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Influence of Establishment Methods and Nutrient Management on Productivity of *Kharif* Rice (*Oryza sativa* L.) and their Residual Effect on Succeeding Chickpea (*Cicer arietinum* L.) Crop

H. L. Sonboir[1*], Sanjay Sharma[1], R. Mahender Kumar[2] and Basant Kumar Sahu[1]

[1]Indira Gandhi Krishi Vishwavidyalaya, Raipur-492012 (India)
[2]Indian Institute of Rice Research, Hyderabad-500030 (India)

**Corresponding author*

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A B S T R A C T

A field experiment was conducted at Agriculture Instructional cum Research Farm, IGKV Raipur during *kharif* and rabi seasons of three consecutive years of 2015-16, 2016-17 and 2017-18 with three rice establishment methods; six nutrient management in rice and two nutrient management in chickpea. Dry direct seeded rice before onset of monsoon produced grain and straw yield similar to transplanting method, but higher net return and B: ratio. The seed yield of chickpea under dry direct seeded rice was 9.53 to 27.89% higher over transplanting method of rice. Combined application of 100% RDF and 5t/ha FYM in rice produced grain yield of rice, seed yield and net return of chickpea comparable to 150% RDF. In rice-chickpea cropping system, dry direct seeded rice before onset of monsoon produced 4.85 to 14.72% higher rice equivalent yield and 22.64 to 27.93% net return compared to compared to transplanting method of rice. Combined application of 100% RDF and 5 t/ha FYM recorded higher rice equivalent yield and net return which was however, comparable to application of 150% RDF in net return. Application of 100%RDF in chickpea recorded an increase of 9.37 to 11.72% in seed yield.

Introduction

Rice is a staple food for nearly half of the world's seven billion people. However, more than 90% of this rice is consumed in Asia, where it is a staple for a majority of the population. The rising per capita consumption along with the growing population has enhanced global rice consumption from 150 during 1960-61 to more than 450 million tons during 2010-11 (Mohanty, 2013). It is the leading crop of India grown in 43.19 million ha with productivity of 2550 kg/ha during 2016-17 (Annual Report 2017-18). In Chhattisgarh state, known as rice bowl of India, it is cultivated in about 70% area during *kharif* season with average productivity of 2212 kg/ha during 2016-17 (Anonymous,

2018). Pulses are the most important source of protein in vegetarian diets. United Nations declared 2016 as the International Year of Pulses looking into its dietary essentiality. Chickpea is the most important rabi season crop grown in the Chhattisgarh state with area of 0.37 million ha and productivity of 1100 kg (Krishi Darshika, 2018) and as a pulse crop, it is important for nutritional security along with improving soil fertility.

Cultivation of rice with different establishment methods is unique feature of the state. The most popular transplanting method of rice cultivation requires huge number of labour for different farm operations from sowing to harvesting. In Asia, labour forces in agriculture are declining at 0.1-0.4%, with an average of 0.2% per year (Dawe, 2005). However, due to the decreasing availability of farm labours, less labour requiring technique is required for rice cultivation to sustain its production. The decreasing water availability for agricultural crops has also forced to evolve technologies which need less water with higher productivity of rice.

In Asia, the share of water in agriculture declined from 98% in 1900 to 80% in 2000, and is likely to further decline to 72 % by 2020 (Kumar and Ladha, 2011). Presently, direct seeded rice is one of the options to meet out problems of shortage of labour and water. DSR refers to the process of establishing a rice crop from seeds sown in the field rather than by transplanting seedlings from the nursery. It has been recognized as the principal method of rice establishment since 1950's in developing countries (Pandey and Velasco, 2005).

The nutrients play important role in enhancing productivity and profitability of rice crop which differs in different establishment methods due to variation in microclimate. Application of fertilizer dose may also differ in these establishment methods due to change in mobilization and availability of nutrients in rice ecosystem. The performance of succeeding crop depends not only on fertilizers applied in previous crop but also on methods of establishment followed due to change in soil physico-chemical properties. Chickpea, as being a deep rooted crop can mine nutrients from deeper layer and however, it may depends on root penetration and also capacity to make available those nutrients. Thus, an experiment was laid out to study the effect of different nutrient management practices on productivity of rice crop in varying establishment methods as well as to study their residual effect on performance of succeeding chickpea crop.

Materials and Methods

A field experiment was conducted at Agriculture Instructional cum Research Farm, IGKV Raipur during kharif and rabi seasons of three consecutive years of 2015-16, 2016-17 and 2017-18 in the same field. The experimental soil was clay in texture, neutral in reaction, normal in electrical conductivity, low in available nitrogen, medium in available phosphorus and high in available potassium.

The experiment was laid out in split-split plot design with three replications. The main plot treatments consisted of three rice establishment methods viz., M1- Dry direct seeded rice before onset of monsoon with normal seed rate, M2- Dry direct seeded rice after monsoon with reduced seed rate and M3- Transplanting; sub-plot treatments consisted of six nutrient management practices in rice viz. S1-100%RFD (Inorganic), S2-100% RDF (75% Inorganic+ 25% Organic), S3-150% of RDF (Inorganic), S4- LCC based N application and P& K at RD, S5-100%RFD (Organic)+ 5t FYM and

S6- Control and sub-sub plot treatments consisted of two nutrient management practices in chickpea viz., F0-control and F1-100% RDF (Inorganic). The recommended dose of fertilizer (RDF) was 100:60:40 kg NPK/ha for rice and 20:50:30 kg NPK/ha for chickpea applied through urea, single super phosphate and muriate of potash applied as per treatments. The test variety was IGKV R1 (125 days) of rice and JG-130 (115 days) of chickpea.

The date of sowing for dry direct seeded rice after monsoon (M2) and transplanting (M3) was same whereas, dry direct seeded rice before monsoon (M1) was done 3-4 days before anticipation of monsoon and irrigation was given for establishment of the crop. The rice crop was harvested at maturity and sowing of chickpea was done after field preparation. The date of sowing for chickpea was same in all the treatments.

The observations were recorded from net plot area in each treatment and were statistically anaysed as suggested by Gomez and Gomez (1983) for interpretation of the result. Cost of cultivation was calculated based on market price of the inputs and outputs. B:C ratio was calculated by dividing gross return to cost of cultivation of the respective treatments.

Results and Discussion

Number of total tillers and panicles of rice

Dry direct seeded rice before onset of monsoon with normal seed rate registered significantly higher number of total tillers and panicles compared to other methods. Dry direct seeded rice after monsoon with reduced seed rate recorded significantly the least number of total tillers and panicles per unit area. Regarding nutrient management in rice, combined application of 100% RDF and 5 t/ha FYM produced number of total tillers and panicles of rice comparable to 150% RDF which was significantly higher than other nutrient management practices. Nitrogen application based on LCC recorded statistically at par number of total tillers and panicles per unit area compared to 100%RDF (Inorganic) and 100% RDF (75% inorganic+25% organic) (Table 1).

Panicle weight and test weight of rice

Transplanting method of rice recorded significantly higher panicle weight compared other methods of establishment. However, test weight was not influenced significantly by establishment methods.

Regarding nutrient management in rice, combined application of 100% RDF and 5 t/ha FYM registered panicle weight and test weight comparable to 150% RDF and significantly higher than other nutrient management practices. Nitrogen application based on LCC recorded statistically at par panicle weight and test weight compared to 100%RDF (Inorganic) and 100% RDF (75% inorganic+25% organic) (Table 2).

Grain and straw yield of rice

Grain and straw yield of rice was significantly influenced by establishment methods and nutrient management practices. Dry direct seeded rice before onset of monsoon with normal seed rate produced grain and straw yield statistically comparable to transplanting method. Higher grain yield in DSR is also reported by Gill *et al.,* (2006) and Hayanshi *et al.,* (2007). Dry direct seeded rice after monsoon with reduced seed rate recorded lesser grain and straw yield. The reduction was 4.12 to 7.53 % in grain yield and 4.40 to 12.07 % in straw yield compared to transplanting method in different years. Regarding nutrient management in rice, combined application of 100% RDF and 5

t/ha FYM produced grain and straw yield of rice comparable to 150% RDF which was significantly higher than other nutrient management practices. The increase was 3.23 to 8.82% in grain yield and 3.46 to 6.57 % in straw yield of rice over 100% RDF in different years.

Nitrogen application based on LCC recorded statistically at par grain and straw yield compared to 100% RDF (Inorganic) whereas, application of 100% RDF (75% inorganic+25% organic) recorded statistically lesser grain and straw yield (Table 3).

Economics of rice

Dry direct seeded rice before onset of monsoon with normal seed rate recorded significantly higher net return and B:C ratio compared to other methods, though B:C ratio was comparable to dry direct seeded rice after monsoon with reduced seed rate. Transplanting method of rice gave significantly least net return and B:C ratio.

Higher net return and B: ratio in dry direct seeded rice was due to reduction in labour expenses in transplanting and other operations. Sumita and Ando (2001) report that conventionally planted rice uses 37 % higher labour in as compared to DSR, which is mainly because of transplanting operation.

Regarding nutrient management in rice, combined application of 150% RDF recorded significantly higher net return compared to all other treatments however it was comparable to 100% RDF. The higher net return in150% RDF was due to higher grain and straw yield along with lesser cost of chemical fertilizers compared to organic manures. Nitrogen application based on LCC recorded statistically at par net return and B: ratio compared to 100%RDF (Inorganic) (Table 4).

No. of pods/plant and 100 seed weight of chickpea

Dry direct seeded rice before onset of monsoon and after onset of monsoon registered comparable number of pods per plant of chickpea and significantly higher than transplanting method of rice. This may be due to better growth of chickpea in unpuddled condition causing prevention of compactness of soil which results in better root growth of plants. Although, 100 seed weight of chickpea was influenced by establishment method of rice.

Regarding nutrient management in rice, combined application of 100% RDF and 5 t/ha FYM recorded number of pods per plant of chickpea comparable to 150% RDF and 100% RDF. The 100 seed weight of chickpea was not influenced by nutrient application in rice. Application of 100%RDF in chickpea recorded significantly higher number of pods per plant and 100 seed weight compared to no application of nutrients (Table 5).

Seed and straw yield of chickpea

Establishment methods and nutrient management practices in rice significantly influenced the seed and straw yield of chickpea in succeeding season. Dry direct seeded rice before onset of monsoon and after onset of monsoon produced comparable and higher seed and straw yield of chickpea and significantly higher than transplanting method of rice.

The increase in seed yield of chickpea was 9.53 to 27.89% and in straw yield was 10.27 to 30.09% over transplanting method of rice in different years. This may be due to better expression of growth and yield attributes of chickpea under unpuddled condition which results in better root growth of plants (Table 6).

Although puddling is known to be beneficial for growing rice, it can adversely affect the growth and yield of subsequent upland crops because of its adverse effects on soil physical properties, which includes poor soil structure, sub-optimal permeability in the lower layers and soil compaction (Gathala *et al*., 2011). Regarding nutrient management in rice, combined application of 100% RDF and 5 t/ha FYM recorded seed and straw yield of chickpea comparable to 150% RDF and 100% RDF.

Balanced nutrient application in previous crop maintains soil fertility which might have resulted in higher yield of succeeding chickpea crop. The higher seed yield of chickpea with 100% RDF in rice was also reported by Mansuri (2016). Application of 100% RDF in chickpea recorded significantly higher seed and straw yield of chickpea compared to no application of nutrients. The increase was 9.37 to 11.72% in seed yield and 9.52 to 11.69 % in straw yield of chickpea over no application of nutrients in chickpea in different years.

Economics of chickpea

Establishment methods and nutrient management practices in rice significantly influenced the net return and B:C ratio of chickpea in succeeding season. Dry direct seeded rice before onset of monsoon and after onset of monsoon produced comparable and net return and B:C ratio of chickpea and significantly higher than transplanting method of rice. This was be due to higher seed and straw yield of chickpea under these treatments. Regarding nutrient management in rice, combined application of 100% RDF and 5 t/ha FYM recorded net return and B: ratio comparable to 150% RDF and 100% RDF. Application of 100% RDF in chickpea recorded significantly higher net return but lower BC ratio of chickpea compared to no application of nutrients (Table 7 and 8).

Table.1 Number of total tillers and panicles of rice as influenced by different establishment methods and nutrient management

Treatments	Total tillers, no./m2				Panicles, no./m2			
	2015	2016	2017	Mean	2015	2016	2017	Mean
Rice establishment methods								
M1-Dry DSR before monsoon	378	412	407	399	241	269	286	265
M2-Dry DSR after monsoon	342	323	391	352	194	232	280	235
M3-Transplanting	325	341	370	345	224	249	261	245
CD (P=0.05)	22	27	24		8	17	7	
Nutrient management in rice								
S1-100%RFD (Inorganic)	369	373	387	376	225	264	275	255
S2-100%RDF (75% Inorg+25% Org)	358	351	371	360	204	234	265	234
S3-150% RDF	388	399	408	398	237	267	288	264
S4-LCC based nitrogen	-	359	380	370	-	234	269	252
S5-100%RFD+ 5t FYM	383	411	399	398	247	266	280	264
S6-Control	242	259	-	251	184	233	-	209
CD (P=0.05)	25	30	19		19	23	5	

Table.2 Panicle weight and test weight of rice as influenced by different establishment methods and nutrient management

Treatments	Panicle weight, g/panicle				Test weight, g			
	2015	2016	2017	Mean	2015	2016	2017	Mean
Rice establishment methods								
M1-Dry DSR before monsoon	2.91	3.62	3.27	3.27	29.8	31.5	31.1	30.8
M2-Dry DSR after monsoon	3.03	4.03	3.45	3.50	29.9	31.6	31.4	31.0
M3-Transplanting	3.17	4.28	3.83	3.76	30.0	32.1	31.2	31.1
CD (P=0.05)	0.09	0.34	0.35		NS	NS	NS	
Nutrient management in rice								
S1-100%RFD (Inorganic)	3.09	4.16	3.50	3.58	30.0	32.0	30.8	30.9
S2-100%RDF (75% Inorg+25% Org)	2.97	3.91	3.32	3.40	29.5	31.9	31.2	30.9
S3-150% RDF	3.22	4.37	3.82	3.80	31.1	32.0	31.2	31.4
S4-LCC based nitrogen	-	4.01	3.40	3.71	-	31.8	31.3	31.6
S5-100%RFD+ 5t FYM	3.32	4.47	3.55	3.78	30.9	32.2	31.6	31.6
S6-Control	2.59	2.93	-	2.76	28.1	30.4	-	29.3
CD (P=0.05)	0.10	0.38	0.27		0.68	0.72	NS	

Table.3 Grain and straw yield of rice as influenced by different establishment methods and nutrient management

Treatments	Grain yield, kg/ha				Straw yield, kg/ha			
	2015	2016	2017	Mean	2015	2016	2017	Mean
Rice establishment methods								
M1-Dry DSR before monsoon	4784	4980	5051	4938	5841	6359	6477	6226
M2-Dry DSR after monsoon	4411	4844	4773	4676	5195	5884	6240	5773
M3-Transplanting	4770	5118	4978	4955	5434	6692	6964	6363
CD (P=0.05)	89	170	178		333	751	524	
Nutrient management in rice								
S1-100%RFD (Inorganic)	4974	5225	4919	5039	5679	6367	6557	6201
S2-100%RDF (75% Inorg+25% Org)	4630	5119	4598	4782	5542	6219	5915	5892
S3-150% RDF	5225	5532	5353	5370	5923	6783	6967	6558
S4-LCC based nitrogen	-	5164	4722	4943	-	6226	6379	6303
S5-100%RFD+ 5t FYM	5318	5676	5078	5357	5941	6644	6784	6456
S6-Control	3129	3168	-	3149	4364	5737	-	5051
CD (P=0.05)	122	210	215		319	604	383	

Table.4 Economics of rice as influenced by different establishment methods and nutrient management

Treatments	Net return, Rs/ha				B:C ratio			
	2015	2016	2017	Mean	2015	2016	2017	Mean
Rice establishment methods								
M1-Dry DSR before monsoon	43226	55101	55628	51318	2.44	2.75	2.74	2.64
M2-Dry DSR after monsoon	38720	53539	52493	48251	2.34	2.78	2.72	2.61
M3-Transplanting	37765	53128	49991	46961	2.08	2.44	2.34	2.29
CD (P=0.05)	1422	1134	3105		0.05	0.09	0.10	
Nutrient management in rice								
S1-100%RFD (Inorganic)	46344	54980	55237	52187	2.58	2.83	2.81	2.74
S2-100%RDF (75% Inorg+25% Org)	36153	49159	44130	43147	2.05	2.40	2.23	2.23
S3-150% RDF	47380	56332	59934	54549	2.49	2.72	2.81	2.67
S4-LCC based nitrogen	-	54211	52666	53439		2.83	2.75	2.79
S5-100%RFD+ 5t FYM	44992	54930	51554	50492	2.26	2.50	2.39	2.38
S6-Control	24649	29071	-	26860	2.04	2.20	-	2.12
CD (P=0.05)	1862	3540	3222		0.06	0.11	0.10	

Table.5 Residual effect of establishment methods and nutrient management of kharif rice on number of pods/plant and seed weight of chickpea

Treatments	No. of pods/plant				100 seed weight, g			
	2015	**2016**	**2017**	**Mean**	**2015**	**2016**	**2017**	**Mean**
Rice establishment methods								
M1-Dry DSR before monsoon	39.2	39.2	40.8	39.7	22.53	23.54	23.55	23.21
M2-Dry DSR after monsoon	38.8	39.2	39.9	39.3	22.24	23.54	23.66	23.15
M3-Transplanting	35.3	36.4	36.2	36.0	22.68	23.45	24.03	23.39
CD (P=0.05)	1.0	0.9	2.5		NS	NS	NS	
Nutrient management in kharif rice								
S1-100%RFD (Inorganic)	38.0	39.9	39.9	39.3	22.50	23.69	23.79	23.33
S2-100%RDF (75% Inorg+25% Org)	37.2	37.9	37.9	37.7	22.67	23.32	23.84	23.28
S3-150% RDF	38.4	40.1	38.9	39.1	22.33	23.67	23.81	23.27
S4-LCC based nitrogen	-	36.6	37.8	37.2	-	23.33	23.56	23.45
S5-100%RFD+ 5t FYM	39.6	40.6	40.3	40.2	22.72	23.74	23.72	23.39
S6-Control	35.7	34.5	-	35.1	22.20	23.31	-	22.76
CD (P=0.05)	1.5	1.3	1.2		NS	NS	NS	
Nutrient management in Chickpea								
F0-Control	35.7	36.0	36.9	36.2	22.30	23.34	23.62	23.09
F1-100% RDF	39.8	40.6	41.0	40.5	22.68	23.68	23.87	23.41
CD (P=0.05)	1.3	1.0	1.0		0.35	0.26	0.15	

Table.6 Residual effect of establishment methods and nutrient management of kharif rice on seed and straw yield of chickpea

Treatments	Seed yield, kg/ha				Straw yield, kg/ha			
	2015	2016	2017	Mean	2015	2016	2017	Mean
Rice establishment methods								
M1-Dry DSR before monsoon	2068	2319	2334	2240	3908	4331	4432	4224
M2-Dry DSR after monsoon	2090	2303	2308	2234	3931	4351	4366	4216
M3-Transplanting	1888	1848	1825	1854	3544	3474	3407	3475
CD (P=0.05)	64	55	81		95	133	155	
Nutrient management in kharif rice								
S1-100%RFD (Inorganic)	2041	2215	2158	2138	3821	4180	4079	4027
S2-100%RDF (75% Inorg+25% Org)	1951	2128	2102	2060	3707	3963	4000	3890
S3-150% RDF	2033	2130	2190	2118	3801	4018	4109	3976
S4-LCC based nitrogen	-	2069	2066	2068	-	3907	3899	3903
S5-100%RFD+ 5t FYM	2084	2225	2263	2191	3954	4183	4255	4131
S6-Control	1967	2172	-	2070	3689	4063	-	3876
CD (P=0.05)	71	99	89		130	180	182	
Nutrient management in Chickpea								
F0-Control	1890	2037	2050	1992	3559	3827	3865	3750
F1-100% RDF	2141	2277	2262	2227	4030	4277	4272	4193
CD (P=0.05)	35	54	52		78	111	111	

Table.7 Residual effect of establishment methods and nutrient management of kharif rice on net return and B: C ratio of chickpea

Treatments	Net return, Rs/ha				B:C ratio			
	2015	**2016**	**2017**	**Mean**	**2015**	**2016**	**2017**	**Mean**
Rice establishment methods								
M1-Dry DSR before monsoon	46051	65818	71691	61187	2.63	3.26	3.42	3.10
M2-Dry DSR after monsoon	46838	65166	70567	60857	2.66	3.24	3.38	3.09
M3-Transplanting	39596	46520	49535	45217	2.40	2.60	2.67	2.56
CD (P=0.05)	2277	2253	3497		0.08	0.08	0.12	
Nutrient management in kharif rice								
S1-100%RFD (Inorganic)	45071	61580	64034	56895	2.59	3.12	3.16	2.96
S2-100%RDF (75% Inorg+25% Org)	41885	57972	61613	53823	2.49	2.99	3.08	2.85
S3-150% RDF	44772	58069	65385	56075	2.59	2.99	3.20	2.93
S4-LCC based nitrogen	-	55606	60039	57823	-	2.92	3.02	2.97
S5-100%RFD+ 5t FYM	46659	61979	68585	59074	2.65	3.13	3.31	3.03
S6-Control	42422	59801	-	51112	2.50	3.06	-	2.78
CD (P=0.05)	2522	4035	3879		0.09	0.14	0.13	
Nutrient management in Chickpea								
F0-Control	41680	56288	61354	53107	2.59	3.08	3.22	2.96
F1-100% RDF	46643	62047	66508	58399	2.54	2.99	3.09	2.87
CD (P=0.05)	1248	2215	2277		0.05	0.08	0.08	

Table.8 Rice equivalent yield and net return of rice-chickpea cropping system as influenced by rice establishment methods and nutrient management in rice and chickpea

Treatments	Rice equivalent yield, Kg/ha				Net return, Rs/ha			
	2015	2016	2017	Mean	2015	2016	2017	Mean
Rice establishment methods								
M1-Dry DSR before monsoon	9916	11291	11451	10886	89277	116976	127319	111191
M2-Dry DSR after monsoon	9599	11110	11102	10604	85558	114773	123060	107797
M3-Transplanting	9457	10145	9982	9861	77361	95096	99526	90661
CD (P=0.05)	216	251	203		3408	4124	3546	
Nutrient management in kharif rice								
S1-100%RFD (Inorganic)	10039	11253	10836	10709	91415	116560	119271	109082
S2-100%RDF (75% Inorg+25% Org)	9474	10909	10362	10248	78038	107132	105743	96971
S3-150% RDF	10270	11327	11356	10984	92153	118401	125319	111958
S4-LCC based nitrogen	-	10795	10387	10591	-	109817	112705	111261
S5-100%RFD+ 5t FYM	10492	11731	11284	11169	91651	116909	120138	109566
S6-Control	8012	9079	-	8546	67070	88872	-	77971
CD (P=0.05)	204	303	317		3180	4930	4904	
Nutrient management in Chickpea								
F0-Control	9346	10523	10554	10141	81584	106069	114058	100570
F1-100% RDF	9969	11175	11136	10760	86547	111828	119212	105862
CD (P=0.05)	86	147	144		1248	2215	2277	

Rice equivalent yield and net return of rice-chickpea cropping system

Dry direct seeded rice before onset of monsoon produced significantly the highest rice equivalent yield and net return of rice-chickpea cropping system with significant difference to other methods. Transplanting method recorded the least equivalent yield and net return. The increase was 4.85 to 14.72% in rice equivalent yield and 22.64 to 27.93% in net return over transplanting method of rice in different years. Regarding nutrient management in rice, combined application of 100% RDF and 5 t/ha FYM recorded the highest rice equivalent yield with significant difference to other nutrient management practices, however it was closely followed by 150% RDF.

Moreover, regarding net return, application of 150% registered the highest net return which was comparable to 100% RDF and 5 t/ha FYM and with significantly higher than other nutrient management practices. Application of 100%RDF in chickpea recorded significantly higher rice equivalent yield of the system compared to no application of nutrients. The increase was 5.51 to 6.67% in rice equivalent yield and 4.52 to 6.08% in net return in different years.

In rice-chickpea cropping system, Dry direct seeded rice before onset of monsoon with normal seed rate produced significantly the highest rice equivalent yield and net return compared to transplanting method of rice with increase of 4.85 to 14.72% in rice equivalent yield and 22.64 to 27.93% in net return.

Combined application of 100% RDF and 5 t/ha FYM recorded higher rice equivalent yield and net return which was however, comparable to application of 150% RDF in net return. Application of 100%RDF in chickpea recorded an increase of 9.37 to 11.72% in seed yield of chickpea and 5.51 to 6.67% in rice equivalent yield over no application of nutrients.

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