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Research Paper

Crop diversification with high-value crops for higher productivity and profitability under irrigated ecosystem

B. BHARGAVI[1], U.K. BEHERA[2], K.S. RANA[3], RAJ SINGH[4], SHIV PRASAD[5], R.N. PANDEY[6] AND GEETA SINGH[7]

ICAR–Indian Agricultural Research Institute, New Delhi 110 012

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ABSTRACT

A field investigation was carried out during the rainy (*kharif),* winter (*rabi*) and summer seasons of 2015–17 on sandy- clay- loam soil at ICAR-Indian Agricultural Research Institute, Pusa, New Delhi to evaluate 5 cropping systems, viz. maize (*Zea mays* L.) –pea (*Pisum sativum* L.) –okra [*Abelmoschus esculentus* (L.)], maize–mustard–[*Brassica juncea* (L.) Czernj] greengram [*Vigna radiata* (L.) R. Wilczek], cotton (*Gossypium hirsutum* L.) –wheat (*Triticum aestivum* L.), bottle gourd [*Lagenaria siceraria* (Molina) Standl] –onion (*Allium cepa* L.) and okra–wheat, for productivity, profitability and labour requirement. The experiment was laid out in randomized block design with 4 replications. Bottle gourd–onion cropping system recorded the highest wheat-grain-equivalent yield (WGEY) 19.9 t/ha, followed by maize–pea–okra (14.06 t/ha). The lowest WGEY was recorded with maize–mustard–greengram (9.12 t/ha). The net returns (₹216.34 × 10^3/ha) were higher with bottle gourd–onion cropping system, while maize–mustard–greengram registered lowest net returns (₹73.39 × 10^3/ha). Highest labour requirement was observed in maize–pea–okra system (197 man-days/ha) followed by okra–wheat system (166 man-days/ha). The minimum number of labour was required for maize–mustard–greengram system (117 man-days/ha) followed by cotton–wheat system (121 man-days/ha); however, there is no significant difference between the two systems.

Key words **:** Crop diversification, Cropping systems, Employment generation, High-value crops, Productivity, Profitability

The new agricultural technology widens the income inequality among the different sections of farming population and provides proportionately large benefits to the big farmers as compared to the small farmers, because the small farmers are slow to accept the new technology (Wilson, 2002). Also, the small farmers could not afford farm investment from their own savings to transform traditional agriculture into scientific farming.

The success of one such agricultural technology was Green Revolution. In the Green Revolution areas of the Indo/Gangetic Plains (IGP), continued adoption of the rice–wheat system for over 4 decades has posed a serious threat to agricultural sustainability in that region (Bhatt *et al*., 2016). These problems include deterioration of land, build-up of obnoxious weeds, declining factor productivity, plateauing of yield, receding water tables, loss of biodiversity and development of multiple nutrient deficiencies (Bhullar and Chauhan, 2015). Concerns about stagnating productivity, increasing production costs, declining resource quality, declining water tables and increasing environmental problems are the major forcing factors to look for alternative technologies in the IGP region of India. The traditional monoculture and disciplinary approach is unable to meet the growing and changing food demand and improve the livelihood of these smallholders on a sustainable basis (Mahapatra and Behera, 2011). Now, there is a growing demand for agricultural diversification and reorientation of strategies with emphasis on resource conservation technologies for improving productivity on a sustainable basis. Crop diversification and integrated farming systems (IFS) are very often advocated for alleviating the problems encountered in the post Green Revolution era (Behera *et al*., 2007).

Among rice and wheat cropping systems, irrigated rice is a heavy water consumer as it took around 5,000 litres of water to produce 1 kg of rice. Rice–wheat cropping system

[1]**Corresponding author's e-mail:** bhargavibussa@gmail.com
[1]Scientist, ICAR–Central Institute for Cotton Research, Nagpur, Maharashtra 440 010; [2]Dean, College of Agriculture, Central Agricultural University, Umiam, Meghalaya 7931 03; [3,4]Principal Scientists, Division of Agronomy, [5]Principal Scientist, Centre for Environment Science and Climate Resilient Agriculture, [6]Principal Scientist, Division of Soil Science and Agricultural Chemistry; [7]Principal Scientist, Division of Microbiology, ICAR–Indian Agricultural Research Institute, New Delhi 110 012.

consumes about 11,650 m^3/ ha water out of which 7,650 m^3 is by rice (Bhatt *et al*., 2016). Thus, the water table in IGP is declining down at alarming rates (Soni, 2012). As a result, submersible pumps are replacing the centrifugal pumps which lift up water from the deeper depths but they require more energy for this purpose (Hira, 2009). In the era of shrinking resource base of land, water and energy, resource use efficiency is an important aspect for considering the suitability of a cropping system. Hence, selection of component crops needs to be suitably planned to harvest the synergism among them towards efficient utilization of resource base and to increase overall productivity (Singh *et al*., 2017). With increasing purchasing power of people in the country, the demand for vegetable crops has increased enormously leading to sharp increase in their prices, and it has been the dominant factor for high inflationary pressure in Indian economy during recent years. Inclusion of crops like oilseeds, pulses, vegetables and fodder crops will improve the economic condition of small and marginal farmers owing to higher price and/or higher volume of their main and by-products (Sharma *et al*., 2007). Hence efforts are needed to promote diversification of rice-based cropping sequence in the country with high-value crops for sustaining the productivity and meet out demand for vegetables, pulses and oilseeds. Therefore, the present investigation was carried out to find out most productive, resource use-efficient and remunerative cropping system for this region.

MATERIALS AND METHODS

A field experiment was conducted from the rainy season (*kharif*) 2015 to summer 2017 at ICAR–Indian Agricultural Research Institute, New Delhi (28°38' N and 77°38' E, 228.6 m above mean sea-level). The climate of the region is semi-arid with dry hot summers and cold winters with an average annual rainfall of 1,088 mm, 83% of which is received through south-west monsoon during July–September. Soil of the experimental field was sandy clay loam in texture, slightly alkaline in reaction (*p*H 6.9), low in organic carbon (0.38%), available nitrogen (251.8 kg/ha), available phosphorus (11.2 kg/ha) and medium in potassium (254 kg/ha). The experiment was carried out in randomized block design with 4 replications. The treatments included 5 cropping systems, viz. maize–pea–okra, maize–mustard–greengram, cotton–wheat, bottle gourd–onion and okra–wheat. The net plot size of each treatment was 150 m^2.

The details of varieties used, seed rate, fertilizer doses and spacing are given in Table 1. Nitrogen (N), phosphorus (P) and potassium (K) were applied through urea, diammonium phosphate and muriate of potash respectively. In maize, half dose of N and full doses of P and K were applied at the time of sowing, while remaining N was applied 1 month after sowing. Half of N and full dose of P and K was given at the time of sowing and remaining was given before flowering in cotton. Full doses of N, P and K were applied at sowing time in bottle gourd. One-third of N, P and K at sowing and the remaining in 2 splits at 4 weeks and 8 weeks after sowing. All the crops were harvested manually at physiological maturity stage. After drying in the sun, the total biomass was weighed. Economic yield was recorded for all the crops. After harvesting of *kharif* crops, *rabi* crops were sown in the same plots without disturbing the layout as per recommended package of practices mentioned in Table 1. In wheat, half dose of N and full doses of P and K were applied at the time of sowing, while remaining N was top-dressed at the first irrigation. Half of N and full doses of P and K were given at the time of sowing of mustard and remaining half dose of N was applied 1 month after sowing. In onion, one-third dose of N and full dose of P and K were applied with last field operation. Remaining two-thirds N was given in 2 equal splits 30 and 60 days after transplanting. After harvesting of *rabi* crops, summer crops, viz. greengram and okra, were raised as per treatments without disturbing the original layout following standard package of practices (Table 1). Greengram was harvested at physiological stage of maturity, while 5–6 pickings of okra were taken to harvest it in green and immature stage.

Economic yields of the component crops were converted to wheat-grain-equivalent yield (WGEY), taking into account the prevailing minimum support price/market prices of the crops (Bhargavi *et al*., 2019). System productivity was calculated by adding the WGEY of the component crops.

RESULTS AND DISCUSSION

Performance of crops and cropping systems

In maize–pea–okra cropping system, the economic yield of maize (grain), pea (green pod) and okra was 4.46, 1.47 and 3.20 t/ha respectively (Table 2). Similarly, stover yield was 7.20, 3.08 and 3.48 t/ha respectively. The yield of maize (grain), mustard (seed) and greengram (seed) was 4.37, 1.52 and 0.55 t/ha respectively. Similarly, stover yield was 7.19, 4.21 and 0.71 t/ha respectively. The yield of seed cotton was 2.05 t/ha and stover yield was 5.14 t/ha. The grain yield of wheat was 5.19 t/ha. The straw yield obtained from wheat was 6.92 t/ha, during the study period. In bottle gourd – onion cropping system, bottle gourd fruit yield was 8.19 t/ha and stover yield was 3.41 t/ha, whereas the bulb yield of onion was 9.83 t/ha and stover yield obtained from onion was 1.35 t/ha. In okra – wheat cropping system, okra yield was 6.05 t/ha and the stover yield was 3.35 t/ha. The grain yield of wheat was 5.25 t/ha. The straw

Table 1. Production technology adopted for raising crops during 2015–16 and 2016–17

Cropping system	Variety			Seed rate (kg/ha)			Spacing (cm × cm)			Fertilizer (kg/ha) (N:P^{2}O^5:K^{2}O)		
	Kharif	*Rabi*	Summer	*Kharif*	*Rabi*	Summer	*Kharif*	*Rabi*	Summer	*Kharif*	*Rabi*	Summer
Maize–pea–okra	'PMH-1'	'FVS-1000'	'Arka Anamika'	20	60	15	60×15	40×10	60×50	120:60:40	25:50:50	70:40:40
Maize–mustard–greengram	'PMH-1'	'Pusa-25'	'SML-668'	20	6	20	60×15	50×10	30×10	120:60:40	60:60:40	20:40:30
Cotton–wheat	'Shriram-6588' '(BG-II)'	'HD-2967'	–	3	100	–	75×50	20×10	–	120:60:60	120:60:40	–
Bottle gourd–onion	'PSPL'	'Pusa Riddhi'	–	3	8	–	250×100	25×10	–	60:40:50	120:60:80	–
Okra–wheat	'Arka Anamika'	'HD-2967'	–	15	100	–	60×50	20×10	–	60:30:30	120:60:40	–

yield obtained from wheat was 7.0 t/ha.

Among all the *kharif* crops, bottle gourd resulted in higher productivity (8.19 t/ha) followed by okra (6.05 t/ha), while among the *rabi* crops, onion had higher productivity (9.83 t/ha) followed by wheat (5.25 t/ha) and okra (3.20 t/ha) which registered higher tonnage than greengram (0.55 t/ha) during the summer season. Vegetables resulted in higher productivity when compared to grain crops.

System productivity

Among the cropping systems tried, system productivity was significantly higher in bottle gourd–onion cropping system, being 118.1, 89, 50.4 and 41.55% more than maize–mustard–greengram, cotton–wheat, okra–wheat and maize–pea–okra cropping systems respectively. Higher tonnage and better price of both bottle gourd and onion played a vital role in improving the wheat-grain-equivalent yield. The next cropping system in the order was maize–pea–okra with WGEY of about 14.28 and 13.84 t/ha during 2015–16 and 2016–17 respectively. It can be attributed mainly to okra which fetched higher prices in the market besides having higher productivity. However, WGEY of maize–pea–okra was statistically at par with okra–wheat cropping system. The system productivity was higher in cropping systems through the inclusion of high value crops, i.e. vegetables. Mishra *et al*. (2007) also observed higher productivity with the inclusion of vegetables in rice-based cropping systems. These results are in line with the findings of Singh *et al*. (2007), who reported rice–pea–okra followed by rice–pea–onion as the most productive cropping sequence for eastern Uttar Pradesh, India. The lowest wheat–grains– equivalent yield and net returns were noticed in maize–mustard–greengram system but it involved lowest cost of cultivation, which may be suitable for resource poor farmers. Also, in a long run greengram has better soil-building effect and hence soil health.

Economics

The cost of cultivation/ha was higher in maize–pea–okra cropping system ₹97.82 × 10^3/ha (Table 3). To realize higher returns from the vegetable crops, farmers have to spend more on seed, fertilizer, labour, irrigation and adopt newer technologies. Besides, okra and onion crops required more man-days for weeding and harvesting. Therefore, cost of cultivation increased due to inclusion of vegetables as compared to the other cropping systems. Shah *et al*. (2015) concluded that, the inclusion of vegetables in the cropping system increased the total variable cost due to more fertilization and human labour requirement. Jain *et al*. (2015) also reported that, inclusion of vegetable (okra) increased the cost of cultivation. Besides, the lowest cost was incurred in maize–mustard–greengram cropping system owing to less number of man-days and irrigations. Reddy (2014) also reported that the total cost/ha was higher in high value crops (vegetables, fruits and flowers) followed by cotton, oilseeds, rice–wheat, pulse–cereal-based, pulse-based and the least in coarse cereal-based cropping systems.

Significantly higher net returns were realized from bottle gourd–onion cropping system (216.34 × 10^3₹/ha). Bottle gourd – onion cropping system fetched an additional income of 92.84 × 10^3, 142.95 × 10^3, 136.89 × 10^3 and 94.54 × 10^3₹/ha over maize–pea–okra, maize–mustard–greengram, cotton–wheat and okra–wheat cropping systems respectively. This was owing to inclusion of vegetable crops (bottle gourd and onion) in the system, besides improving the system productivity because of their higher tonnage, fetched good market price thereby, increasing net returns. Besides, raising of vegetable crop (onion) during summer season is economically remunerative as supply of vegetables from rainfed area is drastically reduced and vegetable prices are much higher. Therefore, surplus onion produced can be transported in areas of high demand even after 2–3 months after harvesting, as they have good shelf-life. The next cropping system in the order was maize – pea–okra cropping system with net returns of ₹123.50 × 10^3/ha. Kumar *et al*. (2008) reported that inclusion of vegetable crops in rice-based crop sequences improved the net returns. The lowest net returns of ₹73.39 × 10^3 /ha was estimated with maize–mustard–greengram system. This was due to lower yields from mustard and greengram. However, significantly higher benefit : cost ratio was recorded under bottle gourd–onion cropping system probably owing to higher returns in comparison to cost of cultivation.

Labour requirement

The labour requirement for maize cultivation was 57 man-days/ha (Table 3). Man days/ha for the cultivation of pea and okra were 42 and 98, respectively. Employment generation from maize–pea–okra rotation was 197 man-days/ha. Labour requirement of maize–mustard–greengram sequence was 117 man days/ha. To produce cotton in 1 ha area, the man-days needed were 73. Similarly, for wheat the labour requirement were 48 man-days/ha. The labour requirement for the cotton–wheat system was 121 man-days/ha. Bottle gourd cultivation required 58 man-days/ha. Onion cultivation required 81 man-days/ha. Employment generation from bottle gourd–onion rotation was 139 man-days/ha. Labour requirement of okra and wheat was 118 and 48 man-days/ha respectively. Employment generation from okra–wheat sequence was 166 man-days/ha.

Highest labour requirement was observed in maize–pea–okra system (197 man-days/ha) followed by okra–wheat system (166 man-days/ha) owing to peak requirement during weeding and harvesting of okra (Table 3).

Table 2. Performance (economic yield) of different cropping systems (mean data of 2 years)

Treatment	Economic yield (t/ha)			Straw/stover yield (t/ha)			Wheat-grain-equivalent yela (t/ha)		
	Kharif	*Rabi*	Summer	*Kharif*	*Rabi*	Summer	2015–16	2016–17	Mean
Cropping systems									
CS_1, Maize–pea–okra	4.46	1.47	3.20	7.20	3.08	3.48	14.28	13.84	14.06
CS_2, Maize–mustard–greengram	4.37	1.52	0.55	7.19	4.21	0.71	8.93	9.32	9.12
CS_3, Cotton–wheat	2.05	5.19	–	5.14	6.92	–	10.34	10.71	10.53
CS_4, Bottle gourd–onion	8.19	9.83	–	3.41	1.35	–	19.66	20.14	19.90
CS_5, Okra–wheat	6.05	5.25	–	3.35	7.00	–	12.93	13.53	13.23
SEm±	–	–	–	–	–	–	0.42	0.39	0.41
CD (*P*=0.05)	–	–	–	–	–	–	1.29	1.19	1.24

Table 3. Economics (cost of cultivation, net returns) and labour requirement of different cropping systems (mean data of 2 years)

Treatment	Cost of cultivation (×10^3₹/ha)			Net returns (× 10^3₹/ha)			Labour requirement (man-days/ha)			
	2015–16	2016–17	Mean	2015–16	2016–17	Mean	*Kharif*	*Rabi*	Summer	Total
Cropping systems										
CS_1, Maize–pea–okra	95.13	100.50	97.82	122.66	124.34	123.50	57	42	98	197
CS_2, Maize–mustard–greengram	68.20	72.65	70.43	67.95	78.83	73.39	57	30	30	117
CS_3, Cotton–wheat	84.62	88.27	86.45	73.05	85.85	79.45	73	48	–	121
CS_4, Bottle gourd–onion	98.85	95.58	97.22	200.91	231.78	216.34	58	81	–	139
CS_5, Okra–wheat	85.20	88.30	86.75	112.04	131.57	121.80	118	48	–	166
SEm±	–	–	–	2.19	2.57	2.37	–	–	–	3.43
CD (*P*=0.05)	–	–	–	6.74	7.91	7.31	–	–	–	10.57

Minimum number of labour was required for maize–mustard–greengram system (117 man-days/ha) followed by cotton–wheat system (121 man-days/ha); however, there was no significant difference between the 2 systems with respect to the labour requirement.

It can be concluded that bottle gourd–onion cropping system was more productive and profitable followed by maize–pea–okra system. These systems can suitably substitute the existing rice–wheat cropping system under marginal farmers situations. However, the highest labour requirement was observed in maize–pea–okra system followed by okra–wheat system owing to peak requirement during weeding and harvesting of okra. Maize–mustard–greengram system involved the lowest cost of cultivation, which may be suitable for resource poor farmers. These systems not only provide higher productivity and returns, but also provide the farmers a regular return and employment throughout the year.

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