E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; SP-7(3): 216-220
Received: 09-01-2024
Accepted: 16-02-2024

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Effect of on-farm nutrient management practices on soil, yield and economics of rice-chickpea cropping system at north Bastar Kanker district of Chhattisgarh

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i3Sc.438

Abstract
On - farm experiments were conducted during *Kharif* and *Rabi* seasons of 2019-20 at 24 farmer's fields at 6 villages *viz.* Aturgaon, 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 (188.16 kg ha^{-1}) and available phosphorus (10.76 kg ha^{-1}) and medium in available potassium (321.16 kg ha^{-1}) and organic carbon (0.56%) and neutral in reaction (7.56 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 (50.40 q ha^{-1}), chick pea (13.15 q ha^{-1}) and RGEY (85.85 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+ micro nutrient recorded significantly higher nutrient uptake N (153.41 kg ha^{-1}), P (32.79 kg ha^{-1}) and K (174.08 kg ha^{-1}) by rice- chickpea cropping system. Application of recommended dose of NPK + micro nutrient recorded significantly higher organic carbon (0.61%), available nitrogen (200.65 kg ha^{-1}), phosphorus (11.42 kg ha^{-1}), potassium (316.60 kg ha^{-1}) at end of the cropping system. Highest positive balance of available nitrogen (165.9 kg ha^{-1}) and phosphorus (33.45 kg ha^{-1}) and potassium (169.52 kg ha^{-1}) recorded in application of recommended dose of NPK + micronutrient. Highest gross return (156585 Rs ha^{-1}), net return (100620 Rs ha^{-1}) and B: C ratio (2.80) 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% of crop area is covered under *Kharif* rice. Rice occupies an area of 3.89 million hectares with the production of 15.0 million tones and average productivity of 3857 kg ha^{-1} and chickpea occupies an area of 0.37 million hectares with the production of 0.32 million tones and average productivity of 853 kg ha^{-1} during 2022-23 (Anonymous, 2023) [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.

Intensive cultivation and growing exhaustive crops have made the soil deficient in plants nutrients. The success of any cropping system depends upon the appropriate management of resources including balanced crop nutrition. Occurrence of multi-nutrient deficiency due to imbalanced use of nutrients and declining 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. 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) [11]. 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]. 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. 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]. The role of plant nutrient management would be extremely important from sustainability point of view. With the increasing trend in price of fertilizers and the reduction in the use of imbalance chemical fertilizers it has become necessary to judiciously manage the inflow of balanced nutrients and suitable fertilizers. 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 2019-20 at 24 farmer's fields at 6 villages *viz*. Aturgaon, 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 (188.16 kg ha^{-1}) and available phosphorus (10.76 kg ha^{-1}) and medium in available potassium (321.16 kg ha^{-1}) and organic carbon (0.56%) and neutral in reaction (7.56 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. 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) [10].

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 (50.40 q ha^{-1}), chick pea (13.15 q ha^{-1}) and RGEY (85.85 q ha^{-1}), followed by recommended dose of NPK *i.e.*,48.80 q ha^{-1} of rice,12.41 q ha^{-1} of chick pea and 82.41 q ha^{-1} of RGEY. The increase in grain yield 35, 57, 49, 84, 90, 59 percent of rice and 24, 54, 40, 79, 89, 57 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 (64.83 q ha^{-1}) and chick pea (13.15 q ha^{-1}), followed by recommended dose of NPK *i.e.*, 63.02 q ha^{-1} of rice and 12.41 q ha^{-1} of chick pea. Application of NPK + micro nutrient in cropping system recorded significantly higher Rice Grain Equivalent Yield (85.85 q ha^{-1}) fallowed by NPK (82.41 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], Netam *et al.* (2020) [8] and Netam *et al.* (2023) [9] conducted On-farm experiments at villages of district - Kabirdham, Uttar Bastar, Kanker, 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, Mansuri, R.N. (2016) [7] 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 (9.92). 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) [8] 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 (58.12 kg ha^{-1}), P (15.12 kg ha^{-1}), K (12.49 kg ha^{-1}) by rice grain and N (42.57 kg ha^{-1}) P (11.43 kg ha^{-1}) and K (112.54 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 (37.57kg ha^{-1}), P (4.04 kg ha^{-1}) and K (12.09 kg ha^{-1}) by chickpea grain and N (15.15 kg ha^{-1}), P (2.20 kg ha^{-1}) and K (36.96 kg ha^{-1}) by chickpea straw followed by recommended dose of NPK. Application of recommended dose of NPK + micro nutrient recorded significantly higher nutrient uptake N (153.41 kg ha^{-1}), P (32.79 kg ha^{-1}) and K (174.08 kg ha^{-1}) by rice- chickpea cropping system followed by application of recommended dose of NPK. C. K. Chandrakar *et al.* (2017) [5], Netam *et al.* (2020) [8] and Netam *et al.* (2023) [9] conducted On-farm experiments at villages of district - Kabirdham, Uttar Bastar, Kanker 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, Mansuri, R.N. (2016) [7] 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+ micro nutrient recorded significantly higher organic carbon (0.61%) and available nitrogen (200.65 kg ha^{-1}), available phosphorus (11.42 kg ha^{-1}) and available potassium (316.60 kg ha^{-1}), followed by the application of NPK. pH and electric conductivity not influenced significantly. Similarly, C.K. Chandrakar *et al.* (2017) [5], Netam *et al.* (2020) [8] and Netam *et al.* (2023) [9] conducted On-farm experiments at villages of district - Kabirdham, Uttar Bastar, Kanker and Uttar Bastar, Kanker, Chhattisgarh respectively and recorded significantly higher available nitrogen, phosphorus and potassium with application of recommended dose of NPK + micronutrients attend of the cropping system.

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 (165.9 kg ha^{-1}), phosphorus (33.45 kg ha^{-1}) and potassium (169.52 kg ha^{-1}) recorded in application of recommended dose of NPK + micronutrient followed by application of recommended dose of NPK. Lowest balance of available nitrogen (56.23 kg ha^{-1}), phosphorus (14.41 kg ha^{-1}) and potassium (44.12 kg ha^{-1}) recorded in control. Similarly, R.N. Mansuri (2016) [7] 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) [8] and Netam *et al.* (2023) [9] 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 cannot be assessed without the gross and net return from those treatments. The economics of different treatments presented in Table 2. Highest gross return (92488 Rs ha^{-1}) and net return (58516 Rs ha^{-}) of rice, gross return (64097 Rs ha^{-1}) and net return (42104 Rs ha^{-1}) of chickpea and gross return (156585 Rs ha^{-1}), net return (100620 Rs ha^{-1}) and B: C ratio (2.80) 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], Netam *et al.* (2020) [8] and Netam *et al.* (2023) [9] conducted On-farm experiments at villages of district -Kabirdham, Uttar Bastar, Kanker and Uttar Bastar, Kanker, Chhattisgarh respectively and recorded higher gross return, 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	26.49	26.93	45.68	6.95	8.48	-	-
N	35.66	40.02	59.15	8.61	10.47	9.03	15.15
NP	41.65	51.26	70.90	10.73	12.71	8.61	5.50
NK	39.60	47.63	66.45	9.71	11.44	8.82	9.92
NPK	48.80	63.02	82.41	12.41	14.19	9.92	6.50
NPK + $ZnSO_4$/S	50.40	64.83	85.85	13.15	14.99	9.41	6.94
Farmers practice	42.09	49.26	71.50	10.88	12.78	11.49	10.90
SEm±	0.23	0.44	0.45	0.14	0.19	-	-
CD (P = 0.05)	0.68	1.27	1.29	0.42	0.55	-	-

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	27280	48612	21332	19355	33891	14536	46635	82504	35869	1.77
N	28565	65445	36880	19612	41964	22352	48177	107408	59231	2.23
NP	31909	76428	44519	21842	52328	30486	53751	128756	75005	2.40
NK	29827	72670	42843	20243	47330	27087	50070	120000	69930	2.40
NPK	33172	89556	56384	22473	60514	38041	55645	150070	94425	2.70
NPK + $ZnSO_4$/S	33972	92488	58516	21993	64097	42104	55965	156585	100620	2.80
Farmers practice	29736	77238	47502	20914	53031	32117	50650	130269	79619	2.57

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	7.01	0.163	0.57	175.90	10.40	291.50
N	7.05	0.165	0.58	187.64	10.51	293.27
NP	7.06	0.171	0.58	188.64	11.14	294.27
NK	7.07	0.167	0.59	189.66	10.67	307.47
NPK	7.08	0.171	0.60	199.42	11.41	316.14
NPK + $ZnSO_4$/S	7.08	0.171	0.61	200.65	11.42	316.60
Farmers practice	7.08	0.173	0.59	188.02	10.69	304.27
SEm±	0.02	0.003	0.002	1.00	0.05	0.93
CD (P = 0.05)	NS	NS	0.005	2.90	0.15	2.70

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	28.13	15.67	7.40	4.31	6.06	42.79	17.06	7.63	1.95	1.11	6.13	18.80	68.49	14.77	73.78
N	38.71	23.93	10.17	6.52	10.96	66.03	22.52	9.58	2.47	1.39	7.67	23.54	94.73	20.55	108.20
NP	46.32	31.53	12.14	8.63	9.84	84.81	28.69	11.94	3.20	1.78	9.63	28.95	118.48	25.75	133.23
NK	44.19	29.53	11.39	7.98	9.65	80.17	26.19	11.04	2.82	1.54	8.82	27.63	110.94	23.74	126.27
NPK	54.85	40.62	14.62	10.94	12.15	108.83	35.33	14.07	3.78	2.06	11.35	34.41	144.86	31.41	166.73
NPK + $ZnSO_4$/S	58.12	42.57	15.12	11.43	12.49	112.54	37.57	15.15	4.04	2.20	12.09	36.96	153.41	32.79	174.08
Farmers practice	44.86	31.19	12.32	8.35	10.19	82.53	29.59	12.24	3.20	1.77	9.86	30.38	117.88	25.64	132.95
SEm±	0.88	0.34	0.08	0.11	1.02	0.92	0.54	0.19	0.06	0.03	0.14	0.55	1.30	0.17	1.60
CD (P = 0.05)	2.56	0.99	0.24	0.33	2.95	2.67	1.56	0.56	0.17	0.08	0.42	1.60	3.75	0.49	4.60

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

Treatment	Nitrogen (kg ha^{-1})						Phosphorus (kg ha^{-1})						Potassium (kg ha^{-1})					
	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	188.16	0	68.49	119.67	175.90	56.23	10.76	0	14.77	-4.01	10.40	14.41	321.16	0	73.78	247.38	291.50	44.12
N	188.16	120	94.73	93.43	187.64	94.21	10.76	0	20.55	-9.79	10.51	20.3	321.16	0	108.20	212.96	293.27	80.31
NP	188.16	120	118.48	69.68	188.64	118.96	10.76	100	25.75	-14.99	11.14	26.13	321.16	0	133.23	187.93	294.27	106.34
NK	188.16	120	110.94	77.22	189.66	112.44	10.76	0	23.74	-12.98	10.67	23.65	321.16	60	126.27	194.89	307.47	112.58
NPK	188.16	120	144.86	43.3	199.42	156.12	10.76	100	31.41	-20.65	11.41	32.06	321.16	60	166.73	154.43	316.14	161.71
NPK + $ZnSO_4$/S	188.16	120	153.41	34.75	200.65	165.9	10.76	100	32.79	-22.03	11.42	33.45	321.16	60	174.08	147.08	316.60	169.52
Farmers practice	188.16	70	117.88	70.28	188.02	117.74	10.76	60	25.64	-14.88	10.69	25.57	321.16	40	132.95	188.21	304.27	116.06

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.

Acknowledgement

The authors wish to acknowledge Dr. A.S. Panwar, Director, and Dr. N. Ravisankar, Principal Scientist (Agronomy) & Programme Facilitator (Coordination Unit) ICAR-Indian Institute of Farming Systems Research Modipuram, Meerut (U.P) and Dr. M.C. Bhambri, Chief Agronomist, AICRP on Integrated Farming Systems, IGKV, Raipur (C.G.) for providing technical guidance and financial support to carry out this research work.

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