Indian Journal of Agronomy **60** (4): 524–533 (December 2015)

Research Paper

Optimizing nutrient and irrigation requirement of sugarcane (*Saccharum* species hybrid complex) and French bean (*Phaseolus vulgaris*) intercropping system

NAVNIT KUMAR[1], GEETA KUMARI[2] AND SUDHIR PASWAN[3]

Sugarcane Research Institute, Rajendra Agricultural University, Pusa, Bihar 848 125

Received : July 2015; Revised accepted : December 2015

ABSTRACT

A field experiment was conducted during 2010–13, on a sandy-loam soil at Pusa, Bihar to find out optimum nutrient and irrigation requirement of French bean (*Phaseolus vulgaris* L.) when intercropped with autumn sugarcane (*Saccharum* spp. hybrid complex). Fifteen treatment combinations consisted of 5 fertility levels [sugarcane + French bean (1: 2) with 100% recommended dose of fertilizer (RDF) to both the crops and residue incorporation, sugarcane + French bean (1: 2) with 100% RDF to sugarcane and 50% RDF to French bean and residue incorporation, sugarcane + French bean (1: 2) with 100% RDF to sugarcane and 100% N to French bean and residue removal (existing recommendation), sugarcane + French bean (1: 2) with 100% RDF to sugarcane and 100% N and P to French bean and residue incorporation, sugarcane + French bean (1: 2) with 100% RDF to sugarcane and 100% N and K to French bean and residue incorporation) and 3 irrigation schedules [no irrigation, 1 irrigation at 45 days after sowing (DAS) and 2 irrigations at 45 and 75 DAS] were evaluated in factorial randomized block design with 2 additional treatments as sole sugarcane and sole French bean. Application of 100% RDF to sugarcane and French bean with residue incorporation produced significantly higher grain (1.15 t/ha) and haulm yield (1.90 t/ha) of French bean. The treatments of sugarcane + French bean with 100% RDF to both the crops and residue incorporation, sugarcane + French bean with 100% RDF to sugarcane and 100% N and K to French bean and residue incorporation and sugarcane + French bean with 100% RDF to sugarcane and 100% N and P to French bean and residue incorporation being similar noticed significantly enhanced cane-equivalent yield (100.0, 95.8 and 94.8 t/ha), gross returns (₹2,29,400; 2,19,600 and 2,17,300/ ha), net returns (₹1,41,900; 1,33,100 and 1,30,100/ha) and benefit: cost ratio (2.62, 2.53 and 2.49), respectively, over rest of the treatments. The same treatment also accounted for higher land-equivalent ratio, area-time equivalent ratio and N, P and K uptake of sugarcane and French bean with greater available N, P and K status in post-harvest soil. Among the irrigation schedules, the highest cane yield (89.0 t/ha), French bean grain (1.20 t/ha), haulm yield (1.98 t/ha) and cane equivalent yield (106.0 t/ha) were recorded in treatment that received 2 irrigations at 45 and 75 DAS. Similarly, the maximum land-equivalent ratio, area time-equivalent ratio, gross returns, net returns, benefit: cost ratio and N, P and K uptake was noted from the enhanced levels of irrigation. The sugar yield was significantly increased with each successive increase in level of irrigation. Considering the total productivity and economics, sugarcane + French bean (1: 2) with 100% RDF to sugarcane and 100% N and K to French bean and residue incorporation, could be adopted under similar agro–ecological situations with twice irrigation up to the period of French bean at 45 and 75 DAS and normal irrigation for sugarcane after harvest of French bean.

***Key words* :** Autumn sugarcane, Fertility level, French bean, Irrigation schedule, Nutrient uptake, Residue incorporation, System productivity

Sugarcane, being a C_4 plant, has yield potential far higher than other field crops. India is second largest sugarcane producer in the world with a production level of 15 and 25% of global sugar and sugarcane respectively (Solomon, 2014). In Bihar, it occupies an area of 0.26 million ha with the production of 15.68 million tonnes and productivity is 56.1 t/ha (ISMA, 2014). In recent years the emphasis has been shifted from sole cropping to intercropping. Since the responses in component crops of the intercropping system are greatly influenced by the fertilizer and irrigation applied to the individual crop. Sugarcane-based intercropping system is one of the productive, sustainable and economically viable systems as sugarcane is a long-

[1]**Corresponding author Email:** navnitsripusa@gmail.com
[1]Junior Scientist-cum-Asstt. Professor, Department of Agronomy; [2]Junior Scientist-cum-Asstt. Professor, Department of Microbiology, FBS & H, RAU, Pusa, Samastipur, Bihar 848 125. [3]Junior Scientist-cum-Asstt. Professor, Department of Statistics,

duration, widely spaced (75 to 150 cm) and slow-growing crop up to 80 to 90 days and its efficient root-system helps to tap plant nutrients and moisture from deeper layers allowing the intercrops to feed at top layers of the soil. The major objectives of intercropping are to produce an additional crop, to optimize the use of natural resources and to stabilize the yield of crops (Willey, 1979). In order to meet the growing demand of diverse crop and to arrest further decline in factor productivity and to make the sugarcane production system more viable, it is necessary to enhance the productivity of the system as a whole (Kumar *et al.,* 2012). Growing pulses with sugarcane crop not only increases the area under pulse crop but also reduces the intensity of weeds and provides mid-season income to house-holds for further use of critical inputs to sugarcane along with additional employment opportunities. The compatibility of French bean in autumn sugarcane has also been reported by Singh and Lal (2007). Being a shy nodulated crop, its fertilizer requirement is like that of cereals. Therefore, study on requirement of fertilizer for this crop particularly under mixed stand is of prime importance. Excessive use and continuous increase in cost of irrigation and fertilizers inspired the scientists to explore the possibilities to restrict the irrigation and fertilizers use and way for its economy in sugarcane based cropping system. A plant residue, which is of organic origin, offers the twin benefits of soil microclimate improvement and restoration of soil fertility (Shukla *et al.,* 2011) besides improvement in yield and quality of sugarcane. But neither organic matter nor chemical fertilizers alone can be used to overcome declining crop productivity (Tyagi *et al.,* 2011) (Patel *et al.,* 2013). Therefore, fertilizers are to be integrated with plant residues to replenish the continuous removal of plant nutrients. In Bihar, majority of farmers not apply separate nutrients for intercrops and addition of organic matter is also not practiced, though very few farmers apply only nitrogen in varying proportion to the intercrops. However, the intercropping system is still not understood adequately with that of sole cropping especially in terms of its residue management, nutrients, irrigation schedules and their economization. Nutrients and irrigation being costly inputs, it is important to make its proper assessment for intercrops too. Hence with a view to find out optimum fertilizer and irrigation requirement of French bean grown as intercrop, an experiment was conducted to study the effect of different levels of fertilizers and irrigation to French bean with residue incorporation on productivity of sugarcane + French bean intercropping systems.

MATERIALS AND METHODS

A field experiment was conducted during autumn seasons of 2010–13 at Sugarcane Research Institute, Pusa, (25^{o} 59' N, 85^{o} 40' E, 52.1 m above mean sea-level), Bihar. The soil was sandy loam alkaline (pH 8.3) and low in available N (208 kg/ha), P (8.1 kg/ha), K (103 kg/ha), organic carbon (0.43%) and electrical conductivity (0.28 dS/m) but high in $CaCO_3$ (29.7%) before starting the experiment. The rainfall during the cropping season was 1,194 mm in 56 rainy days. In this region, south-west monsoon (July–September) is responsible for nearly 80% of annual precipitation and the period between the last week of December and first half of January receives occasional winter showers. The experiment was laid out in randomized block design with 3 replications. The treatments comprised 5 fertility levels, viz. sugarcane + French bean (1: 2) with 100% recommended dose of fertilizer (RDF) to both the crops and residue incorporation, sugarcane + French bean (1: 2) with 100% RDF to sugarcane + 50% RDF to French bean and residue incorporation, sugarcane + French bean (1: 2) with 100% RDF to sugarcane + 100% N to French bean and residue removal (existing recommendation), sugarcane + French bean (1: 2) with 100% RDF to sugarcane + 100% N and P to French bean and residue incorporation, sugarcane + French bean (1: 2) with 100% RDF to sugarcane + 100% N and K to French bean and residue incorporation and 3 irrigation levels [no irrigation, 1 irrigation at 45 days after sowing (DAS) and 2 irrigations at 45 and 75 DAS]. Along with these treatments a sole sugarcane and sole French bean with 100% RDF and recommended irrigation for both the crops were included for valid conclusion. The recommended dose of N, P and K (RDF) for sugarcane was 150–37.1–49.8 kg/ha and for French bean 100–21.8–24.9 kg/ha. As per treatment half of nitrogen and entire dose of phosphorus and potassium to sugarcane and French bean were applied basal in the form of urea, diammonium phosphate and muriate of potash respectively. Remaining nitrogen was applied in 2 equal splits at initial and final stages of tillering in sugarcane and 30 and 60 days after sowing in French bean. The sugarcane crop was planted with recommended seed rate, i.e 50 q/ ha in sole as well as in intercrop, while the French bean was sown with 66.6% (73.3 kg/ha) of normal seed-rate in intercropping system based on the area in comparison to sole crop. The seed rate for sole French bean was 110 kg/ha. Sugarcane 'BO 141' was planted at 90 cm-row spacing in the first fortnight of November. Two rows of French bean 'PDR 14' was sown (1: 2 row ratios) at 30 cm apart on next day of sugarcane planting. Uniform distance of 10 cm was maintained between the plants by thinning and gap-filling 15 days after sowing. The recommended irrigation for sugarcane was applied after harvest of French bean. French bean harvested in second week of March, while sugarcane harvested in the last week of January in both the years. French bean haulm was incorporated in to soil at the time of earthing up in sugarcane. However, French bean plants removed manually after the last picking of pods in the plots received 100% RDF to sugarcane and only 100% N to French bean (without residues incorporation). Sugar yield was calculated as; sugar yield (t/ha) = [S – 0.4 (B – S) × 0.73] × cane yield (t/ha)/ 100; where, S and B are sucrose and brix per cent in cane juice respectively. The land equivalent ratio (LER) was worked out as per Willey, (1979) and area time-equivalent ratio (ATER) as per Hiebsch, (1980).

Sugarcane-equivalent yield was obtained by dividing the economic value of the produce (grain yield of French bean × price of French bean grain) with the price of the sugarcane. Net returns and benefit: cost ratio were also calculated. Productivity was calculated by dividing the gross returns with crop duration and expressed as ₹/day/ha. Plant samples were analysed for uptake of nitrogen, phosphorus and potassium and post-harvest soil samples collected from 0–30 cm depth for analysis of N, P and K status using standard laboratory procedure (Jackson, 1973).

RESULTS AND DISCUSSION

Yield components, yield and quality

The fertility levels did not brought significant differences in the millable canes of sugarcane. However, comparatively higher values were noticed at higher level of fertilization (Table 1). The non-significant variation in millable canes of sugarcane indicated negligible influence of French bean fertilization on sugarcane. The sole crop of sugarcane showed superiority to intercropping in cane and sugar yields (Table 1). The higher cane and sugar yield under sole cropping was owing to no inter-specific competition. Similarly, sole French bean obtained significantly higher grain yield and haulm yield. This was primarily owing to 100% area of French bean under sole cropping compared to 66.6% plant stand in intercropping system. However, among intercropping system, fertility level could not cause significant variation in cane yield (Table 1), though comparatively higher values of cane yield was recorded with 100% RDF to both the crops and residue incorporation. The maximum grain (1.15 t/ha) and haulm yield (1.90 t/ha) of French bean was obtained with the application of 100% RDF to sugarcane and French bean which was significantly superior to rest of the treatments (Table 1). Greater availability of nutrients under balanced fertilization led to realization of higher grain and haulm yields of French bean. Rana *et al.* (2006) also reported similar findings.

Irrigation schedule had distinct effect on millable canes, cane yield, sugar yield and French bean yield (Table 1). The higher number of millable canes was obtained with 2 irrigations applied at 45 and 75 days after sowing (DAS), which showed significant edge over 1 irrigation applied at 45 DAS and no irrigation, being 7.3 and 21.1% more number of millable canes. Kumar *et al.* (2013) also reported a marked variation in millable canes due to irrigation regimes. Application of 2 irrigations at 45 and 75 DAS recorded 7.9 and 9.6% higher cane and sugar yields than 1 irrigation applied at 45 DAS and 26.2 and 29.8% higher cane and sugar yields than no irrigation, respectively. The reduction (%) in cane and sugar yields was very much high due to no irrigation, indicating decrease in soil-water content leading to reduced cell turgidity, photosynthesis and hence suboptimal assimilate supply to sink site. Kumar *et al.* (2013) reported a significant increase in cane yield with irrigation at an IW: CPE ratio 0.75 over IW: CPE ratio of 0.50. Like cane yield, the grain and haulm yields of French bean were also affected significantly with each successive rise in irrigation level (Table 1). The irrigation applied at 45 and 75 DAS showed best performance in increasing the grain and haulm yield and resulted 27.7 and 110.5% higher grain yield and 31.1 and 120.0% higher in haulm yield over 1 irrigation at 45 DAS and no irrigation, respectively.

Yield advantage and competition indices

Application of 100% RDF to sugarcane and French bean recorded the highest partial land-equivalent ratio (LER) of 0.92 and 0.71, followed by sugarcane + French bean (1:2) with 100% RDF to sugarcane and 100% N and K to French bean (0.90 and 0.58) and sugarcane + French bean (1:2) with 100% RDF to sugarcane and 100% N and P to French bean (0.87 and 0.57) in sugarcane and French bean, respectively. In general, partial LER of above 0.5 indicates that competitive pressures among the treatment were low and that both the crops could be complementary in mixture. Partial area-time equivalent ratio (ATER) of French bean was significantly higher (0.20) with 100% RDF to both crops. It indicates that this treatment was more efficient in utilizing resources in the respective fertilizer combinations. Total LER and ATER ranged from 1.30 to 1.62 and 0.98 to 1.12 respectively (Table 1). When the LER and ATER are more than unity, indicate biological sustainability of intercropping over sole cropping. Sugarcane + French bean (1: 2) with 100% RDF to both the crops and residue incorporation recorded the higher total LER of 1.62 and ATER of 1.12 indicating that intercropping though reduced the yield of sugarcane by 11.5%, this system as a whole was more productive with yield advantage of 62 and 12%, respectively on LER and ATER basis. This indicates that intercrops raised on balanced fertilization was more efficient in utilizing natural resources than

Table 1. Effect of fertility levels and irrigation schedules in sugarcane + French bean intercropping system on productivity, economics and resource-use efficiency (pooled data of 2 years)

Treatment	Millable canes (× 10^3 /ha)	Cane yield (t/ha)	Sugar yield (t/ha)	French bean yield (t/ha)		CEY (t/ha)	Cost of cultivation (× 10^3 ₹/ha)	Gross returns (× 10^3 ₹/ha)	Net returns (× 10^3 ₹/ha)	Benefit: cost ratio	Productivity (₹/day/ ha)	LER			ATER	
				Grain	Haulm							Sugar-cane	French-bean	Total	French-bean	Total
Nutrient management																
Sugarcane + French bean (1 : 2) with 100% RDF to both the crops and residue incorporation	108.5	83.7	9.66	1.15	1.90	100.0	87.5	229.4	141.9	2.62	509	0.92	0.71	1.62	0.20	1.12
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 50% RDF to French bean and residue incorporation	101.7	79.0	8.98	0.80	1.29	90.3	86.4	202.4	120.2	2.34	449	0.85	0.45	1.30	0.13	0.98
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 100% N to French bean and residue removal	98.9	76.6	8.89	0.68	1.09	86.3	86.2	201.8	111.3	2.34	447	0.86	0.45	1.30	0.13	0.98
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 100% N and P to French bean and residue incorporation	106.0	81.7	9.34	0.92	1.50	94.8	87.2	217.3	130.1	2.49	482	0.87	0.57	1.46	0.16	1.06
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 100% N and K to French bean and residue incorporation	106.9	82.4	9.44	0.95	1.54	95.8	86.5	219.6	133.1	2.53	487	0.90	0.58	1.48	0.17	1.07
SEm±	2.95	2.08	0.260	0.025	0.051	2.35	-	7.32	4.16	0.063	-	0.021	0.012	0.038	0.003	0.023
CD (P=0.05)	NS	NS	NS	0.07	0.14	6.8	-	21.6	12.0	0.18	-	NS	0.040	0.11	0.01	0.07
Irrigation schedule																
No irrigation	93.8	70.5	7.98	0.57	0.90	78.6	85.2	179.9	94.7	2.11	399	0.77	0.34	1.12	0.10	0.87
45 DAS	105.9	82.5	9.45	0.94	1.51	95.8	86.8	219.5	132.7	2.53	487	0.91	0.58	1.48	0.17	1.07
45, 75 DAS	113.6	89.0	10.36	1.20	1.98	106.0	88.4	242.8	154.4	2.75	538	0.98	0.73	1.71	0.21	1.18
SEm±	2.29	1.61	0.200	0.019	0.039	1.82	-	5.67	3.22	0.048	-	0.016	0.009	0.030	0.002	0.019
CD (P=0.05)	6.6	4.7	0.58	0.06	0.11	5.3	-	16.2	9.3	0.14	-	0.05	0.03	0.09	0.01	0.05
Interaction (F × I)	NS	NS	NS	NS	NS	NS	-	NS	NS	NS	-	NS	S	NS	S	NS
Intercrop vs sole crop																
Intercrop	104.4	80.7	9.26	0.9	1.46	93.4	86.8	214.1	127.3	2.46	475	0.88	0.55	1.43	0.16	1.04
Sole crop	114.3	91.2	10.62	1.64	2.60	91.2	80.2	209.8	129.4	2.61	465	1.00	1.00	1.00	1.00	1.00
						(23.2)	(33.1)	(53.4)	(19.9)	(1.61)	(118)					
SEm±	1.32	0.93	0.12	0.01	0.02	1.05	-	3.27	1.86	0.03	-	0.009	0.005	0.017	0.001	0.01
CD (P=0.05)	3.98	2.7	0.34	0.03	0.06	NS	-	NS	NS	NS	-	0.03	0.01	0.05	0.003	NS

RDF, Recommended dose of fertilizer; DAS, days after sowing; selling price (₹/tonne), Sugarcane ₹2,300; French bean ₹32,500; CEY, cane-equivalent yield; LER, land-equivalent ratio; ATER, area time equivalent ratio sole cropping, resulting in higher yield per unit area than that given by either of the sole crops. These results are in accordance with the studies of Singh *et al.* (2009) in sugarcane + grain amaranth intercropping system.

Significant improvement in LER as well as in ATER was noticed with successive increase in level of irrigation (Table 1). The application of 2 irrigations at 45 and 75 DAS induced 15.5 and 52.7% increase in total LER and 10.3 and 35.6% in total ATER over 1 irrigation at 45 DAS and no irrigation respectively. The significant increase in LER and ATER among the level of irrigation might be ascribed to adequate supply of the moisture to the active root zone of crops at appropriate stages, significantly induced physiological processes leading to higher use efficiency of natural resources resulted in higher productivity per unit area. The interaction effect of fertility levels and irrigation schedule on partial LER and ATER of French bean were also found significant and positive. The maximum partial LER and ATER of French bean were obtained with the combined application of 100% RDF to both the crops and 2 irrigations applied at 45 and 75 DAS followed by the application of 100% RDF to sugarcane and 100% N and K French bean with twice irrigation at 45 and 75 DAS.

System productivity and economic viability

The comparatively higher cane-equivalent yield (CEY) was recorded in intercropping as compared to sole cropping. The application of 100% RDF to both the crops and residue incorporation recorded significantly higher cane-equivalent yield was statistically similar to 100% RDF to sugarcane and 100% N and K to French bean and residue incorporation and 100% RDF to sugarcane and 100% N and P to French bean and residue incorporation, providing significantly higher CEY of 10.7 and 15.9% over 100% RDF to sugarcane and 50% RDF to French bean and residue incorporation and 100% RDF to sugarcane and 100% N to French bean and residue removal respectively. It seems to be associated with increased yield of French bean and sugarcane, both at optimum level of fertilization. Our results corroborate the findings of Kumar *et al.* (2006). The fertility levels remarkably influenced the economics of system (Table 1). Application of 100% RDF to sugarcane and French bean and residue incorporation recorded significantly higher gross returns, net returns and benefit: cost ratio when compared to 100% RDF to sugarcane and 50% RDF to French bean and residue incorporation and 100% RDF to sugarcane and 100% N to French bean and residue removal. However, application of 100% RDF to sugarcane and French bean and residue incorporation, 100% RDF to sugarcane and 100% N and P to French bean and residue incorporation and 100% RDF to sugarcane and 100% N and K to French bean and residue incorporation were statistically comparable to each other. Similarly, highest productivity in terms of monetary returns was also incurred with the application of 100% RDF to sugarcane and French bean and residue incorporation followed by 100% RDF to sugarcane and 100% N and K to French bean and residue incorporation, and 100% RDF to sugarcane and 100% N and P to French bean and residue incorporation.

Each incremental level of irrigation noticed pronounced effect on cane-equivalent yield, gross returns, net returns and benefit: cost ratio of sugarcane + French bean intercropping system (Table 1). The cane-equivalent yield of sugarcane + French bean intercropping system was registered significantly higher with the treatment receiving 2 and 1 irrigation over no irrigation. The magnitude of increase in CEY at 2 irrigations (45 and 75 DAS) over 1 and no irrigation was 10.6 and 34.9% respectively. Similarly, significantly highest gross returns, net returns and benefit: cost ratios realized with 2 irrigations at 45 and 75 DAS could be attributed to increased tonnage under the treatment. The highest productivity was achieved when 2 irrigations were applied at 45 and 75 DAS and least with no irrigation.

Nutrient uptake

In general, nutrient removal by sugarcane was higher than that by French bean, mainly due to higher yield of sugarcane (Table 2). Sole sugarcane and French bean recorded significantly higher nutrient uptake than the intercropping system. The application of 100% RDF to sugarcane and French bean and residue incorporation recorded higher nitrogen, phosphorus and potassium uptake in sugarcane, being at par with 100% RDF to sugarcane and 100% N and P to French bean and residue incorporation and 100% RDF to sugarcane and 100% N and K to French bean and residue incorporation in case of nitrogen and phosphorus uptake and 100% RDF to sugarcane and 100% N and K to French bean and residue incorporation in case of potassium uptake and significantly superior to rest of the treatments. Further, application of 100% RDF to both the crops and residue incorporation significantly enhanced the nutrient uptake (NPK) by intercropping system (Table 3). The variation in nutrient uptake under different treatments is the cumulative effect of the differences in the amount of nutrients supplied, changes in physico-chemical properties of the soil, plant nutrient content (%) and biomass yield of the crops. Kumar *et al.* (2014) also reported the similar results. Likewise, application of 100% RDF to sugarcane and French bean also induced marked variation in N, P and K uptake in grain and haulm of French bean over other treatments. This was due to higher

Table 2. Effect of fertility levels and irrigation schedules in sugarcane + French bean intercropping system on nutrient uptake at harvest and post-harvest nutrient status in soil (pooled data of 2 years)

Treatment	Nutrient uptake (kg/ ha)									Available nutrient status in post-harvest soil (kg/ha)					
	Sugarcane			French bean						After harvest of sugarcane			After harvest of French bean		
	N	P	K	N		P		K		N	P	K	N	P	K
				Grain	Haulm	Grain	Haulm	Grain	Haulm						
Nutrient management															
Sugarcane + French bean (1 : 2) with 100% RDF to both the crops and residue incorporation	245.2	22.8	290.5	37.1	11.4	5.6	3.1	21.3	26.7	248	15.7	121.2	264	17.4	128.7
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 50% RDF to French bean and residue incorporation	210.0	20.0	240.9	24.5	7.4	3.7	2.0	14.3	18.0	233	13.9	115.7	237	15.0	118.7
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 100% N to French bean and residue removal	221.6	19.4	233.8	21.6	6.7	3.2	1.6	12.2	15.1	241	13.2	112.3	256	14.2	116.2
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 100% N and P to French bean and residue incorporation	233.6	21.9	249.4	29.6	9.1	4.5	2.5	16.7	21.1	245	14.9	114.5	259	16.4	122.6
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 100% N and K to French bean and residue incorporation	241.3	21.5	280.3	30.3	9.3	4.6	2.5	17.5	21.8	245	14.2	118.7	260	15.7	126.3
SEm±	5.81	0.54	6.72	0.76	0.26	0.14	0.08	0.46	0.51	6.24	0.39	2.96	6.4	0.43	3.08
CD (P=0.05)	16.8	1.6	19.4	2.2	0.7	0.4	0.2	1.3	1.5	NS	1.1	NS	19	1.3	8.9
Irrigation schedule															
No irrigation	190.1	17.3	210.9	17.4	5.3	2.6	1.4	10.1	12.5	234	13.5	112.8	246	15.1	119.5
45 DAS	239.8	21.8	266.8	29.7	9.2	4.5	2.4	17.0	21.5	244	14.5	117.5	258	16.0	124.6
45, 75 DAS	261.2	24.3	299.2	38.7	11.8	5.8	3.1	22.0	27.6	249	15.1	119.2	261	16.0	123.5
SEm±	4.49	0.42	5.21	0.59	0.19	0.11	0.06	0.36	0.39	4.83	0.30	2.29	4.92	0.33	2.38
CD (P=0.05)	13.0	1.2	15.0	1.7	0.6	0.3	0.2	1.0	1.1	NS	0.9	NS	NS	NS	NS
Interaction (F × I)	NS	NS	NS	S	S	NS	S	S	S	NS	NS	NS	NS	NS	NS
Intercrop vs sole crop															
Intercrop	230.3	21.1	259.0	28.6	8.8	4.3	2.3	16.4	20.5	242	14.4	116.5	255	15.7	122.5
Sole crop	267.0	24.8	310.8	51.8	15.8	7.9	4.3	30.1	37.8	247	15.0	118.4	261	16.8	126.1
SEm±	2.60	0.24	3.01	0.34	0.11	0.06	0.03	0.21	0.23	2.79	0.17	1.32	2.84	0.19	1.38
CD (P=0.05)	7.4	0.7	8.6	1.0	0.3	0.2	0.1	0.6	0.7	NS	0.5	NS	NS	NS	NS

Table 3. Effect of fertility levels and irrigation schedules in sugarcane + French bean intercropping system on nutrient balance (kg/ha) in the soil after harvesting of sugarcane (pooled data of 2 years)

Treatment	Nutrient added (B)			Nutrient uptake by intercropping system (C)			Soil nutrient status after harvest of last crop (D)			Soil nutrient balance (D–A*)		
	N	P	K	N	P	K	N	P	K	N	P	K
Nutrient management												
Sugarcane + French bean (1 : 2) with 100% RDF to both the crops and residue incorporation	216.6	51.6	49.8	293.7	31.5	338.5	248	15.7	121.2	+ 40	+ 7.6	+ 18.2
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 50% RDF to French bean and residue incorporation	183.3	44.4	41.5	241.9	25.7	273.2	233	13.9	115.7	+ 25	+ 5.8	+ 12.7
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 100% N to French bean and residue removal	216.6	37.1	33.2	249.9	24.2	261.1	241	13.2	112.3	+ 33	+ 5.1	+ 9.3
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 100% N and P to French bean and residue incorporation	216.6	51.6	33.2	272.3	28.9	287.2	245	14.9	114.5	+ 37	+ 6.8	+ 11.5
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 100% N and K to French bean and residue incorporation	216.6	37.1	49.8	280.9	28.6	319.6	245	14.2	118.7	+ 37	+ 6.1	+ 15.7
SEm±	–	–	–	7.21	0.68	7.34	6.24	0.39	2.96	–	–	–
CD (P=0.05)	–	–	–	20.9	2.0	21.2	NS	1.1	NS	–	–	–
Irrigation schedule												
No irrigation	209.9	44.4	41.5	212.8	21.3	233.5	234	13.5	112.8	+ 26	+ 5.4	+ 9.8
45 DAS	209.9	44.4	41.5	278.7	28.7	305.3	244	14.5	117.5	+ 36	+ 6.4	+ 14.5
45, 75 DAS	209.9	44.4	41.5	311.7	33.2	348.8	249	15.1	119.2	+ 41	+ 7.0	+ 16.2
SEm±	–	–	–	5.59	0.53	5.69	4.83	0.30	2.29	–	–	–
CD (P=0.05)	–	–	–	16.2	1.5	16.4	NS	0.9	NS	–	–	–
Interaction (F × I)	–	–	–	NS	NS	S	NS	NS	NS	–	–	–
Intercrop vs sole crop												
Intercrop	209.9	44.4	41.5	267.7	27.8	295.9	242	14.4	116.5	+ 34	+ 6.3	+ 13.5
Sole crop	150	37.1	49.8	267.0	24.8	310.8	247	15.0	118.4	+ 39	+ 6.9	+ 15.4
	(100)	(21.8)	(24.9)	(67.6)	(12.2)	(67.9)	(261)	(16.8)	(126.1)	(+ 53)	(+ 8.7)	(+ 23.1)
SEm±	–	–	–	3.78	0.30	3.28	2.79	0.17	1.32	–	–	–
CD (P=0.05)	–	–	–	NS	0.9	9.8	NS	0.5	NS	–	–	–

*Initial nutrient status, 208 : 8.1 : 103 kg N : P : K/ha

NPK content and greater biomass production of the crop.

The effect of irrigation level on N, P and K uptake in sugarcane and grain and haulm of French bean and intercropping system were found to be significant (Table 2). The highest uptake of N, P and K were noticed with 2 irrigations applied at 45 and 75 DAS, whereas the lowest at no irrigation. A drastic reduction in the total uptake of N, P and K under no irrigation could be the result of insufficient soil water content for dissolving nutrients and causing their mineralization. Interaction effect of fertility levels and irrigation schedule on nutrient uptake of French bean was synergistic and significant where, the combination of 100% RDF to both the crops with 2 irrigations at 45 and 75 DAS resulted in significantly higher N uptake by grain and haulm of French bean. The maximum P uptake by French bean haulm was also noticed with the application of 100% RDF to both the crops in combination with 2 irrigations at 45 and 75 DAS. Similarly, sugarcane + French bean with 100% RDF to both the crops along with 2 irrigations at 45 and 75 DAS recorded significantly higher K uptake by grain and haulm of French bean as well as K uptake by sugarcane + French bean intercrop-

Table 4. Interaction effect of fertility levels and irrigation schedules on K uptake by French bean grain, haulm and sugarcane + French bean intercropping system (kg/ha)

Nutrient management x Irrigation schedule	K uptake (kg/ha)		
	Irrigation schedule		
	No irrigation	45 DAS	45, 75 DAS
		By French bean grain	
Sugarcane + French bean (1 : 2) with 100% RDF to both the crops and residue incorporation	13.1	22.2	28.6
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 50% RDF to French bean and residue incorporation	8.8	14.8	19.2
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 100% N to French bean and residue removal	7.5	12.7	16.4
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 100% N and P to French bean and residue incorporation	10.3	17.2	22.5
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 100% N and K to French bean and residue incorporation	10.8	18.1	23.5
SEm±	0.81		
CD (P=0.05)	2.3		
		By French bean haulm	
Sugarcane + French bean (1 : 2) with 100% RDF to both the crops and residue incorporation	16.3	28.1	35.8
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 50% RDF to French bean and residue incorporation	11.0	18.8	24.1
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 100% N to French bean and residue removal	9.1	15.9	20.3
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 100% N and P to French bean and residue incorporation	12.9	22.0	28.3
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 100% N and K to French bean and residue incorporation	13.4	22.8	29.3
SEm±	0.88		
CD (P=0.05)	2.5		
		By Intercropping system	
Sugarcane + French bean (1 : 2) with 100% RDF to both the crops and residue incorporation	267.1	349.2	399.0
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 50% RDF to French bean and residue incorporation	215.6	281.9	322.0
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 100% N to French bean and residue removal	206.0	269.4	307.8
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 100% N and P to French bean and residue incorporation	226.6	296.3	338.5
Sugarcane + French bean (1 : 2) with 100% RDF to sugarcane and 100% N and K to French bean and residue incorporation	252.2	329.7	376.7
SEm±	12.72		
CD (P=0.05)	36.7		

ping system. Later was similar to the application of 100% RDF to sugarcane and 100% N and K to French bean and residue incorporation in combination with 2 irrigations at 45 and 75 DAS (Table 4).

Post-harvest fertility status and nutrient balance in soil

Application of 100% RDF to sugarcane and French bean and residue incorporation significantly improved soil-available P after harvesting of sugarcane, being at par with 100% RDF to sugarcane and 100% N and P to French bean and residue incorporation and significantly superior to the other treatments, but available N and K were not affected significantly due to fertility levels (Table 2). The significant variation in available P after harvesting of sugarcane might be due to the direct effect of treatments and indirect effect of residue incorporation of mature French bean plant resulting in solubilization of native P and P availability due to reduced P fixation. Significantly enhanced N, P and K status in soil analysed after harvesting of French bean pods was observed under treatment of 100% RDF to sugarcane and French bean, which was statistically similar to 100% RDF to sugarcane and 100% N to French bean, 100% RDF to sugarcane and 100% N and P to French bean and 100% RDF to sugarcane and 100% N and K to French bean in case of available N and 100% RDF to sugarcane and 100% N and P to French bean and 100% RDF to sugarcane and 100% N and K to French bean in case of available K status except P where 100% RDF to sugarcane and French bean was statistically similar to 100% RDF to sugarcane and 100% N and P to French bean and significantly superior over 100% RDF to sugarcane and 100% N and K to French bean.

There was no significant differences among the levels different of irrigation for nutrient status after the harvesting of sugarcane and French bean pods except P status after sugarcane harvesting (Table 2) where higher available P content was noticed when 2 irrigations were applied at 45 and 75 DAS and it was at par with 1 irrigation applied at 45 DAS and significantly superior to no irrigation.

Positive balance of N, P and K in soil at sugarcane harvesting (Table 3) indicates soil fertility-enriching effect of fertility level and irrigation schedule with residue incorporation, indicating adequate availability of major nutrients (N, P and K) and moisture to ensure sustainability for sugarcane + French bean intercropping system. Kumar (2012) also reported positive effects of fertility level on nutrient balance.

Thus, an intercropping of autumn sugarcane + French bean (1: 2 row ratio) with 100% RDF to sugarcane and 100% N and K to French bean along with residue incorporation was equally productive and economical as with an application of 100% RDF to both the crops and residue incorporation and 100% RDF to sugarcane and 100% N and P to French bean and residue incorporation, hence providing an opportunity to save phosphorus of French bean for resource scarce farmers of state, who presently apply only nitrogenous fertilizer to intercrops. Application of 2 irrigations at 45 and 75 DAS of French bean was found optimum up to the period of French bean. However, normal irrigation to sugarcane should be applied after harvest of French bean.

REFERENCES

Hiebsch, C.K. 1980. Effect of N fertilization and crop duration on equivalency ratios in intercrops versus monoculture comparisons. Ph.D. thesis, North Carolina State University, Raleigh, N.C., USA.

ISMA. 2014. Indian Sugar Mills Association. *Indian Sugar* **63**(11): 60–62.

Jackson, M.L. 1973. *Soil Chemical Analysis*, pp. 183–84. Prentice Hall of India Pvt. Ltd, New Delhi, India.

Kumar, Navnit. 2012. Productivity, quality and nutrient balance in spring sugarcane (*Saccharum* spp. hybrid complex) under organic and inorganic nutrition. *Indian Journal of Agronomy* **57**(1): 68–73.

Kumar, Navnit., Singh, H. and Alam, M. 2012. Crop diversification with sugarcane for maximizing productivity, profitability and resource use efficiency: A review. (In:) *Abstract, National Seminar on Improving Cane Productivity and Sugar Recovery to Sustain Sugar Industries,* held during 27–29 November 2012 at Sugarcane Research Institute, Rajendra Agricultural University, Pusa, Bihar, India, pp. 59–60.

Kumar, Navnit,. Singh, H., Kumar, R. and Geeta, Kumari. 2014. Nutrient uptake, sugarcane yield and economics of high sugar early genotypes of sugarcane (*Saccharum* spp. hybrid complex) under various planting seasons and fertility levels in Bihar. *Indian Journal of Agricultural Sciences* **84**(4): 444–51.

Kumar, Navnit., Singh, H., Kumar, V. and Singh, V.P. 2013. Productivity and water-use efficiency of spring-planted sugarcane (*Saccharum* sp. hybrid complex) under various planting methods and irrigation regimes. *Indian Journal of Agronomy* **58**(4): 592–96.

Kumar, S., Rana, N.S., Singh, R. and Singh, A. 2006. Production potential of spring sugarcane as influenced by intercropping of dual – purpose legumes under tarai conditions of Uttarakhand. *Indian Journal of Agronomy* **51** (4) : 271–73.

Patel, K.P., Thanki, J.D., Patel, D.D., Bafna, A.M., Arvadia, M.K. and Gami, R.C. 2013. Integrated nutrient management in rice (*Oryza sativa*)–sugarcane (*Saccharum officinarum*) (plant) – sugarcane (ratoon) cropping sequence. *Indian Journal of Agronomy* **58** (1) : 9–14.

Rana, M.C., Datt, N. and Singh, M. 2006. Effect of *Rhizobium* culture in combination with organic and chemical fertilizers on french bean (*Phaseolus vulgaris*) under dry temperate conditions of Himachal Pradesh. *Indian Journal of Agronomy* **76** (3) : 151–53.

Shukla, S.K., Singh, P.N. and Chauhan, R.S. 2011. Effect of organic wastes amended with *Trichoderma* and *Gluconacetobacter* on physiological properties of soil and sugarcane ratoon yield in *Udicustochrept. Indian Journal of Agronomy* **56** (3): 254–59.

Singh, A. K. and Lal, M. 2007. Assessment of system productivity, cane physiology and economic viability of sugarcane (*Saccharum* complex hybrid)–based crop diversification options through on–station trials. *Indian Journal of Agricultural Sciences* **77** (12) : 866–89.

Singh, A. K. and Lal, M., Singh, P., Singh, I. and Yadav, D.V. 2009. System productivity and profitability of sugarcane (*Saccharum* spp. hybrid complex)+grain amaranth (*Amaranthus hypochondriacus*) intercropping system. *Indian Journal of Agronomy* **54** (3) : 296–300.

Solomon, S. 2014. Sugarcane agriculture and sugar industry in India: At a glance. *Sugar Technology* **16** (2) : 113–24.

Tyagi, S., Saini, S.K. and Kumar, V. 2011. Yield and soil nutrient balance of sugarcane (*Saccharum officinarum*) plant–ratoon system under integrated nutrient management. *Indian Journal of Agronomy* **56** (3) : 247-53.

Willey, R.W. 1979. Intercropping – its importance and research needs. Competition and yield advantages. *Field Crops Abstracts* **32** (1) : 1–10.