Nitrogen management in direct seeded rice, agronomic, physiological and economical perspectives

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Abstract

Site specific nitrogen (N) management require development of plant based approaches for wide scale recommendation. Among different splits, two N splits (sowing and anthesis) showed growth, yield and total N uptake similar to three splits (sowing, tillering and anthesis) in direct seeded rice. Increasing N supply from 80 to 160 kg N ha^{-1} improved recovery efficiency while reduced agronomic efficiency attributed to low soil NH_4^+-N subjected to unaccounted gaseous losses. Positive association of NDVI at booting stage with leaf N contents and of total N uptake with grain yield suggest to predict economical N application using this index. NDVI and SPAD-chlorophyll at booting did not vary for two or three N splits, however, response was genotype specific with highest N requirement for coarse than medium grain rice types.

Keywords: N splitting, normalized difference vegetation index, nitrogen use efficiency

1. Introduction

Among different challenges, next to water is nitrogen (N) nexus, the great intractable development challenges facing humanity. Sustainable production of rice is crucial for the food security and livelihoods of smallholders in Pakistan (Ahmad et al., 2015) but is constrained by water shortage (Awan et al., 2015), low nitrogen use efficiency - NUE - (Shahzad et at., 2019) and climate change (Arshad et al., 2017). The water productivity of rice in Pakistan is 0.45 kg/m3 of irrigation water which is 55% less than the average value (1 kg/m3) for Asia. Per capita water availability already crossed the threshold of water scarcity in 2005 and the prevailing situation may lead to absolute water scarcity by 2025 (Qureshi and Ashraf, 2019). Fresh water availability decreased by 18.9 % during 2018-19. Efficient use of water by reducing its losses and yield gap, which is now exceeding 43%, will sustain rice production in Pakistan and reduce CH4 emissions from rice fields. The switch to low-emission cultivation can have a tremendous potential to reduce baseline emissions from irrigated rice by more than 26%.

Likely, increasing nitrogen (N) fertilizer use not only greatly threatens crop sustainability but also contributes to water and air pollution due to low NUE (Shahzad et al., 2019). Among three major crops, rice has the lowest N use efficiency (<30%) in Pakistan which is is lowest compared among major rice producing countries including India, China and Bangladesh. Excessive use of N fertilizers along with low productivity of rice (Raza et al., 2018) is due to poor farm management exacerbated by very generalized N fertilizer recommendations and there is a drastic increase in N fertilization per hectare, whereas NUE is going down (Shahzad et al., 2019).

Sustainable development of direct seeded rice systems in South Asia depends on developing cultivars efficient in nitrogen and water use. And critical challenge is to develop economic N optimum to identify cultivars producing higher yields at low N inputs (Swarbreck et al. 2019) and high throughput phenotypic strategies with wide application such as use of optical sensors and crop indices to measure crop nutritional status with respect to canopy development for site specific N management strategies (Hawkesford and Griffith, 2019).

2. Methods

The different N splits in two- and three splits at different crop stages were compared in direct seeded rice (Rehman et al. 2016). In experiment 2, two -and three splits were compared at 80, 120 and 160 kg N ha^{-1} including no N control. In experiment 3, two and three splits at 120 kg N ha^{-1} were compared in diverse sixteen rice cultivars. Each

experiment was conducted for two growing seasons. N response was predicted by SPAD-chlorophyll and greenseeker based NDVI at tillering, booting and heading stages. At physiological maturity total N uptake including leaf N contents were determined using micro-kjeldhal digestion method. Relationship between leaf N, total N uptake and grain yield with SPAD- chlorophyll and NDVI were developed.

3. Results and Implications

3a) Experiment 1: Highest paddy yields was found for two splits followed by three splits. Difference among N splits for total nitrogen uptake was non-significant and attributed to high soil NO_3-N as compared to NH_4-N. Two splits were more profitable than three splits (Table 1).

Table 1: Analysis of variance for different traits in DSR

Factors	Paddy Yield (kg ha^{-1})	Total N uptake (kg ha^{-1})	Soil NH4 (mg kg^{-1})
Year	**	**	**
N splits	**	**	**
Year x N splits	**	**	**

** >P=0.001

3b) Experiment 2: In season N estimation and supply at panicle or heading stages can be determined from relationship between NDVI and SPAD-chlorophyll at booting (Fig. 1). The sufficiency index of N uptake and fertilizer application using NDVI at panicle initiation stages provides the concept for site specific N management using temporal variability.

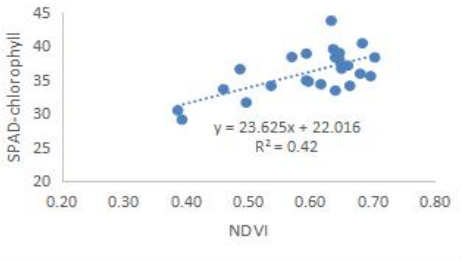

Fig. 1: Relationship between SPAD-chlorophyll and NDVI at booting

3c) Experiment 3: The NDVI and SPAD-chlorophyll at booting stage did not vary between two or three splits and response was genotype specific. Short duration coarse rice genotypes require high N to meet crop requirement for growth and produce better yield than medium grain types.

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