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Energy Use Efficiency of Late Sown Short Duration Rice Varieties Under Different Nitrogen Management Practices

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Abstract

One of the major causes of low nitrogen use efficiency in rice is the application of fertilizer nitrogen (N) more than crop requirement at times when it is not required by plant during late sown conditions. This experiment was conducted at Rajendranagar farm of ICAR-Indian Institute of Rice Research, Hyderabad during *kharif* 2021. The experiment was laid out in split plot design with three replications. Main plots consisted of three short duration rice varieties DRR Dhan-44, MTU 1010, MTU 1156 and four nitrogen management practices (sub-plots) *viz.,* recommended dose of nitrogen (RDN) @ 120 kg N ha^{-1}, Silicon coated urea (SCU) @ 90 kg ha^{-1}, Leaf Colour Chart based N application (LCC) @ 105 kg N ha^{-1}, Soil test crop response based N application (STCR) @ 114.5 kg N ha^{-1}. Among the varieties highest energy input (13.22 GJ ha^{-1}) was recorded in DRR Dhan-44 but energy output (172.6 GJ ha^{-1}) and energy use efficiency (10.26 GJ ha^{-1}) were recorded in MTU 1156. Among the N management practices highest energy input (13.94 GJ ha^{-1}) was recorded in RDN @ 120 kg N ha^{-1} and energy use efficiency (10.38 GJ ha^{-1}) was recorded with Leaf colour chart based N application@105 kg Nha^{-1}.

Key words: LCC, nitrogen use efficiency, STCR, short duration variety, silicon coated urea.

Introduction

Rice (*Oryza sativa* L.) is a staple food for more than half of the world's population. India is the world's second largest producer of rice, accounting for 20 per cent of world rice production. Global warming and aberrant weather conditions causes unpredictable rainfall during monsoon and it leads to late sowing of rice specially in *kharif*. Late sown long duration rice varieties are often victims of cyclones. So, there is a great need to introduce short duration rice varieties in such areas which can escape these extreme climatic aberrations. And also proper sowing time of *rabi* crops therefore, improving the cropping intensity. Under late sown conditions, sowing of medium and short duration varieties is the best option as they will be exposed to high or low temperature stress for shorter time in their reproductive phase compared to long duration varieties, therefore, reducing the chances of spikelet sterility and poor grain filling (Murthy *et al*., 2010). Energy use in agricultural production has become more intensive now a days due to the use of fossil fuel, inorganic fertilizers, pesticides, machinery and electricity to provide substantial increases in food production (Tuti *et al.,* 2014, 2013). Hence, energy use efficiency has been important for sustainable development in agriculture systems. Efficient use of input energy resources such as fertilizers and seeds not only save fossil fuel resources but also provides financial savings of farmers (Singh and Singh, 2004).

Recently, by knowing the initial soil nitrogen status with STCR and with the help of Leaf Color Chart (LCC) real-time N management strategies have been developed for rice (Ladha *et al*., 2005). Recent research has mentioned that efficient use of energy in agriculture is one of the requisites for sustainable agricultural production, since it offers financial savings, fossil resource preservation and above all reduction in its global warming potential (Agha Alikhani *et al.,* 2013). Besides land, farm power is the second most important input to agriculture production. So, there is great need to improve the energy use efficiency of input energy resources such as fertilizers and varieties under the late sown and climatic aberration conditions.

Materials and Methods

The trial was conducted at Indian Institute of Rice Research (IIRR) farm, Rajendranagar geographically situated at an altitude of 542.3 m above the mean sea level and located at 17° 19' N latitude and 78° 23" E longitude, Hyderabad. During the crop growth period, a total rainfall of 782.6 mm was received. The daily mean bright sunshine during the crop growth period ranged from 1.7 to 8.1 hours, with an average of 4.6 hours and the daily mean evaporation (mm) during the crop growth period was 3.36 mm. The weekly mean maximum temperature ranged from 27.6 to 31.6 °C with an average of 29.6 °C, weekly mean minimum temperature ranged from 16.4 to 25.5 °C with an average of 21.2 °C. The soil of the experimental site was clay loam in texture, non-saline in nature, low in available soil nitrogen is (250 kg ha^{-1}), phosphorus (34.0 kg ha^{-1}) and potassium (265.5 kg ha^{-1}) with pH of 7.4.

The trial was laid out in split plot design with three replications. And it consists of 3 main plots three short duration rice varieties DRR Dhan-44, MTU 1010, MTU 1156 with 120 days duration was selected for the study. Good quality seed of three varieties @ 25 kg/ha was soaked and incubated in moist gunny bag for 24 hours. The sprouted seed was broadcasted uniformly on a well-prepared nursery bed for transplanting in respective beds. The seedlings were maintained in the nursery for up to 30 days and Thirty days old seedlings were line planted by adopting a spacing of 20 cm x 15 cm. and sub-plots with four N management practices *viz.,* recommended dose of N (RDN) @ 120 kg N ha^{-1}, Silicon coated urea (SCU) @ 90 kg ha^{-1}, Leaf Colour Chart based N application (LCC) @ 105 kg N ha^{-1} Soil test crop response based N application (STCR) @ 114.5 kg N ha^{-1} with target yield of 6 t ha^{-1}.

All rice varieties are short duration (120 days) and sown at August 1st week 2021 and harvested at December 18th 2021. Recommended dose of N-P_2O_5-K_2O was 120-60-40 kg per hectare. Recommended dose of nitrogen (120 kg ha^{-1}) was applied through urea in three equal splits at basal, active tillering and panicle initiation stages. Silicon coated slow-release urea was developed in laboratory of ICAR-IIRR and applied @ 75% of RDN (90 kg ha^{-1}) in equal three splits. Whenever, the LCC values were found to be below the fixed critical level of three, the recommended quantity of N was applied @ 25 kg ha^{-1} and the basal dose of N was applied at 30 kg ha^{-1}. In LCC based N management total 105 kg N ha^{-1} was applied in 4 splits. The fertilizer prescription equation to attain specific yield targets based on soil available nutrient levels for the experimental field was FN = 42 T - 0.55 SN. The targeted yield was 6 t ha^{-1}. Accordingly, the N dose was 114.5 kg ha^{-1}.

Weeds in the experimental field were managed by hand weeding at critical period of crop weed competition *i.e.,* 15 and 45 DAT to keep the field weed free. Bispyribac sodium was applied at 2-3 leaf stage of weeds at 15 DAT of rice crop to control the weeds. At the time of sowing a thin film (2-3 cm) of water was maintained for better establishment of seedlings. A depth of 5 to 2 cm water level was maintained during the entire crop period except at the time of top dressing of fertilizers. From panicle initiation stage to 21 days after flowering, 5 cm depth of water was maintained. Last irrigation was provided at seven to ten days before physiological maturity stage of the crop. Spraying of chloripyriphos 1.6 ml $L^{-1}$and carbofuran granules 7.5 kg ha^{-1}, Cartap hydrochloride 50% SP @ 2g L^{-1} for the control of leaf folder and yellow stem borer respectively. The crop was harvested when grain and straw color changed from green to straw yellow colour. Harvesting was carried out manually with the help of sickles leaving about 5 to 10 cm stubbles in the field. Energy input, output and energy use efficiency of individual varieties and nitrogen management practices was calculated using an energy co-efficient value for each treatment. The energy input was calculated as the summation of energy requirements for labour, farm machinery, seed, fertilizers and irrigation used in the system and expressed in (GJ ha^{-1}). output energy from the main product (grain) and byproduct (straw) was calculated by multiplying the amount of production by its corresponding energy equivalent expressed as (GJ ha^{-1}) and the energy use efficiency was calculated by using the following formula.

$$\text{Energy Use Efficiency} = \frac{\text{Gross energy output (GJ ha}^{-1}\text{)}}{\text{Total energy input (GJ ha}^{-1}\text{)}}$$

The level of significance used in 'F' and 't' test was at 5% probability. Wherever 'F' test was found significant, the 't' test was used to estimate critical differences among various treatments **(Table 1).**

Table 1: Yield total input energy, energy output and energy use efficiency of rice varieties and nitrogen management practices

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)	Energy Input (GJ ha^{-1})	Energy Output (GJ ha^{-1})	Energy use Efficiency (GJ ha^{-1})
Varieties						
M_1: DRR Dhan-44	5314	6636	44.50	13.22	161.0	9.52
M_2: MTU 1010	4856	6054	44.43	13.17	147.0	8.72
M_3: MTU 1156	5707	7102	44.60	13.14	172.6	10.26
SEm (±)	96.7	116	0.75	-	1.85	0.06
CD (P=0.05)	379	456	NS	-	7.2	0.26
CV (%)	6.3	6.1	5.8	-	4.1	3.25
N management practices (kg ha^{-1})						
S_1: RDN @ 120 kg N ha^{-1}	5478	6778	44.71	13.94	165.2	9.37
S_2: Silicon coated urea @ 90 kg N ha^{-1}	4731	5967	44.21	12.12	144.1	9.12
S_3: Leaf colour chart @ 105 kg N ha^{-1}	5758	7112	44.79	13.03	173.5	10.38
S_4: Soil test crop response @ 114.5 kg N ha^{-1}	5203	6530	44.34	13.61	158.1	9.14
SEm (±)	127	147.8	0.82	-	2.69	0.16
CD (P=0.05)	378	439	NS	-	7.9	0.48
CV (%)	7.2	6.7	5.59	-	5.1	5.25

Results and Discussions

Yield and Harvest Index

Among short-duration rice varieties, MTU 1156 recorded the highest grain yield (5707 kg ha^{-1}), followed by DRR Dhan-44 (5314 kg ha^{-1}), both significantly outperforming MTU 1010 (4856 kg ha^{-1}). These results align with Mohapatra *et al.,* (2021). Higher seed yield is associated with a greater number of tillers per square meter (Nayaka *et al.,* 2021). Similar results were also reported by Senthil Kumar *et al.,*

(2021) short duration variety CO 53 and Anna 4 is best suitable under semi-dry system with 100 per cent recommended dose of fertilizer.

In terms of nitrogen management, the highest grain yield was observed with LCC @ 105 kg N ha^{-1} (5758 kg ha^{-1}), on par with RDN @ 120 kg N ha^{-1} (5478 kg ha^{-1}). STCR @ 114.5 kg N ha^{-1} yielded 5203 kg ha^{-1}, like RDN @ 120 kg N ha^{-1}. The lowest yield was with silicon-coated urea @ 90 kg N ha^{-1} (4731 kg ha^{-1}). Effective nitrogen management during critical physiological phases enhances photosynthate assimilation (Suresh *et al.,* 2017; Moharana *et al.,* 2017). The nitrogen level 120 kg N ha^{-1} recorded the highest grain yield as compared to the 80 kg N ha^{-1} (Kacha *et al.,* 2023).

MTU 1156 also achieved the highest straw yield (7102 kg ha^{-1}), significantly higher than other varieties, with MTU 1010 having the lowest (6054 kg ha^{-1}). This is attributed to MTU 1156's higher tiller production and nitrogen use efficiency (Chandra and Kumar, 2020). LCC @ 105 kg N ha^{-1} led to the highest straw yield (7112 kg ha^{-1}), similar to RDN @ 120 kg N ha^{-1} (6778 kg ha^{-1}). STCR @ 114.5 kg N ha^{-1} recorded 6530 kg ha^{-1}, superior to silicon-coated urea @ 90 kg N ha^{-1} (5967 kg ha^{-1}) due to better growth parameters (Kumar *et al.,* 2018).

MTU 1156 had the highest harvest index (44.60%). Among N management practices, LCC based N management showed the highest harvest index (44.79%) due to effective N application and increased efficiency, leading to higher grain yield and harvest index (Huang *et al.,* 2021; Moharana *et al.,* 2017).

Total input energy

Among the varieties (**Figure 1**) DRR Dhan-44 recorded the highest total input energy (13.22 GJ ha^{-1}) followed by MTU 1010 (13.17 GJ ha^{-1}) and the lowest input energy was found with MTU 1156 (13.14 GJ ha^{-1}). Among the N management practices (**Figure 2**) RDN @ 120 kg N ha^{-1} resulted in the highest total input energy (13.94 GJ ha^{-1}) followed by STCR @ 114.5 kg N ha^{-1} (13.61 GJ ha^{-1}). LCC @ 105 kg N ha^{-1} recorded the total input energy of 13.03 GJ ha^{-1}. The lowest total input energy (12.12 GJ ha^{-1}) was recorded in silicon coated slow-release urea @ 90 kg N ha^{-1}.

Total output energy and energy use efficiency

Regarding the total output energy and energy use efficiency among the varieties MTU 1156 recorded the highest total output energy (172.60 GJ ha^{-1}) so it has higher energy use efficiency of 10.26 GJ ha^{-1}. MTU 1010 recorded the lowest total output energy (147.0 GJ ha^{-1}) and energy use efficiency (8.72 GJ ha^{-1}). Among the N management practices, LCC @ 105 kg N ha^{-1} recorded the highest total output energy (173.5 GJ ha^{-1}) and energy use efficiency (10.38 GJ ha^{-1}). RDN @ 120 kg N ha^{-1} recorded total output energy and energy use efficiency of 165.2 GJ ha^{-1} and 9.37 GJ ha^{-1}, respectively. STCR @ 114.5 kg N ha^{-1} recorded with total output energy and energy use efficiency of 158.1 GJ ha^{-1} and 9.14 GJ ha^{-1}, respectively. The lowest total output energy (144.1 GJ ha^{-1}) and energy use efficiency (9.12 GJ ha^{-1}) were recorded with silicon coated slow-release urea @ 90 kg N ha^{-1}.

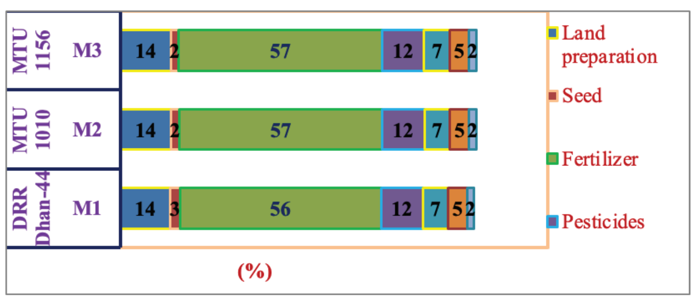

Figure 1: Distribution of total input energy (%) of short duration varieties

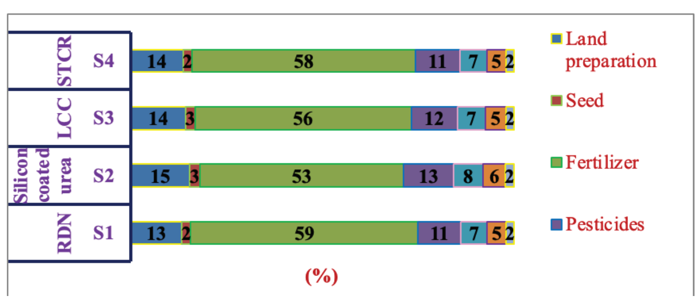

Figure 2: Distribution of total input energy (%) of rice cultivation as influenced by nitrogen management practices

Higher total input energy in DRR Dhan-44 this might be due the more seed rate as compared to other varieties. Higher total input energy in RDN @ 120 kg N ha^{-1} might be due to the more application of N as compared to the other management practices (Paramesh *et al.,* 2017). Soni and Soe (2016) also reported that higher total energy input in rice due to application more N fertilizers, manure management (FYM application) and frequent irrigation in rice. Regarding total output energy and energy use efficiency among the varieties, MTU 1156 had produced the highest grain and straw yield as compared to rest of the varieties. Higher grain and straw yields in MTU 1156 led to higher gross output energy and net energy. Nayaka *et al.,* (2021) reported that among the varieties, significant variations in grain and straw yields brought out dissimilarity in gross output energy and energy use efficiency.

Among the N management practices, the highest total output energy and energy use efficiency was recorded in LCC @ 105 kg N ha^{-1}. This might be due to the higher grain and straw yield in this treatment compared to other N management practices. Variation in energy input among nutrient management practices may be attributed to varying inputs and crop management practices like tillage, fertilizer application, water, weed, pest and disease management, etc. Likewise, higher energy consumption under this practice was due to higher energy equivalents of fertilizers applied to the crop (Varatharajan *et al.,* 2019). Application of nitrogen based on LCC and STCR recorded significantly higher gross output energy and net energy as compared to other nitrogen management practices. The higher gross output energy with LCC was attributed to maximum grain and straw yields, higher net energy due to less input energy and more total energy output (Sudhakara *et al.,* 2017).

Conclusion

From the results of the present study it can be concluded that among the varieties MTU 1156 recorded the highest in yield, harvest index and energy output, energy use efficiency of 172.and 10.26 respectively under late sown conditions and among the nitrogen management practices LCC@105 kg N recorded the highest in yield, energy output (173.5), energy use efficiency (10.38) of rice. Even though low application of nitrogen as compared to RDN@120 kg N due to real time nitrogen management it escapes the climatic aberrations like cyclone and performs better. So, under late sown conditions MTU 1156 with LCC@105 kg N recommended to the farmers of Telangana to get normal yield without reduction in yield.

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