

Influence of manuring and irrigation scheduling on system productivity, resource use efficiency, nutrient uptake and incidence of early shoot-borer (*Chilo infuscatellus*) in sugarcane (*Saccharum* spp. hybrid complex) and garlic (*Allium sativum*) intercropping system

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Received : April 2016; Revised accepted : July 2016

ABSTRACT

A field experiment was conducted during the autumn seasons of 2010–13 at Pusa, Bihar, to identify suitable fertilizer and irrigation requirement in sugarcane (*Saccharum* spp. hybrid complex) + garlic (*Allium sativum* L.) intercropping system for system productivity, resource-use efficiency, nutrient utilization and early shoot borer (*Chilo infuscatellus* Snellen) incidence in sugarcane. Sugarcane + garlic (1: 2) with 100% recommended dose of fertilizer (RDF) to sugarcane (150, 37.1, 49.8 kg N, P, K/ha) and garlic (100, 34.9, 66.4 kg N, P, K/ha) showed significantly higher dry weight of garlic bulb (1.14 t/ha), bulb yield of garlic (3.5 t/ha), cane-equivalent yield (130.3 t/ha), land-equivalent ratio (1.30), area-time equivalent ratio (1.08), net returns (₹ 1,96,300/ha) and benefit: cost ratio (2.96) than rest of the fertilizer treatments. The total N, P and K uptake by sugarcane and garlic were also found the maximum in this treatment. Fertility levels did not affect available N and K status after harvesting of sugarcane and garlic but significantly increased organic carbon and available P when analyzed after harvesting of sugarcane and garlic. Intercropping system exhibited significantly lowest incidence of early shoot borer (6.7%) than sole sugarcane (11.4%). Different irrigation schedules significantly influenced growth and yield attributes. Application of 4 irrigations at 30, 60, 90 and 120 days after sowing (DAS), being at par with 3 irrigations, resulted in higher cane yield (92.4 t/ha), bulb yield of garlic (3.6 t/ha) and land-equivalent ratio (1.36) than the remaining irrigation levels. With the increase in irrigation from 1 to 4 resulted increase in cane-equivalent yield, area-time equivalent ratio and net returns, maximum being recorded with 4 irrigations at 30, 60, 90 and 120 DAS. However, benefit: cost ratio (3.05) and N, P and K uptake by sugarcane were significantly improved up to 3 irrigations (30, 60 and 90 DAS). There was increasing trend of soil organic carbon and available N, P and K in post-harvest soil with increasing irrigation levels, whereas increasing level of irrigation reduced the incidence of early shoot borer in sugarcane. Sugarcane + garlic with 100% RDF to both the crops in combination with 4 irrigations (30, 60, 90 and 120 DAS) resulted in the highest N (29.1 kg/ha), P (12.5 kg/ha) and K (27.6 kg/ha) uptake by garlic. The interaction effects showed that sugarcane + garlic (1: 2) with 100% RDF to both the crops in combination with 3 irrigations at 30, 60 and 90 DAS gave at par net returns with that of sugarcane + garlic with 100% RDF to both the crops along with 4 irrigations at 30, 60, 90 and 120 DAS in sugarcane + garlic intercropping system.

Key words: Fertilizer, Irrigation, Nutrient uptake, Resource–use efficiency, Shoot borer, Sugarcane + garlic

Sugarcane is an important agro-industrial crop in many tropical and subtropical countries and accounts for over 70% of world sugar production that sustains sugar industry in particular and many allied industries like paper, wax, card board, ethanol and liquor etc. in general. Traditionally, mono-crop culture of sugarcane prevailed in most of

the cane-growing areas during autumn season is not well remunerative. As it is long duration, widely spaced and initially slow growing with least crop growth rate after settling emergence because of sub-optimal temperature during winter months (November–February), there exists good scope for high-value, short-duration, short-stature and dissimilar growing habit crop like garlic as an intercrop. The shallow root-system of garlic further complement the deep root-system of sugarcane leading to better below and above-ground adjustment in exploiting the rhizosphere as well as micro-environment above the soil

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surface with benefits to lesser insect-pest incidence to base crop has been recommended for stabilizing farmer's income from autumn sugarcane. Among the several pests infesting sugarcane, borers continued to be an important group. Early shoot-borer is major pest affecting sugarcane productivity and quality to a greater extent. Intercropping helps in reducing early shoot-borer incidence as compared to sole sugarcane (Rao *et al.*, 2010). In this context, it is imperative to select such crop as an intercrop which, besides, increasing the profit of the farmers is able to reduce pest incidence. Selection of spice crop like garlic may be answer to this problem, as they invite less insect-pest and are considered as secondary cash crop in Bihar. Earlier efforts were focused on selection of compatible intercrops for sugarcane-based cropping system. Although there have been several compatible intercrops for autumn sugarcane, the sustainable yield potential has not been achieved. This could be because of lack of appropriate fertilizer and irrigation scheduling for sugarcane-based intercropping system. Fertilizer and irrigation requirements are based only on individual crop basis which may not be applicable for intercropping too. However, majority of farmers not apply additional nutrients for intercrops, though some of the farmers apply only nitrogen to intercrops. Although any curtailment in fertilizers reduced the yield of component crops remarkably (Gangwar *et al.*, 2003). The present experiment described here represents an optimum fertilizer and irrigation requirement for sugarcane based cropping system. Optimum fertilizer and irrigation not only increases crop productivity but also helps their judicious utilization. The over-and under-use of inorganic fertilizers in the intensive cropping system leads to decline in crop factor productivity and adversely affects soil physico-chemical properties. Judicious use of irrigation water is an important step towards sustainable crop production and any ignorance in this may results hazardous for crop growth and soil health. Irrigation scheduled at critical growth stages of intercrop improved growth and yield of sugarcane, apart from sustaining higher intercrop yield (Saini *et al.*, 2008). Hence there is an urgent need for research on fertilizer and irrigation management that would help in making sugarcane + garlic intercropping system more remunerative. In this context, the present study was planned to find out optimum combination of fertilizer and irrigation to garlic when grown as an intercrop with sugarcane to get the sustainable production of sugarcane + garlic intercropping system.

MATERIALS AND METHODS

A field experiment was conducted during the autumn season of 2010–13 at Research Farm of Sugarcane Research Institute, Pusa, (25° 59' N, 85° 40', E and 52.1 m

above mean sea-level), Bihar. The rainfall during cropping season was 1,194 mm. The soil at site was sandy loam and calcareous (29.7% CaCO₃), having pH 8.3, electrical conductivity 0.28 dS/m and organic carbon 0.43%. The available nitrogen, phosphorus and potassium were 207, 8.0 and 103 kg/ha respectively. Twenty treatments comprising 5 fertility levels, viz. F₁, sugarcane + garlic (1 : 2) with 100% recommended dose of fertilizer (RDF) to both the crops; F₂, sugarcane + garlic (1 : 2) with 100% RDF to sugarcane + 50% RDF to garlic; F₃, sugarcane + garlic (1:2) with 100% RDF to sugarcane + 100% N to garlic; F₄, Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane + 100% N and P to garlic; and F₅, sugarcane + garlic (1 : 2) with 100% RDF to sugarcane + 100% N and K to garlic, and 4 irrigation schedules, viz. I₁, 30 days after sowing (DAS); I₂, 30 and 60 DAS; I₃, 30, 60 and 90 DAS; and I₄, 30, 60, 90 and 120 DAS with 2 additional treatments as sole sugarcane and sole garlic with recommended fertilizer and irrigation were arranged in randomized block design (RBD) as a check with 3 replications. The recommended dose of fertilizers for sole sugarcane and sole garlic were 150, 37.1, 49.8 and 100, 34.9, 66.4 kg N, P, K/ha respectively. However, only nitrogen is the existing recommendation for garlic when grown as an intercrop. Both sole and intercropped sugarcane received 100% recommended dose of P and K and 50% N as basal at the time of planting, while 50% N was applied in 2 equal splits at initial and final stages of tillering. In sole stand, garlic was applied with 100% of recommended dose of N, P and K, whereas the intercrop garlic was applied based on its per cent population (33.3%) in the system. As per treatment and proportionate area half of N and entire dose of P and K to garlic was applied basal, and the remaining N was top-dressed at the time of earthing-up. The N, P and K to both the crops were applied through urea, single super phosphate and muriate of potash respectively. The recommended irrigation for sugarcane was applied after harvesting garlic. The sugarcane crop was planted with recommended seed rate, i.e 50 q/ha in sole as well as intercropping system, while the garlic was sown with 33.3% (133 kg/ha) of sole seed rate (400 kg/ha) in intercropping system based on the proportionate area with respect to sole crop. Variety 'BO 141' of sugarcane and 'Saidpur Local' of garlic were sown 90 and 30 cm apart on 3 November 2010 and 4 November 2010 during the first year and 27 October 2011 and 29 October 2011 during the second year respectively. In intercropping system, 2 rows of garlic (1 : 2 row ratios) were sown at 10 cm planting distance between the rows of sugarcane. The recommended spacing for sole garlic is 15 cm × 10 cm. Garlic crop was digged on 30 March 2011 and 27 March 2012 while sugarcane was harvested on 30 January 2012 and 28

January 2013 during 2 years. Cane-growth attributes, viz. plant population, leaf-area index and dry-matter accumulation, were recorded as per standard method at appropriate stages. Millable canes were counted in December. The incidence of early shoot-borer was recorded 150 days after planting of sugarcane on the basis of dead-hearts. Five canes were randomly selected from each plot for estimation of yield attributes (length, diameter and weight) and sucrose content juice. Cane juice was extracted with power crusher and sucrose content juice was estimated as per method given by Spencer and Meade (1955). Economic analysis of treatment was done on the basis of prevailing market price of inputs used and the output obtained under each treatment during respective year. Land-equivalent ratio and area-time equivalent ratios were computed as per formulae given by Willey (1979) and Hiebsch (1980), respectively. Plant samples were analyzed for uptake of nitrogen, phosphorus and potassium and post-harvest soil samples collected from 0–30 cm depth for analysis of electrical conductivity, organic carbon, N, P and K status using standard laboratory procedure (Jackson, 1973).

RESULTS AND DISCUSSION

Yield-contributing characters

Different fertility levels did not affect growth and yield attributes of sugarcane except dry-matter accumulation of sugarcane and garlic at harvesting (Table 1). Sugarcane + garlic (1 : 2) system with 100% RDF to both the crops showed significantly higher dry-matter accumulation in sugarcane and garlic, whereas sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N to garlic recorded the lowest dry matter of sugarcane and garlic bulb (0.65 t/ha).

Irrigation schedules increased yield-contributing characters markedly. Application of 4 irrigations at 30, 60, 90 and 120 DAS (I_4) recorded the maximum plant population, dry-matter accumulation and millable canes which were at par to 3 irrigations applied at 30, 60 and 90 DAS but were significantly higher than rest of the treatments (Table 1). A marked variation in growth and yield attributes of sugarcane due to irrigation schedules was also observed by Kumar *et al.* (2013). Cane length, leaf-area index (LAI) and cane diameter increased significantly up to 2 irrigations applied at 30 and 60 DAS; however, dry weight of garlic bulb increased significantly up to 4 irrigations applied at 30, 60, 90 and 120 DAS. The increased dry-matter production in turn resulted in greater synthesis of photosynthates. Tillers mortality of sugarcane decreased with increasing levels of irrigation. The markedly highest mortality of tillers (28.9%) was associated with 1 irrigation (30 DAS) and the lowest observed under 4 irrigations (30, 60, 90 and 120 DAS). The results clearly indicated that the

application of irrigation water to an optimum level was beneficial for retention of tillers, whereas insufficient irrigation water enhanced tillers mortality.

Yield and sucrose

Sugarcane and bulb yields of garlic were reduced under the intercropping system as compared to sole cropping (Table 1). Different fertility levels in garlic had no significant effect on cane yield. However, significantly higher bulb yield of garlic was obtained with the sugarcane + garlic with 100% RDF to both the crops (F_1). Application of recommended dose of fertilizers to both the crops proved beneficial for bulb yield of garlic, perhaps because of its adequate availability and least competition among component crops. The positive response with phosphorus and sulphur on bulb yield of garlic was also reported by Majumdar *et al.* (2003). The highest cane-equivalent yield (CEY) was recorded under intercropping system and the lowest in sole sugarcane. The highest CEY in intercropping system was owing to statistically similar yield of sugarcane to that of its pure stand and an additional yield of garlic bulb as a bonus in intercropping system. Among the intercropping system, application of 100% RDF to both the crops recorded significantly higher CEY, showing 24.1% higher cane-equivalent yield than farmers practice (sugarcane + garlic with 100% RDF to sugarcane and 100% N to garlic). These results confirm the findings of Kumar *et al.* (2015) in sugarcane + French bean intercropping system. Irrigation schedule had significant effect on sugarcane, garlic (Table 1) and cane-equivalent yields (Table 2). Sugarcane yield and bulb yields of garlic increased significantly up to 3 irrigations applied at 30, 60 and 90 DAS. However, the cane-equivalent yield increased significantly with each successive increase in irrigation level up to 4 irrigations (30, 60, 90 and 120 DAS). Significant improvement in sugarcane-equivalent yield was attributed to adequate and timely availability of water increased the cane and garlic yield by enhanced cell turgidity thereby increased photosynthates and its subsequent translocation to sink sites resulting in enhanced system productivity. Four irrigations resulted in 57.3, 21.2 and 5.7% higher CEY over 1, 2 and 3 irrigations respectively. Irrespective of the treatments, sucrose content juice did not vary significantly by fertility levels, irrigation schedule and sole vs intercrop. Similar trend of results owing to fertility level was also reported by Kumar *et al.* (2014), whereas non-significant variation in sucrose content juice with irrigation schedule was also reported by Kumar *et al.* (2013) in previous studies.

Early shoot-borer incidence

Results revealed that intercropping system showed sig-

Table 1. Effect of fertility levels and irrigation schedules in sugarcane + garlic intercropping system on growth, yield components, yield of sugarcane and garlic and sucrose content in sugarcane juice (pooled data of 2 years)

Treatment	Plant population at 125 DAP ($\times 10^3$ /ha)	Cane length (cm)	Leaf-area index	Dry-matter accumulation at harvesting (t/ha)	Cane diameter (cm)	Tiller mortality (%)	Single cane weight (g)	Millable canes ($\times 10^3$ /ha)	Cane yield (t/ha)	Sucrose in juice (%)	Dry weight of garlic bulb (t/ha)	Bulb yield of garlic (t/ha)
<i>Fertility level</i>												
F ₁ , Sugarcane + garlic (1 : 2) with 100% RDF to both the crops	163.0	241	4.06	32.7	2.19	25.7	750	121.5	87.1	16.91	1.14	3.5
F ₂ , Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 50% RDF to garlic	152.8	237	3.84	28.4	2.13	26.2	737	113.4	82.2	16.84	0.75	2.4
F ₃ , Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N to garlic (farmers practice)	150.7	233	3.73	27.6	2.00	26.9	729	110.4	80.0	16.73	0.65	2.1
F ₄ , Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N and P to garlic	154.8	239	3.95	29.6	2.15	26.2	743	114.4	83.2	16.78	0.84	2.6
F ₅ , Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N and K to garlic	155.8	237	3.96	30.1	2.17	26.1	744	115.3	83.9	16.86	0.98	3.0
SEM \pm	3.81	5.51	0.09	0.77	0.050	0.76	18.2	2.74	2.18	0.08	0.028	0.08
CD (P=0.05)	NS	NS	NS	2.2	NS	NS	NS	NS	NS	NS	0.08	0.2
<i>Irrigation schedule</i>												
I ₁ , 30 DAS	141.0	224	3.65	23.8	1.97	28.9	720	100.3	71.4	16.70	0.41	1.2
I ₂ , 30, 60 DAS	152.0	235	3.91	29.1	2.12	26.1	737	112.4	81.3	16.82	0.82	2.6
I ₃ , 30, 60, 90 DAS	161.8	242	4.01	32.2	2.19	25.0	749	121.4	88.0	16.86	1.07	3.4
I ₄ , 30, 60, 90, 120 DAS	166.9	246	4.05	33.7	2.23	24.8	756	125.6	92.4	16.90	1.18	3.6
SEM \pm	3.40	4.93	0.08	0.68	0.048	0.68	16.3	2.45	1.95	0.07	0.025	0.07
CD (P=0.05)	9.7	14.1	0.24	2.0	0.14	2.0	NS	7.0	5.6	NS	0.07	0.2
<i>Interaction (F \times I)</i>												
Intercrop vs sole crop												
C ₁ , Intercrop	155.4	237	3.91	29.7	2.13	26.2	741	115.0	83.3	16.82	0.87	2.7
C ₂ , Sole crop	166.4	243	4.05	33.5	2.23	24.9	758	125.0	92.0	16.92	3.25	10.1
SEM \pm	1.70	2.46	0.04	0.34	0.02	0.34	8.1	1.22	0.98	0.03	0.013	0.04
CD (P=0.05)	4.9	NS	0.11	0.97	0.06	NS	NS	3.5	2.8	NS	0.04	0.11

RDF, Recommended dose of fertilizer; DAS, days after sowing; DAP, days after planting

nificantly lower incidence of early shoot-borer (6.7%) than sole crop (11.4%) of sugarcane (Fig. 1). Among the fertility levels, application of 100% RDF to both the crops exhibited significantly lower incidence of early shoot-borer (5.6%), being statistically at par with sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N and P to garlic (6.5%) (F_4) and sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N and K to garlic (6.0%) (F_5) and significantly superior to the remaining fertilizer treatments. However, sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N to garlic (F_3) registered higher incidence (8.2%) of early shoot-borer. These results were due to the availability of balanced quantity of nutrients in recommended level, resulting better growth of shoot during early stage of crop which led to less infestation of early shoot-borer and increased survival. Further higher incidence of early shoot-borer with the sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and only 100% N to garlic indicates that the only N to garlic was inadequate to produce healthy crop. However, Srikanth *et al.* (2002) did not observe significant effect on shoot-borer due to differential nutrient supply system.

Irrigation schedule had marked effect on incidence of early shoot-borer in sugarcane (Fig. 1). Application of 4 irrigations at 30, 60, 90 and 120 DAS resulted in significantly lowest incidence (5.7%) of early shoot-borer which was statistically similar to 3 irrigations applied at 30, 60 and 90 DAS and significantly superior to rest of the irrigation treatments. However, maximum incidence of 7.8% was observed in the plots where only 1 irrigation was applied up to the period of garlic. Randhawa *et al.* (2009) also reported similar results.

Yield advantage and competition indices

Sugarcane + garlic intercropping system exhibited significantly higher land-equivalent ratio than sole cropping (Table 2), indicating biological sustainability of intercropping over sole cropping. Among the fertility levels, sugarcane + garlic (1 : 2) with 100% RDF to both the crops revealed the maximum LER compared with others, indicating better performance of both the components at that level in utilizing natural resources with total yield advantage of 30%. The maximum area-time equivalent ratio (ATER) value was observed with sugarcane + garlic (1 : 2) with 100% RDF to both the crops (F_1) followed by sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N and K to garlic (1.01) (Table 2). The value greater than 1 indicates a more efficient use of hectare-days at optimum fertility level. Further, more the ATER obtained due to the application of 100% RDF to sugarcane + garlic (1.07) was 14% higher over existing recommendation, i.e. sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and

100% N to garlic (0.94). This shows that the existing recommendations (farmers practice) is not sustaining in present situation. Singh *et al.* (2009) reported similar results in sugarcane + grain amaranth intercropping system.

Irrigation schedules influenced the LER and ATER of sugarcane + garlic intercropping system (Table 2). The highest LER was obtained with 4 irrigations applied at 30, 60, 90 and 120 DAS, which was statistically similar to 3 irrigations applied at 30, 60 and 90 DAS and both of them were significantly superior to the other levels of irrigations. However variation in ATER was observed with each successive increase in irrigation level, being the highest

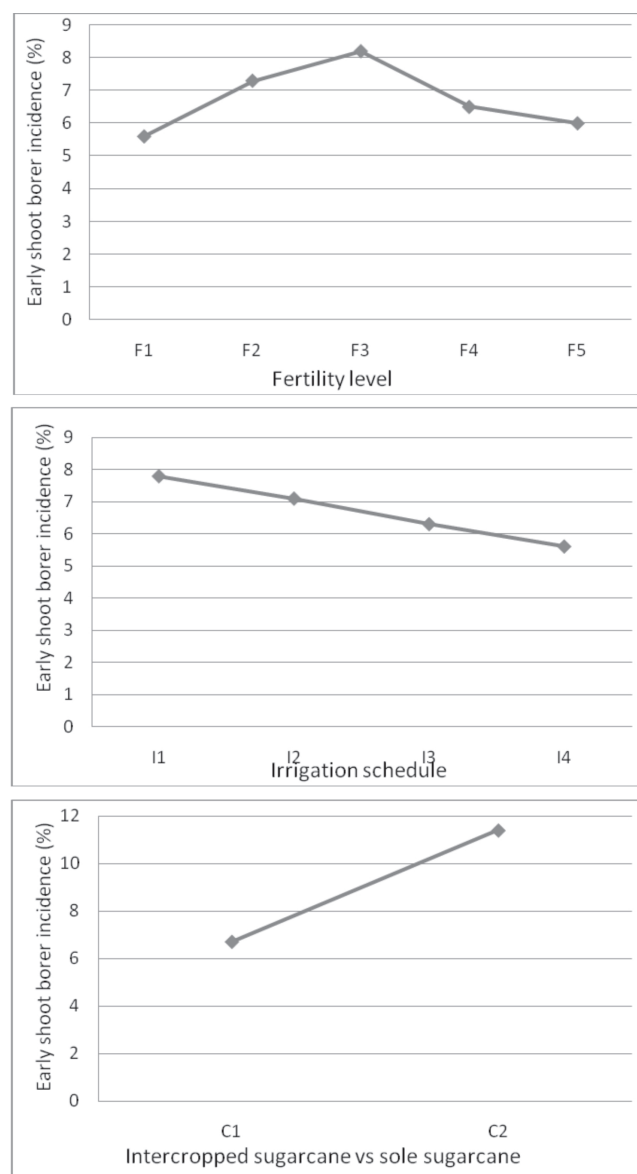


Fig. 1. Incidence of early shoot-borer (%) in sugarcane as influenced by fertility level, irrigation schedule and intercropped sugarcane vs sole sugarcane in sugarcane + garlic intercropping system

Table 2. Effect of fertility levels and irrigation schedules in sugarcane + garlic intercropping system on resource-use efficiency, productivity, economics and nutrient uptake by sugarcane and garlic (pooled data of 2 years)

Treatment	LER	ATER	CEY (t/ha)	Cost of cultivation ($\times 10^3 \text{ ₹/ha}$)	Net returns ($\times 10^3 \text{ ₹/ha}$)	Benefit: cost ratio	Nutrient uptake (kg/ha)					
							Sugarcane		Garlic bulb			
							N	P	K			
<i>Fertility level</i>												
F ₁ , Sugarcane + garlic (1 : 2) with 100% RDF to both the crops	1.30	1.08	130.3	100.4	196.3	2.96	249	24.0	289	20.7	8.6	19.5
F ₂ , Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 50% RDF to garlic	1.13	0.97	110.9	99.6	153.4	2.54	208	20.3	245	12.8	4.8	12.3
F ₃ , Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N to garlic (farmers practice)	1.08	0.94	105.0	99.1	140.4	2.42	205	18.9	233	11.4	4.0	9.3
F ₄ , Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N and P to garlic	1.16	0.99	113.9	99.8	160.0	2.60	223	21.8	250	14.2	6.2	13.5
F ₅ , Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N and K to garlic	1.21	1.01	120.1	99.3	174.0	2.75	229	21.2	266	17.0	7.0	16.1
SEm±	0.026	0.021	2.57	-	3.75	0.06	6.8	0.63	8.1	0.41	0.18	0.42
CD (P=0.05)	0.08	0.06	7.3	-	10.7	0.17	20	1.8	23	1.2	0.5	1.2
<i>Irrigation schedule</i>												
I ₁ , 30 DAS	0.90	0.82	86.6	97.2	100.1	2.04	166	15.7	195	6.3	2.2	5.8
I ₂ , 30, 60 DAS	1.14	0.97	112.4	98.8	157.5	2.60	215	20.7	250	13.9	5.5	13.0
I ₃ , 30, 60, 90 DAS	1.29	1.07	128.9	100.4	193.3	2.93	247	23.8	277	19.3	7.8	17.8
I ₄ , 30, 60, 90, 120 DAS	1.36	1.13	136.2	102.1	208.4	3.05	263	24.7	304	21.3	8.8	19.9
SEm±	0.023	0.018	2.30	-	3.35	0.05	6.1	0.56	7.3	0.37	0.16	0.37
CD (P=0.05)	0.07	0.05	6.6	-	9.5	0.14	17	1.6	21	1.1	0.5	1.1
<i>Interaction (F × I)</i>												
Intercrop vs sole crop	NS	NS	NS	NS	S	NS	NS	NS	NS	S	S	S
C ₁ , Intercrop	1.18	1.00	116.0	99.6	164.8	2.65	223	21.2	257	15.2	6.1	14.1
C ₂ , Sole crop	1.00	1.00	92.0	80.1	130.5	2.63	258	24.5	298	55.1	22.1	54.1
SEm±	0.012	0.009	1.15	-	1.68	0.02	3.1	0.28	3.6	0.18	0.08	0.18
CD (P=0.05)	0.034	NS	3.3	-	4.8	NS	9	0.8	11	0.5	0.2	0.5

Selling price (₹/tonne): Sugarcane, ₹2,300; garlic, ₹27,500; CEY, cane-equivalent yield; LER, land-equivalent ratio; ATER, area-time equivalent ratio; Figures in parentheses indicate values of sole garlic

with the application of 4 irrigations (30, 60, 90 and 120 DAS).

Economic feasibility

Intercropping system exhibited 26.3 and 0.8% higher net returns and benefit: cost ratio than sole sugarcane (Table 2). Singh and Lal (2007) also reported higher net returns and benefit: cost ratio under intercropping systems. Net returns as well as benefit: cost ratio were significantly influenced by fertility levels. The maximum net returns and benefit: cost ratio were recorded under sugarcane + garlic (1: 2) with 100% RDF to both the crops which was found significantly remunerative compared to remaining fertility levels (Table 2). The lowest net returns and benefit: cost ratio were noted with sugarcane + garlic (1: 2) with 100% RDF to sugarcane and 100% N to garlic (farmers practice). The increase in net returns owing to sugarcane + garlic (1: 2) with 100% RDF to both the crops (F₁), sugarcane + garlic (1: 2) with 100% RDF to sugarcane and 100% N and K to garlic (F₅), sugarcane + garlic (1: 2) with 100% RDF to sugarcane and 100% N and P to garlic (F₄), sugarcane + garlic (1: 2) with 100% RDF to sugarcane and 50% RDF to garlic (F₂) over sugarcane + garlic (1: 2) with 100% RDF to sugarcane and only 100% N to garlic (F₃) (farmers practice) was 39.8, 24.0, 14.1 and 9.3%, respectively. The corresponding increase in benefit: cost ratio was 22.3, 13.6, 7.4 and 5.0%. This indicates that the sugarcane + garlic (1: 2) with 100% RDF to sugarcane and 100% N to garlic (existing recommendation/ farmers practice) was inadequate to obtain the optimum returns, hence, supplemental application of P and K to garlic up to recommended level was essential. Irrigation schedules showed significant effect on net returns and benefit: cost ratio of sugarcane + garlic intercropping system (Table 2). Application of 4 irrigations at 30, 60, 90 and 120 DAS incurred higher cost of cultivation (₹1,02,100/ha) of sugarcane + garlic intercropping system but gave 7.8 and 4.1% higher net returns and benefit: cost ratio, respectively, over 3 irrigations applied at 30, 60 and 90 DAS. Though 3 and 4 irrigations remain statistically at par in respect to benefit: cost ratio.

Interaction effect of fertility levels and irrigation schedules on net returns of sugarcane + garlic intercropping system was significant and

Table 3. Changes in soil chemical properties of soil due to fertility levels and irrigation schedules in sugarcane + garlic intercropping system (pooled data of 2 years)

Treatment	After harvesting of sugarcane				After harvesting of garlic					
	EC (dS/m)	OC (%)	Available nutrients (kg/ha)			EC (dS/m)	OC (%)	Available nutrients (kg/ha)		
			N	P	K			N	P	K
<i>Fertility level</i>										
F ₁ , Sugarcane + garlic (1: 2) with 100% RDF to both the crops	0.23	0.49	249	15.8	118.3	0.23	0.48	253	16.4	121.3
F ₂ , Sugarcane + garlic (1: 2) with 100% RDF to sugarcane and 50% RDF to garlic	0.26	0.46	230	14.2	109.8	0.26	0.45	234	15.2	115.5
F ₃ , Sugarcane + garlic (1: 2) with 100% RDF to sugarcane and 100% N to garlic (farmers practice)	0.25	0.47	235	13.8	109.8	0.26	0.46	240	14.8	111.8
F ₄ , Sugarcane + garlic (1: 2) with 100% RDF to sugarcane and 100% N and P to garlic	0.25	0.46	247	15.0	112.3	0.25	0.46	251	16.0	115.8
F ₅ , Sugarcane + garlic (1: 2) with 100% RDF to sugarcane and 100% N and K to garlic	0.24	0.47	243	14.8	115.5	0.24	0.46	247	15.6	118.3
SEm±	0.003	0.005	7.8	0.40	3.23	0.003	0.005	5.4	0.38	2.69
CD (P=0.05)	0.01	0.01	NS	1.2	NS	0.01	0.01	NS	1.1	NS
<i>Irrigation schedule</i>										
I ₁ , 30 DAS	0.26	0.45	233	13.7	108.0	0.26	0.45	237	14.4	111.2
I ₂ , 30, 60 DAS	0.25	0.47	238	14.3	112.0	0.25	0.46	243	15.2	115.4
I ₃ , 30, 60, 90 DAS	0.24	0.47	244	15.2	115.8	0.25	0.47	249	16.0	119.4
I ₄ , 30, 60, 90, 120 DAS	0.22	0.48	247	15.6	116.6	0.23	0.47	252	16.7	120.0
SEm±	0.002	0.005	6.9	0.36	2.88	0.002	0.005	4.8	0.34	2.40
CD (P=0.05)	0.01	0.01	NS	1.0	NS	0.01	NS	NS	1.0	6.9

RDF, Recommended dose of fertilizer; DAS, days after sowing; EC, electrical conductivity; OC, organic carbon

positive (Table 3). The maximum net returns were obtained with the sugarcane + garlic with 100% RDF to both the crops in combination with 4 irrigations at 30, 60, 90 and 120 DAS ($F_1 I_4$) was statistically on a par with sugarcane + garlic with 100% RDF to both the crops with 3 irrigations at 30, 60 and 90 DAS ($F_1 I_3$).

Nutrient uptake

The pooled data of 2 years (Table 2) indicates that N, P and K uptake in sugarcane and garlic differed significantly due to levels of fertilizer. The maximum uptake of N and K by sugarcane was recorded when the sugarcane + garlic fertilized with 100% RDF (F_1) and it was found statistically on a par with sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N and K to garlic and significantly higher over rest of the treatments, while P uptake by sugarcane was significantly higher with the sugarcane + garlic (1 : 2) with 100% RDF to both the crops. The significant removal of N, P and K by sugarcane was due to residual effect of NPK application to garlic crop was observed in sugarcane crop. Kumar *et al.* (2014) and Meena *et al.* (2015) observed significant improvement in N, P and K uptake by sugarcane with balanced fertilization.

Sole garlic recorded significantly higher N, P and K uptake as compared to intercropped garlic primarily due to 100% area under sole garlic and only 33.3% area occupied by intercropped garlic (Table 2). Among fertility levels significantly higher N, P and K uptake by garlic was obtained with sugarcane + garlic (1 : 2) with 100% RDF to both the crops. The increase was 21.8% in N uptake, 22.9% in P uptake and 21.1% in K uptake with sugarcane + garlic (1 : 2) with 100% RDF to both the crops over sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N and K to garlic (next best treatment). The increase in nutrient uptake was in consonance with higher dry weight of garlic bulb and increase in nutrient content in plant tissues with balanced fertilization.

Among the irrigation schedules, N and P uptake by sugarcane increased significantly only up to 3 irrigations; however, the K uptake increased significantly up to 4 irrigations applied at 30, 60, 90 and 120 DAS (Table 2). Significantly higher N (21.3 kg/ha), P (8.8 kg/ha) and K (19.9 kg/ha) uptake by garlic bulb were obtained from the treatment received 4 irrigations at 30, 60, 90 and 120 DAS. The increased dry-matter production at optimum level of irrigation might have resulted in higher nutrient uptake by garlic.

The results of interaction effect of fertility levels and irrigation schedules showed that sugarcane + garlic (1 : 2) with 100% RDF to both the crops along with 4 irrigations at 30, 60, 90 and 120 DAS recorded significantly higher N, P and K uptake than with other treatment combinations

(Table 4). Improvement in nutrient uptake with the application of 100% RDF to both the crops along with irrigations at appropriate stages was owing to the increase in dry-matter accumulation and nutrient concentration with least competition from base crop to the garlic.

Post-harvest soil-nutrient status

The residual soil fertility was analyzed in terms of electrical conductivity (EC), organic carbon and available N, P and K after harvesting of sugarcane and garlic (Table 3). Application of 100% RDF to sugarcane + garlic (1 : 2) resulted in significantly lower electrical conductivity after harvesting of sugarcane and garlic followed by sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N and K to garlic, whereas significantly higher organic carbon after harvesting of sugarcane and garlic was recorded with the sugarcane + garlic (1 : 2) with 100% RDF to both the crops (Table 3). The available P after harvesting of sugarcane and garlic was significantly improved owing to sugarcane + garlic (1 : 2) with 100% RDF to both the crops which was statistically on par with sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N and P to garlic and sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N and K to garlic and significantly superior to rest of the treatments. The treatment difference with respect to available nutrients after harvesting of sugarcane was mainly because of the differences in fertility levels of garlic rather than fertilizer applied to sugarcane, indicating that left-over nutrient after harvesting of garlic influenced the fertility status of soil after harvesting of sugarcane. Further, the positive effect of intercrop fertilization on available P after harvesting of sugarcane was also observed by Kumar *et al.* (2015) in sugarcane + French bean intercropping system.

Among the irrigation schedules, significantly lower electrical conductivity after harvesting of sugarcane and garlic was recorded with 4 irrigations applied at 30, 60, 90 and 120 DAS which was significantly higher over all other irrigation levels. The organic carbon content after harvesting of sugarcane was enhanced significantly up to 2 irrigations applied at 30 and 60 DAS. Whereas available P after harvesting of sugarcane increased from 13.7 kg at 1 irrigation to 15.6 kg/ha at 4 irrigations applied at 30, 60, 90 and 120 DAS. Application of 4 irrigations at 30, 60, 90 and 120 DAS improved the available N by 6.3, 3.7 and 1.2%; available P by 16.0, 9.9 and 4.4%; and available K by 7.9, 4.0 and 0.5% over 1, 2 and 3 irrigations, respectively.

Thus, sugarcane + garlic (1 : 2) with 100% RDF to both crops along with 3 irrigations (30, 60 and 90 DAS) up to the period of garlic is essential for exploiting the potential productivity, profitability as well as resource-use effi-

Table 4. Interaction effect of fertility levels and irrigation schedules on net returns of sugarcane + garlic intercropping system and nutrient uptake by garlic bulb

<i>Fertility level × irrigation schedule</i>	Irrigation schedule (DAS)			
	30	30, 60	30, 60, 90	30, 60, 90, 120
	Net returns ($\times 10^3$ ₹/ha)			
Sugarcane + garlic (1 : 2) with 100 % RDF to both the crops	117.5	188.7	230.9	248.0
Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 50% RDF to garlic	94.8	145.4	179.8	193.7
Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N to garlic (farmers practice)	85.3	134.3	164.1	177.8
Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N and P to garlic	97.7	152.8	187.1	202.3
Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N and K to garlic	105.2	166.2	204.7	220.1
SEm±	7.49			
CD (P=0.05)	21.3			
	<i>N uptake by garlic bulb (kg/ha)</i>			
Sugarcane + garlic (1 : 2) with 100 % RDF to both the crops	8.6	18.8	26.2	29.1
Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 50% RDF to garlic	5.3	11.8	16.2	18.0
Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N to garlic (farmers practice)	4.7	10.5	14.6	15.9
Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N and P to garlic	5.9	13.0	18.0	20.0
Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N and K to garlic	7.1	15.5	21.6	23.7
SEm±	0.83			
CD (P=0.05)	2.4			
	<i>P uptake by garlic bulb (kg/ha)</i>			
Sugarcane + garlic (1 : 2) with 100 % RDF to both the crops	3.1	7.7	10.9	12.5
Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 50% RDF to garlic	1.7	4.3	6.1	6.9
Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N to garlic (farmers practice)	1.4	3.6	5.1	5.7
Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N and P to garlic	2.3	5.6	7.9	9.0
Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N and K to garlic	2.6	6.3	8.9	10.1
SEm±	0.35			
CD (P=0.05)	1.0			
	<i>K uptake by garlic bulb (kg/ha)</i>			
Sugarcane + garlic (1 : 2) with 100% RDF to both the crops	7.9	17.9	24.5	27.6
Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 50% RDF to garlic	5.0	11.3	15.4	17.3
Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N to garlic (farmers practice)	3.8	8.6	11.8	13.0
Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N and P to garlic	5.5	12.4	16.9	19.0
Sugarcane + garlic (1 : 2) with 100% RDF to sugarcane and 100% N and K to garlic	6.6	14.8	20.2	22.6
SEm±	0.84			
CD (P=0.05)	2.4			

ciency of sugarcane + garlic intercropping system, which deserves adoption by farmers of Bihar.

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