https://doi.org/10.56093/ijas.v90i7.105574

Indian Journal of Agricultural Sciences **90** (7): 1254–7, July 2020/Article

Improved agro-management in rice (*Oryza sativa*) and chickpea (*Cicer arietinum*) at rainfed lowland ecology

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Received: 25 February 2019; Accepted: 15 October 2019

ABSTRACT

An on-farm study was conducted in Odisha during 2014-2016 growing *kharif* rice (*Oryza sativa* L.) and chickpea (*Cicer arietinum* L.) at rainfed lowland ecology. Impacts of improved tillage and nutrient management was studied along with supplementary irrigation in chickpea. Rice producing comparable grain yields (3.45-3.72 t/ha) at minimum and conventional tillage (3.50-3.75 t/ha) was significantly higher than that (2.52-2.65 t/ha) at zero tillage. Chickpea produced comparable seed yields at zero (14.4-14.9 q/ha), minimum (14.4-14.8 q/ha) or conventional tillage (14.5-14.8 q/ha) also. Rice with state recommended dose of fertilizers (SRDF) or INM produced comparable grain yields (3.10-3.20 t/ha and 3.08-319 t/ha). Chickpea also with SRDF or INM produced comparable seed yields (15.20-15.50 q/ha and 15.00-15.40 q/ha). Irrigation in chickpea either at pod development stage alone or also at pre-flowering stage enhanced seed yields (15.50-16.20 q/ha and 14.80-15.60 q/ha respectively), significantly higher than that (8.80-9.20 t/ha) at residual soil moisture situations. Thus, the study ensured maximum profitability of around ₹ 100000.0/ha while growing rice with improved nutrient management at conventional or minimum tillage followed by chickpea at conventional, minimum or zero tillage management. Therefore, the study could suggest the prospect of system based improved rainfed lowland rice fallow management in a rice-chickpea cropping system.

Key words: Chickpea, Irrigation management, Nutrient, Productivity, Profitability, Rainfed lowland ecology, Rice, Tillage

In the state Odisha, rice occupies around 4 million ha, where approximately 1.0 million ha remain unutilised at rainfed lowland ecology due to dearth of appropriate technology of rice fallow management. As a result, meager productivity hovering around 1.0-1.20 t/ha of traditional mono-cropping rice alone often demoralizes poor and marginal rice farmers thriving hard with this harsh situation (Adhya *et al*. 2008). Thus, addressing the adversity of this situation is a major challenge sustainably enhancing system productivity for higher profitability. Ironically, rich native soil fertility endowed with high soil organic matter (SOM) content at this ecology was not explored in right perspective, which becomes vulnerable to substantial losses following frequent tillage operations along with primitive crop and soil management aggravated with uncontrolled water stagnation. While, residual soil moisture and nutrients in the rice fallow situation are barely utilized unless explored with short duration legumes namely chickpea (Ali and Kumar 2005). Hitherto, no sustainable efforts were initiated in a system mode addressing utilization of such native resources with improved agro - management.

Therefore, a better understanding of proper utilization of these left-over natural resources could suggest a system based agro-management practices, instead. Thus, a field study was conducted with farmer's participatory mode optimizing tillage, nutrient and irrigation management in a perspective manner for developing a system based improved agro-management in rainfed lowland rice-chick pea production system.

MATERIALS AND METHODS

Field experiments were conducted during wet and dry season in 2014-15 and 2015-16 successively at the farmers' fields at district Sundargarh, Odisha. A long duration (160 days) and medium stature (100 cm) rice variety Gayatri was directly sown @ 50 kg seed /ha at spacing of 15 × 20 cm (plant × row) during 2nd week of May. Treatments included three tillage managements namely conventional, minimum and zero tillage, and two nutrient managements, 100% state recommended dose of fertilizers (N, P_2O_5 and K_2O: 60, 30 and 30 kg/ha) and INM with FYM at 5 t/ha (N-P-K: 0.6-0.2-0.5%) supplemented with 75% of SRDF. Entire dose of NPK fertilizers were applied within furrow during sowing.

Immediately after the harvest of rice and Chickpea, cv. ICCC 37 was sown @ 75 kg seed/ha with all three tillage managements during 1st week of December with two

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nutrient managements namely basal application of SRDF (100 kg / ha of di-ammonium phosphate) or seed treatment with *Rhizobium* culture *(Rhizobium* sp.*)* supplemented with basal application of 20 kg/ha of single super phosphate (SSP). In chickpea, soil moisture was maintained with one irrigation at pod development stage alone or twice also at pre-flowering stage, and without irrigation at residual soil moisture condition.

Nodulation and seed protein content in chickpea

Nodulation pattern of chickpea plant was studied at 55 days growth stage (maximum nodulation stage) following standard methodology. Seed protein content was estimated following the standard laboratory analytical procedure using micro Kjeldahl method.

Statistical design and analysis

A permanent field block was maintained for both the crops during the study randomizing treatments in a split plot design considering tillage management as main factor and nutrient management as sub factor, and irrigation management as sub-sub factor in five farmer's fields considered as replicate. ANOVA of the data were statistically done following the 'CropStat' (version 6.1) package. The treatment means were compared using least significant difference tests at $P < 0.05$ level of significance.

RESULTS AND DISCUSSION

Growth, yield attributes and grain yield of rice

Results showed no adverse impacts of minimum tillage on growth and development of rice crop. Plant heights were comparable at minimum tillage (98-100 cm) and at conventional tillage management (100-102 cm) across the year and significantly higher than at zero tillage management (90-92 cm). Lower plant height at zero tillage management was ascribed with delayed germination and subsequent suppression in stand elongation at the on-slaught of water stagnation. Panicle development at minimum tillage (262 – 270 panicles/ m^2) and conventional tillage (275-285 panicles/ m^2) were comparable over the years, and significantly higher than those (200-208 panicles/m^2) at zero tillage management. Accordingly, grain yields at minimum tillage (3.45-3.72 t /ha) and at conventional tillage (3.50-3.75 t/ha) were comparable and was significantly higher than those (2.52-2.65 t /ha) at zero tillage management over the years (Table 1). Straw yields at conventional tillage (5.25-5.45 t/ha) and at minimum tillage management (5.05-5.10 t/ha) were also significantly higher than those (4.70-4.85 t/ha) at zero tillage management over the years of the study.

Thus, the results implied adverse impacts of zero tillage on overall crop performance resulting poor development of yield parameters compared with other tillage situations.

Table 1 Influence of tillage, nutrient and irrigation management on performance of rice and chickpea at rainfed lowland rice ecology during 2014 - 2016

Treatment	Grain yield				No./dry mass (g) of nodules per plant		Chickpea SPC (%)		Chickpea protein yield (kg/ha)	
	Rice, t/ha		Chickpea, q/ha							
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
Tillage management (T)										
Conventional tillage	3.50	3.75	14.5	14.8	32 /0.68	36/0.75	18.60	19.15	167.40	180.0
Minimum tillage	3.45	3.72	14.4	14.8	30/0.65	35/0.72	19.00	19.50	173.0	185.25
Zero tillage	2.52	2.65	14.4	14.9	22/0.40	26/0.45	19.50	19.75	177.45	185.64
$SE_{m\pm}$	0.09	0.10	1.50	1.60	2/0.045	3/0.048	1.2	1.3	--	--
LSD (P=0.05)	0.25	0.28	NS	NS	7/0.150	8/0.160	NS	NS	--	--
Nutrient management (N)										
RDF of NPK	3.10	3.20	15.2	15.5	28/0.45	30/0.62	20.20	20.60	182.8	193.64
FYM + 75% RDF	3.08	3.19	15.0	15.4	35/0.72	36/0.75	19.95	20.20	183.54	193.92
$SE_{m\pm}$	0.10	0.15	1.3	1.4	1.2/0.15	1.6/0.18	0.40	0.15	---	--
LSD- N(P=0.05)	NS	NS	NS	NS	4.0/0.40	5.0/0.54	NS	NS	--	--
T × N	0.32	0.40	---	----	--	--	---	---	--	--
Irrigation management (I)										
Pre-flowering + pod development			15.5	16.2	30/0.50	34/0.52	16.60	17.00	156.04	163.20
Pod development			14.8	15.6	28/0.53	32/0.55	17.95	18.25	165.14	173.37
Residual moisture			8.8	9.2	22/0.48	24/0.50	20.25	20.50	178.20	184.50
$SE_{m\pm}$			1.2	1.3	1.5/0.12	1.8/0.10	0.30	0.38	---	---
LSD-I (P=0.05)			3.2	4.0	5.0/0.40	6.0/0.40	1.00	1.20	---	--
T × N × I			4.0	4.5	5.0/0.50	6.0/0.50	0.85	0.92	---	--

This was ascribed with typical nature of hard textured soil at rainfed lowland situation characterized with high clay content that becomes very hard on dryness restricting infiltration/movement of water for subsequent availability of soil moisture essential for germination and subsequent plant growth (Singh *et al*. 2011).

Unlike tillage management, no significant variations occurred between different nutrient management resulting comparable plant heights with improved management (100-101 cm) and SRDF application (102-104 cm), and also panicle development with improved management (265-278 panicles/plant) and with SRDF(260-270 panicles/plant). As a result, grain yields (3.08 - 3.19 t/ha) in crops stands treated with improved management were comparable those (3.10-3.20 t/ha) with SRDF.

As a result, overall partial factor productivity was around 35% higher (70.0 kg grain/kg N applied) with improved management than that (52.0 kg grain/kg N applied) with the SRDF application. This was attributed to the proper crop and nutrient management exploring rich inherent nutrient resources at such rainfed lowland rice soil (Ghosh and Rao 2010). Adding to that, uncontrolled losses of nitrogen and potassium at this waterlogged situation were supplemented with concomitant release of these nutrients from FYM across the growth stages. Interaction between tillage and nutrient management showed significantly higher grain yield at conventionally tilled or minimum tilled stands treated either with improved nutrient management or SRDF application.

Growth, yield attributes and seed yield of chickpea

Unlike rice growth, plant heights in chick pea were comparable at zero (41-43 cm), conventional (42-44 cm) and minimum tillage (42-43 cm) management, and with seed inoculation (37-40 cm) and RDF (40-42 cm), and irrigation at pod development stage alone (35-38 cm) or along with that at pre-flowering stage (38-42 cm), significantly higher than at residual soil moisture condition (30-32 cm).

Similar was the results in pod development showing comparable pod at zero (39-40 pods/plant), with conventional (38–41 filled pods/plant) and minimum tillage (39-40 filled pods/plant) management, and with seed inoculation (36-40 filled pods/plant) and with RDF (38-41 filled pods/plant). While, one or two irrigations produced significantly more pods (35-36 or 34-38 pods/plant) than those (24-26 pods/plant) in residual soil moisture, corroborating with the reports of Tuba *et al.* (2004). As a result, seed yields were comparable at zero (14.4-14.9 q/ha), conventional (14.5-14.8 q/ha) and minimum tillage (14.4-14.8 q/ha) respectively (Table 1).

Nutrient management also recorded comparable seed yield in crops with seed inoculation (15.0-15.4 q/ha) and with RDF (15.2-15.5 q/ha) (Table 1). Thus, FYM application in rice crop supplemented with seed inoculation in chickpea was attributed for adequate nutrient requirements (Karasu *et al,* 2009).

Supplementary irrigation at pod development stage alone or preceded with that at pre-flowering stage resulted in comparable seed yields (14.8-15.6 q/ha and 15.5-16.2 q/ha), which was significantly higher than that (8.8-9.2 q/ha) at residual soil moisture alone (Table 1). Thus, inadequate soil moisture at fallow situations implied the need of supplementary irrigation for optimum soil water availability ensuring better growth and subsequent development of yield parameters (Singh and Pandey 2005).

Nodulation and seed protein content in chickpea

Nodule numbers (32-36 nodules/plant) and dry masses (0.68-0.75 g/plant) at conventional and minimum tillage (30-35 nodules/plant and 0.65-0.72 g/plant) were significantly more than those (22-26 nodules / plant and 0.40-0.45 g / plant)) at zero tillage management (Table 1). Poor nodule growth and development at zero tillage management was ascribed with relatively greater soil compaction along with less soil moisture availability.

Seed inoculation also stimulated nodulation producing significantly more numbers (35-36 nodules/plant) and dry masses (0.72-0.75 g /plant) than those (28-30 nodules/plant and 0.45 – 0.62 g/plant) in stand with SRDF (Mukherjee and Rai, 2000).

Supplementary irrigation (s) also showed significantly more numbers (28-34 nodules/plant) and dry masses (0.50-0.55 g/plant) of nodule than those (22-24 nodules/plant and 0.48-0.50 g/plant) in stand without irrigation (Pramanik and Singh 2003).

However, chickpea seed protein content (SPC) remained unaffected with different tillage recording comparable SPC (19.5-19.75%) and total protein yields (177.45-185.64 kg/ha) at zero, minimum (19.00-19.50% and 173.0-1858.25 kg/ha) and at conventional tillage (18.60-19.15% and 167.40-180.0 kg/ha) management (Table 1) (Singh and Pandey 2005).

SPC (19.95-20.20%) and total protein yield (183.54-193.92 kg/ha) were also comparable in crops with RDF and improved nutrient management (20.20-20.60% and 182.8-193.64 kg/ha) (Shaban 2013).

However, significantly higher SPC (20.25-20.50%) and total protein yields (178.20-184.50 kg/ha) were recorded in stands at residual soil moisture; which however, showed a declining trend with increasing irrigation application (Kassab 2012).

Total system productivity and profitability

Maximum system productivity (6.99-7.03 t/ha) and profitability (₹ 102753.0-103341.0) were achieved in the system of growing rice either at conventional or minimum tillage followed by chickpea at any tillage situation (Table 2). While, RDF or INM in rice followed by chickpea with RDF achieved maximum system productivity (6.73 t/ha) and profitability (₹ 98931.0).

Thus, research information generated in this farmer's field study could promote cultivation of chickpea at rainfed lowland rice fallow situations utilizing the left over resources mostly soil moisture and nutrients. Although, zero tilled rice has less prospects, minimum tillage would be beneficial,

Table 2 System productivity (REY*) and profitability in a rice-chickpea cropping system as influenced by tillage and nutrient management at rainfed lowland situations (pooled over two years)

Chickpea	Rice					
	Productivity (t/ha)	Profitability (₹/ha)	Productivity (t/ha)	Profitability (₹/ha)	Productivity (t/ha)	Profitability (₹/ha)
	Conventional Tillage		Minimum tillage		Zero tillage	
Tillage						
Conventional tillage	7.03	103341.0	7.00	102900.0	5.99	88053.0
Minimum tillage	7.02	103194.0	6.99	102753.0	5.98	87906.0
Zero tillage	7.03	103341.0	7.00	102900.0	5.99	88053.0
Nutrient management						
	RDF		*INM*			
	Productivity (t/ha)	*Profitability (₹/ha)*	*Productivity (t/ha)*	*Profitability (₹/ha)*		
RDF	6.73	98931.0	6.73	98931.0		
INM	6.69	98343.0	6.67	98049.0		

*REY- Rice equivalent yield. MSP of rice – ₹ 14100.00 and 14700.00 per ton in 2014 and 2015 respectively, MSP of chickpea- ₹ 31750.00 and 34250.00 per ton in 2015 and 2016 respectively

the study suggested. The study could also encourage the practice of legume seed inoculation and supplementary irrigations while aiming at resource conservation/utilization at such ecologically harsh situation.

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