Indian Journal of Agricultural Sciences **93** (11): 1254–1257, November 2023/Short Communication
https://doi.org/10.56093/ijas.v93i11.124114

Yield and quality of dry direct-seeded rice (*Oryza sativa*) as influenced by nitrogen and weed management practices in Eastern India

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Received: 21 May 2022; Accepted: 29 August 2023

Keywords: Brown manuring, Leaf colour chart, Nitrogen management, Weed management

Dry seeding of rice (*Oryza sativa* L.) avoids the need for ponding water *vis-a-vis* transplanting, requiring ~36% less water, ~60% less labour (Kumar and Ladha 2011). In absence of effective weed control measures, yield losses are greater in DSR than in transplanted, which vary from 50–91% (Sen *et al.* 2018). However, severe crop weed competition is the crux of the problem affecting N use efficiency that could result drastic yield reduction. Effective weed management is therefore, key to sustainable rice production under dry-seeded condition. However, sole application of either pre- or post-emergence herbicides could not control diverse weeds effectively in DSR. Traditional N management is non-sustainable and leads to low N recovery (30–40%) which is great concern in upland condition (Ghosh 2018). Improving nitrogen (N)-use efficiency in rice is vital to achieve high grain yields and reduce N losses (Gupta *et al.* 2011). The guidelines evolved using leaf colour chart (LCC), can help in site-specific N management based on crop demand. The need-based N management in DSR using LCC has the potential of replacing the blanket fertilizer application rates recommended across vast areas (Satpute *et al.* 2014). Therefore, a field study was undertaken to study the effect of nitrogen and weed management practices in direct-seeded rice for higher productivity and grain quality in Eastern India.

The experiment was conducted during rainy (*kharif*) season of 2020 at the research farm of Central Rainfed Upland Rice Research Station (CRURRS), Hazaribagh (23°56′34″ N and 85°21′46″ E with an altitude of 614 m MSL), Jharkhand (ICAR-National Rice Research Institute, Cuttack, Odisha). Soil texture of experimental field was silty loam. The experiment was laid out in a split-plot design taking three nitrogen treatments i.e. No N (RDF of P and K only), RDF (N: P_2O_5: K_2O = 80:17:33 kg/ha) (3 splits of nitrogen application; 50% basal +25% at tillering + 25% at panicle initiation stage), 50% N from FYM + 50% N as real time nitrogen management (yop dressing) as per LCC (RTNM (LCC)) up to panicle initiation stage in main plots. Four weed management treatments, viz. un-weeded control (UWC); weed-free control (WFC); pendimethalin 1.5 kg/ha as pre-emergence *fb* brown manuring with *Sesbania aculeata* (knocking down *Sesbania* by bispyribac-Na 25 g/ha at 25 DAS); pendimethalin 1.5 kg/ha as pre-emergence *fb* bispyribac -Na 25 g/ ha at 25 DAS in sub-plots with three replications.

Grain yield: The plot treated with FYM + LCC based N management produced the highest grain yield (3.25 t/ha) which was at par with the application of recommended dose of fertilizer (3.15 t/ha). Both the treatments were significantly higher than the plot without N application (1.56 t/ha) (Table 1). This might be due to enhanced photosynthetic activity and translocation of photosynthates by providing nutrients according to crop needs in real time which led to increased grain filling and number of filled grains. FYM also worked as a surface mulch which escaped initial moisture stress (Naorem *et al.* 2023) by reducing evaporation losses from soil surface and conserving moisture resulting in greater availability of nutrients to crop by enhancing solubility and translocations of nutrients and increasing the yield subsequently in rainfed upland condition. FYM also increase porosity and lead to more water retention in pore spaces which helps to increase yield (Tripathy *et al.* 2021). The FYM act as a surface mulch which escaped initial moisture stress by reducing evaporation losses from soil surface and conserving moisture resulting in greater availability of nutrients to crop and increasing the yield subsequently in rainfed up-land condition (Singh *et al*. 2023). LCC based RTNM provides simple and quick way to assess N deficiency of crop during its growth stage which helps the farmers to apply N at right time, preventing deficiencies and ensuring optimal crop growth and development which may lead to enhanced yield (Bhat *et al.* 2022).

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Table 1 Hulling, milling, head rice recovery, crude protein percentage, protein yield and grain yield of rice, variety CR Dhan 202

Treatment	Hulling (%)	Milling (%)	Head rice recovery (%)	Crude protein (%)	Protein yield (kg/ha)	Grain yield (t/ha)
Nitrogen management (N)						
No N (RDF of P and K only)	62.1	46.9	56.7	7.1	111	1.56
RDF (N:P_2O_5: K_2O=80:17:33 kg/ha)	65.5	49.9	57.8	7.3	230	3.15
50% FYM + 50% RTNM (LCC)	66.7	50.5	59.8	7.5	244	3.25
SEm±	0.8	0.8	0.6	0.05	4.7	0.07
CD (P=0.05)	3.0	2.7	2.2	0.2	18.6	0.26
Weed management (W)						
Un-weeded control (UWC)	60.7	46.6	56.0	6.4	132	2.06
Weed free control (WFC)	67.3	50.3	59.3	7.7	238	3.09
Pendimethalin 1.5 kg/ha *fb* brown manuring	65.8	50.0	59.1	7.6	211	2.78
Pendimethalin *fb* bispyribac-Na	65.3	49.5	58.2	7.5	205	2.70
SEm±	1.2	0.9	0.6	0.04	6.3	0.08
CD (P=0.05)	4.0	2.6	1.7	0.14	18.8	0.24

In case of weed management, yield obtained in the plot treated with pendimethalin 1.5 kg/ha as pre-emergence *fb* brown manuring with *Sesbania aculeata* (knocking down *Sesbania* by bispyribac-Na 25 g/ha at 25 DAS) (2.78 t/ha) was at par with the plot treated with pre-emergence application of pendimethalin *fb* bispyribac-Na (2.70 t/ha). Both the treatments gave significantly higher yield than the un-weeded control plot (2.06 t/ha). Weed growth was low under *Sesbania* treated plot because of its smothering effect both at initial and at later stage of crop growth. After knocking down *Sesbania,* its residues acted as surface mulch which restricted penetration of solar radiation on soil surface which resulted in reduced germination of weed seeds (Mahajan *et al.* 2009). *Sesbania* is a fast-growing crop with high biomass (6.7 t/ha) production that could have fixed atmospheric N (234.5 kg/ha) in the soil and provided the same through its residues after decomposition which helped in better crop growth and higher grain yield (Sah and Singh 2023).

Physical grain quality: Hulling, milling, head rice recovery, crude protein, and protein yield in plot treated with LCC + FYM based N management practices were *at par* with RDF (Table 1). Both the treatments were significantly higher than the crop stands without N application plot. This might be due to N supply to the crop throughout the growing period by need based split application of N based on LCC. Also, nutrients holding capacity of FYM is high and released N slowly which helps in better uptake of N at panicle initiation and grain filling stage. This resulted in an increase in protein content in endosperm. Higher protein content in endosperm helped to reduce grain breakage during hulling and milling process providing better strength to the grain and improve milling and hulling percentage. Similar research finding was reported by Perez *et al.* (1996). Moreover, higher milling recovery under LCC based N management might be attributed to increased assimilate translocation to grain, better grain filling, and ultimately improved milling recoveries (Zhou *et al.* 2018).

In case of weed management practices, it was observed that hulling, milling, head rice recovery, crude protein (%) and protein yield of rice in the crops treated with Brown manuring with *Sesbania aculeata* (Knocking down *Sesbania* by Bispyribac-Na 25g/ha at 25 DAS as at par with that treated with pre-emergence application of pendimethalin *fb* bispyribac-Na. Both treatments were significantly higher than the un-weeded control plot (Table 1). *Sesbania* as a legume crop fixed atmospheric N. It also increased microbial activity of soil after decomposition which enhanced the uptake of N by plant at panicle initiation and grain filling stage and helps in improving physical quality of grain, i.e. hulling (%,) milling (%), head rice recovery and protein content.

The N content (grain and straw) in crops treated with LCC + FYM based N management was *at par* with the application of RDF which was significantly higher than the crops treated without N application (Table 2). This might be due to higher uptake of N in LCC + FYM based crop management because of need based application of FYM which supplied all essential macro and micronutrients to the crop along with soil moisture conservation. FYM also add organic carbon which increase adsorption capacity of nutrients (Singh and Mukharjee 2023).

Phosphorus content in grain and straw in crop treated with LCC + FYM based N management was significantly higher than the crop treated with recommended dose of nitrogen as well as without N treated plot. Andriamananjara *et al.* (2018) also reported that FYM application in upland soils sharply increase phosphate fertilizer use efficiency for

Table 2 Nitrogen, phosphorus, and potassium concentration in grain and straw of rice, variety CR Dhan 202

Treatment	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	Grain	Straw	Grain	Straw	Grain	Straw
Nitrogen management (N)						
No N (RDF of P and K only)	1.20	0.35	0.14	0.07	0.31	1.48
RDF ($N:P_2O_5$: K_2O=80:17:33 kg/ha)	1.23	0.39	0.16	0.07	0.32	1.53
50% FYM + 50% RTNM (LCC)	1.26	0.40	0.17	0.08	0.33	1.56
SEm±	0.008	0.01	0.003	0.002	0.008	0.003
CD (P=0.05)	0.033	0.03	0.01	0.007	NS	0.010
Weed management (W)						
Un-weeded control (UWC)	1.07	0.24	0.13	0.06	0.28	1.29
Weed-free control (WFC)	1.30	0.44	0.17	0.08	0.35	1.63
Pendimethalin 1.5 kg/ha *fb* brown manuring	1.28	0.41	0.16	0.07	0.33	1.59
Pendimethalin *fb b*ispyribac-Na	1.27	0.40	0.15	0.07	0.32	1.58
SEm±	0.008	0.03	0.004	0.003	0.011	0.009
CD (P=0.05)	0.024	0.1	0.011	0.01	0.033	0.026

upland rice. FYM also enhances the absorption and uptake of nutrients from the soil. It improves soil structure, allowing better root penetration and nutrient access, increases water-holding capacity and microbial activity, aiding nutrient release and availability. The organic matter in FYM acts as a source of nutrients itself, and its decomposition products create a favourable environment for nutrient exchange between soil and roots. This overall promotes healthier plant growth and nutrient uptake (Meena *et al.* 2018).

In case of weed management nitrogen, phosphorus and potassium content in grain and straw in crop treated with brown manuring was at par with plot treated with pendimethalin *fb* bispyribac-Na which was significantly higher than crop stand with un-weeded control plot. Highest nitrogen, phosphorus and potassium content (%) both in grain and straw was observed in the crop treated with brown manuring due to enhanced soil organic carbon (SOC) and subsequent nutrient availability resulting from incorporation of *Sesbania* in the soil (Nawaz *et al.* 2017).

SUMMARY

Combined use of FYM and LCC based N management gave the highest grain yield, hulling, milling, head rice recovery, crude protein, protein yield (kg/ha) as well as highest nitrogen, phosphorus and potassium in grain and straw. In case of weed management practices, the sequential application of pendimethalin (1.5 kg/ha) as pre-emergence *fb* brown manuring with *Sesbania aculeata* (knocking down *Sesbania* by bispyribac-Na 25 g/ha at 25 DAS) resulted in better control of diverse weeds. It also proved to be the best treatment in terms of yield, physical and chemical grain quality parameters.

AKNOWLEDGEMENTS

Authors are grateful to the ICAR- Indian Agricultural Research Institute, New Delhi and the Central Rainfed Upland Rice Research Station (CRURRS) Hazaribagh, Jharkhand (ICAR-National Rice Research Institute, Cuttack, Odisha) for providing the financial assistance.

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