (109.1 t/ha). Higher yield advantage (LER 1.92) was realized with sugarcane + amaranth (2:2) intercropping system followed by sugarcane + amaranth (1:1). Sugarcane + amaranth fertilized at 150% RDF fetched the highest net return (Rs 78,135/ha) and B: C ratio (3.14). It was concluded that 2 rows of grain amaranth can be intercropped in autumn sugarcane planted in paired rows (45:135 cm) with 150% RDF to achieve highest system productivity and profitability.

Key words: Amaranth, Intercropping, Nutrients, Planting, Profitability, Sugarcane

Sugarcane (*Saccharum* spp. hybrid complex) is major cash–cum-industrial crop of India planted in autumn, spring and summer under north Indian conditions. Area under autumn sugarcane is very low despite the fact that 15-20% higher yield and 0.5 units of more sugar recovery higher than spring crop. The wide space of inter-row 90 cm available between 2 rows of sugarcane, long duration for bud sprouting, initial slow rate of growth and its ability to compensate for any loss of tillers due to intercrop competition have helped in successful intercropping of grain legumes, oilseeds, potato and maize, in plant crop and forage legumes in winter initiated ratoon (Lal and Singh, 2004). The pulses like green gram and black gram have also been recommended as intercrop in spring sugarcane and ratoon (Singh and Ahlawat, 2005). The grain amaranth (*Amaranthus hypochondriacus* L.) is a potential multipurpose tropical and sub-tropical protein rich pseudocereal cultivated widely in India. It contains unsaturated lipids, dietary fibre and high quality protein. The value of amaranth as an intercrop in sugarcane could be recognized from the fact that it can be grown parallel to sugarcane in unutilized inter-row spaces without affecting or even sometimes promoting the growth of sugarcane. Observations indicated that intercropping of grain amaranth in autumn sugarcane exhibited effect on its growth and yield. However, the factors related to positive associability are rather not known. It could be associated with certain allelopathic effects, accordingly the population density of amaranth and fertilizer schedule in intercropping systems merit due consideration for investigation. For promoting the area under autumn planted sugarcane along with mid-season income generation, intercropping of grain amaranth, vis-à-vis matching agro-technique was necessitated. This communication deals with the modification of planting geometry to accommodate grain amaranth as an intercrop and the effect of higher level of crop nutrition on system productivity.

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MATERIALS AND METHODS

Field experiments were conducted for two consecutive years of 2003-04 and 2004-05 on two plant crop cycles at the Research Farm of Indian Institute of Sugarcane Research, Lucknow located at $26^0 50^I$ N latitude, $80^0 52^I$ E longitude and 111 m above mean sea level in central part of Uttar Pradesh falling in sub-tropical belt of sugarcane cultivation. The soil of experimental site is categorized in order inceptisol under the group Udic Ustochrepts, neutral in reaction (pH 7.4), low in organic C (0.34%) and available N (148.5 kg/ha), medium in available P (13.6 kg/ha) and K (212.3 kg/ha). The experimental field was sandy loam in soil texture (14.1 % clay, 22.6 % silt and 63.3 % sand). The climate of Lucknow is semi-arid, sub-tropical with dry hot summers (April - June) and cold winters (November - January). The average annual rainfall is 985 mm and nearly 85% of the total rainfall is received through north-west monsoon during second fortnight of June to September. The average monthly minimum and maximum temperatures fluctuate from 6.5 to 7.8 and 20.6 to 22.5^0C in winter and from 22.8 to 25.6 and 39.5 to 41.6^0C during summer, respectively. The experimental treatments consisted of 4 planting geometries (sugarcane sole at 90 cm row spacing, amaranth sole at 45 cm row spacing, sugarcane + amaranth in 1:1 row ratio and sugarcane paired (45:135 cm) + amaranth 2 rows in 135 cm spacing in 2:2 row ratio) and 5 nutrient doses (50% of RDF, 75% RDF, 100% RDF, 125% RDF, 150% RDF for the system). The recommended dose of N, P and K (RDF) for sugarcane was 150-26.2-49.8 kg/ha and for amaranth 60-17.5-49.8 kg/ha. Sugarcane 'CoS 94257' was planted in mid-October and sowing of amaranth 'Sidhpur - 1' was done after irrigating the field during both the crop cycles. Full amount of P and K fertilizers and $^1/_3$ N in sugarcane and ½ in amaranth were applied as basal. Remaining amount of the nitrogen was applied in 2 equal splits at initial and final stages of tillering in sugarcane. In amaranth, rest half nitrogen was applied 30 days after sowing. The seed rate for vegetatively propagated sugarcane crop was 6 t cane setts/ha while for amaranth it was 0.6 kg/ha. Amaranth was harvested in the last week of March with hand sickle during both the years. Sugarcane was harvested during third week of January.

Five millable canes (ripen canes ready to supply to sugar mills) were randomly sampled for observations on yield attributes (length, girth and average cane weight) and juice quality parameters (brix, pol and purity). Juice purity and commercial cane sugar (CCS) were calculated by the formulae as described by Gupta (1977):

Juice purity (%) = Sucrose (%) in juice/corrected brix x 100 .. (i)

CCS (%) = {S-(B-5) x 0.4} x 0.73 .. (ii)

where, S is sucrose % in juice, and B is corrected brix determined as per the method of Meade and Chen (1977).

RESULTS AND DISCUSSION

Growth and yield attributes of sugarcane

Highest number of tillers (318.9 thousand /ha) were recorded in sugarcane + amaranth (2:2 at 45:135 cm paired row planting geometry) during June (240 days after planting, DAP). The increase in doses of fertilizer nutrients increased the tiller production linearly (Table 1). Maximum tillers were counted with 150% RDF. The height of sugarcane was significantly affected by amaranth association and varying nutrient doses. The tallest plants (348.4 cm) were observed during the month of September (330 DAP) under 50% higher doses of fertilizer nutrition. Sooparmanien and Julien (1980) opined that the inter-tiller competition, which is related to the micro-climate with in the crop canopy, is the main cause of tiller population. The increase in population under the treatment was due to lower rate of tiller mortality as a result of less competition. Patel *et al.* (1988) also observed lesser mortality of tillers in wider spaced sugarcane crop.

Significantly higher number of millable canes (120.9 thousand/ha) were recorded under sugarcane + amaranth (2:2) intercropping system. Application of 150% RDF produced the highest number of millable canes (135.1 thousand/ha). The length of cane was significantly affected by planting geometries and nutrient application. Significantly taller canes (248.2 cm) were recorded under sugarcane + amaranth (2:2) followed by sugarcane + amaranth in 1:1 row ratio (234.4 cm) intercropping system. The girth and individual cane weight were not affected significantly by intercropping of amaranth. Nourishing the crops with higher nutrient levels recorded progressive attributes for yield. Inturn 50% higher nutrient level produced cane length of 256.5 cm having a girth of 2.63 cm and weight of 1.13 kg. These were found to be significantly higher than lower doses, but were on par with 125% RDF. The higher growth and yield attributes of sugarcane under sugarcane + amaranth (2:2) system might be due to congenial rhizosheric environment provided to sugarcane by sugarcane paired (45:135 cm) planting geometry. Optimum planting geometry provides better opportunity to every plant to develop its rhizosphere domain for uptake of water and nutrients (Yadav *et al.*, 2008).

Productivity of component crops

Significantly higher cane yield (75.7 t/ha) was recorded under sugarcane + amaranth (2:2) intercropping system (Table 2), which was at par with sole sugarcane (72.4 t/ha). Positive response in yield was observed by increasing the nutrient levels. The yield of sugarcane was also increased significantly with increasing levels of N-fertilizers in a study by Singh *et al*. (2007) and Manickam *et al*. (2008). Higher yield of amaranth grain was obtained when sown as sole crop (1.07 t/ha) followed by sugarcane + amaranth (1:1) (0.96 t/ha) and sugarcane + amaranth (2:2) intercropping system (0.94 t/ha). However, the yield of grain maranth was significantly higher (1.34 t/ha) at 50% higher RDF (Table 1). This was possibly due to compensatory mechanism of growth in amaranth producing more vigorous plants, when grown at wider spacing (Table 3). In autumn planted (October) sugarcane, the growth of sugarcane ceases just after germination, due to low temperature regime during the months of December and January in north Indian conditions. However, amaranth crop sown in between two rows of sugarcane grows very fast taking the advantage of slow growth of sugarcane with almost no interspecies competition and congenial growing season for amaranth during winter. This in turn resulted into higher biomass production, plant height and yield at-

Table 1. Growth and yield attributes and yield (t/ha) of sugarcane as affected by different treatments (pooled data of 2 years)

Treatment	No. of tillers ($x10^3$/ha)			NMC ($x10^3$/ha)	Plant height (cm)	Cane length (cm)	Cane weight (kg)	Cane yield	Amaranth grain yield	Cane equivalent yield	CCS	Sugar equiva-lent yield
	April	June	August									
Cropping system												
Sugarcane (Sc) sole	300.5	301.2	226.3	115.7	314	233.3	0.95	72.4		72.4	8.34	8.34
Amaranth (A) sole									1.07			
Sc + A (1:1)	237.7	299.7	222.0	115.2	321	234.4	0.98	71.3	0.96	91.2	8.41	10.76
Sc paired + A (2:2)	238.3	318.9	228.3	120.9	325	248.2	1.03	75.7	0.94	94.6	8.77	11.04
SEm±	4.7	3.6	3.9	1.6	3	4.0	0.06	1.2	0.42	3.6	0.14	0.55
CD (P= 0.05)	13.6	10.3	NS	4.5	10	11.6	NS	3.6	0.12	10.5	0.40	1.58
Nutrient levels (% RDF)												
50	220.5	289.8	209.7	96.9	293	222.1	0.84	57.4	0.66	66.2	6.74	7.78
75	236.1	307.8	214.6	109.9	308	242.0	0.93	66.1	0.86	77.4	7.63	8.93
100	253.8	314.5	224.6	119.4	321	243.6	0.99	74.0	0.98	86.9	8.58	10.08
125	279.3	308.7	233.7	125.0	331	245.8	1.04	78.3	1.09	92.7	9.20	10.90
150	304.4	312.1	245.0	135.0	348	256.5	1.13	89.2	1.34	109.1	10.38	12.71
SEm±	5.5	4.7	5.1	3.3	4.9	4.9	0.04	3.6	0.05	4.0	0.24	0.67
CD (P= 0.05)	15.9	13.6	14.6	9.7	14.2	14.2	0.12	10.3	0.15	11.5	0.70	1.95

NMC: Number of millable cane

Prices: Sugarcane - Rs 850/t (2003 & 04), Rs 1,070/t (2004-05) ; Amaranth–Rs 20,000/t (2003-04 and 2004-05)

Table 2. Effect of different treatments on nutrient uptake (kg/ha) by component crops and their soil status after cane harvest

Treatment	Sugarcane			Amaranth			Total			Soil status after cane harvest (kg/ha)		
	N	P	K	N	P	K	N	P	K	N	P	K
Cropping system												
Sugarcane (Sc) sole	110.4	26.1	137.5				110.4	26.1	137.5	150.6	13.6	200.9
Amaranth (A) sole				84.3	14.4	94.8	84.3	14.4	94.8			
Sc + A (1:1)	110.5	25.2	142.9	78.5	13.7	88.5	188.9	38.9	231.4	155.5	14.2	206.7
Sc paired + A (2:2)	124.1	30.8	152.6	80.5	14.6	90.5	204.6	45.4	243.1	156.7	14.9	210.5
SEm±	2.3	0.8	2.3	1.3	1.2	1.1	4.4	2.2	5.1	1.3	0.6	1.7
CD (P= 0.05)	6.6	2.4	6.5	3.6	NS	3.3	12.6	6.2	14.6	3.7	NS	3.6
Nutrient levels (% RDF)												
50	87.2	21.1	108.2	53.4	9.0	61.4	140.6	30.1	169.6	137.9	11.9	186.3
75	98.1	22.2	121.9	70.9	12.9	81.3	169.0	35.1	203.2	142.1	12.8	195.7
100	111.4	25.9	143.9	80.8	13.9	90.3	192.2	39.8	171.1	154.7	14.0	209.9
125	125.9	32.3	162.4	93.5	15.6	106.1	219.4	47.9	199.6	161.9	15.4	217.0
150	152.4	35.2	185.2	106.7	19.7	117.4	259.1	54.9	224.1	174.6	16.9	221.3
SEm±	3.6	2.2	3.9	3.3	2.6	2.2	6.6	3.0	6.7	2.9	1.0	3.6
CD (P=0.05)	10.4	6.4	11.3	9.4	7.4	6.2	18.8	8.6	19.2	8.3	2.8	10.4

tributes (Table 3). More so, in intercropping system amaranth plant may have taken advantage of high management given to sugarcane like intercultural operations and fertilizer application.

The magnitude of increase in the yield of sugarcane at higher doses of fertilizer nutrients was more when compared with the amaranth. The cane equivalent yield calculated on the basis of existing market prices of component crops under sub-tropics of India was maximum (94.6 t/ha) under sugarcane + amaranth (2:2) system (Table 1) against sugarcane sole (72.4 t/ha). Higher doses of fertilizer nutrients accounted for higher cane equivalent yield when compared with recommended and sub-optimum doses. These results are in close conformity with the findings of Rana *et al*. (2006).

Table 3. Plant height, yield attributes and yield of amaranth under different cropping system (Pooled data of 2 years)

Treatment	Plant height (cm)	Length of ear/ inflores-cence (cm)	No. of branches/ ear (Rachis/ inflores-cence)	Grain yield/ plant (g)
Cropping system				
Amaranth (A) sole	97.3	17.9	6.29	20.1
Sc + A (1:1)	117.3	31.9	17.29	38.9
Sc paired + A (2:2)	101.3	26.8	14.91	35.5
SEm±	2.54	1.80	1.29	2.70
CD (P=0.05)	7.34	5.21	3.73	7.80
Nutrient levels (% RDF)				
50	91.9	15.3	9.61	20.6
75	97.3	20.9	10.69	24.5
100	106.0	27.8	12.24	31.6
125	112.6	30.7	13.62	35.3
150	118.6	32.9	17.98	45.4
SEm±	4.38	2.56	2.17	4.23
CD (P= 0.05)	12.67	7.39	6.27	12.24

Sc: Sugarcane

The sugar yield obtained under various treatments also differed significantly. The highest sugar yield (8.77 t/ha) was obtained from sugarcane + amaranth (2:2) system which was closely followed by sugarcane + amaranth (1:1 row ratio). Fifty per cent higher dose of fertilizer nutrients produced the highest sugar of 10.38 t/ha while it reduced significantly under sub-optimal (25% lower) and below sub-optimal (50% lower) doses. Significantly higher sugar yield (11.04 t/ha) was recorded under sugarcane + amaranth (2:2) system which was on par with that under sugarcane + amaranth (1:1) system (Table 1). The increase in the sugar yield might be due to higher cane yield and quality juice producted under the treatments. The increase in sugar yield due to higher doses of fertilizer application as also reported by Kadam *et al.* (2008).

Nutrient uptake

The uptake of nutrients by sugarcane was significantly highest (N: 124.1 kg/ha, P: 30.8 kg/ha and K: 152.6 kg/ha) under sugarcane + amaranth (2:2) system (Table 2). However, maximum nutrient (NPK) was harnessed by amaranth under sole system followed by sugarcane + amaranth (2:2) intercropping. The nutrient uptake was increased with an increase of fertilizer doses for component crops and were observed to be maximum at 150% recommended doses of fertilizer. The total nutrient uptake also showed the similar trend. The increase in uptake by component crops grown as sole as well as in intercropping systems might be due to variation in production of biomass under different treatments. Kumar *et al*. (2007) also reported similar results.

Table 4. Yield and economic advantages of different treatments (mean of 2 years)

% RDF	Cropping system			
	Sugarcane (Sc)	Sc + amaranth (1:1)	Sc + amaranth (2:2)	Mean
	Land equivalent ratio (LER)			
50	1.00	1.90	1.94	1.61
75	1.00	1.88	1.84	1.57
100	1.00	1.88	1.90	1.59
125	1.00	1.90	1.97	1.62
150	1.00	1.90	1.96	1.62
Mean	1.00	1.89	1.92	
	Cost of production ($x10^3$Rs./ha)			
50	25.5	30.5	30.5	28.9
75	26.6	32.0	32.0	30.2
100	27.6	33.6	33.6	31.6
125	28.7	35.1	35.1	32.9
150	29.8	36.6	36.6	34.3
Mean	27.6	33.6	33.6	
	Net return ($x10^3$Rs./ha)			
50	28.5	35.7	39.4	34.5
75	38.8	47.2	47.6	44.0
100	42.9	55.0	57.4	51.8
125	44.4	58.7	63.8	55.6
150	55.6	73.1	78.1	68.9
Mean	41.7	53.9	57.3	
	Cropping system	Nutrient levels	Interaction	
SEm	2.51	1.78	5.66	
CD (P= 0.05)	7.26	5.14	16.36	
	B:C ratio			
50	2.12	2.17	2.29	2.19
75	2.46	2.47	2.49	2.48
100	2.55	2.64	2.71	2.61
125	2.55	2.68	2.83	2.68
150	2.87	3.00	3.14	3.00
Mean	2.51	2.59	2.69	

Yield advantage and profitability

Land Equivalent Ratio (LER) was maximum (1.92) under sugarcane + amaranth (2:2) system (Table 4) followed by sugarcane + amaranth (1:1). On the basis of LER values, 125 and 150% RDF were found to be equally advantageous. The highest net returns (Rs 57,272/ha) as well as B: C ratio (2.69) occurred in sugarcane + amaranth (2:2) system. A combination of sugarcane + amaranth receiving 50% higher doses of nutrients fetched the highest net return of Rs 78,135/ha and B:C ratio of 3.14. Singh and Lal (2007) also reported higher net returns and benefit: cost ratio under intercropping systems in autumn and spring planted sugarcane.

It was concluded that 2 rows of grain amaranth can be intercropped in autumn sugarcane planted in paired rows (45:135 cm) fertilized with 50% higher doses of fertilizer nutrients to achieve high system productivity and profitability.

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