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Effect of nutrient management practices on soil, yield and economics of rice- chickpea cropping system at farmer's fields in Chhattisgarh

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Abstract
On –farm experiments were conducted during *Kharif* and *Rabi* seasons of 2018-19 at 24 farmer's fields at 6 villages viz. Aaturgaon, Bevarti and Mohpur of Block- Kanker and Hatkondal, Gotulmunda and Damkasa villages of Block- Durgukondal, District- Uttar Bastar Kanker, situated in Chhattisgarh Plain Zone (CG-1) and Bastar Plateau Zone (CG-2) of Chhattisgarh. Experiment conducted at 4 farmer's field in each village. The soils of experimental site were sandy loam to loam; with low in available nitrogen (175.45 kg ha^{-1}) and available phosphorus (8.68 kg ha^{-1}) and medium in available potassium (290.24 kg ha^{-1}) and organic carbon (0.50%) and acidic in reaction (6.5 pH). The rice- chickpea cropping system experiments were conducted with seven treatments viz. control (T_1), N (T_2), NP (T_3), NK (T_4), NPK (T_5), NPK+ micro nutrient (T_6) and Farmers practice (T_7). For Zn micro nutrient $ZnSO_4$ applied in rice and Single Super Phosphate applied for both P and S in chickpea under T_6 treatment. The recommended dose of nutrients were: 100:60:40 kg ha^{-1} N: P_2O_5: K_2O + 20 kg ha^{-1} $ZnSO_4$ for rice and 20:40:20:20 kg ha^{-1} N: P_2O_5: K_2O: S for chickpea. Nutrients dose 60:40:30 kg ha^{-1} N: P_2O_5: K_2O and 10:20:10 kg ha^{-1} N: P_2O_5: K_2O were applied in rice and chickpea crops respectively under farmer's practice. IGKV R-2 variety of rice and JAKI-9218 variety of chickpea grown with recommended package of practices under irrigated condition. The application of recommended dose of NPK + micro nutrient recorded significantly higher grain yield of rice (51.03 q ha^{-1}), chick pea (13.34 q ha^{-1}) and RGEY (84.19 q ha^{-1}). Farmers practice treatment recorded highest nutrient response 11.49 kg grain/ kg nutrient and application of recommended dose of N in rice- chickpea cropping system recorded highest nutrient response Rs/Re (15.15). Application of recommended dose of NPK + micronutrient recorded significantly higher nutrient uptake N (144.18 kg ha^{-1}), P (30.42 kg ha^{-1}) and K (132.56 kg ha^{-1}) by rice- chickpea cropping system. Application of recommended dose of NPK+ micronutrient recorded significantly higher organic carbon (0.56%), available nitrogen (194.57 kg ha^{-1}) and phosphorus (9.24 kg ha^{-1}), while application of recommended dose of NPK recorded higher potassium (306.63 kg ha^{-1}) at end of the cropping system. Highest positive balance of available nitrogen (163.3 kg ha^{-1}) and phosphorus (30.98 kg ha^{-1}) recorded in application of recommended dose of NPK + micronutrient and application of recommended dose of NPK recorded higher potassium (144.68 kg ha^{-1}). Highest gross return (151954 Rs ha^{-1}), net return (97197 Rs ha^{-1}) and B: C ratio (2.78) of rice- chickpea cropping system recorded under application of recommended dose of NPK + micronutrient.

Keywords: On farm, nutrient management, rice, chickpea, cropping system, yield, nutrient uptake, soil, economics

Introduction

Chhattisgarh state is popularly recognized as "Rice Bowl" of the country, as rice is the principal crop of this state and about 84.35 per cent of crop area is covered under *kharif* rice. Rice occupies an area of 3.89 million hectares with the production of 12.49 million tones and average productivity of 3212 kg ha^{-1} and chickpea occupies an area of 0.38 million hectares with the production of 0.27 million tones and average productivity of 719 kg ha^{-1} during 2021-22 (Anonymous, 2022) [1] in the state and most of the area under rice- chickpea system. An intensive cropping which is not only highly productive and profitable but also stable over time and maintains soil fertility has a great importance in present conditions. Inclusion of pulses and oilseeds in a sequence changes the economics of the cropping sequences. Pulses are integral part of the cropping system because these crops fit well in the cropping system *viz.* crop rotation, mixed cropping, intercropping and sequential cropping.

Fertilizer response in irrigated areas of country has declined almost three times from 13.4 kg grain/kg NPK in 1970 to 3.7 kg grain/kg NPK in 2005 (Samra and Sharma, 2009) [9]. In 1970, only 54 kg NPK/ha was required for a yield of 20 q/ha, but approximately 218 kg NPK/ha is now being used to obtain the same yield (Biswas and Sharma, 2008) [4]. For the present level of production, the estimated nitrogen– phosphorus–potassium removal is about 28 metric tonne, resulting in a negative balance of about 10 metric tones in India (Mangal *et al.* 2018) [6]. Balanced fertilization of a crop needs supply of major, minor and micronutrients. So better matching of nutrient supply with crop demand is often considered a basis for improving and stabilizing yield, in irrigated as well as rain-fed systems. The nutrients, their sources, method and time of application form an important component of fertilizer management strategies. Besides major nutrients, Zn and S are the most important micro and secondary nutrient particularly in our country because most of Indian soils are deficient. Occurrence of multi-nutrient deficiency due to imbalanced use of nutrients and decline soil organic matter are the factor affecting the productivity of major food crops at farmer's fields and these contribute the wider gap between on-station and on-farm condition. It is worthwhile to mention that although organic manures ameliorate the physical, chemical and biological properties of the soils, they cannot substitute chemical fertilizers because of the low amount of plant nutrients present in them. The productivity of rice and chickpea of Chhattisgarh state are lower than national productivity might be due to low and imbalance application of nutrients. Application of imbalanced and excessive nutrients leads to declining nutrient use efficiency making fertilizer consumption uneconomic and producing adverse effect on ecosystem (Aulakh and Adhya, 2005) [2] and ground water quality causing health hazards and climate change (Aulakh *et al.* 2009) [3]. Therefore, to overcome this problem there is need to develop balance nutrient management for cropping system, helps to conserve land, water, biodiversity, living organisms and ecosystem which is technically appropriate, productive, economically viable and socially acceptable.

Materials and Methods

On –farm experiments were conducted during *Kharif* and *Rabi* seasons of 2018-19 at 24 farmer's fields at 6 villages viz. Aaturgaon, Bevarti and Mohpur of Block- Kanker and Hatkondal, Gotulmunda and Damkasa villages of Block- Durgukondal, District- Uttar Bastar Kanker, situated in Chhattisgarh Plain Zone (CG-1) and Bastar Plateau Zone (CG-2) of Chhattisgarh. Experiment conducted at 4 farmer's field in each village. The soils of experimental site were sandy loam to loam; with low in available nitrogen (175.45 kg ha^{-1}) and available phosphorus (8.68 kg ha^{-1}) and medium in available potassium (290.24 kg ha^{-1}) and organic carbon (0.50%) and acidic in reaction (6.5 pH). The rice- chickpea cropping system experiments were conducted with seven treatments viz. control (T_1), N (T_2), NP (T_3), NK (T_4), NPK (T_5), NPK+ micro nutrient (T_6) and Farmers practice (T_7). For Zn micro nutrient $ZnSO_4$ applied in rice and Single Super Phosphate applied for both P and S in chickpea under T_6 treatment. The recommended dose of nutrients were: 100:60:40 kg ha^{-1} N: P_2O_5: K_2O + 20 kg ha^{-1} $ZnSO_4$ for rice and 20:40:20:20 kg ha^{-1} N: P_2O_5: K_2O: S for chickpea. Nutrients dose 60:40:30 kg ha^{-1} N: P_2O_5: K_2O and 10:20:10 kg ha^{-1} N: P_2O_5: K_2O were applied in rice and chickpea crops respectively under farmer's practices. Half of the nitrogen and full doses of P_2O_5, K_2O and $ZnSO_4$ were applied at the time of transplanting of rice and remaining ¼ N applied at tillering (30 DAT) and ¼ N applied at panicle emergence stage. In chickpea entire quantity of N, P_2O_5, K_2O and S applied at the time of sowing. IGKV R-2 variety of rice and JAKI-9218 variety of chickpea grown with recommended package of practices under irrigated condition.

Both the crops were evaluated in terms of total system productivity, gross return, net return and benefit: cost ratio. On system basis, chickpea seed yield converted into rice grain equivalent yield (RGEY). Soil samples were analyzed for available N, P, and K, OC, pH and Electric conductivity at initial and end of the cropping system. The plant samples were analyzed for N, P and K concentration in grain and straw and total N, P and K uptake was calculated by multiplying the respective nutrient concentrations with the yield. Balance sheet of nutrient in soil was calculated by using the formulae as suggested by Raghuwanshi *et al.* (1991) [3].

Results and Discussion

Productivity of crops and cropping system

The grain and straw yield of rice and chickpea significantly influenced due different nutrient management practices (Table 1). Results reveal that application of recommended dose of NPK + micro nutrient recorded significantly higher grain yield of rice (51.03 q ha^{-1}), chick pea (13.34 q ha^{-1}) and RGEY (84.19 q ha^{-1}), followed by recommended dose of NPK *i.e.*, 49.71 q ha^{-1} of rice, 12.59 q ha^{-1} of chick pea and 81 q ha^{-1} of RGEY. The increase in grain yield 38, 59, 47, 93, 98, 60 percent of rice and 23, 52, 41, 74, 84, 53 percent of chick pea respectively with the application of recommended dose of N, NP, NK, NPK, NPK + micro nutrient, Farmers practice over control. The application of recommended dose of NPK + micronutrient recorded significantly higher straw yield of rice (48.34 q ha^{-1}) and chick pea (15.13 q ha^{-1}), followed by recommended dose of NPK *i.e.*, 49.71 q ha^{-1} of rice and 12.59 q ha^{-1} of chick pea. Application of NPK + micro nutrient in cropping system recorded significantly higher Rice Grain Equivalent Yield (84.19 q ha^{-1}) fallowed by NPK *i.e.* 81 q ha^{-1}. Increase in grain and straw yield of rice and chickpea may be due to optimum and balance supply of plant nutrients which increase the growth and yields of crops. C.K. Chandrakar *et al.* (2017) [5] and Netam *et al.* (2020) [7] conducted On-farm experiments at villages of district - Kabirdham and Uttar Bastar, Kanker, Chhattisgarh respectively and recorded higher grain and straw yield of rice - chickpea cropping system with application of recommended dose of NPK + micronutrients. Similarly, at Navsari, Gujarat, R. N. Mansuri (2016) [10] recorded significantly higher grain and straw yield of rice and chickpea with application of 100% RDN through inorganic fertilizers.

Nutrients response in cropping system

In rice – chickpea cropping system, application of 60:40:30 kg NPK ha^{-1} (FP) recorded highest nutrient response 11.49 kg grain/ kg applied nutrient followed by application of recommended dose of NPK. Application of recommended dose of N in rice- chickpea cropping system resulted highest nutrient response in terms of Rupees return per Rupee investment (15.15 Rs/Re) followed by farmers practice with application of 60:40:30 kg NPK ha^{-1} (10.90 Rs/Re). Netam *et al.* (2020) [7] conducted On-farm experiments at villages of district - Uttar Bastar, Kanker, Chhattisgarh and recorded highest nutrient response 16.09 kg grain/ kg applied nutrient under application of 60:40:30 kg NPK ha^{-1} (FP) and Highest Rupees return per Rupee investment (8.62 Rs/Re) recorded with application of recommended dose of N.

Nutrient Uptake

Data presented in Table 4, reveal that application of recommended dose of NPK + $ZnSO_4$ recorded significantly higher nutrient uptake N (53.13 kg ha^{-1}), P (15.83 kg ha^{-1}), K (12.82 kg ha^{-1}) by rice grain and N (31.83 kg ha^{-1}) P (8.22 kg ha^{-1}) and K (82.55 kg ha^{-1}) by rice straw followed by recommended dose of NPK. Application of recommended dose of NPK+ S recorded significantly higher nutrient uptake N (44.32 kg ha^{-1}), P (4.45 kg ha^{-1}) and K (8.75 kg ha^{-1}) by chickpea grain and N (14.9 kg ha^{-1}), P (1.92 kg ha^{-1}) and K (28.43 kg ha^{-1}) by chickpea straw followed by recommended dose of NPK. Application of recommended dose of NPK+ micronutrient recorded significantly higher nutrient uptake N (144.18 kg ha^{-1}), P (30.42 kg ha^{-1}) and K (132.56 kg ha^{-1}) by rice- chickpea cropping system followed by application of recommended dose of NPK. C.K. Chandrakar *et al.* (2017) [5] and Netam *et al.* (2020) [7] conducted On-farm experiments at villages of district -Kabirdham and Uttar Bastar, Kanker, Chhattisgarh respectively and recorded that N, P and K uptake of rice-chickpea cropping system significantly higher with application of recommended dose of NPK + micronutrients. Similarly, R. N. Mansuri (2016) [10] recorded significantly higher N, P and K uptake of rice and chickpea with application of 100% RDN through inorganic fertilizers at Navsari, Gujarat.

Fertility status of soil

Fertility status of soil at end of the cropping system presented in Table 3 and reveal that Application of NPK + micronutrient recorded significantly higher organic carbon (0.56%) and available nitrogen (194.57 kg ha^{-1}) followed by the application of only N (191.82 kg ha^{-1}). The application of NPK + micronutrient recorded significantly higher phosphorus (9.24 kg ha^{-1}) followed by the application of NPK (9.08 kg ha^{-1}), whereas the application of recommended dose of NPK recorded significantly higher potassium (306.63 kg ha^{-1}) followed by application of NPK + micronutrient (302.06 kg ha^{-1}). pH and electric conductivity not influenced significantly. Similarly, C.K. Chandrakar *et al.* (2017) [5] and Netam *et al.* (2020) [7] conducted On-farm experiments at villages of district -Kabirdham and Uttar Bastar, Kanker, Chhattisgarh respectively and recorded significantly higher available nitrogen, phosphorus and potassium with application of recommended dose of NPK + micronutrients.

Nutrient balance

Data on balance sheet of available nitrogen, phosphorus and potassium in soil indicated that there was a positive balance of available nitrogen, potassium and potassium in the soil under all treatments (Table 5). All the treatments showed positive balance of available nitrogen and highest positive balance of available nitrogen (163.3 kg ha^{-1}) recorded in application of recommended dose of NPK + micronutrient followed by application of recommended dose of NPK (150.32 kg ha^{-1}). The application of recommended dose of NPK + micronutrient recorded higher balance of available phosphorus (30.98 kg ha^{-1}) followed by application of recommended dose of NPK (29.4 kg ha^{-1})). Highest positive balance of available potassium (144.68 kg ha^{-1}) recorded under the application of recommended dose of NPK followed by application of recommended dose of NPK + micronutrient (144.38 kg ha^{-1}). Lowest balance of available nitrogen (74.71 kg ha^{-1}), phosphorus (13.72 kg ha^{-1}) and potassium (63.72 kg ha^{-1}) recorded in control. Similarly, R.N. Mansuri (2016) [10] conducted an experiment at Navsari, Gujarat and recorded positive balance of available nitrogen, phosphorus and potassium with application of 100% RDN through inorganic fertilizers. Similarly, Netam *et al.* (2020) [7] conducted On-farm experiments at villages of district- Uttar Bastar, Kanker, Chhattisgarh and recorded highest positive balance of available nitrogen and potassium with application of recommended dose of NPK + micronutrient.

Economics of cropping system

Effect of different treatments can not be assessed without the gross and net return from those treatments. The economics of different treatments presented in Table 2. Highest gross return (90323 Rs ha^{-1}) and net return (56716 Rs ha^{-}) of rice, gross return (61631 Rs ha^{-1}) and net return (40481 Rs ha^{-}) of chickpea and gross return (151954 Rs ha^{-1}), net return (97197 Rs ha^{-1}) and B: C ratio (2.78) of rice- chickpea cropping system recorded under application of recommended dose of NPK + micronutrient followed by application of recommended dose of NPK. Similarly, C.K. Chandrakar *et al.* (2017) [5] and Netam *et al.* (2020) [7] conducted On-farm experiments at villages of district -Kabirdham and Uttar Bastar, Kanker, Chhattisgarh respectively and recorded significantly higher net return, and B: C ratio with application of recommended dose of NPK + micronutrients.

Table 1: Yield parameters and nutrient response of rice-chickpea cropping system as influenced by nutrient management practices

Treatment	Yield of rice (q ha^{-1})		RGEY (q ha^{-1})	Yield of chickpea (q ha^{-1})		Nutrient response	
	Grain	Straw		Grain	Straw	Kg grain/kg nutrient	Rs/Re
Control	25.79	26.90	43.81	7.25	8.85	-	-
N	35.55	34.72	57.78	8.95	10.58	9.03	15.15
NP	41.11	40.68	68.50	11.02	13.08	8.61	5.50
NK	37.96	37.92	63.29	10.19	12.01	8.82	9.92
NPK	49.71	47.21	81.00	12.59	14.47	9.92	6.50
NPK + $ZnSO_4$/S	51.03	48.34	84.19	13.34	15.13	9.41	6.94
Farmers practice	41.29	40.34	68.91	11.11	13.28	11.49	10.90
SEm±	0.83	1.22	0.85	0.18	0.22	-	-
CD (P = 0.05)	2.40	3.54	2.46	0.54	0.65	-	-

Table 2: Economics of rice-chickpea cropping system as influenced by nutrient management practices

Treatment	Rice (Rs. ha^{-1})			Chickpea (Rs. ha^{-1})			Cropping system (Rs. ha^{-1})			
	Cost of cultivation	Gross return	Net return	Cost of cultivation	Gross return	Net return	Cost of cultivation	Gross return	Net return	B:C ratio
Control	27566	45648	18082	18595	33495	14900	46161	79143	32982	1.71
N	28855	62924	34069	18950	41349	22399	47805	104273	56468	2.18
NP	31912	72765	40853	21091	50912	29821	53003	123677	70674	2.33
NK	29750	67189	37439	19500	47078	27578	49250	114267	65017	2.32
NPK	32807	87987	55180	21538	58166	36628	54345	146153	91808	2.69
NPK + $ZnSO_4$/S	33607	90323	56716	21150	61631	40481	54757	151954	97197	2.78
Farmers practice	29647	73083	43436	20067	51328	31261	49714	124411	74697	2.50

Table 3: Final soil nutrient status of rice-chickpea cropping system as influenced by nutrient management practices

Treatment	pH	EC (ds/m)	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Control	6.55	0.16	0.50	179.96	8.01	285.60
N	6.64	0.16	0.52	191.82	8.24	289.35
NP	6.54	0.16	0.55	188.34	8.94	289.28
NK	6.61	0.15	0.54	191.13	8.37	299.35
NPK	6.63	0.16	0.56	188.25	9.08	306.63
NPK + $ZnSO_4$/S	6.59	0.16	0.56	194.57	9.24	302.06
Farmers practice	6.60	0.15	0.52	185.04	8.47	295.37
SEm$\pm$	0.03	0.01	0.01	2.96	0.30	3.51
CD (P = 0.05)	NS	NS	0.02	8.56	0.86	10.12

Table 4: Nutrient uptake by rice-chickpea cropping system as influenced by nutrient management practices

Treatment	Nutrient uptake (kg ha^{-1}) by Rice						Nutrient uptake (kg ha^{-1}) by Chickpea						Total uptake (kg ha^{-1}) by Rice - chickpea system		
	N		P		K		N		P		K				
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	N	P	K
Control	25.48	15.83	7.27	3.91	5.72	42.95	20.87	8.02	2.15	1.05	4.41	15.27	70.20	14.39	68.36
N	35.98	21.72	10.41	5.67	8.30	56.73	28.43	10.09	2.82	1.29	5.66	18.56	96.23	20.19	89.25
NP	42.16	25.71	12.40	6.63	9.88	67.34	35.77	12.55	3.56	1.64	7.06	23.29	116.18	24.24	107.58
NK	38.67	24.25	11.28	6.05	9.27	63.74	33.21	11.67	3.19	1.45	6.65	22.15	107.81	21.97	101.81
NPK	50.98	30.76	15.17	7.87	12.41	80.65	41.65	14.13	4.13	1.82	8.25	26.98	137.52	29.00	128.29
NPK + $ZnSO_4$/S	53.13	31.83	15.83	8.22	12.82	82.55	44.32	14.90	4.45	1.92	8.75	28.43	144.18	30.42	132.56
Farmers practice	41.00	24.52	12.17	6.13	9.63	66.06	33.49	11.96	3.38	1.61	6.93	23.41	110.96	23.29	106.04
SEm$\pm$	0.92	0.85	0.33	0.26	0.26	2.10	0.69	0.25	0.08	0.03	0.15	0.43	1.64	0.52	2.19
CD (P = 0.05)	2.66	2.47	0.97	0.75	0.76	6.07	2.00	0.72	0.23	0.09	0.43	1.23	4.74	1.50	6.23

Table 5: Balance sheet of Nitrogen, Phosphorus and Potassium at end of cropping system as influenced by nutrient management practices

	Nitrogen (kg ha^{-1})						Phosphorus (kg ha^{-1})						Potassium (kg ha^{-1})					
Treatment	Initial status	Applied	Uptake by crop	Expected balance	Final status	Balance	Initial status	Applied	Uptake by crop	Expected balance	Final status	Balance	Initial status	Applied	Uptake by crop	Expected balance	Final status	Balance
Control	175.45	0	70.2	105.25	179.96	74.71	8.68	0	14.39	-5.71	8.01	13.72	290.24	0	68.36	221.88	285.6	63.72
N	175.45	120	96.23	79.22	191.82	112.6	8.68	0	20.19	-11.51	8.24	19.75	290.24	0	89.25	200.99	289.35	88.36
NP	175.45	120	116.18	59.27	188.34	129.07	8.68	100	24.24	-15.56	8.94	24.5	290.24	0	107.58	182.66	289.28	106.62
NK	175.45	120	107.81	67.64	191.13	123.49	8.68	0	21.97	-13.29	8.37	21.66	290.24	60	101.81	188.43	299.35	110.92
NPK	175.45	120	137.52	37.93	188.25	150.32	8.68	100	29	-20.32	9.08	29.4	290.24	60	128.29	161.95	306.63	144.68
NPK + $ZnSO_4$/S	175.45	120	144.18	31.27	194.57	163.3	8.68	100	30.42	-21.74	9.24	30.98	290.24	60	132.56	157.68	302.06	144.38
Farmers practice	175.45	70	110.96	64.49	185.04	120.55	8.68	60	23.29	-14.61	8.47	23.08	290.24	40	106.04	184.2	295.37	111.17

Conclusion

On the basis of experimental findings, it is concluded that the application of 100: 60: 40 kg ha^{-1} N: P_2O_5: K_2O + 20 kg ha^{-1} $ZnSO_4$ in rice and 20:40:20:20 kg ha^{-1} N: P_2O_5: K_2O: S in chickpea could be recommended for higher productivity, soil nutrient status and profitability of rice- chickpea cropping system for the district of Uttar Bastar, Kanker of Chhattisgarh state.

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