International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(3): 513-516
www.biochemjournal.com
Received: 30-01-2024
Accepted: 07-03-2024

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Drought tolerant indices of rainfed rice under different levels of N & K splitting regimes

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DOI: https://doi.org/10.33545/26174693.2024.v8.i3f.802

Abstract
Rainfed rice productions under drought stress are serious limiting factors, the results in quantity of economic losses. It is becoming a more serious problem with respect to the global environment changes. The current and forecasted global foods requirements, it has become to enhancing the crop productions on the drought stress rainfed areas with the fundamentality. In order to achieve the production goal from rainfed lands there is a requirement of varieties of the rice with drought tolerance, and amendment for drought stress tolerant should be a high precursory theme of research in the next ensuing. A field experiment was undertaken during wet seasons of 2017 and 2018 to evaluate the response of soil applied Potassium and Nitrogen splitting in rice (Sahbhagi Dhan) under rainfed lowland conditions. The experimental was laid out on a sandy loam soil of Bihar Agricultural College farm, Sabour to derive inputs for rationalizing the use of Potassium (K) and Nitrogen (N) fertilizers by splitting and real time management respectively for making them more suitable for rainfed conditions. Nutrient and water management are important for diversifying and intensifying the rainfed rice based cropping systems. The greatest progress has been made during last two decades in our understanding of the mechanisms & strategy involved in adaptation and tolerance to rainfed rice productions under lowland conditions. The experiment involved three K splitting schemes *viz*., K_0 (No K application), K_{40} (K applied as basal @ 40 kg K_2O per ha) and K_{20+20} (K application as basal, and at panicle initiation stage each @ 20 kg K_2O per ha) in main plots, and five N splitting schemes in sub plots *viz*., N_0 (No N application), N_{50+50} (N application as basal and at active tillering, each @ 50 kg per ha) N_{SPAD} (N application as basal each application @ 33.33 kg ha^{-1} and top dressing as guided by SPAD meter with critical SPAD value of 38, N_{GS} (N application as basal @ 33.3 kg per ha and top dressing as guided by Green Seeker optical sensor) and $N_{33+33+33}$ (N application as basal, at active tillering and at panicle initiation, each @ 33.3 kg per ha.). The results revealed that the tolerance indexinN_{50+50}, N_{GS} and $N_{33+33+33}$ was at par with each other, but that in N_{SPAD} was significantly greater than that in N_{50+50}, N_{GS} and $N_{33+33+33}$. The mean productivity in N_{50+50}, N_{GS} and $N_{33+33+33}$ was at par with each other. The rice crop mean productivity in N_{SPAD} was significantly greater than that in N_{50+50}, N_{GS} and $N_{33+33+33}$. Across various N splitting schemes, the stress tolerance index was found to be significantly lower in N-control in comparison to other N-splitting schemes.

Keywords: Rainfed rice, Indices to water deficit tolerance, under K & N-splitting schemes

Introduction

Rice (*Oryza sativa* L.) is one of the most widely consumed staple foods for a large part of the world's human population, especially in Asia (Samal *et al*., 2018) [11]. Asia is on the top most production and consumptions of the rice. According to FAO report (2016-2017), average productions of rice is estimated as fifty crore metric ton, and due to rise in population, to the requirement is expected to increase up to two arab metric ton by the year 2030. Climate change, influence of the regularity and levels of hydrological drought fluctuations, is a major threat to agriculture particularly in developing nations, and causes various stresses for the plants. In India, 47 million hectares are under rice production, of which 45% is irrigated, 33% is rainfed lowland, 15% is rainfed upland and 7% is flood-prone. The rainfed rice area is about 24.4 million hectare in India out of which the rainfed lowland area (17 million hectares) is mostly in eastern India. Drought is the most important factor limiting rice productivity in the rainfed rice agro-ecosystem (Pandey and Shukla (2015) [8]. Climate change is predicted to increase the frequency and severity of drought, which will likely result in increasingly serious constraints to rice production worldwide.

Therefore, the present study described the effects of rainfed rice and highlighted the recent progresses in physiological and biochemical adaptation of rice under drought tolerance conditions.

Materials and Methods

Experimental site description

A field experiment was conducted during wet seasons of 2017 and 2018 at Bihar Agricultural University, Sabour, Bhagalpur. Sabour is situated in the Middle Gangetic Plain region of Agro-climatic Zone III (A) located at 25˚15′40″ N latitude, 87˚2′42″ E longitude and an altitude of 37 meter above mean sea level. The crop received a total rainfall of 862.1 mm and 1101.6 mm during *kharif* 2017 and 2018, respectively. The weekly weather condition of the experimental site during the crop growth period of the year 2017 and 2018. The daily maximum and minimum temperature during the crop growth period varied from 29.2-36.4ºC and 11.8 - 26.3 °C, respectively during the crop growth period of the year 2017 whereas, in the year 2018 the maximum and minimum temperatures ranged from 29.2-37.4 °C and 12.6- 26.8 °C, respectively. The crop received a total rainfall of 862.1 mm and 1101.6 mm during the year 2017 and 2018, respectively. The relative humidity at 07:00 AM and 02:00 PM during 2017 & 2018 ranged from 81.9% to 94%, 44.7% to 81.9%, 80.2% to 91.7% and 45.1% to 81.2% in the same order.

The soil is Typic Haplustept (US Soil Taxonomy, Soil Survey Staff 2003) and clay loam in texture average (40.4% sand, 52.9% silt, and 31.25% clay) with general initial properties ranged from: pH 7.11-7.38, electrical conductivity 0.1-0.08 dsm^{-1}, and organic carbon 0.43-.44%, available N 113-218 kg ha^{-1}, available P_2O_5 28-30 kg ha^{-1} and available K_2O 120-187 kg ha^{-1}. This data presented in table 1.

Table 1: Physicochemical properties of experimental soil before planting

Parameter	2017	2018	Methods
Sand (%)	39.5	41.3	Bouyoucos
Silt (%)	34.8	36.2	
Clay (%)	21.2	20.1	
Textural Class	Loam	Loam	
Bulk density (Mg M^{-3})	1.51	1.52	Jackson
pH (1:2.5 soil: water suspension)	7.38	7.11	
EC (dS m^{-1})	0.12	0.08	
Oxidizable organic carbon (%)	0.43	0.44	Walkley and Black
Available nitrogen (kg ha^{-1})	218	213	Subbiah and Asija
Available phosphorus (kg ha^{-1})	28	30	Olsen *et al.*
Available potassium (kg ha^{-1})	220	287	Jackson

Experimental design and management under drought tolerance

The experiment was laid out in split plot design with three replications and consisted of the following fifteen treatments as enlisted in table 1. The net plot size of each treatment is $8.1m^2$. While, the recommended dose of fertilizers the main plot treatment were K_0 (No K application), K_{40} (K applied as basal @ 40 kg K_2O per ha) and K_{20+20} (K splitting as basal, and at panicle initiation stage @ 20 kg K_2O per ha) and in sub plots treatment N_0 (No N application), N_{50+50} (N application as basal and at active tillering, each @ 50 kg per ha) N_{SPAD} (N application as basal @33.3 kg per ha and top dressing as guided by SPAD meter, critical SPAD reading considered as 38), N_{GS} (N application as basal @ 33.3 kg per ha and top dressing as guided by Green Seeker optical sensor) and $N_{33+33+33}$ (N application as basal, at active tillering and at panicle initiation, each @ 33.3 kg per ha.) and zinc were applied as per area-specific recommended rates @ 25 kg ha^{-1}, and full dose of phosphorous @ 60 kg ha^{-1} single super phosphate (SSP) along with zinc as zinc sulfate hepta-hydrate were applied as basal at the time transplanting. The nursery of rice variety Sahbhagi Dhan was sown in an adjacent plot which was tilled and puddled followed by on 25-06-2017 and same date in 2018 broadcasting of the pre-germinated seeds @ 30 g m^2 and N: P_2O_5: K_2O@75-50-50 kg ha^{-1}wereapplied. Twenty-one days old seedlings were transplanted at a spacing of 20 cm × 15 cm with 2 seedlings per hill on 16^{th}July and 17^{th} July during 2017 & 2018 respectively. Drought indices In order to study of the different nitrogen and potassium levels, to rainfed rice different indices were calculating and using the following relationship

Indices to characterize stress tolerance

TOL (Tolerance index) = $Yp - Ys$ (Rosielle and Hamblin (1981) [10], where Yp is grain yield under no stress condition and Ys is grain yield under stress.

Lower values means it is tolerant to drought.

MP (Mean productivity) = $(Yp + Ys)/2$ (Rosielle and Hamblin (1981) [10]. Higher value means it is tolerant.

STI (Stress tolerance index) = $(Yp)(Ys)/\overline{(Ys)}^2$ (Fernandes, 1992) [14]. Higher STI shows that the particular genotype has higher tolerance to drought.

GMI (Geometric mean index) =$\sqrt{(Yp)(Ys)}$ (Fernandes, 1992) [14]. Higher value means it is tolerant.

HMI (Harmonic mean index) = $\frac{2(Yp)(Ys)}{Yp+Ys}$ (Fernandes, 1992) [4].

Statistical analysis

The data were analysed statistically by applying "Analysis of Variance" (ANOVA) technique for split plot design (Cochran and Cox, 1985) [15]. Microsoft Office Excel 2010 was used to calculate different NUE parameters. The significance of different sources of variation was tested by Error mean square of Fisher Snedecor's 'F' test at probability level 0.05. Standard error of mean (SEm±) and least significant difference (LSD) at 5% level of significance were worked out for each character and provided in the summary tables of the results to compare the difference between the treatment means.

Results and Discussion

Tolerance index

Under rainfed conditions, rice crop usually encounters drought during the grain filling period. Drought is one of the most damaging abiotic stresses affecting agriculture. It is an important abiotic factor affecting the yield and yield stability of food cereals and acts simultaneously on many traits leading to a decrease in yield (Boyer, 1982; Ludlow and Muchow, 1990; Abebe *et al*. 2003; Zhang *et al*. 2006) [2, 4, 1, 13]. The precision nutrient management techniques such as SPAD based nitrogen application and Green seeker based nitrogen application have a potential to improve the yields of rainfed rice crops. The data pertaining to tolerance index, mean productivity, stress tolerance index, geometric mean index and harmonic mean index of rice under various treatments for the two years and pooled over the two years is presented in table 2. The tolerance index was significantly higher with K_{20+20} in comparison to K_0 as well as K_{40}. Potash application in two split doses increased the tolerance index by 16.71 per cent over no potash application and by 9.15 per cent over single basal application. However, the rice crop tolerance index in K_{40} and K_0 was at par with each other. Response of sequentially grown rice and wheat to applied potassium is influenced by time and method (like potassium splitting and application on critical stage) of application of potassium and interaction of potassium with other nutrients to reduce the water stress and leads to increased yields of both rice and wheat. Substantial potassium applications will have to be made to sustain high production levels of the rice-wheat cropping systems and to avoid further advancement of weathering front of potassium bearing minerals in the soil. Potassium is a mineral element taken up in large amounts by plants and plays an important role in the regulation of water status (Mengel and Kirkby, 2001) [6]. Potassium is characterized by high mobility in plant parts at all levels (within individual cells and tissues as well as in long-distance transport via the xylem and phloem, so split application of potassium improves the number of effective tillers under rainfed conditions (Manzoor *et al*. 2008) [5]. Across various N splitting methods, tolerance index, mean productivity, stress tolerance index, geometric mean index and harmonic mean index was found to be significantly lower in N-control in comparison to other N-splitting methods. Tolerance index in N_{50+50}, N_{GS} and $N_{33+33+33}$ was at par with each other, but that in N_{SPAD} was significantly greater than that in N_{50+50}, N_{GS} and $N_{33+33+33}$.

Stress tolerance index
Rice tolerance index was up to 15.54, 21.33 and 21.32 per cent the increased tolerance index in N_{SPAD} in comparison to N_{50+50}, N_{GS} and $N_{33+33+33}$ respectively. A suitable index must have a significant correlation with grain yield under both the conditions (Mitra, 2001) [7]. Based on the stress tolerance index (STI) and grain yield; tolerance index fully depends on grain yield under water stress conditions. Under control plot no nitrogen application due to lower grain yield in comparison to other N splitting methods. Lower value of Tol (stress tolerance) indicates the high stress tolerance ability of a given cultivar. Similar finding were reported by Raman *et al*. (2012) [9]. Stress susceptibility index assesses the reduction in yield caused by no fertilizer applied in compared to fertilizer applied plot. Nitrogen application @ 33.33 kg/ha when the below critical limit is 38, as dictated by SPAD meter has shown significantly higher yields over other methods of N application, which might be due to significantly more protein content, protein production and nitrogen uptake in grain and straw to reduced the stress tolerance indices.

Mean productivity
The mean productivity in N_{50+50}, N_{GS} and $N_{33+33+33}$ was at par with each other. The rice crop mean productivity in N_{SPAD} was significantly greater than that in N_{50+50}, N_{GS} and $N_{33+33+33}$. Rice crop mean productivity was up to 4.90, 6.72 and 6.71 per cent the increased mean productivity in N_{SPAD} in comparison to N_{50+50}, N_{GS} and $N_{33+33+33}$ respectively. Roselle and Hamblin (1981) [10] reported that stress tolerance index and mean productivity were defined as the difference in yield and the average yield between stress and non-stress conditions, respectively.

Geometric mean index
The stress tolerance index in N_{50+50}, N_{GS} and $N_{33+33+33}$ was at par with each other, but that in N_{SPAD} was significantly greater than that in N_{50+50}, N_{GS} and $N_{33+33+33}$. Rice crop stress tolerance index was up to 7.61, 10.55 and 10.21 per cent the increased stress tolerance index in N_{SPAD} in comparison to N_{50+50}, N_{GS} and $N_{33+33+33}$ respectively. The geometric mean index in N_{50+50}, N_{GS} and $N_{33+33+33}$ was at par with each other. Further, the rice crop geometric mean index in N_{SPAD} was significantly greater than that in N_{50+50}, N_{GS} and $N_{33+33+33}$. Rice crop geometric mean index was up to 3.80, 5.25 and 5.19 per cent the increased geometric mean index in N_{SPAD} in comparison to N_{50+50}, N_{GS} and $N_{33+33+33}$ respectively. The harmonic mean index in N_{50+50}, N_{GS} and $N_{33+33+33}$ was at par with each other. Further, the harmonic mean index in N_{SPAD} and N_{GS} was statistically similar. The harmonic mean index in N_{SPAD} was significantly greater than that in N_{GS} and $N_{33+33+33}$.

Harmonic mean index
Rice crop harmonic mean index was up to 3.76 and 3.65 per cent the increased harmonic mean index in N_{SPAD} in comparison to N_{GS} or $N_{33+33+33}$ respectively. Ilker *et al*. (2011) [3] concluded that MP, GMP and STI values are convenient parameters to select high yielding wheat genotypes in both stress and non-stress conditions whereas relative decrease in yield, TOL and SSI values are better indices to determine tolerance levels. These findings indicated that all stress tolerance indices in N_{SPAD} were significantly greater than in all other N splitting methods, due to precision nutrient management techniques such as SPAD based nitrogen application.

Table 2: Tolerance index (TOL), Mean productivity (MP), Stress tolerance index (STI), Geometric mean index (GMI) and Harmonic mean index (HMI) across all levels of K &N splitting for rainfed rice at BAC, Sabour (pooled over 2017-18)

Treatment	Tolerance index (TOL)			Mean productivity (MP)			Stress tolerance index (STI)			Geometric mean index (GMI)			Harmonic mean index (HMI)		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
K splitting schemes															
K_0	990.12	1383.29	1186.71	2404.53	2885.88	2645.21	1925.92	2012.93	969.43	2339.46	2784.85	2562.16	2276.84	2687.58	2482.21
K_{40}	1109.96	1479.01	1294.49	2464.44	2933.74	2699.09	2003.66	2065.95	2034.81	2388.32	2819.01	2603.67	2315.10	2709.30	2512.20
K_{20+20}	1277.37	1572.35	1424.86	2548.15	2980.41	2764.28	2115.74	2119.04	2117.39	2449.12	2855.79	2652.45	2355.49	2736.95	2546.22
SEm (±)	33.86	54.33	36.96	16.93	27.17	18.48	22.60	30.65	21.98	14.67	19.35	14.02	13.57	13.54	11.09
CD (P=0.05)	132.94	NS	127.90	66.43	NS	63.95	88.73	NS	76.08	57.59	NS	48.51	53.30	NS	38.30
N splitting schemes															
N_0	58.44	49.11	53.77	1938.68	2218.79	2078.74	1305.43	1261.83	1283.63	1935.79	2215.87	2075.83	1932.92	2212.56	2072.74
N_{50+50}	1316.87	1873.80	1595.34	2567.90	3131.14	2849.52	2145.86	2288.98	2217.42	2477.07	2986.63	2731.85	2390.05	2848.30	2619.17
N_{SPAD}	1739.37	2038.27	1888.82	2779.15	3213.37	2996.26	2419.60	2380.39	2399.99	2635.55	3043.90	2839.73	2500.26	2883.29	2691.77

N_{GS}	1135.80	1836.21	1486.01	2477.37	3112.35	2794.86	2026.01	2267.49	2146.75	2408.99	2972.46	2690.73	2342.73	2838.42	2590.58
$N_{33+33+33}$	1378.60	1593.69	1486.15	2598.77	2991.08	2794.92	2178.63	2131.19	2154.91	2504.10	2880.56	2692.33	2413.10	2773.80	2593.45
SEm (±)	85.20	111.34	88.66	42.60	55.67	44.33	56.47	62.52	53.28	34.22	43.37	34.94	27.27	32.73	26.94
CD (P=0.05)	248.69	324.97	252.13	124.35	162.48	126.06	164.83	182.49	151.51	99.89	126.57	99.35	79.61	95.52	76.61
CD K × N (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Conclusion

In the present study, it was found that the overall the tolerance index was significantly higher with K_{20+20} in comparison to K_0 as well as K_{40}. Potash application in two split doses increased the tolerance index by 16.71 per cent over no potash application and by 9.15 per cent over single basal application. However, the rice crop tolerance index in K_{40} and K_0 was at par with each other. Response of sequentially grown rice and wheat to applied potassium is influenced by time and method (like potassium splitting and application on critical stage) of application of potassium and interaction of potassium with other nutrients to reduce the water stress and leads to increased yields of rainfed rice. Stress susceptibility index assesses the reduction in yield caused by no fertilizer applied in compared to fertilizer applied plot. Nitrogen application @ 33.33 kg/ha when the below critical limit is 38, as dictated by SPAD meter has shown significantly higher yields over other methods of N application, which might be due to significantly more protein content, protein production and nitrogen uptake in grain and straw to reduced the stress tolerance indices.

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