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Effects of Different Rice Ecosystems, Nutritional Approaches and Nitrogen Sources on the Yield and Yield Parameters of Blackgram (*Vigna mungo*)

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KEYWORDS

Transplanted rice, SSNM, neem coated urea, dry matter production, seed yield, haulm yield.

ABSTRACT:

A study was conducted on nutrient management approaches in rice-blackgram cropping system under different ecosystems at the Agricultural Research Station, Dhadesugur, University of Agricultural Sciences, Raichur. The dry matter production parameters were recorded at 30 DAS, 60 DAS and at harvest and yield parameters, seed yield and haulm yield were recorded at harvest of blackgram crop. The results indicated that the DMP, number of pods per plant, number of seeds per pod, 1000 seed weight seed yield and haulm yield had increased with the residual effect of nutrients and nutritional approaches. The three way interaction of ecosystem, nutritional approaches and N sources (M x N x S) had proved that significantly higher DMP, number of pods per plant, number of seeds per pod, 1000 seed weight, seed yield and haulm yield 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} ($M_2N_4S_2$).

1. Introduction

Black gram, being a short-duration and hardy crop, is well-suited for inclusion in the cropping sequence, as it efficiently utilizes residual nutrients, moisture and other inputs from the preceding rice crop. The extensive practice of cultivating rice through monocropping, coupled with the excessive application of chemical fertilizers and inadequate management of crop and nutrients, has led to the degradation of soil physico-chemical and biological properties. This degradation poses a significant threat to the productivity and sustainability of the agricultural system (Patra *et al*., 2019). One potential partial solution to this problem is transitioning to a ric-legume cropping system (Deep *et al*., 2018). 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).

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 slow release of nutrients provided a sustained supply of essential elements to the crops over an extended period, ensuring optimal nutrient availability and uptake by the plants. 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.

2. 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).

3. Results

Dry matter production

The dry matter production was continuously monitored in order to assess the accumulation pattern as influenced by the type of rice ecosystems and nutrient management approaches and with varying slow release N applications (Table 1). The results had shown that the accumulation of the dry matter was significantly linear with the advancement of crop growth.

Table 1 Residual effect of ecosystems, nutrient management approaches and nitrogen sources on dry matter production (g plant^{-1}) at various stages of blackgram during *rabi* season of 2018-19 and 2019-20 (pooled data)

	30 DAS	60 DAS	Harvest			30 DAS			60 DAS			Harvest		
Ecosystem (M)														
M_1	1.82^{b}	2.21^{b}	10.58^{b}											
M_2	1.95^{a}	4.06^{a}	12.71^{a}											
S.Em±	0.018	0.245	0.193											
C.D (0.05)	0.112	1.488	1.176			**Ecosystem x Nutrient management approaches (M x N)**								
Nutrient management approaches (N)				**M x N**		**M_1**	**M_2**	**N mean**	**M_1**	**M_2**	**N mean**	**M_1**	**M_2**	**N mean**
N_0	1.80^{c}	2.66^{c}	8.72^{b}	**N**	**N_0**	1.78^{c}	1.81^{bc}	$\mathbf{1.80^{c}}$	2.86^{b-d}	2.46^{d}	$\mathbf{2.66^{c}}$	9.36^{e-g}	8.08^{g}	$\mathbf{8.72^{b}}$
N_1	1.87^{bc}	3.10^{bc}	11.87^{a}		**N_1**	1.78^{c}	1.96^{ab}	$\mathbf{1.87^{bc}}$	1.99^{d}	4.20^{ab}	$\mathbf{3.10^{bc}}$	10.39^{ef}	13.34^{bc}	$\mathbf{11.87^{a}}$

N_2	1.84^{bc}	3.06^{bc}	11.95^{a}
N_3	1.93^{ab}	3.42^{ab}	12.34^{a}
N_4	1.99^{a}	3.84^{a}	12.61^{a}
N_5	1.86^{bc}	2.79^{c}	11.79^{a}
N_6	1.88^{bc}	3.12^{bc}	12.26^{a}
S.Em±	0.033	0.172	0.480
C.D (0.05)	0.095	0.502	1.401
Nitrogen sources (S)			
S_1	1.81^{b}	2.51^{b}	10.77^{b}
S_2	1.96^{a}	3.76^{a}	12.53^{a}
S.Em±	0.017	0.122	0.213
C.D (0.05)	0.048	0.353	0.616

	N_2	1.75^{c}	1.94^{ab}	**1.84^{bc}**	2.02^{d}	4.11^{ab}	**3.06^{bc}**	12.80^{b-d}	11.11^{d-f}	**11.95^{a}**
	N_3	1.89^{a-c}	1.98^{a}	**1.93^{ab}**	2.48^{cd}	4.36^{ab}	**3.42^{ab}**	11.36^{c-e}	13.32^{bc}	**12.34^{a}**
	N_4	2.01^{a}	1.98^{a}	**1.99^{a}**	2.38^{d}	5.21^{a}	**3.84^{a}**	9.73^{e-g}	15.49^{a}	**12.61^{a}**
	N_5	1.78^{c}	1.95^{ab}	**1.86^{bc}**	1.51^{d}	4.07^{ab}	**2.79^{c}**	9.18^{fg}	14.39^{ab}	**11.79^{a}**
	N_6	1.73^{c}	2.03^{a}	**1.88^{bc}**	2.21^{d}	4.02^{a-c}	**3.12^{bc}**	11.25^{c-f}	13.27^{bc}	**12.26^{a}**
	M mean	**1.82^{b}**	**1.95^{a}**		**2.21^{b}**	**4.06^{a}**		**10.58^{b}**	**12.71^{a}**	
		S.Em±	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**	
		0.018	0.052		0.132	0.382		0.230	0.665	
	N x S	**Nutrient management approaches x Nitrogen sources (N x S)**								
N		**S_1**	**S_2**	**N mean**	**S_1**	**S_2**	**N mean**	**S_1**	**S_2**	**N mean**
	N_0	1.74^{d}	1.85^{b-d}	**1.80^{c}**	2.85^{d-g}	2.47^{fg}	**2.66^{c}**	8.57^{g}	8.87^{fg}	**8.72^{b}**
	N_1	1.83^{b-d}	1.91^{b}	**1.87^{bc}**	2.55^{e-g}	3.65^{b-d}	**3.10^{bc}**	11.15^{de}	12.58^{b-d}	**11.87^{a}**
	N_2	1.78^{cd}	1.91^{b}	**1.84^{bc}**	2.19^{g}	3.94^{a-c}	**3.06^{bc}**	12.19^{b-e}	11.71^{c-e}	**11.95^{a}**
	N_3	1.82^{b-d}	2.04^{a}	**1.93^{ab}**	2.34^{g}	4.40^{ab}	**3.42^{ab}**	10.75^{e}	13.93^{ab}	**12.34^{a}**
	N_4	1.82^{b-d}	2.16^{a}	**1.99^{a}**	3.18^{c-f}	4.51^{a}	**3.84^{a}**	10.78^{de}	14.44^{a}	**12.61^{a}**
	N_5	1.83^{b-d}	1.90^{bc}	**1.86^{bc}**	2.25^{g}	3.32^{c-e}	**2.79^{c}**	10.50^{ef}	13.08^{a-c}	**11.79^{a}**
	N_6	1.86^{b-d}	1.91^{bc}	**1.88^{bc}**	2.24^{g}	4.00^{a-c}	**3.12^{bc}**	11.42^{c-e}	13.10^{a-c}	**12.26^{a}**
	S mean	**1.81^{b}**	**1.96^{a}**		**2.51^{b}**	**3.76^{a}**		**10.77^{b}**	**12.53^{a}**	
		S.Em±	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**	
		0.018	0.052		0.132	0.382		0.230	0.665	
S	**M x S**	**Ecosystem x Nitrogen sources (M x S)**								
		M_1	**M_2**	**S mean**	**M_1**	**M_2**	**S mean**	**M_1**	**M_2**	**S mean**
	S_1	1.75	1.87	**1.81^{b}**	1.87^{b}	3.16^{b}	**2.51^{b}**	10.29^{b}	11.24^{b}	**10.77^{b}**
	S_2	1.88	2.03	**1.96^{a}**	2.54^{b}	4.97^{a}	**3.76^{a}**	10.87^{b}	14.19^{a}	**12.53^{a}**
	M mean	**1.82^{b}**	**1.95^{a}**		**2.21^{b}**	**4.06^{a}**		**10.58^{b}**	**12.71^{a}**	
		S.Em±	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**	
		0.005	NS		0.038	0.109		0.066	0.190	

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Table 1 Contd…

M x N x S		Ecosystem x Nutrient management 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	1.80^{e-j}	1.69^{j}	**1.74**	4.07^{b-d}	1.63^{h-k}	**2.85**	9.88^{g-k}	7.26^{l}	**8.57**
	S_2	1.76^{g-j}	1.94^{b-f}	**1.85**	1.64^{h-k}	3.30^{d-f}	**2.47**	8.83^{j-l}	8.90^{j-l}	**8.87**
N_1	S_1	1.77^{f-j}	1.88^{c-i}	**1.83**	1.52^{jk}	3.58^{d-f}	**2.55**	9.25^{i-l}	13.06^{b-d}	**11.15**
	S_2	1.80^{e-j}	2.03^{b-d}	**1.91**	2.47^{f-j}	4.83^{a-c}	**3.65**	11.52^{b-i}	13.63^{b}	**12.58**
N_2	S_1	1.71^{ij}	1.85^{d-j}	**1.78**	1.59^{i-k}	2.80^{e-g}	**2.19**	13.71^{b}	10.68^{d-k}	**12.19**
	S_2	1.78^{f-j}	2.03^{b-d}	**1.91**	2.45^{f-j}	5.42^{a}	**3.94**	11.88^{b-h}	11.53^{b-i}	**11.71**
N_3	S_1	1.74^{g-j}	1.90^{c-g}	**1.82**	1.28^{k}	3.40^{d-f}	**2.34**	12.24^{b-g}	9.26^{i-l}	**10.75**
	S_2	2.04^{bc}	2.05^{bc}	**2.04**	3.69^{c-e}	5.33^{a}	**4.51**	10.49^{e-k}	17.37^{a}	**13.93**
N_4	S_1	1.75^{g-j}	1.90^{c-h}	**1.82**	1.50^{jk}	4.86^{ab}	**3.18**	8.37^{kl}	13.20^{bc}	**10.78**
	S_2	2.27^{a}	2.05^{bc}	**2.16**	3.26^{d-f}	5.55^{a}	**4.40**	11.09^{c-j}	17.79^{a}	**14.44**
N_5	S_1	1.77^{f-j}	1.89^{c-h}	**1.83**	1.41^{jk}	3.09^{d-f}	**2.25**	8.58^{kl}	12.41^{b-f}	**10.50**
	S_2	1.79^{f-j}	2.01^{b-d}	**1.90**	1.61^{h-k}	5.04^{ab}	**3.32**	9.79^{h-k}	16.38^{a}	**13.08**
N_6	S_1	1.75^{g-j}	1.97^{b-e}	**1.86**	1.74^{g-k}	2.74^{e-h}	**2.24**	10.02^{f-k}	12.82^{b-e}	**11.42**
	S_2	1.72^{h-j}	2.10^{ab}	**1.91**	2.68^{e-i}	5.31^{a}	**4.00**	12.47^{b-e}	13.72^{b}	**13.10**
	M mean	$\mathbf{1.82^{b}}$	$\mathbf{1.95^{a}}$		$\mathbf{2.21^{b}}$	$\mathbf{4.06^{a}}$		$\mathbf{10.58^{b}}$	$\mathbf{12.71^{a}}$	
	Control	**1.72**	**1.75**		**2.12**	**2.27**		**7.72**	**8.70**	

		S.Em±	C.D (0.05)	S.Em±	C.D (0.05)	S.Em±	C.D (0.05)
M x N x S		0.036	0.104	0.263	0.763	0.459	1.330
Control Vs Rest	M_1	0.070	0.204	0.276	0.799	0.852	2.468
	M_2	0.052	0.150	0.501	1.452	0.835	2.418

Note :														
NS : Non significant														
Main plot	:	**Ecosystem (M)**	M_1	:	Direct seeded rice	M_2	:	Transplanted rice						
Sub plot	:	**Nutrient management 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						

The blackgram grown under TPR ecosystem (M_2) recorded significantly higher DMP per plant (1.95, 4.06 and 12.71 g, respectively), followed by DSR (M_1) during various stages of crop growth (1.82, 2.21 and 10.58 g, respectively) as compared between the rice establishment methods (M).

Among the different nutrient management approaches (N), significant and positive influence on the DMP per plant was observed, whereas higher DMP per plant (1.99, 3.84 and 12.61 g, respectively) was recorded with the fertilizer application based on SSNM for yield target of 7 t ha^{-1} (N_4), though other treatments were inferior and comparable. Numerically lower DMP per plant of 1.80 g at 30 DAS, 2.66 g at 60 DAS and 8.72 g at harvest, respectively, was recorded in the RDF (N_0) applied plots.

As the crop advanced to maturity the DMP increased significantly with the use of slow release N sources (S). The residual effect of the application of NCU (S_2) had registered higher DMP per plant (1.96, 3.76 and 12.53 g, respectively), followed by USG treated plots (S_1) with 1.81, 2.51 and 10.77 g at 30 DAS, 60 DAS and at harvest, respectively.

The interaction of ecosystems with nutritional methods (M x N) had revealed that response of fertilizer application based on NE for yield target of 7 t ha^{-1} is best suited for blackgram grown under TPR soils (M_2N_4) by registering higher DMP at 30 DAS (2.03 g). Though, at 60 DAS (5.21 g) and at harvest (15.49 g), it was found on SSNM approach for the yield target of 7 t ha^{-1} in TPR ecosystem (M_2N_4). However, irrespective of the nutrient management approaches, the treatments were inferior and comparable under different rice ecosystems. The residual effect of NE approach (7 t ha^{-1}) based fertilizer application in DSR soils (M_1N_6) registered the lowest DMP per plant at 30 DAS (1.73 g), NE approach for the yield target of 6 t ha^{-1} (M_1N_5) at 60 DAS (1.51 g) and in RDF treated plots of TPR soils (M_2N_0) at harvest (8.08 g), respectively.

The interaction of nutrient management approaches with sources of urea (N x S) had clearly brought out the fact that at all stage of sampling, soils which contained NCU under SSNM approach for the yield target of 7 t ha^{-1} (N_4S_2) resulted in significantly higher DMP per plant (2.16, 4.51 and 14.44 g, respectively). Furthermore, the plots applied with NCU based on SSNM approach for the yield target of 6 t ha^{-1} (N_3S_2), STCR approach (N_2S_2) and NE approach for the yield target of 7 t ha^{-1} (N_6S_2) were comparable. The plot applied with USG based on RDF (N_0S_1) had resulted in lower DMP per plant (1.74 and 8.57 g, respectively) at 30 DAS and at harvest, whereas at 60 DAS, application of USG based on STCR approach for the yield target of 7 t ha^{-1} (N_2S_1) recorded lower DMP (2.19 g).

The interaction of ecosystems with N sources (M x S) remains unaltered at 30 DAS. The results had shown that the TPR soils applied with NCU (M_2S_2) resulted in significantly higher DMP per plant at 60 DAS and harvest (4.97 and 14.19 g, respectively). However, USG treated plots in DSR ecosystem (M_1S_1) had resulted in lower DMP per plant (1.87 and 10.29 g at 60 DAS and at harvest, respectively).

The three way interaction (M x N x S) of ecosystems with nutrient management approaches and N sources had proved that the superiority of NCU in recording significantly higher DMP was noticed in SSNM (7 t ha^{-1}) treated plot in DSR ecosystem ($M_1N_4S_2$) at 30 DAS (2.27 g), whereas at 60 DAS and at harvest, higher DMP per plant (5.55 and 17.79 g, respectively) had obtained in the NCU treated plots through SSNM approach (6 t ha^{-1}) in TPR soils ($M_2N_4S_2$). Though, it was comparable with the TPR applied with NCU through STCR approach for the yield target of 7 t ha^{-1} ($M_2N_2S_2$), SNNM approach for the yield target of 6 t ha^{-1} ($M_2N_3S_2$) and NE approach for the yield target of 6 and 7 t ha^{-1} ($M_2N_{5\text{-}6}S_2$). On the whole, three way interactions revealed that the lower DMP per plant was observed in TPR plot applied with USG based on RDF ($M_2N_0S_1$) at 30 DAS (1.69 g) and at harvest (7.26 g), whereas at 60 DAS, DSR plot applied with USG based on SSNM approach for the yield target of 6 t ha^{-1} ($M_1N_3S_1$) registered lower DMP (1.28 g).

Interestingly, among all treatment combinations with nutrient management approaches for different yield targets applied with various sources of N, the DMP per plant were found higher than control plots of blackgram grown under DSR (1.72, 2.12 and 7.72 g, respectively) and TPR ecosystems (1.75, 2.27 and 8.70 g, respectively) except RDF treated plots in TPR soils at 30 DAS and 60 DAS. The plots applied with USG based on different nutrient management approaches in DSR were lower than control at 60 DAS.

The increased dry matter was usually associated with higher number of branches per plant which led to greater accumulation of photosynthesis in TPR ecosystem which possessed NCU based on SSNM for yield target of 7 t ha^{-1} ($M_2N_4S_2$). The similar results reported by Abarna (2017) stated that, higher dry matter in blackgram at higher application of nutrients in TPR based on SSNM

approach targeted yield of 8.0 t ha^{-1} which leads to increased nutrient status in the soil. The higher dry matter accumulation in pods might be due to higher photosynthetic ability of the crop as reflected through higher total DMP in leaf and higher translocation of metabolites from leaf and stem to reproductive part during reproductive phase. Several research workers also reported higher total DMP and accumulation in reproductive part of residual crop with elevated fertility level of preceding crop. Patil *et al.* (2018) reported that the application of fertilizers based on SSNM for targeted yield of 2.5 t ha^{-1} produced maximum (32.82 g plant^{-1}) total dry matter accumulation in chickpea, which were significantly superior over RDF (24.00 g plant^{-1}). The higher total dry matter might be due to the improvement in plant growth parameters as a result of increased nutrient concentration in plant parts which are the constituent of proteins, chlorophyll and in turn resulted in increased synthesis of carbohydrates that are being utilized for build-up of new cells and their accumulation leading to higher dry matter production. Similar results were also reported by Veeramani and Subrahmaniyan (2012) and Bholanath *et al.* (2015).

The higher leaf area per plant was responsible to capture more solar radiation resulting in high photosynthetic rate which in turn resulted in higher DMP. The factors associated with higher leaf area contributed towards significant improvement in growth and yield attributes due to varied quantum of post harvest residual fertility of blackgram. The better performance of growth and yield of blackgram further traced back to the improvement in nutrient uptake. The similar interpretation was also reported by Biradar *et al*. (2006), Kedar *et al.* (2008) and Ashok and Jayadeva (2013).

Moreover, high concentration of N and P in soil and application of recommended dose of P as basal and NCU as split dose based on soil test value in rice significantly increased the DMP of succeeding blackgram. Phosphorus being the constituent of nucleic acids, phytin and phospholipids, its application increased different growth parameters and also active involvement of P in carbohydrate metabolism, which might have helped in putting more vegetative growth and DMP (Arya and Kalra, 1988; Patel and Thakur, 1997). Agarwal *et al*. (1996) stated that, the improvement in DMP with the application of P might be ascribed to the active participation of P in chlorophyll biosynthesis, thereby increasing the photosynthetic efficiency of blackgram which led to higher DMP. The results obtained from this experiment were in conformity with the above findings.

Number of seeds per pod

The number of seeds per pod was found to be significantly varying with the rice ecosystems, nutrient management approaches and N sources except the two way interaction of ecosystems with nutrient management approaches (M x S) and is presented in Table 2.

It was revealed that the highest number of seeds per pod (6.97) was recorded in the soils of transplanted rice (M_2), followed by DSR (M_1) at harvest (4.87) as compared between the rice ecosystems (M).

The plot which received the fertilizer based on SSNM for yield target of 7 t ha^{-1} (N_4) resulted in more number of seeds per pod (6.44), though it was comparable with fertilizer application based on SSNM (N_3) for yield target of 6 t ha^{-1} (6.33). The other nutrient management approaches were significantly inferior and comparable. Numerically, lower number of seeds per pod (4.46) was recorded in the RDF (N_0) treated plots.

Among the slow release N sources (S), application of NCU (S_2) had registered higher number of seeds per pod (6.41), followed by USG (5.42) treated plots (S_1).

The interaction of ecosystems with nutrient management approaches (M x N) had indicated that in all soils that received fertilizer application based on SSNM for yield target of 6 t ha^{-1} is best suited for blackgram grown under TPR soils (M_2N_3) had recorded higher number of seeds per pod (8.53) and it was on par with SSNM approach (7 t ha^{-1}) in TPR ecosystem (M_2N_4). It was further noticed that there were no marked variations was observed among the nutritional methods in registering number of seeds per pod of blackgram grown under TPR soils. Though, lower number of seeds per pod (3.47) was noticed in DSR plot which received nutrients based on NE approach for the yield target of 7 t ha^{-1} (M_1N_5).

Table 2 Residual effect of ecosystems, nutrient management approaches and nitrogen sources on number of seeds per pod, number of pods per plant and thousand seed weight (g) at harvest of blackgram during *rabi* season of 2018-19 and 2019-20 (pooled data)

	No. of seeds pod^{-1}	**No. of pods plant^{-1}**	**1000 seed weight**
Ecosystem (M)			
M_1	4.87^{b}	24.52^{b}	44.11^{b}
M_2	6.97^{a}	29.68^{a}	49.52^{a}
S.Em±	0.035	0.251	0.736
C.D (0.05)	0.213	1.527	4.481
Nutrient management approaches (N)			
N_0	4.46^{d}	20.50^{d}	44.69^{c}
N_1	5.29^{bc}	27.67^{bc}	46.03^{bc}
N_2	5.44^{b}	28.44^{a-c}	47.46^{b}
N_3	6.33^{a}	28.71^{ab}	49.54^{a}
N_4	6.44^{a}	29.21^{a}	49.37^{a}
N_5	4.90^{cd}	27.93^{a-c}	44.89^{c}
N_6	5.31^{bc}	27.25^{c}	45.72^{c}
S.Em±	0.168	0.459	0.580
C.D (0.05)	0.492	1.340	1.693
Nitrogen sources (S)			
S_1	5.42^{b}	26.03^{b}	44.92^{b}
S_2	6.41^{a}	28.17^{a}	48.72^{a}
S.Em±	0.093	0.196	0.384
C.D (0.05)	0.270	0.569	1.112

		Number of seeds pod^{-1}			**Number of pods plant^{-1}**			**1000 seed weight (g)**		
		Ecosystem x Nutrient management 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**	6.29^{e}	3.64^{g}	**4.46^{d}**	19.53	21.46	**20.50^{d}**	42.05^{g}	47.34^{b-e}	**44.69^{c}**
	N_1	4.32^{g}	6.75^{d}	**5.29^{bc}**	24.01	31.33	**27.67^{bc}**	44.40^{d-g}	47.66^{b-d}	**46.03^{bc}**
	N_2	4.22^{g}	7.16^{cd}	**5.44^{b}**	24.90	31.97	**28.44^{a-c}**	45.43^{c-g}	49.50^{a-c}	**47.46^{b}**
	N_3	5.64^{fg}	8.53^{a}	**6.33^{a}**	25.96	31.47	**28.71^{ab}**	44.93^{c-g}	54.16^{a}	**49.54^{a}**
	N_4	6.18^{ef}	8.19^{ab}	**6.44^{a}**	26.42	32.00	**29.21^{a}**	46.86^{c-f}	51.88^{ab}	**49.37^{a}**
	N_5	3.47^{h}	6.83^{d}	**4.90^{cd}**	26.19	29.66	**27.93^{a-c}**	42.34^{fg}	47.44^{b-e}	**44.89^{c}**
	N_6	3.93^{h}	7.70^{bc}	**5.31^{bc}**	24.65	29.85	**27.25^{c}**	42.78^{e-g}	48.65^{b-d}	**45.72^{c}**
	M mean	**4.87^{b}**	**6.97^{a}**		**24.52^{b}**	**29.68^{a}**		**44.11^{b}**	**49.52^{a}**	
		S.Em±	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**	
		0.101	0.292		0.061	NS		0.415	1.201	
	N x S	**Nutrient management approaches x Nitrogen sources (N x S)**								
N		**S_1**	**S_2**	**N mean**	**S_1**	**S_2**	**N mean**	**S_1**	**S_2**	**N mean**
	N_0	5.34^{d}	4.58^{d}	**4.46^{d}**	19.97^{h}	21.02^{h}	**20.50^{d}**	42.75^{f}	46.64^{cd}	**44.69^{c}**
	N_1	5.06^{d}	6.01^{c}	**5.29^{bc}**	27.02^{d-g}	28.32^{c-e}	**27.67^{bc}**	46.14^{cd}	45.92^{c-e}	**46.03^{bc}**
	N_2	4.86^{d}	6.52^{bc}	**5.44^{b}**	27.76^{c-g}	29.12^{bc}	**28.44^{a-c}**	45.57^{c-e}	49.36^{b}	**47.46^{b}**
	N_3	7.33^{b}	6.83^{b}	**6.33^{a}**	26.60^{fg}	30.83^{ab}	**28.71^{ab}**	45.77^{c-e}	53.31^{a}	**49.54^{a}**
	N_4	5.95^{c}	8.43^{a}	**6.44^{a}**	26.66^{e-g}	31.75^{a}	**29.21^{a}**	46.15^{cd}	52.59^{a}	**49.37^{a}**
	N_5	4.43^{d}	5.87^{c}	**4.90^{cd}**	28.11^{c-f}	27.74^{c-g}	**27.93^{a-c}**	44.57^{d-f}	45.21^{d-f}	**44.89^{c}**
	N_6	5.01^{d}	6.62^{c}	**5.31^{bc}**	26.07^{g}	28.43^{cd}	**27.25^{c}**	43.45^{ef}	47.98^{bc}	**45.72^{c}**
	S mean	**5.42^{b}**	**6.41^{a}**		**26.03^{b}**	**28.17^{a}**		**44.92^{b}**	**48.72^{a}**	
		S.Em±	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**	
		0.101	0.292		0.061	0.615		0.415	1.201	
S	**M x S**	**Ecosystem x Nitrogen sources (M x S)**								
		M_1	**M_2**	**S mean**	**M_1**	**M_2**	**S mean**	**M_1**	**M_2**	**S mean**

		S_1	4.51	5.62	**5.42^{b}**	23.41^{d}	28.64^{b}	**26.03^{b}**	42.97^{b}	46.86^{b}	**44.92^{b}**
		S_2	5.21	8.32	**6.41^{a}**	25.63^{c}	30.72^{a}	**28.17^{a}**	45.26^{b}	52.18^{a}	**48.72^{a}**
		M mean	**4.87^{b}**	**6.97^{a}**		**24.52^{b}**	**29.68^{a}**		**44.11^{b}**	**49.52^{a}**	
			S.Em±	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**	
			0.029	NS		0.212	0.615		0.118	0.343	

Table 2 Contd…

M x N x S		**Ecosystem x Nutrient management approaches x Nitrogen sources (M x N x S)**								
		Number of seeds pod^{-1}			**Number of pods $plant^{-1}$**			**1000 seed weight (g)**		
		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**	6.76^{e-h}	3.44^{k-o}	**5.10**	18.64^{q}	21.30^{op}	**19.97**	39.37^{m}	46.13^{e-j}	**42.75**
	S_2	6.31^{e-g}	3.86^{j-n}	**5.08**	20.43^{pq}	21.62^{op}	**21.02**	44.73^{g-k}	48.54^{c-f}	**46.64**
N_1	**S_1**	4.18^{i-l}	4.95^{f-i}	**4.57**	22.75^{no}	31.30^{b-f}	**27.02**	45.48^{e-j}	46.80^{e-i}	**46.14**
	S_2	4.47^{k-o}	8.56^{bc}	**6.52**	25.28^{k-m}	31.37^{b-f}	**28.32**	43.31^{h-l}	48.53^{c-f}	**45.92**
N_2	**S_1**	3.47^{no}	5.75^{d-f}	**4.61**	24.04^{l-n}	31.47^{b-e}	**27.76**	43.89^{h-k}	47.24^{d-h}	**45.57**
	S_2	4.98^{g-j}	8.57^{bc}	**6.78**	25.76^{j-l}	32.47^{a-c}	**29.12**	46.97^{d-i}	51.75^{c}	**49.36**
N_3	**S_1**	5.44^{j-m}	7.73^{c}	**6.59**	23.57^{l-o}	29.64^{e-h}	**26.60**	44.23^{g-k}	47.32^{d-h}	**45.77**
	S_2	5.84^{h-k}	9.33^{ab}	**7.59**	28.34^{g-i}	33.31^{ab}	**30.83**	45.63^{e-j}	61.00^{a}	**53.31**
N_4	**S_1**	4.70^{lm}	6.20^{de}	**5.45**	23.41^{m-o}	29.91^{d-h}	**26.66**	44.61^{g-k}	47.70^{d-g}	**46.15**
	S_2	8.18^{d}	10.19^{a}	**9.19**	29.42^{e-h}	34.09^{a}	**31.75**	49.11^{c-e}	56.06^{b}	**52.59**
N_5	**S_1**	2.70^{o}	5.15^{f-i}	**3.93**	27.09^{i-k}	29.13^{f-i}	**28.11**	43.03^{j-m}	46.12^{e-j}	**44.57**
	S_2	3.73^{l-o}	8.52^{bc}	**6.13**	25.29^{k-m}	30.20^{c-h}	**27.74**	41.66^{k-m}	48.77^{c-f}	**45.21**
N_6	**S_1**	3.35^{o}	6.18^{de}	**4.77**	24.39^{l-n}	27.75^{ij}	**26.07**	40.19^{lm}	46.71^{e-i}	**43.45**
	S_2	4.02^{m-o}	9.22^{b}	**6.62**	24.90^{k-n}	31.96^{a-d}	**28.43**	45.38^{f-j}	50.58^{cd}	**47.98**
	M mean	**4.87^{b}**	**6.97^{a}**		**24.52^{b}**	**29.68^{a}**		**44.11^{b}**	**49.52^{a}**	
	Control	**3.41**	**3.86**		**15.50**	**18.95**		**38.24**	**34.65**	
		S.Em±	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**		**S.Em±**	**C.D (0.05)**	
M x N x S		0.201	0.583		0.424	1.229		0.829	2.402	
Control Vs Rest	**M_1**	0.396	1.147		0.921	2.667		1.625	4.709	
	M_2	0.268	0.776		0.653	1.891		1.859	5.384	

Note :														
NS : Non significant														
Main plot	:	**Ecosystem (M)**	**M_1**	:	Direct seeded rice	**M_2**	:	Transplanted rice						
Sub plot	:	**Nutrient management 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 supergranules	**S_2**	:	Neem coated urea						

The interaction of nutrient management approaches with sources of urea (N x S) had revealed that in all soils applied with NCU through SSNM approach for the yield target of 7 t ha^{-1} (N_4S_2) resulted in significantly higher number of seeds per pod (8.43), followed by the plots which received NCU based on STCR for the yield target of 6 t ha^{-1} (N_2S_2) and NCU and USG applied plots through SSNM approach for the yield target of 6 t ha^{-1} (N_3S_{1-2}). The plot applied with USG based on NE approach for the yield target of 6 t ha^{-1} (N_5S_1) had resulted in lower number of seeds per pod (4.43).

The three way interaction (M x N x S) of ecosystems with nutrient management approaches and N sources had proved that the superiority of NCU in recording significantly higher number of seeds per pod (10.19) was noticed in SSNM (7 t ha^{-1}) treated plot in TPR ($M_2N_4S_2$), while it was comparable with the soils in TPR treated with NCU based on SSNM approach for the yield target of 6 t ha^{-1} ($M_2N_3S_2$). It was further revealed that the lower number of seeds per pod (2.70) was observed in DSR plot applied with USG based on NE approach for the yield target of 6 t ha^{-1} ($M_1N_5S_2$).

Interestingly in DSR and TPR, both the sources of N with different nutritional methods were comparable but superior to control plots except RDF plots in TPR applied with USG ($M_2N_0S_1$) and in DSR applied with USG through NE approach for the yield target of 6 and 7 t ha^{-1} ($M_1N_{5-6}S_1$). Among all treatment combinations with nutrient management approaches for different yield targets applied with various sources of N, the number of seeds per pod was found higher than control plots of blackgram grown under DSR (3.41) and TPR (3.86) ecosystems.

In this investigation, pooled results showed that the residual effect of nutrients applied in TPR ecosystem which possessed NCU based on SSNM for yield target of 7 t ha^{-1} ($M_2N_4S_2$) plus recommended dose of FYM as basal exerted significant influence on the number of seeds per pod. The better performance of succeeding blackgram could be due to higher amount of available nutrients after harvest of DSR and TPR. The better utilization of available N, P and K facilitates the seed filling and increases the number of seeds per pod. Meena *et al*. (2018) studied that the residual effect of combined application of 100 per cent RDF and 5 t FYM ha^{-1} in rice resulted in significantly higher number of seeds per pods (3.05) in blackgram.

Number of pods per plant

The residual effect of the application of slow release N fertilizers through different nutrient management approaches under various rice establishment methods and their interactions had significant influence on number of pods per plant except the interaction between ecosystems with nutrient management approaches (M x N) are presented in Table 2.

Among the main effects, residual effect of rice ecosystems (M) induce significant changes in number of pods plant^{-1}, while the effects under TPR soils (M_2) resulted in maximum number of pods plant^{-1} (29.68), followed by DSR (M_1) at harvest (24.52).

Among the nutritional methods (N), significantly higher number of pods plant^{-1} (29.21) was recorded in the plot which received the fertilizer based on SSNM for yield target of 7 t ha^{-1} (N_4), which was comparable with the plot contained the nutrients through STCR approach for the yield target of 7 t ha^{-1} (N_2) and SSNM approach (N_3) and NE approach for the yield target of 6 t ha^{-1} (N_5). However, there were no marked differences noticed among the nutrient management approaches. The residual effect of soil that contained nutrients based on RDF (N_0) registered lowest number of pods plant^{-1} (20.50).

Application of slow release N sources (S) showed significant variation in the number of pods plant^{-1}, while NCU (S_2) applied plots had registered higher number of pods plant^{-1} (28.17), followed by USG (26.03) treated plots (S_1).

The interaction of nutrient management approaches with sources of urea (N x S) was significant, wherein application of NCU by SSNM approach for the yield target of 7 t ha^{-1} (N_4S_2) resulted in maximum number of pods plant^{-1} (31.75) and it was comparable with the plots which received NCU based on SSNM for the yield target of 6 t ha^{-1} (N_3S_2). The plot applied with USG based on RDF (N_0S_1) recorded lowest number of pods plant^{-1} (19.97).

The interaction of ecosystems with N sources (M x S) had shown that the number of pods plant^{-1} was higher (30.72) in plots which received N as NCU in TPR

(M_2S_2), followed by TPR plot applied with USG (M_2S_1). Application of N as NCU could significantly enhance the number of pods plant^{-1} in both TPR and DSR ecosystems. However, in the DSR ecosystem, USG treated plots (M_1S_1) had resulted in lower number of pods plant^{-1} (23.41).

The interaction of ecosystems with nutrient management approaches and N sources (M x N x S) was significant and the higher number of pods plant^{-1} (324.09) was noticed in SSNM (7 t ha^{-1}) treated plot with NCU in TPR-blackgram ecosystem ($M_2N_4S_2$), though it was comparable with the plots applied with NCU through SSNM for yield target of 6 t ha^{-1} ($M_2N_3S_2$), STCR for yield target of 7 t ha^{-1} ($M_2N_2S_2$) and NE for yield target of 7 t ha^{-1} ($M_2N_6S_2$) in TPR ecosystem. However, there were no marked differences was observed among the treatment combinations in DSR and TPR ecosystems. It was further revealed that the lowest value of number of pods plant^{-1} (18.64) was observed in DSR plot applied with USG based on RDF ($M_1N_0S_1$).

Among all treatment combinations with nutrient management approaches for different yield targets applied with various sources of N, the number of pods plant^{-1}was found higher than control plots of blackgram grown under DSR (15.50) and TPR soils (18.95), respectively.

The current study showed that the residual effect of nutrients applied through TPR ecosystems which possessed NCU based on SSNM for yield target of 7 t ha^{-1} ($M_2N_4S_2$) plus recommended dose of FYM as basal exerted significant influence on the number of pods plant^{-1}. The better performance of succeeding blackgram could be due to higher amount of available N, P, K, Zn and Fe after harvest of DSR and TPR. The balanced supply of nutrients through nutrient management approaches based on the soil test value to rice crop utilized sufficient quantity of nutrients for its entire crop growth period and made substantial build up of nutrients in soil as reflected higher soil nutrient status after harvest of rice. Meena *et al.* (2018) studied that the residual effect of combined application of 100 per cent RDF and 5 t FYM ha^{-1} to rice resulted in significantly higher number of pods per plant in blackgram.

Thousand seed weight

The result of statistical scrutiny had shown that the application of slow release N fertilizers through different nutrient management approaches under various rice establishment methods and their interactions had significant influence on 1000 seed weight of blackgram (Table 2).

Among the rice ecosystems (M), blackgram cultivated in TPR soils (M_2) registered the highest 1000 seed weight (49.52 g), followed by plot of DSR (M_1) had weight of 44.11 g at harvest.

Among the nutritional methods (N), significantly higher 1000 seed weight (49.54 g) was recorded in the plot which received the fertilizer based on SSNM for yield target of 6 t ha^{-1} (N_3), which was comparable (49.37 g) with the plot supplied with the nutrients through SSNM for the yield target of 7 t ha^{-1} (N_4). The soil with nutrients based on RDF (N_0) application had the lower test weight (44.69 g).

Application of slow release N sources (S) showed significant variation in the 1000 seed weight, while NCU (S_2) applied plots had registered higher test weight of 48.72 g, followed by USG (44.92 g) treated plots (S_1). However, there were marginal difference was noticed in the 1000 seed weight of blackgram due to the residual effect of N sources.

The interaction of ecosystems with nutrient management approaches (M x N) studies had revealed that in all soils received fertilizer application through SSNM for yield target of 6 t ha^{-1} in TPR ecosystem (M_2N_3) had registered higher 1000 seed weight (54.16 g) and it was on par with the plots treated with SSNM approach (M_2N_4) and STCR approach for yield target of 7 t ha^{-1} in TPR plots (M_2N_2). Though, marginal differences were observed among the different treatment combinations for both DSR and TPR ecosystems. The lowest value of test weight was noticed in DSR soils (42.05 g) which received nutrients based on RDF (M_1N_0).

The interaction of nutrient management approaches with sources of urea (N x S) were significant, wherein application of NCU by SSNM approach for the yield target of 6 t ha^{-1} (N_3S_2) resulted in maximum 1000 seed weight (53.31 g), while it was comparable with the plots applied with NCU based on SSNM approach for the yield

target of 7 t ha^{-1} (N_4S_2). The plot applied with USG based on RDF (N_0S_1) recorded lowest test weight (42.75 g).

The interaction of ecosystems with N sources (M x S) had shown that the 1000 seed weight was higher (52.18 g) in plots which received N as NCU in TPR soils (M_2S_2). However, in the DSR-blackgram soils, the residual effect of USG (M_1S_1) had resulted in lower test weight (42.97 g).

The interaction of ecosystems with nutrient management approaches and N sources (M x N x S) was significant and the higher test weight (61.00 g) was noticed in SSNM (6 t ha^{-1}) treated plot with NCU in TPR ($M_2N_3S_2$), though it was comparable with the plots applied with NCU through SSNM approach for yield target of 7 t ha^{-1} ($M_2N_4S_2$). However, only marginal difference was observed among the treatment combinations between DSR and TPR ecosystems. It was further revealed that the lowest count of 1000 seed weight (39.37 g) was observed in DSR plot applied with USG based on RDF ($M_1N_0S_1$).

The residual effect of all treatment combinations with nutrient management approaches for different yield targets applied with various sources of N revealed that the 1000 seed weight was found higher than control in blackgram plots grown under DSR (38.24 g) and TPR soils (34.65 g).

In the present investigation, the higher 1000 seed weight was recorded in TPR ecosystems which possessed NCU based on SSNM for yield target of 6 and 7 t ha^{-1} ($M_2N_{3-4}S_2$) and least was in absolute control. This may be credited to increased growth parameters and yield parameters due to additional dose of NPK as evidenced earlier from increased total dry matter accumulation. Improved supply of photosynthates to the reproductive parts more precisely to the sink might have helped in producing fully developed bolder seeds, thus resulted in higher 1000 seed weight. Similarly, Abarna (2017) found that SSNM approach resulted in significantly higher 1000 seed weight (69.82 g) over farmer's practice and RDF in rice-blackgram cropping system.

Seed yield

The seed yield of the blackgram crop was significantly influenced by different nutrient management approaches and N sources in various types of rice establishment methods and their interactions are presented in Table 3.

The submerged condition in TPR soils (M_2) had significantly increased the seed yield of blackgram (756.36 kg ha^{-1}), followed by the soil irrigated with alternate wetting and drying in DSR soils (M_1) at harvest (607.48 kg ha^{-1}) when compared between the rice ecosystems (M).

It was observed that application of fertilizer through SSNM for yield target of 7 t ha^{-1} (N_4) had recorded the highest seed yield (736.81 kg ha^{-1}), followed by the plots applied with the nutrients through SSNM for the yield target of 6 t ha^{-1} (N_3), STCR approach (N_2) and NE approach for the yield target of 7 t ha^{-1} (N_6). Significantly lower seed yield (611.25 kg ha^{-1}) was registered with the soil containing nutrients based on RDF (N_0).

It was clearly brought out that application of slow release N sources (S) in the form of NCU (S_2) had recorded higher seed yield (733.23 kg ha^{-1}), followed by the plots (630.61 kg ha^{-1}) treated with USG (S_1). Furthermore, marked differences were observed in the seed yield due to the residual effect of N sources.

The interaction of ecosystems with nutritional methods (M x N) had further revealed that fertilizer application through SSNM approach for yield target of 7 t ha^{-1} in TPR soils (M_2N_4) had registered higher seed yield (843.12 kg ha^{-1}), followed by the TPR plots treated with SSNM for yield target of 6 t ha^{-1} (M_2N_3), STCR approach (M_2N_2) and NE approach for the yield target of 7 t ha^{-1} (M_2N_6). Though, marked differences were observed among the different treatment combinations between DSR and TPR ecosystems. The lowest seed yield of blackgram was noticed in DSR plot (553.67 kg ha^{-1}) which received nutrients based on RDF (M_1N_0).

The interaction of nutritional methods with sources of urea (N x S) had indicated that in the presence of NCU, the application of nutrients through SSNM method for the yield target of 7 t ha^{-1} (N_4S_2) recorded higher seed yield (783.65 kg ha^{-1}) and comparable with the plot treated with NCU through SSNM for yield target of 6 t ha^{-1} (N_3), STCR approach (N_2S_2) and NE approach for the yield target of 7 t ha^{-1} (N_6S_2). The residual effect of the application of USG through RDF (N_0S_1) recorded lower seed yield (608.78 kg ha^{-1}).

Table 3 Residual effect of ecosystems, nutrient management approaches and nitrogen sources on seed yield and haulm yield (kg ha^{-1}) during *rabi* season of 2018-19 and 2019-20 (pooled data)

	Seed yield	**Haulm yield**
Ecosystem (M)		
M_1	607.48^{b}	2043.67^{b}
M_2	756.36^{a}	2195.12^{a}
S.Em±	6.967	7.537
C.D (0.05)	42.394	45.859
Nutrient management approaches (N)		
N_0	611.25^{d}	2038.93^{d}
N_1	662.98^{c}	2099.77^{c}
N_2	700.83^{b}	2141.59^{b}
N_3	702.66^{b}	2146.78^{ab}
N_4	736.81^{a}	2171.63^{a}
N_5	661.34^{c}	2100.89^{c}
N_6	697.56^{b}	2136.18^{b}
S.Em±	7.891	9.254
C.D (0.05)	23.033	27.011
Nitrogen sources (S)		
S_1	630.61^{b}	2069.57^{b}
S_2	733.23^{a}	2169.22^{a}
S.Em±	3.861	4.717
C.D (0.05)	11.184	13.665

		Seed yield (kg ha^{-1})			**Haulm yield (kg ha^{-1})**		
		Ecosystem x Nutrient management approaches (M x N)					
	M x N	**M_1**	**M_2**	**N mean**	**M_1**	**M_2**	**N mean**
N	**N_0**	553.67^{f}	668.82^{d}	**611.25^{d}**	1982.54^{g}	2095.32^{e}	**2038.93^{d}**
	N_1	607.53^{e}	718.43^{c}	**662.98^{c}**	2046.16^{ef}	2153.39^{d}	**2099.77^{c}**
	N_2	621.69^{de}	779.98^{b}	**700.83^{b}**	2059.17^{ef}	2224.02^{b}	**2141.59^{b}**
	N_3	625.47^{de}	779.86^{b}	**702.66^{b}**	2069.48^{ef}	2224.09^{b}	**2146.78^{ab}**
	N_4	630.50^{de}	843.12^{a}	**736.81^{a}**	2063.63^{ef}	2279.63^{a}	**2171.63^{a}**
	N_5	597.61^{ef}	725.06^{c}	**661.34^{c}**	2032.01^{fg}	2169.77^{cd}	**2100.89^{c}**
	N_6	615.87^{e}	779.24^{b}	**697.56^{b}**	2052.71^{ef}	2219.65^{bc}	**2136.18^{b}**
	M mean	**607.48^{b}**	**756.36^{a}**		**2043.67^{b}**	**2195.12^{a}**	
		S.Em±	**C.D (0.05)**		**S.Em±**		**C.D (0.05)**
		4.170	12.080		5.095		14.760
	N x S	**Nutrient management approaches x Nitrogen sources (N x S)**					
		S_1	**S_2**	**N mean**	**S_1**	**S_2**	**N mean**
N	**N_0**	608.78^{c}	613.72^{c}	**611.25^{d}**	2045.06^{cd}	2032.79^{d}	**2038.93^{d}**
	N_1	615.00^{c}	710.95^{b}	**662.98^{c}**	2051.62^{cd}	2147.93^{b}	**2099.77^{c}**
	N_2	626.40^{c}	775.26^{a}	**700.83^{b}**	2065.18^{cd}	2218.01^{a}	**2141.59^{b}**
	N_3	629.66^{c}	775.67^{a}	**702.66^{b}**	2074.34^{c}	2219.23^{a}	**2146.78^{ab}**
	N_4	689.97^{b}	783.65^{a}	**736.81^{a}**	2120.88^{b}	2222.39^{a}	**2171.63^{a}**
	N_5	620.89^{c}	701.79^{b}	**661.34^{c}**	2067.03^{cd}	2134.74^{b}	**2100.89^{c}**
	N_6	623.56^{c}	771.55^{a}	**697.56^{b}**	2062.89^{cd}	2209.47^{a}	**2136.18^{b}**
	S mean	**630.61^{b}**	**733.23^{a}**		**2069.57^{b}**	**2169.22^{a}**	
		S.Em±	**C.D (0.05)**		**S.Em±**		**C.D (0.05)**
		4.170	12.080		5.095		14.760
S	**M x S**	**Ecosystem x Nitrogen sources (M x S)**					
		M_1	**M_2**	**S mean**	**M_1**	**M_2**	**S mean**
	S_1	568.31^{d}	692.91^{b}	**630.61^{b}**	2005.07^{d}	2134.07^{b}	**2069.57^{b}**
	S_2	646.65^{c}	819.81^{a}	**733.23^{a}**	2082.27^{c}	2256.17^{a}	**2169.22^{a}**
	M mean	**607.48^{b}**	**756.36^{a}**		**2043.67^{b}**	**2195.12^{a}**	
		S.Em±	**C.D (0.05)**		**S.Em±**		**C.D (0.05)**
		1.191	3.452		1.456		4.217

Table 3 Contd…

M x N x S		Seed yield (kg ha^{-1})			M x N x S		Haulm yield (kg ha^{-1})		
		M_1	M_2	N x S			M_1	M_2	N x S
N_0	S_1	542.68^{e}	674.88^{c}	**608.78**	N_0	S_1	1981.45^{g}	2108.67^{c-e}	**2045.06**
	S_2	564.67^{e}	662.77^{cd}	**613.72**		S_2	1983.63^{g}	2081.96^{de}	**2032.79**
N_1	S_1	565.59^{e}	664.40^{cd}	**615.00**	N_1	S_1	2002.21^{g}	2101.04^{c-e}	**2051.62**
	S_2	649.46^{cd}	772.45^{b}	**710.95**		S_2	2090.11^{c-e}	2205.75^{b}	**2147.93**
N_2	S_1	573.80^{e}	679.00^{c}	**626.40**	N_2	S_1	2008.50^{g}	2121.87^{cd}	**2065.18**
	S_2	669.57^{cd}	880.95^{a}	**775.26**		S_2	2109.84^{c-e}	2326.17^{a}	**2218.01**
N_3	S_1	579.50^{e}	679.82^{c}	**629.66**	N_3	S_1	2025.95^{fg}	2122.73^{cd}	**2074.34**
	S_2	671.44^{cd}	879.90^{a}	**775.67**		S_2	2113.01^{c-e}	2325.45^{a}	**2219.23**
N_4	S_1	583.52^{e}	796.42^{b}	**689.97**	N_4	S_1	2011.17^{g}	2230.59^{b}	**2120.88**
	S_2	677.48^{c}	889.82^{a}	**783.65**		S_2	2116.10^{cd}	2328.68^{a}	**2222.39**
N_5	S_1	562.99^{e}	678.78^{c}	**620.89**	N_5	S_1	1998.87^{g}	2135.19^{c}	**2067.03**
	S_2	632.23^{d}	771.34^{b}	**701.79**		S_2	2065.14^{ef}	2204.34^{b}	**2134.74**
N_6	S_1	570.05^{e}	677.07^{c}	**623.56**	N_6	S_1	2007.35^{g}	2118.43^{cd}	**2062.89**
	S_2	661.69^{cd}	881.42^{a}	**771.55**		S_2	2098.07^{cd}	2320.88^{a}	**2209.47**
M mean		**607.48^{b}**	**756.36^{a}**		**M mean**		**2043.67^{b}**	**2195.12^{a}**	
Control		**528.30**	**579.30**		**Control**		**1902.55**	**1980.88**	
		S.Em±	**C.D (0.05)**				**S.Em±**	**C.D (0.05)**	
M x N x S		8.340	24.161		**M x N x S**		10.190	29.520	
Control Vs Rest	M_1	13.098	37.944		**Control Vs Rest**	M_1	22.783	66.001	
	M_2	22.041	63.852			M_2	23.486	68.035	

Note :														
NS : Non significant														
Main plot	:	**Ecosystem (M)**	M_1	:	Direct seeded rice	M_2	:	Transplanted rice						
Sub plot	:	**Nutrient management 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 supergranules	S_2	:	Neem coated urea						

The interaction of rice ecosystems with N sources (M x S) had shown that application of NCU in TPR soils (M_2S_2) had registered higher seed yield (819.81 kg ha^{-1}), though were followed by TPR plot applied with USG (M_2S_1). Irrespective of the rice establishment methods adopted, the residual effect of the application of NCU had significantly increased the seed yield of blackgram. However, in the DSR ecosystem, USG treated plots (M_1S_1) had resulted in lower seed yield (568.31 kg ha^{-1}).

The interaction of ecosystems with nutrient management approaches and N sources (M x N x S) revealed that, if NCU was added through either SSNM, STCR and NE method for yield target of 6 and 7 t ha^{-1} in DSR and TPR recorded significantly higher yield than RDF treated plots. If N was added as NCU through SSNM (7 t ha^{-1}) approach in TPR soils ($M_2N_4S_2$) registered higher seed yield (889.82 kg ha^{-1}), which was comparable with the plots applied with NCU through SSNM for yield target of 6 t ha^{-1} ($M_2N_3S_2$), STCR approach ($M_2N_2S_2$) and NE approach for the yield target of 7 t ha^{-1} for TPR soils ($M_2N_6S_2$). It was further revealed that significantly lower seed yield (542.68 kg ha^{-1}) was observed in DSR plot applied with USG through RDF approach ($M_1N_0S_1$).

As regard to seed yield, all the nutrient management approaches for different yield targets applied with various sources of N in DSR and TPR soils were significantly superior to the control plots of blackgram (528.30 and 579.30 kg ha^{-1}, respectively) with regard to seed yield.

The factors which have direct influence on the seed yield are the yield components *viz.,* number of pods per plant, number of seeds per plant, thousand seed weight and haulm yield have an indirect influence on seed yield through the yield components. The reason for higher seed yield of blackgram where N was added as NCU through SSNM (7 t ha^{-1}) approach under TPR soils ($M_2N_4S_2$) might be attributed to the higher values of yield components which intern depends on different growth components *viz.,* plant height, number of branches per plant and total DMP at different growth stages. The total dry matter produced in the blackgram crop differed significantly due to the application of nutrients through the target yield approach along with NCU addition at all stages of crop growth. The similar interpretation was also reported by Abarna (2017) that the better seed (1179 kg ha^{-1}) and haulm yield (1897 kg ha^{-1}) of succeeding blackgram could be due to higher amount of available N, P and K after harvest of rice. These findings are also in line with those reported by Shankar *et al*. (2014) and Meena *et al*. (2018).

The increase in the seed and haulm yields of succeeding blackgram with P applied to rice could be attributed to the increased residual available P, which helped in developing profuse root system resulting in increased nutrient uptake, higher dry matter accumulation and translocation of photosynthates from vegetative parts to seeds. The results confirm the findings of Patel *et al*. (1984) and Khade *et al*. (1987). Rao and Bharadwaj (1979) also reported that the haulm and seed production of blackgram during *rabi* season was improved due to the residual effects of P fertilizers supplied at higher levels to rice in the preceding *kharif* season. This indicates that in cereal-legume rotation, the legume is benefited from the P applied to the preceding crops. These findings are also in line with those reported by Kuldeep *et al*. (2018) and Patil *et al.* (2018) that the application of micronutrient *viz*., Fe and Zn had significant effect on the seed and haulm yield of chickpea.

Haulm yield

Similar to seed yield, haulm yield varied significantly due to different nutrient management approaches and N sources in various types of rice establishment methods and their interactions (Table 3).

The blackgram grown under TPR soils (M_2) had significantly increased the haulm yield (2195.12 kg ha^{-1}) followed by the soil irrigated with alternate wetting and drying in DSR soils (M_1) at harvest (2043.67 kg ha^{-1}).

It was observed that application of fertilizer through SSNM for yield target of 7 t ha^{-1} (N_4) had recorded the highest haulm yield (2171.63 kg ha^{-1}), which was comparable with the nutrients applied through SSNM for the yield target of 6 t ha^{-1} (N_3). The soil containing nutrients based on RDF (N_0) produced significantly lower haulm yield (2038.93 kg ha^{-1}).

It was clearly brought out that application of slow release N sources (S) in the form of NCU (S_2) had recorded higher haulm yield (2169.22 kg ha^{-1}) and lower in the plots (2069.57 kg ha^{-1}) treated with USG (S_1).

The interaction of ecosystems with nutritional methods (M x N) had further revealed that fertilizer application through SSNM for yield target of 7 t ha^{-1} under TPR soils (M_2N_4) had registered higher haulm yield (2279.63 kg ha^{-1}), followed by the TPR plots treated with SSNM for yield target of 6 t ha^{-1} (M_2N_3), STCR approach (M_2N_2) and NE approach for yield target of 7 t ha^{-1} (M_2N_6). The lowest haulm yield was noticed in DSR ecosystem (1982.54 kg ha^{-1}) which received nutrients based on RDF (M_1N_0).

The interaction of nutritional methods with sources of urea (N x S) had indicated that in the presence of NCU, the application of nutrients through SSNM method for the yield target of 7 t ha^{-1} (N_4S_2) recorded maximum haulm yield (2222.39 kg ha^{-1}) and it was on par with the plot treated with NCU through SSNM for yield target of 6 t ha^{-1} (N_3S_2), STCR approach (N_2S_2) and NE approach for the yield target of 7 t ha^{-1} (N_6S_2). Application of USG through RDF (N_0S_1) recorded lower haulm yield (2032.79 kg ha^{-1}, respectively).

The two way interaction of rice ecosystems with N sources (M x S) had shown that application of NCU in TPR ecosystem (M_2S_2) had registered higher haulm yield (2256.17 kg ha^{-1}), though were followed by TPR plot applied with USG (M_2S_1). However, plots of DSR applied with USG (M_1S_1) had resulted in lower haulm yield (2005.07 kg ha^{-1}).

Overall, the three-way interaction (M x N x S) revealed that, if NCU was added through either SSNM, STCR and NE method for yield target of 6 and 7 t ha^{-1} under DSR and TPR ecosystems recorded significantly higher haulm yield than RDF treated plot. If N was added as NCU through SSNM (7 t ha^{-1}) approach in TPR soils ($M_2N_4S_2$) registered higher haulm yield (2328.68 kg ha^{-1}), which was comparable with the plots applied with NCU through SSNM for yield target of 6 t ha^{-1} ($M_2N_3S_2$), STCR approach ($M_2N_2S_2$) and NE approach for the yield target of 7 t ha^{-1} ($M_2N_6S_2$). Furthermore, significantly lower haulm yield (1981.45 kg ha^{-1}) was observed in DSR plot applied with USG through RDF approach ($M_1N_0S_1$).

With regard to haulm yield, all the nutrient management approaches for different yield targets applied with various sources of N under DSR and TPR soils were significantly superior to the control plots of blackgram (1902.55 and 1980.88 kg ha^{-1}, respectively).

4. Conclusion

Overall, the study revealed that the residual effect of neem coated urea added through either SSNM, STCR and NE method for yield target of 6 and 7 t ha^{-1} under DSR and TPR ecosystems recorded significantly higher yield and yield parameters in blackgram than RDF treated plot.

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Reference

1. Abarna, A. (2017). Investigation on the phosphorus dissolution pattern of mussoorie rock phosphate and its impact on the growth and yield of rice-blackgram cropping system. *Ph.D. Thesis*, Tamil Nadu Agricultural University, Coimbatore, India.
2. Agarwal, V. K., Sangeeta, S., Dwivedi, S. K., Patel, R., Nigam, P. K. and Shrivastava, S. (1996). Influence of phosphorus and zinc on physiological determinants of growth and productivity of soybean. *Crop Res*., 12: 196-199.
3. Arya, M. P. S. and Kalra, G. S. (1988). Effect of phosphorus doses on the growth, yield and quality of summer mungbean and soil nitrogen. *Indian J. Agric. Res*., 22 (1): 23-30.
4. Ashok, B. and Jayadeva, H. M. (2013). Influence of targeted yield approach on yield, yield attributes, nutrient uptake and economics of blackgram. *Madras Agric. J*., 100 (3): 146-149.
5. Bholanath, S., Sushanta, S., Hazra, G. C. and Biswapati, M. (2015). Effect of Zn, B and S on the yield and quality of groundnut. *Legume Res.*, 38(6): 832-836.
6. Biradar, D. P., Aladakatti, Y. R., Rao, T. N. and Tiwari, K. N. (2006). Site specific nutrient management for maximization of crop yields in Northern Karnataka. *Better Crops*, 90(3): 33-35.
7. Buresh, R. J. and De Datta, S. K. (1991). Nitrogen dynamics and management in rice-legume cropping systems. *Adv. Agron*., 45: 1-59.
8. Deep, M., Kumar, R.M., Saha, S. and Singh, A. (2018). Rice-based cropping systems. Indian Farming. 68(1): 27-30.
9. Gomez, A. A. and Gomez, R. A. (1976). Statistical procedure for agricultural research with emphasis on rice. IARI. Los Banos, Manila, Philippines, pp: 294.

10. Kedar, P., Sharma, D. K. and Satish, C. (2008). Yield attributes, yield and economics of chickpea (*Cicer arietinum* L.) as influenced by manure, bio fertilizer and DAP doses. *Int. J. Agric. Sci.*, (4)1: 246-248.
11. Kuldeep, P., Kumawat, D., Vipen, B., Sumeriya, H. K. and Vinod, K. (2018). Effect of iron and zinc Nutrition on growth attributes and yield of chickpea (*Cicer arietinum* L.). *Int. J .Curr. Microbiol. App. Sci.*, 7(8): 2837-2841.
12. Ladha, J. K., Kundu, D. K., Van Coppenolle, M. G. A., Peoples, M. B., Carangal, V. R. and Dart, P. J. (1996). Legume productivity and soil nitrogen dynamics in lowland rice-based cropping systems. *Soil Sci. Soc. Am. J.*, 60: 183-192.
13. Meelu, O. P., Rekhi, R. S., Brar, J. S. and Katyal, J. C. (1983). Comparative efficiency of different modified urea materials in rice. In: Proceedings of the fertilizer association of India-Northern region seminar on fertilizer use efficiency. The Fertilizer Association of India, New Delhi, pp: 47-59.
14. Meena, B. L., Kumar, P. A., Kumar, R. L., Meena, J., Kaledhonkar, M. and Sharma, P. C. (2018). Zinc and iron nutrition to increase the productivity and economics of rice-blackgram cropping system. *Int. J. Curr. Micro. Appl. Sci.*, 7(8): 3201-3211.
15. Patel, P. G., Patel, M. P., Patel, H. C. and Patel, R. B. (1984). Effect of graded levels of nitrogen and phosphorus on growth, yield and economics of summer mungbean. *Ind. J. Agron*., 29(3): 291-294.
16. Patel, S. R. and Thakur, D. S. (1997). Influence of phosphorus and rhizobium on yield attributes, yield and nutrient uptake of greengram. *J. Oilseeds Res*., 14(2): 189-193.
17. Patil, D. H., Shankar, M. A., Krishnamurthy, N., Shadakshari, Y. G. and Ramakrishna Parama, V. R. (2018). Studies on site specific nutrient management (SSNM) on growth and yield of groundnut *(Arachis hypogaea*) under irrigation in Southern Karnataka. *Legume Res.*, 41(5): 728-733.
18. Patra, A. K., Garnayak, L. M., Mishra, K. N., Mohanty, T. R., Mohapatra, B. K. and Swain, S. K. (2019). Balanced fertilization in rice (Oryza sativa)-groundnut (*Arachis hypogaea*) cropping system. Indian Journal of Agronomy. 64(3): 293-297.
19. Rao, J. V. and Bharadwaj, R. B. L. (1979). Influence of residual fertility on greengram in intensive cropping system. *Ind. J. Agron*., 25: 97-101.
20. Shankar, M. A., Maruthi, S. G. R., Thimmegouda, M. N. and Nagamani, M. K. (2014). Micronutrient for soil fertility, nutrients uptake and productivity of greengram (*Vigna radiata*) under semi-arid *Alfisols*. *Indian J. Agron*., 59(2): 306-316.
21. Khade, V. N., Khanvilkar, S. A. and Dongale, J. H. (1987). Response of greengram to residual phosphorus. *J. Maharashtra Agric. Univ*., 12(1): 122-123.
22. Veeramani, P. and Subrahmaniyan, K. (2012). Physical and economic optimum of response model for NPK application in irrigated groundnut (*Arachis hypogaea* L.). *Madras Agril. J.*, 99(9): 526-529.