Residual effect of direct seeded and transplanted rice, nutritional approaches and slow release nitrogen sources on the growth parameters of blackgram crop

ABSTRACT

A study was conducted on nutrient management approaches in rice-blackgram cropping system under different ecosystems. The growth parameters were recorded at 30 DAS, 60 DAS and at harvest of blackgram crop. The results indicated that the plant height and number of branches had increased linearly as the crop attained maturity. The three way interaction of ecosystem, nutritional approaches and N sources (M x N x S) had proved that significantly taller plants of blackgram were associated with the residual effect of transplanted soils which possessed neem coated urea based on SSNM for yield target of 7 t ha^{-1} ($M_2N_4S_2$) at all stages of crop growth and number of branches at 60 DAS and at harvest.

Key words: Transplanted rice, SSNM, neem coated urea, plant height and number of branches

Introduction

Blackgram is a leguminous crop, fixes atmospheric N through symbiosis, therefore improving soil fertility and productivity of subsequent cereal crop. A study in eastern India revealed no positive effect of a post-rice legume crop on subsequent transplanted rice (TPR), whereas another study showed higher yield of direct-seeded rice (DSR) when following legumes rather than a traditional fallow (Patil *et al.*, 2001). Inclusion of blackgram in rice system not only increased the overall productivity of the system but also improved physico-chemical properties of the soil (Arya *et al.*, 2005). However, productivity of blackgram is low due to number of biotic and abiotic stresses. Among different components of production, certain agronomic practices like timely planting, use of improved varieties and a proper method could be of much importance for improving productivity of blackgram.

Post-rice legumes can influence the accumulation, dynamics and carryover of soil inorganic N to a subsequent rice crop (Buresh and De Datta, 1991; Ladha *et al.*, 1996). Nitrogen that accumulates as soil nitrate during the post-rice legume growth and the subsequent dry season is prone to loss by leaching and denitrification during the onset of wet season rains and following the submergence of the soil for establishment of TPR (Buresh *et al.*, 1989).

The site specific nutrient management (SSNM), soil test crop response (STCR) and Nutrient Expert (NE) approach provide principles and tools for supplying crop nutrients as and when needed to achieve higher yield. This also needs to be evaluated for DSR conditions. These will aim to apply nutrients at optimal rates and time to achieve higher yield.

The use of slow release N-fertilizers such as neem coated urea (NCU) and urea supergranules (USG) in rice has been reported to be a better option than ordinary urea in almost all types of soils (Meelu *et al.*, 1983). The physical intromission of urea granules in an appropriate coating material is one such technique that produces controlled release coated urea and loss of N can be reduced which will be available to the subsequent crop. In the view of above, the present investigation was undertaken on residual effect of nutrient management approaches in blackgram crop under different rice ecosystems.

Materials and Methods

Selection of field's soil samples for pot culture experiment

To investigate the residual effect of nutrient management using different techniques and N sources in TPR and DSR-blackgram cropping system, a field experiment was carried out during the *kharif* and *rabi* seasons of 2018-19 and 2019-20 at Agriculture Research Station, Dhadesugur, Raichur. The blackgram variety TAU 1 developed at Tamil Nadu Agriculture University, Coimbatore was used as test crop. The experiment was laid out using Split-Split Plot Design.

Main plot : Ecosystem (M)

M_1 : Direct Seeded Rice (DSR), M_2 : Transplanted rice (TPR)

Sub plot : Nutritional approaches (N)

N_0	:	RDF
N_1	:	Fertilizer based on STCR for yield target of 6 t ha^{-1}
N_2	:	Fertilizer based on STCR for yield target of 7 t ha^{-1}
N_3	:	Fertilizer based on SSNM for yield target of 6 t ha^{-1}
N_4	:	Fertilizer based on SSNM for yield target of 7 t ha^{-1}
N_5	:	Fertilizer based on NE for yield target of 6 t ha^{-1}
N_6	:	Fertilizer based on NE for yield target of 7 t ha^{-1}

Sub-sub plot : Nitrogen sources (S)

S_1 : Urea super granules, S_2 : Neem coated urea

The absolute control for DSR and TPR was maintained outside the treatment plot. Application of FYM @ 7 t ha^{-1} and $ZnSO_4$ @ 25 kg ha^{-1} + foliar spray of $FeSO_4$ @ 0.5 per cent are common to all treatments except absolute control in rice. The fertilizers are applied to rice based on the RDF, STCR, SSNM and NE approach for different yield targets. The soil samples were analyzed for the determination of various available nutrients status after the harvest of rice and blackgram.

The biometrical observations and the analytical data obtained in the study were subjected to statistical scrutiny, by following the procedures outlined by Gomez and Gomez (1976), to derive a valid conclusion. The level of significance used in 'F' and 't' tests was $p = 0.05$. Critical difference values were calculated, wherever 'F' test was found significant. Results have been interpreted and discussed based on the pooled data of two years (2018 and 2019).

Results And Discussion

Plant height

The residual effect of nutrient management approaches along with N sources on plant height at different growth stages of blackgram are presented in Table 1 and the results were found significant. The height of plant was monitored at 30 DAS, 60

Table 1. Residual effect of ecosystem, nutritional approaches and nitrogen sources on plant height (cm) at various stages of blackgram during *rabi* season of 2018-19 and 2019-20 (pooled data)

	30 DAS	60 DAS	Harvest
Ecosystem (M)			
M_1	21.57^{b}	25.46^{b}	50.21^{b}
M_2	24.79^{a}	28.16^{a}	53.32^{a}
S.Em±	0.263	0.197	0.492
C.D (0.05)	1.599	1.196	2.996
Nutritional approaches (N)			
N_0	19.61^{bc}	23.93^{e}	50.90^{bc}
N_1	22.88^{bc}	26.87^{b}	49.90^{bc}
N_2	23.67^{c}	27.50^{ab}	52.07^{a-c}
N_3	24.52^{ab}	27.43^{b}	54.27^{ab}
N_4	25.54^{a}	28.66^{a}	55.88^{a}
N_5	22.76^{c}	26.42^{b}	47.68^{c}
N_6	23.27^{c}	26.85^{b}	51.65^{a-c}
S.Em±	0.245	0.398	1.525
C.D (0.05)	0.714	1.163	4.452
Nitrogen sources (S)			
S_1	22.34^{b}	26.25^{b}	49.89^{b}
S_2	24.02^{a}	27.37^{a}	53.63^{a}
S.Em±	0.154	0.167	0.725
C.D (0.05)	0.445	0.484	2.101

		30 DAS			60 DAS			Harvest		
		Ecosystem x Nutritional approaches (M x N)								
	M x N	**M_1**	**M_2**	**N mean**	**M_1**	**M_2**	**N mean**	**M_1**	**M_2**	**N mean**
N	**N_0**	18.79^{a-d}	20.43^{b-f}	**19.61^{bc}**	23.45^{i}	24.42^{hi}	**23.93^{e}**	49.01^{c-e}	52.79^{bc}	**50.90^{bc}**
	N_1	21.48^{c-f}	24.28^{ab}	**22.88^{bc}**	25.64^{f-h}	28.10^{b-d}	**26.87^{b}**	46.24^{de}	53.55^{bc}	**49.90^{bc}**
	N_2	22.48^{f}	24.87^{ab}	**23.67^{c}**	26.30^{d-g}	28.70^{bc}	**27.50^{ab}**	49.82^{b-e}	54.32^{bc}	**52.07^{a-c}**
	N_3	21.71^{b-f}	27.33^{a}	**24.52^{ab}**	25.12^{g-i}	29.74^{ab}	**27.43^{b}**	53.11^{bc}	55.42^{ab}	**54.27^{ab}**
	N_4	22.83^{a-e}	28.26^{a}	**25.54^{a}**	26.24^{e-h}	31.08^{a}	**28.66^{a}**	50.89^{b-d}	60.86^{a}	**55.88^{a}**
	N_5	21.53^{d-f}	23.99^{a-c}	**22.76^{c}**	25.61^{f-h}	27.23^{c-f}	**26.42^{b}**	51.31^{b-d}	44.05^{e}	**47.68^{c}**
	N_6	22.18^{ef}	24.37^{ab}	**23.27^{c}**	25.84^{f-h}	27.86^{c-e}	**26.85^{b}**	51.09^{b-d}	52.21^{b-d}	**51.65^{a-c}**
	M mean	**21.57^{b}**	**24.79^{a}**		**25.46^{b}**	**28.16^{a}**		**50.21^{b}**	**53.32^{a}**	
		S.Em±	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**	
		0.166	0.481		0.180	0.523		0.783	2.269	
		Nutritional approaches x Nitrogen sources (N x S)								
	N x S	**S_1**	**S_2**	**N mean**	**S_1**	**S_2**	**N mean**	**S_1**	**S_2**	**N mean**
N	**N_0**	19.25^{ab}	19.96^{cd}	**19.61^{bc}**	23.83^{e}	24.04^{e}	**23.93^{e}**	51.33^{c}	50.47^{c}	**50.90^{bc}**
	N_1	22.17^{bd}	23.59^{b-d}	**22.88^{bc}**	27.08^{b-d}	26.67^{cd}	**26.87^{b}**	49.08^{c}	50.72^{c}	**49.90^{bc}**
	N_2	23.29^{cd}	24.06^{b-d}	**23.67^{c}**	27.20^{b-d}	27.80^{bc}	**27.50^{ab}**	50.85^{c}	53.30^{bc}	**52.07^{a-c}**
	N_3	23.10^{cd}	25.94^{ab}	**24.52^{ab}**	26.34^{cd}	28.52^{b}	**27.43^{b}**	50.75^{c}	57.79^{ab}	**54.27^{ab}**
	N_4	23.46^{ab}	27.62^{a}	**25.54^{a}**	27.04^{cd}	30.28^{a}	**28.66^{a}**	49.77^{c}	61.99^{a}	**55.88^{a}**
	N_5	22.34^{d}	23.18^{a-c}	**22.76^{c}**	26.00^{d}	26.84^{cd}	**26.42^{b}**	47.36^{c}	48.00^{c}	**47.68^{c}**
	N_6	22.77^{d}	23.78^{a-c}	**23.27^{c}**	26.26^{d}	27.43^{b-d}	**26.85^{b}**	50.12^{c}	53.17^{bc}	**51.65^{a-c}**
	S mean	**22.34^{b}**	**24.02^{a}**		**26.25^{b}**	**27.37^{a}**		**49.89^{b}**	**53.63^{a}**	
		S.Em±	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**	
		0.166	0.481		0.180	0.523		0.783	2.269	
		Ecosystem x Nitrogen sources (M x S)								
	M x S	**M_1**	**M_2**	**S mean**	**M_1**	**M_2**	**S mean**	**M_1**	**M_2**	**S mean**
S	**S_1**	21.14^{b}	23.54^{ab}	**22.34^{b}**	25.20^{c}	27.29^{b}	**26.25^{b}**	47.15^{b}	52.63^{a}	**49.89^{b}**
	S_2	22.00^{b}	26.04^{a}	**24.02^{a}**	25.71^{c}	29.03^{a}	**27.37^{a}**	53.27^{a}	54.00^{a}	**53.63^{a}**
	M mean	**21.57^{b}**	**24.79^{a}**		**25.46^{b}**	**28.16^{a}**		**50.21^{b}**	**53.32^{a}**	
		S.Em±	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**	
		0.047	0.137		0.052	0.149		0.224	0.648	

Table 1. Continued

M x N x S		Ecosystem x Nutritional approaches x Nitrogen sources (M x N x S)								
		30 DAS			60 DAS			Harvest		
		M_1	M_2	N x S	M_1	M_2	N x S	M_1	M_2	N x S
N_0	S_1	18.23^{n}	20.27^{lm}	**19.25**	22.89^{m}	24.76^{k-m}	**23.83**	48.47^{e-h}	54.19^{b-e}	**51.33**
	S_2	19.35^{mn}	20.58^{k-m}	**19.96**	24.01^{lm}	24.07^{m}	**24.04**	49.55^{e-h}	51.39^{cd}	**50.47**
N_1	S_1	20.60^{j-m}	23.74^{c-e}	**22.17**	25.92^{g-l}	28.23^{b-d}	**27.08**	45.30^{g-i}	52.86^{b-g}	**49.08**
	S_2	22.37^{e-i}	24.81^{bc}	**23.59**	25.36^{i-l}	27.97^{b-f}	**26.67**	47.19^{e-h}	54.25^{b-i}	**50.72**
N_2	S_1	22.22^{f-i}	24.36^{bc}	**23.29**	26.21^{e-k}	28.19^{b-e}	**27.20**	48.77^{e-h}	52.93^{b-g}	**50.85**
	S_2	22.73^{d-h}	25.38^{b}	**24.06**	26.39^{d-k}	29.21^{b}	**27.80**	50.87^{c-e}	55.72^{b-d}	**53.30**
N_3	S_1	22.09^{g-j}	24.11^{b-d}	**23.10**	25.25^{i-l}	27.44^{b-h}	**26.34**	48.47^{e-h}	53.02^{b-g}	**50.75**
	S_2	21.33^{h-l}	30.55^{a}	**25.94**	24.99^{j-l}	32.04^{a}	**28.52**	57.75^{a-c}	57.82^{b}	**57.79**
N_4	S_1	21.89^{h-k}	25.04^{bc}	**23.46**	25.54^{h-l}	28.53^{bc}	**27.04**	41.80^{hi}	57.74^{a-c}	**49.77**
	S_2	23.77^{c-e}	31.47^{a}	**27.62**	26.93^{c-j}	33.63^{a}	**30.28**	59.98^{ab}	63.99^{a}	**61.99**
N_5	S_1	21.10^{i-l}	23.59^{c-g}	**22.34**	25.09^{i-l}	26.92^{c-j}	**26.00**	45.78^{g-i}	48.94^{d-h}	**47.36**
	S_2	21.97^{h-k}	24.39^{bc}	**23.18**	26.13^{f-k}	27.55^{b-g}	**26.84**	56.84^{a-d}	39.16^{i}	**48.00**
N_6	S_1	21.87^{h-k}	23.67^{c-f}	**22.77**	25.53^{h-l}	26.99^{c-i}	**26.26**	51.49^{c-g}	48.76^{e-h}	**50.12**
	S_2	22.49^{e-i}	25.06^{bc}	**23.78**	26.15^{f-l}	28.72^{bc}	**27.43**	50.69^{cd}	55.65^{b}	**53.17**
	M mean	**21.57^{b}**	**24.79^{a}**		**25.46^{b}**	**28.16^{a}**		**50.21^{b}**	**53.32^{a}**	
	Control	**16.96**	**18.72**		**21.23**	**22.21**		**46.13**	**50.58**	
		S.Em±	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**	
M x N x S		0.332	0.962		0.361	1.046		1.567	4.538	
Control Vs Rest	M_1	0.423	1.226		0.541	1.567		3.208	9.293	
	M_2	0.619	1.794		0.810	2.346		2.343	6.787	

Note :														
NS : Non significant														
Main plot	:	**Ecosystem (M)**	M_1	:	Direct seeded rice	M_2	:	Transplanted rice						
Sub plot	:	**Nutritional approaches (N)**	N_0	:	RDF	N_1	:	STCR of 6 t ha^{-1}	N_2	:	STCR of 7 t ha^{-1}	N_3	:	SSNM of 6 t ha^{-1}
			N_4	:	SSNM of 7 t ha^{-1}	N_5	:	NE of 6 t ha^{-1}	N_6	:	NE of 7 t ha^{-1}			
Sub-sub plot	:	**Nitrogen sources (S)**	S_1	:	Urea super granules	S_2	:	Neem coated urea						

DAS and at harvest. It was seen from the results that the plant height had increased linearly as the crop attained maturity.

The establishment of blackgram under various rice ecosystems had revealed that the blackgram grown under TPR soils (M_2) increased plant height significantly (24.79, 28.16 and 53.32 cm at 30 DAS, 60 DAS and at harvest, respectively), followed in the DSR (M_1) ecosystem (21.57, 25.46 and 50.21 cm at 30 DAS, 60 DAS and harvest, respectively).

A close scrutiny had indicated that the different nutritional approaches (N) had a significant and positive influence on the plant height at different stages of crop growth, whereas higher plant height (25.54, 28.66 and 55.88 cm, respectively) was recorded with the residual effect of fertilizer application based on SSNM for yield target of 7 t ha^{-1} (N_4), though it was comparable with SSNM approach for yield target of 6 t ha^{-1} (N_3). At 30 and 60 DAS, the lowest value (19.61 and 23.93 cm, respectively) was in the residual effect of nutrients through RDF (N_0), whereas at harvest (47.68 cm), it was in NE approach for the yield target of 6 t ha^{-1} (N_5).

Similarly, use of slow release N sources (S), neem coated urea (S_2) produced significant variations resulted in higher plant height (24.02, 27.37 and 53.63 cm at 30, 60 DAS and at harvest, respectively), while urea super granules (S_1) recorded significantly lower plant height (22.34, 26.25 and 49.89 cm at 30, 60 DAS and harvest, respectively).

The interaction of rice ecosystem and nutritional approaches (M x N) had further shown that the residual effect of the application of fertilizer based on SSNM for yield target of 7 t ha^{-1} in TPR (M_2N_4) increased the plant height of blackgram significantly (28.26, 31.08 and 60.86 cm at 30, 60 DAS and harvest, respectively). Alternate wetting and drying method in DSR ecosystem along with the fertilizer application based on RDF (M_1N_0) had resulted in the shortest plant of blackgram at 30 DAS (18.79 cm) and 60 DAS (23.45 cm), respectively. Though, at harvest, shorter plant (44.05 cm) was in the NE approach (6 t ha^{-1}) in TPR ecosystem (M_2N_5).

The interaction of nutritional approaches with sources of urea (N x S) had confirmed the superiority of NCU in recording higher plant height in all the nutrient management approaches except RDF treatment. The nutrient management approaches in combinations with N sources registered taller plants (27.62, 30.28 and 61.99 cm at 30, 60 DAS and harvest, respectively) in higher yield target based on SSNM coupled with supply of N from NCU

(N_4S_2). However, it was comparable with the SSNM approach (6 t ha^{-1}) with the application of NCU (N_3S_2) and USG treated plots through SSNM approach for the yield target of 7 t ha^{-1} (N_4S_1). At 30 and 60 DAS, application of NCU based on RDF (N_0S_1) had resulted in shorter plants (19.25 and 23.83 cm, respectively), whereas at harvest (47.36 cm), it was in USG treated plots through NE approach for yield target of 6 t ha^{-1} (N_5S_1).

The interaction of ecosystem with sources (M x S) was found to be significant and indicated that blackgram grown under TPR soils applied with NCU (M_2S_2) could increase the plant height (26.04, 29.03 and 54.00 cm at 30, 60 DAS and harvest, respectively) and plants of blackgram under DSR soils applied with slow release USG (M_1S_1) had shown significantly a lower the plant height (21.14, 25.20 and 47.15 cm at 30, 60 DAS and harvest, respectively).

Overall, the three way interaction of ecosystem, nutritional approaches and N sources (M x N x S) had once again confirmed that significantly taller plants of blackgram (31.47, 33.63 and 63.99 cm at 30, 60 DAS and harvest, respectively) were associated with the residual effect of TPR soils which possessed NCU based on SSNM for yield target of 7 t ha^{-1} ($M_2N_4S_2$). It was further noticed that in the TPR soils which contained NCU with SSNM based fertilizer application for yield target of 6 t ha^{-1} ($M_2N_3S_2$) had shown similar trend. The lower plant height was registered in USG treated plots based on RDF as source in the DSR soils ($M_1N_0S_1$) at 30 DAS (18.23 cm) and 60 DAS (22.89 cm), respectively. At harvest, shorter plants (39.16 cm) were noticed in the treatment with NCU based on NE approach (6 t ha^{-1}) in TPR soils ($M_2N_5S_2$); other treatment combinations fared in between.

The residual effect of all treatment combinations involving nutritional approaches for different yield targets and N sources were found superior over control plots of under DSR (16.96, 21.23 and 46.13 cm at 30, 60 DAS and harvest, respectively) and TPR soils (18.72, 22.21 and 50.58 cm at 30, 60 DAS and harvest, respectively).

Increase in plant height may be attributed due to greater availability of residual nutrients in soil after harvest of DSR and TPR. The higher plant height was observed in the TPR ecosystem which possessed NCU based on SSNM approach ($M_2N_4S_2$) for yield target of 7 t ha^{-1}. The favourable growth condition of TPR ecosystem enables the greater root proliferation and nutrient acquisition from the soils. The plant height could have been promoted by higher residual quantity of nutrients made available by the different treatments to blackgram crop. This was also evidenced through higher uptake of nutrients. These results corroborate with the findings of Abarna (2017) in blackgram that significantly higher plant height was observed in residual effect of nutrients through SSNM approach targeted yield of 8.0 t ha^{-1} (56.55 cm) in rice crop as compared to other treatments. Kowsalya (2018) reported that an increase in plant height at 30 (18.75 cm), 60 DAS (29.66 cm) and at harvest (52.56 cm) with residual effect of SSNM approach targeted yield of 20 q ha^{-1} over control in the TPR-blackgram cropping system.

The neem coated urea and inorganic fertilizers ensure balanced nutrient supply makes the soil rich in nutrients as per crop needs. Greater availability of N enhanced the plant growth through increased photosynthesis and other physiological activities and also helped the plants to better utilize the available nutrients with increased leaf area, high photosynthesis and dry matter accumulation which enhanced crop growth rate. These results corroborate with the findings of Bharti *et al*. (2010). Macronutrients such as N have a structural role in chlorophyll. These elements involve in the enhancement of photosynthetic activity and translocation of the photosynthates and increase the chlorophyll concentration there by it enhances growth parameters. Similar findings had earlier been reported by Halder *et al.* (2007) and Senthil *et al*. (2009).

The beneficial effect of P through the availability of higher energy in the form of ATP molecules which might have favoured multiplication of cells enhancing the plant height was also reported by several workers (Singh and Chaudhan, 1987; Hanumanthappa and Hosamani, 1989).

Number of branches per plant

The number of branches per plant of blackgram as affected by residual effect of the sources of urea and the nutritional methods under different rice ecosystem is presented in Table 2. It was revealed by the statistical scrutiny that the number of branches increased significantly with the growth of the plant due to different factors and their interactions at all the stages of observations during both the years and on pooled basis.

Among the rice establishment methods (M), the maximum number of branches (2.58, 7.49 and 14.25, respectively) was noticed in the plants grown in TPR plots (M_2), followed by DSR (M_1) at various stages of crop growth (2.43, 4.92 and 12.49, respectively).

The results had shown that the different nutritional approaches (N) had a significant and positive influence on the number of branches, whereas higher number of branches per plant (2.67, 7.93 and 17.04, respectively) was recorded in the residual effect of fertilizer

Table 2. Residual effect of ecosystem, nutritional approaches and nitrogen sources on number of branches per plant at various stages of blackgram during *rabi* season of 2018-19 and 2019-20 (pooled data)

	30 DAS	60 DAS	Harvest
Ecosystem (M)			
M_1	2.43^{b}	4.92^{b}	12.49^{b}
M_2	2.58^{a}	7.49^{a}	14.25^{a}
S.Em±	0.017	0.171	0.029
C.D (0.05)	0.101	1.040	0.176
Nutritional approaches (N)			
N_0	2.41^{c}	4.56^{d}	10.88^{d}
N_1	2.48^{bc}	6.36^{bc}	12.05^{c}
N_2	2.45^{c}	6.75^{b}	14.73^{b}
N_3	2.55^{b}	6.81^{b}	15.22^{b}
N_4	2.67^{a}	7.93^{a}	17.04^{a}
N_5	2.47^{bc}	4.99^{d}	11.81^{cd}
N_6	2.47^{bc}	6.02^{c}	11.88^{cd}
S.Em±	0.034	0.172	0.368
C.D (0.05)	0.098	0.502	1.074
Nitrogen sources (S)			
S_1	2.43^{b}	5.52^{b}	12.68^{b}
S_2	2.57^{a}	6.89^{a}	14.07^{a}
S.Em±	0.017	0.085	0.135
C.D (0.05)	0.050	0.246	0.392

		30 DAS			**60 DAS**			**Harvest**		
		Ecosystem x Nutritional approaches (M x N)								
	M x N	**M_1**	**M_2**	**N mean**	**M_1**	**M_2**	**N mean**	**M_1**	**M_2**	**N mean**
N	**N_0**	2.37^{d-f}	2.45^{c-e}	**2.41^{c}**	4.35^{fg}	4.77^{ef}	**4.56^{d}**	11.55^{fg}	10.21^{gh}	**10.88^{d}**
	N_1	2.40^{d-f}	2.57^{a-c}	**2.48^{bc}**	5.36^{d-f}	7.35^{b}	**6.36^{bc}**	10.72^{g}	13.38^{de}	**12.05^{c}**
	N_2	2.33^{ef}	2.56^{a-c}	**2.45^{c}**	5.96^{cd}	7.54^{b}	**6.75^{b}**	15.15^{bc}	14.32^{cd}	**14.73^{b}**
	N_3	2.52^{b-d}	2.59^{a-c}	**2.55^{b}**	4.34^{fg}	9.29^{a}	**6.81^{b}**	14.37^{cd}	16.06^{b}	**15.22^{b}**
	N_4	2.70^{a}	2.64^{ab}	**2.67^{a}**	5.49^{c-f}	10.36^{a}	**7.93^{a}**	14.35^{cd}	19.72^{a}	**17.04^{a}**
	N_5	2.38^{d-f}	2.57^{ab}	**2.47^{bc}**	3.41^{g}	6.57^{bc}	**4.99^{d}**	9.02^{h}	14.60^{cd}	**11.81^{cd}**
	N_6	2.30^{f}	2.65^{a-c}	**2.47^{bc}**	5.52^{c-e}	6.52^{bc}	**6.02^{c}**	12.30^{ef}	11.46^{fg}	**11.88^{cd}**
	M mean	**2.43^{b}**	**2.58^{a}**		**4.92^{b}**	**7.49^{a}**		**12.49^{b}**	**14.25^{a}**	
		S.Em±	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**	
		0.019	0.054		0.092	0.266		0.146	0.424	
		Nutritional approaches x Nitrogen sources (N x S)								
N	**N x S**	**S_1**	**S_2**	**N mean**	**S_1**	**S_2**	**N mean**	**S_1**	**S_2**	**N mean**
	N_0	2.36^{d}	2.46^{cd}	**2.41^{c}**	4.99^{e}	4.13^{f}	**4.56^{d}**	11.26^{ef}	10.57^{ef}	**10.88^{d}**
	N_1	2.45^{cd}	2.52^{c}	**2.48^{bc}**	6.37^{c}	6.34^{c}	**6.36^{bc}**	11.65^{ef}	12.45^{cd}	**12.05^{c}**
	N_2	2.39^{cd}	2.50^{c}	**2.45^{c}**	5.79^{cd}	7.71^{b}	**6.75^{b}**	13.57^{c}	15.90^{b}	**14.73^{b}**
	N_3	2.43^{cd}	2.68^{b}	**2.55^{b}**	5.96^{cd}	7.66^{b}	**6.81^{b}**	14.99^{b}	15.44^{b}	**15.22^{b}**
	N_4	2.48^{c}	2.86^{a}	**2.67^{a}**	5.98^{cd}	9.88^{a}	**7.93^{a}**	15.09^{b}	18.99^{a}	**17.04^{a}**
	N_5	2.44^{cd}	2.51^{c}	**2.47^{bc}**	3.95^{f}	6.02^{cd}	**4.99^{d}**	10.49^{f}	13.05^{cd}	**11.81^{cd}**
	N_6	2.47^{cd}	2.47^{cd}	**2.47^{bc}**	5.57^{de}	6.47^{c}	**6.02^{c}**	11.59^{ef}	12.17^{de}	**11.88^{cd}**
	S mean	**2.43^{b}**	**2.57^{a}**		**5.52^{b}**	**6.89^{a}**		**12.68^{b}**	**14.07^{a}**	
		S.Em±	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**	
		0.019	0.054		0.092	0.266		0.146	0.424	
		Ecosystem x Nitrogen sources (M x S)								
S	**M x S**	**M_1**	**M_2**	**S mean**	**M_1**	**M_2**	**S mean**	**M_1**	**M_2**	**S mean**
	S_1	2.36	2.50	**2.43^{b}**	4.58^{d}	6.45^{b}	**5.52^{b}**	12.29^{c}	13.06^{b}	**12.68^{b}**
	S_2	2.50	2.65	**2.57^{a}**	5.26^{c}	8.52^{a}	**6.89^{a}**	12.70^{bc}	15.44^{a}	**14.07^{a}**
	M mean	**2.43^{b}**	**2.58^{a}**		**4.92^{b}**	**7.49^{a}**		**12.49^{b}**	**14.25^{a}**	
		S.Em±	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**	
		0.005	NS		0.026	0.076		0.042	0.121	

Table 2. Continued

M x N x S		Ecosystem x Nutritional approaches x Nitrogen sources (M x N x S)								
		30 DAS			60 DAS			Harvest		
		M_1	M_2	N x S	M_1	M_2	N x S	M_1	M_2	N x S
N_0	S_1	2.38^{g-i}	2.34^{g-i}	**2.36**	5.10^{i-k}	4.87^{j-l}	**4.99**	12.71^{e-i}	9.82^{k}	**11.26**
	S_2	2.36^{g-i}	2.57^{b-f}	**2.46**	3.60^{m}	4.66^{k-n}	**4.13**	10.38^{jk}	10.61^{jk}	**10.49**
N_1	S_1	2.40^{e-i}	2.50^{c-g}	**2.45**	5.02^{j-l}	7.72^{de}	**6.37**	10.30^{jk}	13.00^{e-h}	**11.65**
	S_2	2.39^{g-i}	2.64^{b-d}	**2.52**	5.70^{h-n}	6.98^{d-f}	**6.34**	11.14^{i-k}	13.76^{ef}	**12.45**
N_2	S_1	2.31^{hi}	2.47^{f-h}	**2.39**	5.61^{h-j}	5.96^{g-i}	**5.79**	14.39^{de}	12.74^{e-i}	**13.57**
	S_2	2.36^{g-i}	2.65^{b-e}	**2.50**	6.30^{f-h}	9.12^{c}	**7.71**	15.91^{cd}	15.90^{cd}	**15.90**
N_3	S_1	2.34^{g-i}	2.51^{c-g}	**2.43**	4.90^{j-l}	7.03^{d-f}	**5.96**	16.18^{c}	13.81^{ef}	**14.99**
	S_2	2.70^{b}	2.67^{b-d}	**2.68**	3.77^{mn}	11.54^{b}	**7.66**	12.55^{f-i}	18.32^{b}	**15.44**
N_4	S_1	2.34^{g-i}	2.62^{b-d}	**2.48**	4.14^{l-n}	7.82^{d}	**5.98**	13.08^{e-h}	17.10^{bc}	**15.09**
	S_2	3.06^{a}	2.67^{b-d}	**2.86**	6.85^{e-g}	12.90^{a}	**9.88**	15.63^{cd}	22.35^{a}	**18.99**
N_5	S_1	2.36^{g-i}	2.51^{c-g}	**2.44**	2.66^{o}	5.25^{i-k}	**3.95**	7.94^{l}	13.19^{e-g}	**10.57**
	S_2	2.40^{e-i}	2.63^{b-d}	**2.51**	4.15^{l-n}	7.89^{d}	**6.02**	10.10^{jk}	16.01^{cd}	**13.05**
N_6	S_1	2.36^{g-i}	2.58b^{-f}	**2.47**	4.62^{k-m}	6.51^{f-h}	**5.57**	11.40^{h-k}	11.79^{g-j}	**11.59**
	S_2	2.23^{i}	2.71^{b}	**2.47**	6.42^{f-h}	6.53^{f-h}	**6.47**	13.20^{e-g}	11.14^{i-k}	**12.17**
	M mean	**2.43^{b}**	**2.58^{a}**		**4.92^{b}**	**7.49^{a}**		**12.49^{b}**	**14.25^{a}**	
	Control	**2.09**	**2.15**		**3.41**	**4.28**		**7.95**	**9.09**	
		S.Em±	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**	
	M x N x S	0.037	0.108		0.184	0.532		0.293	0.848	
Control Vs Rest	**M_1**	0.067	0.195		0.317	0.919		0.546	1.582	
	M_2	0.061	0.176		0.363	1.052		0.728	2.109	

Note :														
NS : Non significant														
Main plot	:	**Ecosystem (M)**	**M_1**	:	Direct seeded rice	**M_2**	:	Transplanted rice						
Sub plot	:	**Nutritional approaches (N)**	**N_0**	:	RDF	**N_1**	:	STCR of 6 t ha^{-1}	**N_2**	:	STCR of 7 t ha^{-1}	**N_3**	:	SSNM of 6 t ha^{-1}
			N_4	:	SSNM of 7 t ha^{-1}	**N_5**	:	NE of 6 t ha^{-1}	**N_6**	:	NE of 7 t ha^{-1}			
Sub-sub plot	:	**Nitrogen sources (S)**	**S_1**	:	Urea super granules	**S_2**	:	Neem coated urea						

application based on SSNM for yield target of 7 t ha^{-1} (N_4) at 30 DAS, 60 DAS and at harvest, respectively. The lowest (2.41, 4.56 and 10.88, respectively) was under RDF treated plots (N_0).

With the advancement of crop growth the number of branches had increased significantly with the use of slow release N sources (S). The maximum number of branches per plant (2.57, 6.89 and 14.07, respectively) was noticed in the plots which received NCU (S_2), followed by USG treated plots (S_1) with 2.43, 5.52 and 12.68, branches per plant at various stages.

The interaction of rice ecosystem and nutritional approaches (M x N) had further shown a comparable change in number of branches per plant due to the irrigation methods applied in DSR and TPR ecosystem. The interaction of ecosystem with nutritional methods had indicated that the fertilizer application based on SSNM for yield target of 7 t ha^{-1} is best suited for blackgram grown under DSR soils (M_2N_4) by registering higher number of branches per plant at 30 DAS (2.70). Though, at 60 DAS (10.36) and at harvest (19.72), it was found on SSNM approach for the yield target of 7 t ha^{-1} in TPR ecosystem (M_2N_4). The plots of DSR applied with NE approach for the yield target of 7 t ha^{-1} (M_1N_6) registered the lowest number of branches per plant at 30 DAS (2.30) and for the yield target of 6 t ha^{-1} (M_1N_5) at 60 DAS (3.41) and at harvest (9.02), respectively.

The interaction of nutritional approaches with sources of urea (N x S) was significant and revealed that the effect of NCU was more pronounced in soils which contained SSNM based fertilizer application for the yield target of 7 t ha^{-1} (N_4S_2) could result in higher number of branches per plant (2.86, 9.88 and 18.99 at 30 DAS, 60 DAS and harvest, respectively) and other treatment combinations were inferior. The residual effect of the application of USG based on RDF (N_0S_1) had resulted in lowest number of branches per plant (2.36) at 30 DAS, while it was in the USG treated plot through NE approach for the yield target of 6 t ha^{-1} (N_5S_1) at 60 DAS (3.95) and at harvest (10.49), respectively. It was further noticed that irrespective of the application of nutritional approaches, the lower number of branches were found only in USG applied plots.

The interaction of ecosystem with N sources (M x S) was not significant at 30 DAS. The results had indicated that the TPR plot applied with NCU (M_2S_2) recorded significant and higher number of branches per plant at 60 DAS and at harvest (8.52 and 15.44, respectively). However, in the USG treated plots in DSR soils (M_1S_1) had resulted in lower number of branches per plant (4.58 and 12.29, respectively) during different stages of crop growth.

The three way interaction (M x N x S) of ecosystem with nutritional approaches and N sources had proved that the application of NCU in recording higher number of branches per plant was noticed in SSNM (7 t ha^{-1}) treated plot of DSR ($M_1N_4S_2$) at 30 DAS (3.06), whereas in TPR ecosystem ($M_2N_4S_2$) at 60 DAS (12.90) and at harvest (22.35), respectively. At harvest, the residual effect of NCU based on NE approach (7 t ha^{-1}) in DSR plot ($M_1N_6S_2$) was registered lower number of branches per plant at 30 DAS (2.23), whereas in the residual plots of USG under NE approach (6 t ha^{-1}) in DSR ecosystem ($M_1N_5S_1$) at 60 DAS (2.66) and at harvest (7.94). Irrespective of the methods of nutrition, the lower number of tillers was observed in DSR plot applied with USG.

The residual effect of all treatment combinations with nutritional approaches for different yield targets and N sources were found superior over control plots of blackgram grown under DSR (2.09, 3.41 and 7.95, respectively) and TPR soils (2.15, 4.28 and 9.09, respectively) at various stages of crop growth.

Increase in number of branches per plant may be attributed due to greater availability of residual nutrients in soil and the combined application of NCU along with inorganic nutrients supplied through SSNM approach (7 t ha^{-1}) in DSR and TPR ecosystem ($M_{1\text{-}2}N_4S_2$). The number of branches per plant could have been promoted by higher residual quantity of nutrients made available by the different treatments to blackgram crop. Similar results also reported by Abarna (2017) in blackgram that significantly higher number of branches was observed in plots with the residual effect of nutrients through SSNM approach targeted yield of 8.0 t ha^{-1} (29.57).

Conclusion

The addition of fertilizers and slow release nitrogen sources based on soil test values for direct seeded rice and transplanted rice had significant influence rice fallow blackgram. The residual effect of neem coated based on SSNM approach for yield target of 7 t ha^{-1} had resulted in increased plant height and number of branches per plant of blackgram during *rabi* season.

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