Assessing The Growth, Yield, Nutrient Use Efficiency aAnd Profitability oOf drought Drought-Tolerant Rice Varieties iIn Dry Season uUnder Varied N Application Rrates

Abstract

Field experiments were carried out at ICAR- Indian Institute of Rice Research, Hyderabad (ICAR-IIRR), Hyderabad, during the dry season of 2015/2016 and 2016/2017 to study the influence of nNitrogen (N) rates and vVarieties on yield attributes, yield, nitrogenN use efficiency (NUE) and economics of puddled direct direct-sown rice (). Moreover, with an aim to assess the performance under direct direct-sown conditions to identify suitable varieties for direct direct-sown conditions during the dry season. Treatments comprised of four rates of nitrogenN- control (no nitrogen), N_{100} (100 kg N ha^{-1}), N_{120} (120 kg N ha^{-1}), and N_{140} (140 kg N ha^{-1}) as main plots and four drought drought-tolerant rice varieties (V_1-DRR Dhan 42; V_2-DRR Dhan 44; V_3-DRR Dhan 46 and V_4-IR 64). The experiment was laid out in a split-plot design with 16 treatment combinations, and each treatment was replicated thrice. The results of experiments revealed that, increasing N application rate from N_0 to N_{140} increased yield of all the varieties, but apparent differences between N_{120} and N_{140} wasinvestigations revealed that increasing the N application rate from N0 to N140 increased the yield of all the varieties, but apparent differences between N120 and N140 were not observed. When cCompared with DRR Dhan 42 or IR 64, DRR Dhan 44 and 46 accumulated greater shoot biomass, tillers m$^{-2,}$ and higher leaf area. Yield The yield was significantly higher, with DRR Dhan 44 closely followed by DRR Dhan 46 than other varieties, reflecting a higher biomass production and harvest index. Grain yield had a positive quadratic relationship with N uptake by grain (r^2= 0.97 and r^2=0.94). The relationship between total N uptake and grain yield was linear for 2015/2016 (r^2=0.98), but quadratic positive relationship was observed in 2016/17 r^2=0.93) and alsoa positive quadratic relationship was observed in 2016/2017 r2=0.93) and showed a high degree of correlation. Grain yields from N_{140} plots was were significantly increased by 39.65% and 41.5% compared to N_0 during 2015/16 and 2016/172017. Results- show- that- both DRR Dhan 44 and DRR Dhan 46 produced higher- grain- yield, had higher N uptake from the soil- in grain and straw and- exhibited- higher NUE compared to DRR Dhan 42 and IR 64 at all the –N -rates (0, 100, 120 or 140 kg ha^{-1}). Agronomic efficiency (ANUE) and recovery efficiency (RE) was higher with DRR Dhan 44 and DRR Dhan 46 and both can be called asere higher with DRR Dhan 44 and DRR Dhan 46, and both can be called nitrogenN economising economizing varieties. However, with increasing the N rates, the use efficiency of applied nitrogen N declined. Also, DRR Dhan 44 was found to be remunerative during both the years and recorded higher net returns and Benefit: Cost ratio. DRR Dhan 44 can be

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Comment [az2]: write the scientific name recommended as a suitable variety for the Telangana zone, adapted to ~~drought~~ drought-prone situations during the dry season.

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Key-words: Direct sown rice; yield; Nitrogen uptake; correlation; B:C ratio

Introduction

Rice (*Oryza sativa* L.) is the ~~major~~ primary food crop of the world and feeds about fifty per-cent of the global population (Fageria, 2007), and it is also the staple food of Asia. Globally, India has the ~~largest~~ most extensive rice area and is second in production after China. The ~~common~~ standard method of rice cultivation is transplanting, and this system requires a large amount of energy~~,~~ labo~~u~~r (Bhushan~~,~~ et al., 2007) and also consumes about 80% of the total irrigated water used in Asia (Bouman and Tuong, 2001) and 34–43% of the ~~world's~~ world's irrigation water (Bouman et al., 2007) and 14.6% of the ~~world's~~ world's fertilizer (Heffer, 2009).~~ ~~ Therefore, there is a need to explore rice production technologies that will eliminate puddling, save labo~~u~~r for transplanting~~ as well as~~, maintain rice yield potential, and be ~~maintain rice yield potential and is~~ sustainable (Thind et al., 2017). A shift from transplanted to ~~direct~~ direct-seeded rice has started occurring in South Asia (Kumar and Ladha, 2011), and the ~~adoption of direct-seeded method for lowland rice culture would significantly decrease costs of rice production~~direct-seeded method for lowland rice culture would significantly decrease rice production costs (Flinn and Mandac, 1986). Among the different resources, ~~nitrogen~~ N ~~play an important role~~is essential in enhancing rice yield. Nitrogen (N) losses and the resulting pollution ~~is becoming a serious global concern and has necessitated for~~are becoming a serious global concern and have necessitated the development of nutrient responsive varieties.

The productivity of ~~direct~~ direct-seeded rice is very low due to ~~inadequate and imbalanced use of nitrogen fertilizers by the farm~~the farmers' inadequate and imbalanced use of N fertilizers. Nitrogen (N) is an ~~important~~ essential nutrient for rice production (Ju et al., 2009) and is required in ~~larger~~ more significant amounts compared to other nutrients (Cassman et al., 2002; Mahajan et al., 2011 b). According to prior reports, the apparent recovery efficiency of applied N fertilizer is only about 33% on ~~an~~ average (Raun and Johnson, 1999; Garnett et al., 2009). The remaining amount of N is lost through different pathways such as surface runoff, leaching as nitrate in groundwater, volatilization to the atmosphere, or denitrification (Vitousek et al., 1997; Raun et al. 1999; Peng et al., 2009; Ju et al., 2009) Low recovery of N fertilizer is the ~~major~~ primary cause for increased costs and environmental degradation (Bijay-Singh and Yadvinder Singh 2003; Fageria and Baligar, 2005; Peng et al.; 2009; Chen XP et al., 2014)~~.~~. ~~The use of efficient and economical rates of nitrogen fertilizer is~~Efficient and economical N fertilizer rates are ~~important~~ essential for enhancing crop productivity and maintaining environmental sustainability.

Variety has a ~~large~~n enormous influence on the grain yield of ~~direct~~ direct-seeded rice. Different varieties exhibit a different response to N fertilizer depending upon their agronomic traits. The development of varieties which can efficiently and economically ~~optimise~~ optimize ~~nitrogen~~ N fertilizer and enhance Nitrogen (N) use efficient varieties are ~~important~~ essential for enhancing crop productivity and maintaining environmental sustainability (Kant et al., 2011; Haegele et al., 2013; Y.L. Chen et al., 2014). Recently ~~a few drought tolerant varieties have been recommended for cultivation under direct seeded condition but their responsiveness at different nitrogen rates has to be studied to come up with a suitable recommendation for~~, a few drought-tolerant varieties have been recommended for cultivation under direct-seeded conditions, but their responsiveness at different N rates has to be studied to develop a suitable recommendation for the Deccan Plateau region of Southern India. Although many studies have investigated the productivity and water-use efficiency of DSR (Zhang et al., 2009; Sudhir-Yadav et al., 2010; Mahajan et al., 2011b), few studies have specifically looked into the interactive effect of ~~nitrogen~~ N and varieties for ~~drought~~ drought-tolerant ~~direct~~ direct-sown rice varieties under Southern Indian conditions. Literature regarding the adaptability of irrigated lowland rice varieties with higher yield potential in direct-seeded rice ~~system~~ systems is still lacking and needs the~~the focus of the researcher~~researchers' focus. ~~Suitable~~ A suitable and sustainable strategy needs to be developed for optimizing nutrient application rates which can be applied to a broader region to obtain sustainable N application rates. The study ~~was taken up with a objective to investigate the~~investigated how N rates influence ~~on~~ different ~~drought~~ drought-tolerant varieties and to understand how varied N rates influenced crop growth, yield, N use efficiency, and profitability to the farmers. This study can provide ~~useful~~ helpful information to ~~the~~ rice growers and achieve higher grain yield and high input use efficiency.

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2 Methodology

2. 1 Experimental site, climate, and soil characteristics

Field experiments were conducted for two consecutive years viz. 2015/2016 and 2016/2017 during the dry season at ~~experimental farm of Indian Institute of rice research~~the Indian Institute of rice research experimental farm, Hyderabad, Telangana, India. The farm is ~~geographically situated~~ at ~~an altitude of~~ 542.7 m above mean sea level on 17°19~~”~~ " N latitude and 78°29~~”~~ " E longitudes. It comes under the Southern Telangana zone. The soil of the ~~the~~ experimental field at the start of the experiment had a Sandy clay loam texture, with a pH of 8.05, organic carbon (0.91%), available N (249 kg ha^{-1}), available P (78.1 kg ha^{-1}), and available K (440.7 kg ha^{-1}). ~~Prior to~~Before ~~the establishment of~~establishing the experiment, the site had been under a rice-rice cropping system for several years.

Comment [az5]: what is this?

2.2 Experimental design, layout, and crop management

The experiment was laid out in a split-plot design with ~~Nitrogen (~~N~~)~~ rates as the main plot and varieties as a sub-plot with three replications for two years. Four ~~nitrogen~~N fertilization rates, viz., 0 kg N ha^{-1} (N_0), 100 kg N ha^{-1} (N_{100}), 120 kg N ha^{-1} (N_{120}), and 140 kg N ha^{-1} (N_{140}), were taken as main plot treatments. The tested varieties were DRR Dhan 42 (V_1), DRR Dhan 44 (V_2), DRR Dhan 46 (V_3), along with check variety IR 64 (V_4) and were assigned to sub-plot and thus, the experiment consisted of sixteen treatment combinations. Rice varieties were chosen mainly based on ~~their~~ better adaptability to the region, optimum growth duration, and ~~strong~~ vital pest and disease resistance. ~~Summarized~~ A summarized description of each variety is presented as~~:~~ DRR Dhan 42 (IR 64 Drt) is a Semi-dwarf; 110-115 days duration; resistant to blast, moderately resistant to bacterial blight, brown spot, and tolerant to drought, especially at flowering and grain filling stage with long slender grain type; DRR Dhan 44 is a semi-dwarf; 110-115 days duration; resistant to blast, moderately resistant to BLB, BPH, and WBPH; tolerant to drought; long slender grain type, good cooking quality and also has good puffing quality (as experienced by farmers of Anantapur district, Andhra Pradesh); DRR Dhan 46 is a Semi-dwarf; 110-115 days duration; shattering tolerant; fertilizer responsive; suitable for early or delayed planting; tolerant to moderate drought; suitable for irrigated/rainfed areas; long slender grain; released for Bihar, Madhya Pradesh and Maharashtra and IR 64 is 120-125 days duration; moderately resistant to BLB, stem borer; resistant to blast; ~~semi~~ semi-dwarf variety with long slender grain type. The rice crop was sown on 06 Jan 2016 in the first year and 17 Jan 2017 in the second year. The plot size for each treatment was 20 m^2 (5 m x 4m). The land was prepared by ~~ploughing once with~~ a mo~~u~~ld-board ~~plough~~plow~~,~~ and ~~followed by~~then harrowing ~~prior to~~before the establishment of the experiment. Nitrogen fertilizer (Urea) was applied in three split doses, 50% at sowing,

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25% at the maximum tillering stage, and 25% at the panicle initiation stage. The P fertiliser fertilizer (DAP) was applied entirely as a basal dose at 60 kg ha^{-1}, and K fertiliser fertilizer (muriate of potash) at 40 kg ha^{-1} was used as a source of potash fertiliserpotash fertilizer source. Cultural practices such as weeding and irrigation were kept uniform for all the experimental treatments to avoid crop damage according to the locally adapted practices. Insects and diseases were controlled according to the locally adapted practices to avoid substantial yield loss.

2.3 Sampling and measurement

At tillering (TL) and flowering (FL) stages, five hills were selected randomly from each plot and tagged to measure agronomic parameters, which included tillers m^{-2}, dry biomass accumulation by shoot (g m^{-2}), and leaf area index (LAI). During the tillering (TL) and flowering (FL) stages, tillers were counted from each hill at three fixed locations in each plot, and biomass was sampled by collecting the fresh shoots with the help of a quadrat (0.25 x 0.25 m) from three locations. Leaf The leaf area index of five individual representative hills was recorded with a digital plant canopy imager to measure the leaf area index. T the measurement of yield attributes viz. Panicles m^{-2}, panicle weight, grain weight, filled grain percentage, and yield was carried out according to the procedure described by Yoshida et al. (1976). Physiological maturity was determined when 80% of the grains had turned into golden-yellow colour. Panicle density was determined with a quadrat (0.25 m × 0.25 m) placed randomly in each plot at four locations. Dried seed samples were drawn randomly from each treatment plot produced, and 100 grains were counted, and their weight was recorded. Before harvest, yield components such as, fertility % and 1000 grain weight (g) were determined. At maturity, each plot was harvested manually, excluding border plants. Crop The crop was harvested on 18th May 2016 in the first year and 24th May 2017 during the second year. After harvest and threshing, the crop produce production was sundried, cleaned, weighed, and dried to 12 to 14 per-cent moisture content in grain. Grain yield was expressed as t ha^{-1} at 14% moisture and then at 0% moisture for calculating N uptake indices. Straw obtained from each net plot area after threshing was sun sun-dried for four days and then weighed and expressed in t ha^{-1} at 0% moisture content. Harvest index was calculated as the ratio of dry grain yield to total biomass at crop harvest.

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Harvest index was calculated by using the following formula

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\quad} \times 100$$

Biological yield (Grain + Straw)

2.4 Nitrogen use efficiencies

The dried samples were ground, and ~~N content in grain and straw was determined by kjeldahl method~~the Kjeldahl method determined N content in grain and straw (Yoshida et al., 1976).~~–~~ N uptake (kg N /ha) of grain and straw was calculated by multiplying Nitrogen content in grain and straw by yield. Recovery efficiency (RE), agronomic ~~nitrogen~~N use efficiency (ANUE), and RE were computed according to the method described by Xue et al., 2013.

$$ANUE = \frac{Y_f - Y_u}{N}$$

where Y_f is the grain yield in the fertilized plot (kg), Yu is the grain yield in the unfertilized plot (kg), and N is the quantity of N applied (kg) and is expressed in kg kg^{-1}.

$RE = (N_f - N_u/N_a) \times 100$

Where~~,~~ N_f is the nutrient accumulation by the total biological yield (grain plus straw) in the fertilized plot (kg), N_u is the nutrient accumulation by the total biological yield (grain plus straw) in the unfertilized plot (kg), and Na is the quantity of nutrient applied (kg)~~.~~ e~~E~~xpressed in %.

The ~~cost~~ cost of production incurred in each treatment was ~~worked out~~calculated by considering the prevailing market price of input used and the produce obtained (grain and straw). The net income was calculated by subtracting the ~~cost~~ cost of cultivation from the gross monetary return. Different values were determined for each treatment as per the details given below:

Gross monetary returns = ~~Cost~~ cost of grain + ~~cost~~ cost of straw

Net monetary returns = Gross monetary returns - Total cost of cultivation

Benefit: cost ratio = Gross return/Total cost of cultivation

2.5 Statistical analyses

The data ~~was~~ were subjected to analysis of variance to determine the influence of treatments (Gomez and Gomez, 1984). Data ~~was~~ were ~~analysed~~ analyzed using analysis of variance (ANOVA) to evaluate the differences among the treatments. The statistical model used included sources of variation due to replication, ~~Nitrogen~~N rates, varieties, and interaction effect of ~~nitrogen~~N rates x varieties. Differences due to treatments were judged by the least significant difference (LSD) at a 5% probability level, and means were separated by Duncans Multiple range test. The relationships between different attributes were assessed using correlation analysis.

3. Results

3.*1 Weather parameters*

The daily average temperature and precipitation during the ~~rice~~ rice-~~growth~~ growing season of both years was measured at an experimental station situated close to the experimental site and is presented in Table 1. The total rainfall during the crop seasons (Jan-May) was 163.0 mm in 2015/2016 and 71.6 mm in 2016/2017. The rainfall was more in ~~May of~~ 2015/2016 (157.4 mm) than in May of 2016/2017 (61.8 mm). Monthly mean maximum and minimum temperatures did not vary ~~greatly~~ significantly in the two years during the rice seasons except in ~~the month of~~ March of 2016/2017, which recorded a higher mean temperature (27.0 ◦C) compared to 2015/2016 (21.5◦C). Maximum temperatures ~~in all the month~~ from Jan-May of 2015/2016 were higher ~~compared to 2016/17 except in March where lower maximum temperature of 32.5◦C was noted in 2015/16 as~~than 2016/2017 except in March, where a lower maximum temperature of 32.5◦C was noted in 2015/2016 compared to 35.7 ◦C in 2016/2017. ~~Average~~ The average maximum temperature during the rice season (Jan-May) ranged from 32.5-42.5◦C in 2015/~~16~~2016 and from 29.3-39.9 ◦C in 2016/2017, while the average minimum temperature ranged from 10.5-20.0 ◦C in 2015/2016 and from 12.2-24.6 ◦C in 2016/2017. The mean daily sunshine hours in February (8.8), March (8.0), and May (8.50) in 2015/~~16~~2016 were lower than in February (9.6), March (8.4), and May (9.3) of 2016/~~17~~2017. Higher mean evaporation was noted in the months of Jan-April of 2015/2016 compared to 2016/2017. Maximum RH ranged from 84-100% and from 60.9-86.9%, whereas minimum RH ranged from 14.0-20.0 in 2015/2016 and 22.5-33.4 in 2016/2017, respectively.

3.2 Biomass accumulation

Biomass accumulation in four rice varieties at TL and FL stages at different N rates during both the years is presented in Fig 1. Shoot dry biomass accumulation– increased with N rate in all the varieties. N_{140} accumulated the highest shoot biomass but showed no apparent difference between N_{140} and N_{120}. The crop of the N_0 plots produced the lowest total biomass gain at both the growth stages and was significantly lower than all N rates in both the years. Biomass at TL increased from 98.70-115.32 g m^{-2} 2015/162016 and from 103.63 to 128.49 g m^{-2} in 2015/2016 and 2016/2017 respectively in DRR Dhan 44.– DRR Dhan 44 recorded the highest biomass irrespective of the N rates, whereas IR 64 recorded the lowest biomass accumulation by a shoot in both the years. At FL stage also, DRR Dhan 44 produced the highest shoot dry matter accumulationDRR Dhan 44 produced the highest shoot dry matter accumulation at the FL stage, with a range of 486.7-636.5 g m^{-2} in 2015/2016 and 491.4-650.2 g m^{-2} in 2016/2017, respectively. DRR Dhan 46 yielded shoot drydry shoot matter ranging from 412.77-571.01 g m^{-2} in 2015/2016 and 467.9-595.7 g m^{-2} in 2016/2017. At all the N application rates, shoot biomass of DRR Dhan 44, and DRR Dhan 46 showed no significant difference. Herein, oOur results demonstrated that DRR Dhan 44 and 46 produced higher shoot biomass at lower N rates. From TL to FL stage, shoot dry matter increased by approximately 4 fourfold during both the years. Biomass accumulation in 2016/2017 was slightly higher compared to 2015/16 during the TL and FL stages respectivelythan in 2015/2016 during the TL and FL stages. Non The nonsignificant interaction between N rate and varieties on shoot biomass at TL and FL stages was recorded.

3.3 Tiller density

The number of tillers varied with different varieties, and significant differences in tiller number was were noted in different varieties. A consistent trend for an increase in tiller density was observed with increasing nitrogenN application rates during both the years with more number of tillers in DRR Dhan 44. At the TL stage, DRR Dhan 44 recorded a tiller density ranging from 343-404 and 362-414 tillers m^{-2} during the first and second year, respectively, at different N rates. Whereas, aAt the FL stage, tiller density ranged from 355 to 467 and 377 to 492 tillers m^{-2} in DRR Dhan 44 during 2015/2016 and 2016/2017 at all the N rates. DRR Dhan 44 and DRR Dhan 46 recorded similar tiller numbers at both the stages of observation. N_{140} had higher tiller production in all the varieties, followed by N_{120}. Interaction The interaction effect between varieties and N rates was non-significant during the flowering stage, but the individual effect of varieties and nitrogenN levels was found to be significant. Higher tiller density was observed in 2016/2017 than in in 2015/2016.

3.4 LAI

~~In consistence~~Consistent with the results on several~~number of~~ tillers, LAI at TL and FL stage increased with the increase in N rates in all the varieties during the two years. The largest LAI was recorded in the variety DRR Dhan 44 at all the N rates (Fig 3). ~~Identical~~ During both years of study, an identical observation trend~~trend of observation during both the years of study~~ was that DRR Dhan 44 showed higher LAI value both at TL and FL stages and was in the range of 1.11-1.19 at TL stage and 4.43-5.53 at FL stage in DRR Dhan 44. N_0 had the lowest LAI in the range of 0.86-1.04 and 2.92-5.53, whereas N_{140} recorded LAI in the range of —1.11-1.30 in 2015/2016 and 4.5-5.53 at TL and FL in 2016/2017.~~–~~ LAI in 2016/2017 was slightly higher than in 2015/2016. ~~Interaction between N rates and varieties was significant at TL and FL stages during both the year~~During both years, the interaction between N rates and varieties was significant at TL and FL stages.

3.5 Yield attributes and yield

~~In general, t~~The grain and straw yield was marginally highe~~he grain and straw yield were marginally higher in second yea~~r in all ~~the~~ varieties (Table). Panicles m^{-2}, Panicle weight, grain weight, filled grain percentage increased with ~~the application of nitroge~~N application, reaching a maximum at N_{140}. All the yield attributes increased significantly up to an ~~nitrogen~~ N level of N_{120}, and a further increase in N level failed to produce significant results. N_{140} and N_{120} resulted in 29.85% and 26.55% more Panicles m^{-2} than N_0 in 2015/2016, while the increase was 29.0% and 25.6%% during 2016/2017, respectively. Filled grain percentage ranged from the ~~the~~ lowest ~~of~~ 79.11 to the highest of 96.45% and from 70.41-93.02% during the first and second years. ~~Grain~~ The grain weight of all ~~the~~ varieties was higher in 2016/2017 than in 2015/2016 and ranged from 2.26-2.62 and 1.87-2.43 in 2015/2016 and 2016/2017. Mean grain yield of all ~~the~~ varieties increased significantly up to N_{120} kg N/ha and ~~thereafter~~ after that remained statistically ~~same~~ same with increased N level but was significantly higher than that of N_0. In contrast, the lowest yield for both ~~the~~ years was observed in the N_0 treatment that received no ~~application of N~~N application in all ~~the~~ cultivars. The results indicated that N_{120} was superior and increased the total yield of rice by 20.28% in 2015/2016 and 25.41 % in 2016/2017, respectively~~, when~~, compared to zero N in~~the~~ control. During the first year, N_{100} and N_{120} resulted in 35.07% and 38.80% higher grain yield than N_0. However, ~~during the second year the respective increase was 36.18% and 39.5%~~the increase was 36.18% and 39.5% during the second year,~~.~~ c~~When c~~ompared to N_0 treatments, mean grain yield in N_{140} increased by 39.65 % in 2015/2016 and 41.56% in 2016/2017, respectively.

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Grain yield differed significantly in varieties in both ~~the~~ years. AmongOf the four promising varieties studied, the difference in yield attributes and yield was significant and different varieties exhibited a consistent response to N rates and values were in the order of DRR Dhan 44> DRR Dhan 46> DRR Dhan 42> IR 64 for both the years. The cultivar DRR Dhan 44 recorded a significantly higher harvest index. Different varieties might respond differently to varying levels of N. Grain yields varied from 3.58-6.30 t ha^{-1} and 3.64-7.03 t ha^{-1} for DRR Dhan 44 in 2015/2016 and 2016/2017 and from 3.55-6.01 and 3.43-5.90 t ha^{-1} for DRR Dhan 46 respectively. Grain yield was ~~very~~ similar between DRR Dhan 44 and DRR Dhan 46 at the same N rate. Both DRR Dhan 44 and DRR Dhan 46 produced the ~~same~~ exact grain yield when N rate was 0, 100, 120, or 140 kg N ha^{-1}. Grain yields of all the four varieties ranged from 3.38-6.30 t ha^{-1} in 2015/2016 and 3.16-7.03 t ha^{-1} in 2016/2017, respectively. ~~Lowest~~ The lowest yield was recorded in IR 64, ranging from 3.38-5.30 t ha^{-1} in the first year and 3.31-5.44 t ha^{-1} in the second year. A higher grain yield for DRR Dhan 44 and DRR Dhan 46 at all the N rates (0–140 kg ha^{-1}) can be mainly attributed ~~either~~ to a higher number of panicles per square meter or a higher filled grain percentage. In both the years, the interaction between varieties and N rates on grain yield was ~~not~~ insignificant (Table 3). Straw yield followed a similar trend as ~~that of~~ grain yield during both the years, and DRR Dhan 44 recorded a higher straw yield. N rate X Varieties interaction for grain straw yield significant during both the years but significant response for harvest index between the treatments was not observed in either of the years.

3.6 Nitrogen uptake by different parts and use efficiency

The nitrogen (N) fertilization significantly affected the ~~nitrogen~~N uptake by different v~~V~~arieties (grain + straw) during 2015/2016 and 2016/2017. The interactions between N rates and Varieties were significant for grain and total N uptake (Fig.4 i & ii). Results indicated that ~~nitrogen~~N uptake ~~clearly~~ followed the yield pattern. Grain and total N uptake increased with the application of N rates in all the v~~V~~arieties except at N0. Total ~~nitrogen~~N uptake had a significant response to N fertilization in different varieties (Table 4 i & ii), and N uptake increased significantly with increased N application and was highest in N_{140} followed by N_{120} and was lowest in N_0. The highest N uptake was with variety DRR Dhan 44 and was closely followed by DRR Dhan 46. Similar to grain yield and total ~~nitrogen~~N uptake, ANUE and RE w~~as significantly higher for both DRR Dhan 44 and DRR Dhan 46 at all the~~ere significantly higher for DRR Dhan 44 and DRR Dhan 46 at all N rates. ANUE varied from 13.52-22.2 kg kg^{-1} and 14.21-22.56 kg kg^{-1}; RE ranged from 38.08-45.12% and 31.96-46.33% in

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2015/~~16~~2016 and 2016/20~~~~17 respectively (Table 4 i & ii). ~~At all the N rates, DRR Dhan had higher RE~~DRR Dhan had higher RE at all the N rates, whereas it was lower in other varieties. During both the years, ANUE and RE declined with increasing N rates. IR 64 and DRR Dhan 42 exhibited lower NUE~~,~~ at~~-~~ all the N rates ~~compared to~~than the other two varieties.

3.7 Relationship between N uptake, grain yield, and ANUE

Grain yield was positively correlated ~~relationship~~ with N uptake with r^2=0.97 for 2015/~~16~~2016 and 0.94 for 2016/~~17~~2017, respectively (fig 4 i). Similarly, the co-~~~~rrelation between total N uptake and grain yield also exhibited a significant positive relationship with a high degree of correlation with an r^2 value~~-~~ of 0.98 for the first year and 0.93 for the second year, demonstrating that the grain yield increased with an increase in ~~nitrogen~~N rates up to 140 kg/ha (fig 4 ii).~~-~~ However, the relationship between total N uptake and grain yield was linear for the first year, whereas a quadratic relationship was observed during the second year. The relationship between grain yield and anue was ~~observed to be positively associated with r^2= 0.39 for first year and r^2=0.48 for~~positively associated with r2= 0.39 for the first year and r2=0.48 for the second year with the quadratic response (fig 4 iii).

3.8 Net returns and B:C ratio

Among the varieties, DRR Dhan 44 was ~~found to be~~ most remunerative and recorded the highest gross and net returns a~~s well as B:C ratio which was~~nd B:C ratio similar to DRR Dhan 46 but significantly higher than DRR Dhan 42 and IR 64 (fig 5). N_{140} was the costliest treatment. B:C ratio was 2.65 for 2015/~~16~~2016 and 2.30 for 2016/~~17~~2017 in DRR Dhan 44 at N_{140} and thus recorded higher profitability (Fig 5).

Discussion

Genotypic variance in rice to N fertilization

Direct seeded rice is a new and emerging production system that aims to make rice production more sustainable and profitable than conventional transplanted rice and helps in reducing labo~~u~~r requirements and ~~economises~~ economizing water (Kumar and Ladha, 2011). Significant variation was reported among rice varieties ~~with respect to~~concerning growth, yield attributes, yield, and ~~nitrogen~~N use efficiency parameters and is in~~ consistence~~ consistent with the previous works (Ju et al., 2015; Zhang Ya-Li et al., 2009). ~~Difference~~ The difference in growth and yield attributes is mainly due to the difference in the genetic constitution of the variety. Among the~~Of the~~ four promising varieties studied, DRR Dhan 44

Comment [az9]: what is this word?

had a higher panicle weight, which remained close to DRR Dhan 46 and ~~is in agreement with the researches~~agreed with the research carried out at different locations (DRR Annual report, 2015/~~16~~2016). The N_{140} registered the highest dry biomass accumulation, tillers m^{-2}, LAI, yield attributes, and yield. Higher dry matter production can be attributed to higher leaf area and more ~~number of~~ tillers m^{-2}. However, N_{120} remained comparable to the best treatment of N_{140}. ~~Difference~~ The difference in yield during both ~~the~~ years can be attributed to variation ~~in environmental situations during both the years~~s in environmental situations (Fageria, 1992). The N_{120} has contributed to the higher grain yield of DRR Dhan 44 (DRR Annual report 2015-~~16~~2016). Koutroubas and Ntanos (2003) reported that more than 50% of the total variation in grain yield was due to variation in the number of panicles and suggested that the most ~~important~~ critical determinant of grain yield is the number of productive tillers.

Yield components increased with increasing N rate and are in corroboration with the studies of Pan et al. (2012). Superior yield response from DRR Dhan 44 during both ~~the~~ years can be attributed to better yield attributes. Consistent with the results from our study, the DRR Progress report, 2015, reported that DSR responded to fertilizer N up to 140 kg N ha^{-1}. Yield differences with each incremental N rates ~~has~~ have also been reported by Wang et al., 2002 and Wang et al., 2012. Contrary to our reports, IIRR Progress reports and Ali et al., 2015 have reported that the maximum grain yield of DSR was observed at ~~the rate of~~ 150 kg N ha. The trend of g~~G~~rain N uptake was similar to grain yield; thus, total N uptake was significantly influenced by grain N uptake resulting in the highest total uptake in DRR Dhan 44. Therefore we speculate that an improved shoot growth leading to larger biomass at lower N rates, contributes to a higher grain yield for DRR Dhan 44 and 46. The significant difference in N uptake among the cultivars and grain yield/ unit of applied N might be due to their genetic characteristic and differential performance in growth and development (Kant et al., 2011). Chen et al., 2015 reported that greater N uptake stimulated the production of more ~~number of~~ panicles m^{-2} and thus higher grain yield. According to Tirol Padre et al.1996, variability in N uptake and yield can be attributed to the ~~differences in N uptake and use efficiency by the varieties~~varieties' differences in N uptake and use efficiency.

In our study, agronomic efficiency ranged between 13.52-22.21 and 14.21-22.56, whereas recovery efficiency ranged from 38.08-45.12 and 31.96-46.33 % in 2015/~~16~~2016 and 2016/~~17~~2017, respectively, which is ~~in~~ consistence with the prior reports (Peng et al., 2002). It has been found that the agronomic efficiency in farmer's rice fields in Asia ranges from 10 to 35 kg grain kg^{-1} N applied, and recovery efficiency ranges from 30 to 50% of the applied N (Dobermann and Fairhurst, 2000). Various studies have reported significant differences in N uptake and N use efficiency among the genotypes (Tirol Padre et al., 1996, Koutroubas and Ntanos, 2003, Ju et al., 2015). It was observed that at higher N rates all the N use efficiency parameters declined which is in consistence, all the N use efficiency parameters declined, consistent with the results of the prior reports (Ju et al., 2015). This decrease can also be attributed to progressive decrease in crop response to applied fertilisera progressive decrease in crop response to applied fertilizers (Fageria, 1992). The agronomic use efficiency of N applied in fertilisfertilizer always continuously decreases as the N-application rate increases (Zhang et al., 2008; Zhang et al., 2015a, Ahmed et al., 2016, Thind et al.2017). Higher N uptake in DRR Dhan 44 is because of its higher grain yield and higher N concentration in grain. Many studies have demonstrated that a significant genetic variability exists among the varieties for NUE (Tirol-Padre et al., 1996; Koutroubas and Ntanos, 2003; Hafele at et al., 2008; Wu et al., 2016). Samonte et al., 2006 and Wu et al., 2016 also observed a quadratic relationship between grain yield and agronomic nitrogenN use efficiency, and similar results were reported in our study. A close correlation between N uptake and crop yield has also been documented by Witt et al. (2000) and Timsina et al. (2006). The higher harvest index in DRR Dhan 44 is reveals that photosynthates were transported to grain efficiently. We observed that grain yield was significantly and positively co correlated with total N uptake, and similar results were also reported by Wu et al., 2016.

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Conclusion

Grain yield of around more than 6.0 t ha^{-1} under direct direct-sown conditions can be reached under proper NitrogenN management and use of appropriate varieties suited to the location with better drought responsiveness and nutrient use efficiency. Higher shoot biomass, tillers, and greater leaf area are the major significant contributors to higher grain yield and thereby increase the, N uptake, and utilisation utilization efficiency. Our findings suggest that optimum rice yields for direct-seeded rice can be obtained by selectingselection of a suitable variety with the use ofusing optimum N rates, which will greatly significantly facilitate the wide broad adoption of this technology in Southern India. Results from this study indicateThis study indicates that genotype differences in NUE existed among different drought drought-tolerant rice varieties; therefore, NUE of different cultivars could be a useful valuable tool to adopt the appropriate cultural practices for achieving higher yield and nutrient response.

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. Table 1: Weather parameters for the year 2015/2016 and 2016/~~17~~2017*

Month	2015/~~16~~2016								2016/~~17~~2017							
	Rainfall (mm)	Temperature (^{0}C)			Relative humidity		Evaporation (mm)	Sunshine (hrs)	Rainfall (mm)	Temperature (^{0}C)			Relative humidity		Evaporation (mm)	Sunshine (hrs)
		Max	Min	Mean	Max (%)	Min (%)				Max	Min	Mean	Max (%)	Min (%)		
January	0.0	32.5	10.5	21.5	91.0	20.0	3.8	8.3	0	29.3	12.2	20.75	86.9	33.4	3.7	8
February	0.0	37.0	12.0	24.5	91.0	18.0	5.8	8.8	0	32.6	13.6	23.1	79.3	26.7	5.1	9.6
March	3.0	32.5	10.5	21.5	91.0	20.0	6.8	8.0	5.6	35.7	18.2	26.95	73.7	24.7	6.5	8.4
April	2.6	42.5	20.0	31.25	84.0	14.0	8.7	9.3	4.2	39.9	22	30.95	60.9	22.5	8.1	9.1
May	157.4	41.5	18.5	30.0	100.0	20.0	7.8	8.5	61.8	39.7	24.6	32.15	63.7	28.9	8.4	9.3

**Rainfall, Sunshine hours, temperature, and Relative humidity during the ~~rice~~ rice-growing season of (A) 2015/~~16~~2016 (B) 2016/~~17~~2017 in Hyderabad, Telangana, India. Rainfall, Sunshine hours are monthly totals, whereas temperature data ~~is~~ are monthly averages.*

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Table 2 (i): Influence of Nitrogen levels and short duration ~~drought~~ drought-tolerant varieties on yield attributes and yield of rice for the year 2015/~~16~~2016

Treatment	No.of Panicles m^{-2}					Panicle weight(g)					Test weight (g)					Filled grain percentage (%)				
	N-Levels					N-Levels					N-Levels					N-Levels				
	N0	**N100**	**N120**	**N140**	**Mean**	**N0**	**N100**	**N120**	**N140**	**Mean**	**N0**	**N100**	**N120**	**N140**	**Mean**	**N0**	**N100**	**N120**	**N140**	**Mean**
DRR-Dhan 42	282	340	390	413	356	1.82	2.09	2.09	2.15	2.03	2.26	2.46	2.48	2.62	2.45	84.00	86.89	89.91	92.90	88.42
DRR-Dhan 44	310	377	423	440	388	2.20	2.59	2.99	3.19	2.74	2.09	2.12	2.25	2.26	2.18	85.45	88.65	93.81	96.45	91.09
DRR-Dhan 46	307	373	407	430	379	1.82	2.47	2.59	2.59	2.36	2.06	2.40	2.41	2.58	2.36	85.06	88.43	93.36	94.81	90.42
IR64	287	335	390	403	354	1.86	1.93	1.99	2.01	1.94	2.24	2.27	2.37	2.52	2.35	79.11	82.26	84.54	85.24	82.79
MEAN	296	356	403	422	-	1.92	2.27	2.41	2.40	-	2.16	2.31	2.37	2.49	-	83.41	86.56	90.41	92.35	-
LSD (0.05) N rates= 41, Variety= 20 , N X V=NS						N rates= 1.66, Variety= 0.79 , N X V=					N rates= 0.10, Variety= 0.12, N X V=NS					N rates= 2.88, Variety=2.30 , N X V=NS				

Table 2 (ii): Influence of Nitrogen levels and short duration ~~drought~~ drought-tolerant varieties on yield attributes of rice for the year 2016/~~17~~2017

Treatment	No.of Panicles m^{-2}					Panicle weigh t(g)					Test weight (g)					Filled grain percentage (%)				
	N-Levels					N-Levels					N-Levels					N-Levels				
	N0	**N100**	**N120**	**N140**	**Mean**	**N0**	**N100**	**N120**	**N140**	**Mean**	**N0**	**N100**	**N120**	**N140**	**Mean**	**N0**	**N100**	**N120**	**N140**	**Mean**
DRR-Dhan 42	304	364	400	426	374	2.04	2.13	2.35	2.60	2.28	1.94	2.11	2.15	2.29	2.12	74.36	86.00	89.84	93.74	86.00
DRR-Dhan 44	322	393	438	459	403	2.20	2.22	2.67	2.87	2.50	2.12	2.34	2.38	2.43	2.32	91.05	91.50	92.45	93.02	92.00
DRR-Dhan 46	318	392	423	448	395	2.13	2.18	2.57	2.62	2.40	2.04	2.14	2.19	2.30	2.17	79.62	83.87	85.19	88.24	84.23
IR64	300	359	409	417	371	1.65	1.80	2.96	2.37	2.20	1.87	1.89	1.91	2.17	1.96	70.41	79.33	81.70	85.23	79.16
MEAN	311	377	418	438	-	2.00	2.08	2.63	2.61	-	1.99	2.12	2.16	2.30	-	78.86	85.17	87.30	90.05	-
CDM	N rates=26.5, variety=20.09, N X V=NS					N rates=0.07, variety=0.08, N x V =NS					N rates=0.09, variety=0.15, N X V= NS					N rates=2.94, variety=2.70, N X V= NS				

Table 3 (i): Influence of Nitrogen levels and short duration ~~drought~~ drought-tolerant varieties on yield and harvest index of rice for the year 2015/~~16~~2016

Treatment	Grain yield (t ha^{-1})					Straw yield (t ha^{-1})					Harvest index (%)				
	N-Levels					N-Levels					N-Levels				
	N0	**N100**	**N120**	**N140**	**Mean**	**N0**	**N100**	**N120**	**N140**	**Mean**	**N0**	**N100**	**N120**	**N140**	**Mean**
DRR-Dhan 42	3.38	5.24	5.45	5.60	4.92	5.44	6.52	7.84	7.80	6.75	34.5	44.6	41.0	41.8	40.48
DRR-Dhan 44	3.58	5.80	6.00	6.30	5.42	5.44	7.96	8.26	8.68	7.58	39.7	42.2	42.10	42.10	41.53

DRR-Dhan 46	3.55	5.40	5.65	5.95	5.14	6.73	7.62	7.92	8.01	7.57	34.5	41.5	41.63	42.62	40.06
IR64	3.40	5.00	5.15	5.30	4.71	5.28	7.20	7.34	7.66	6.87	32.8	41.0	41.20	40.90	38.98
MEAN	3.48	5.36	5.56	5.79		5.27	7.32	7.84	7.88	-	35.38	42.33	41.48	41.86	
	N rates= 0.27 , varieties= 0.29**, N X V= NS					N rates= 0.30, varieties= 0.25, N X V= 0.39					N rates=NS , varieties=NS, N X V=NS				

Table 3 (ii): Influence of ~~N~~nitrogen levels and short duration ~~drought~~ drought-tolerant varieties on yield and harvest index of rice for the year 2016/~~17~~2017

Treatments	Grain yield (t ha^{-1})					Straw yield (t ha^{-1})					Harvest index (%)				
	N-Levels					N-Levels					N-Levels				
	N0	**N100**	**N120**	**N140**	**Mean**	**N0**	**N100**	**N120**	**N140**	**Mean**	**N0**	**N100**	**N120**	**N140**	**Mean**
DRR-Dhan 42	3.31	5.37	5.65	5.85	5.05c	6.58	7.73	7.01	7.46	7.20	33.49	40.16	42.52	43.96	40.03
DRR-Dhan 44	3.64	5.90	6.32	6.60	5.62a	6.69	8.14	8.01	9.01	7.96	36.10	40.13	44.83	43.87	41.23
DRR-Dhan 46	3.63	5.71	6.02	6.20	5.39b	6.59	7.22	7.71	8.72	7.56	34.23	41.92	42.15	40.37	39.67
IR64	3.46	5.00	5.20	5.44	4.78d	5.07	6.13	6.94	7.02	6.29	30.91	40.35	43.14	45.98	40.10
MEAN	3.51d	5.50c	5.80b	6.02a	-	6.23	7.31	7.42	8.05	-	33.68	40.64	43.16	43.55	-
CDM	N rates= 0.22 , varieties= 0.27, N X V=NS					N rates= 0.49 , varieties= 0.35, N X V=0.71					N rates= NS, varieties= 4.23, N X V=NS				

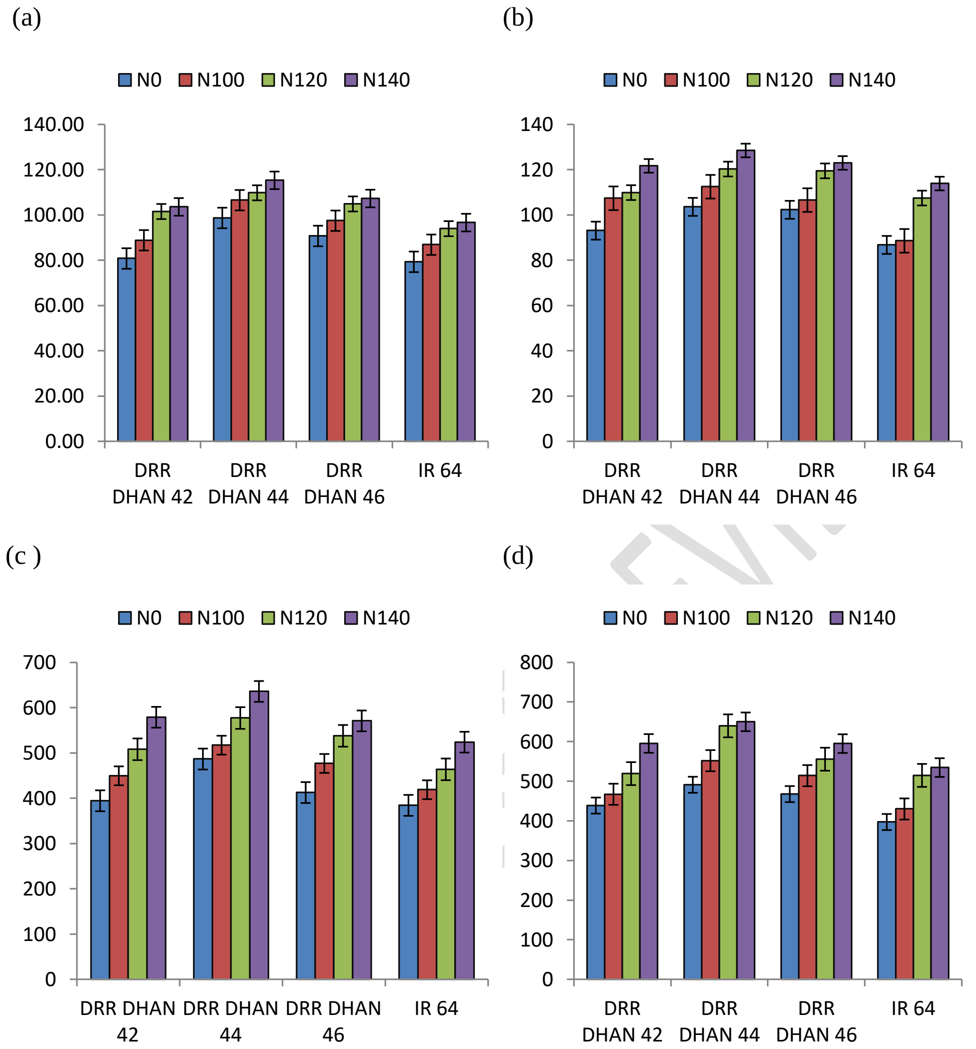
Table 4 (i): Influence of short duration ~~drought~~ drought-tolerant varieties and n~~N~~itrogen levels on p~~P~~hysiological and n~~N~~itrogen use indices of rice 2015/~~16~~2016

Treatments	Total nitrogen uptake (kg ha^{-1})					RE (%)*					ANUE (kg grain kg^{-1})*				
	N-Levels					N-Levels					N-Levels				
	N0	**N100**	**N120**	**N140**	**Mean**	**N0**	**N100**	**N120**	**N140**	**Mean**	**N0**	**N100**	**N120**	**N140**	**Mean**
DRR-Dhan 42	77.36	120.06	125.90	133.0	114.08	-	42.70	40.45	39.74	40.96	-	18.6	17.25	17.57	17.81
DRR-Dhan 44	83.19	128.31	135.44	143.21	122.54	-	45.12	43.54	42.87	43.84	-	22.21	20.17	19.43	20.60
DRR-Dhan 46	77.67	122.65	129.57	136.79	116.67	-	44.98	43.25	42.22	43.48	-	18.50	17.5	17.14	17.71
IR64	66.68	108.64	114.54	120.0	102.47	-	41.96	39.88	38.08	39.97	-	16.07	14.58	13.52	14.72
MEAN	76.23	119.92	126.36	133.25	115.20	-	43.69	41.78	40.73	-		18.85	17.38	16.92	-
LSD (0.05)	N rates =5.72, varieties=5.33, N X V=NS					-					-				

Table 4 (ii): Influence of short duration ~~drought~~ drought-tolerant varieties and Nitrogen levels on Physiological and Nitrogen use indices of rice 2016/~~17~~2017

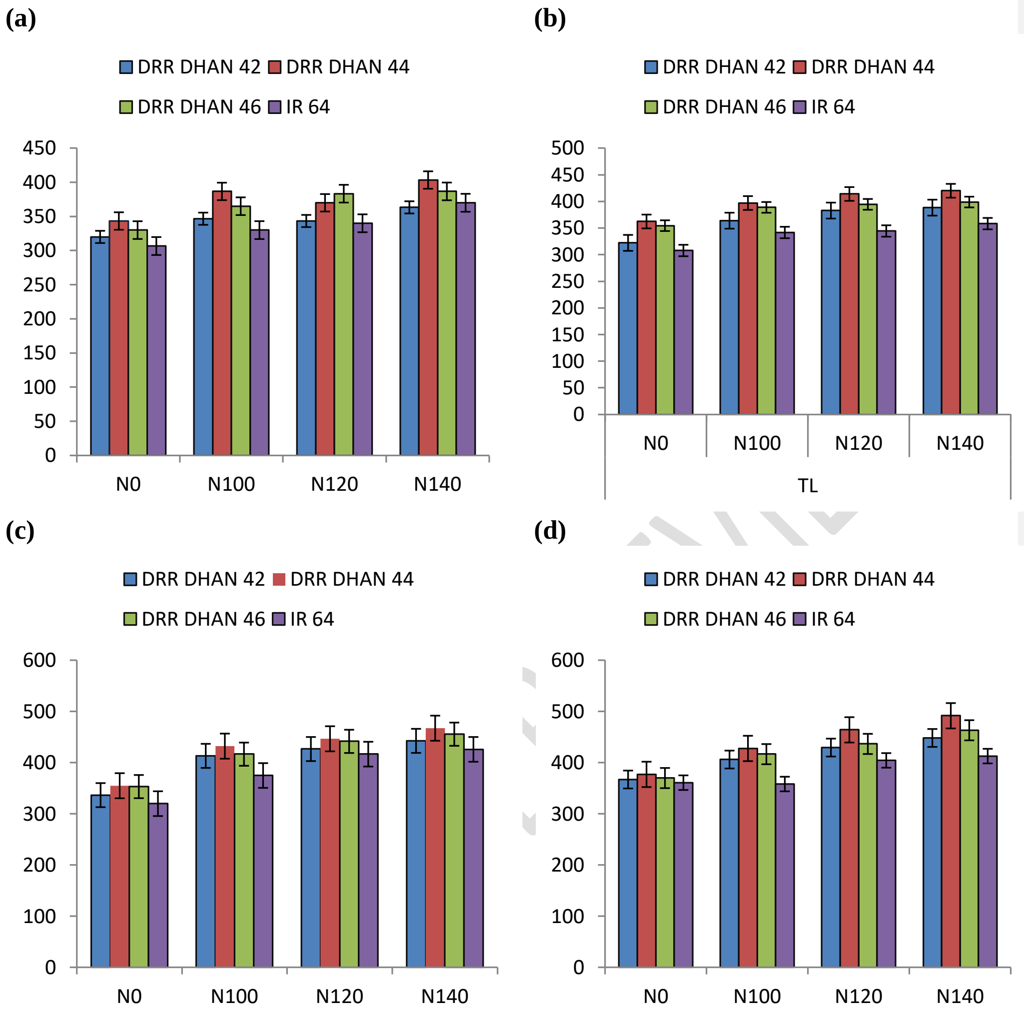
Treatments	**Total nitrogen uptake (kg ha^{-1})**					**RE (%)***					**ANUE (kg grain kg^{-1})***				
	N-Levels					**N-Levels**					**N-Levels**				
	N0	**N100**	**N120**	**N140**	**Mean**	**N0**	**N100**	**N120**	**N140**	**Mean**	**N0**	**N100**	**N120**	**N140**	**Mean**
DRR-Dhan 42	84.6	117.9	125.7	130.0	114.55b	-	33.32	34.25	32.44	33.34	-	20.56	19.47	18.11	19.38
DRR-Dhan 44	97.0	143.3	150.5	154.0	136.20a	-	46.33	44.64	40.75	43.91	-	22.56	22.30	21.11	21.99
DRR-Dhan 46	87.1	122.50	127.8	133.3	117.68b	-	35.44	33.96	32.97	34.12	-	20.8	19.91	18.35	19.69
IR64	78.8	115.60	119.0	123.5	109.23c	-	36.84	33.53	31.96	34.11	-	15.5	14.60	14.21	14.77
MEAN	88.68a	124.83b	130.75c	135.20d	-	-	37.98	36.60	34.53	-	-	19.86	19.07	17.95	-
CDM	N rates= 5.05 , varieties= 3.69, N X V= NS					-					-				

* Data not statistically ~~analysed~~analyzed



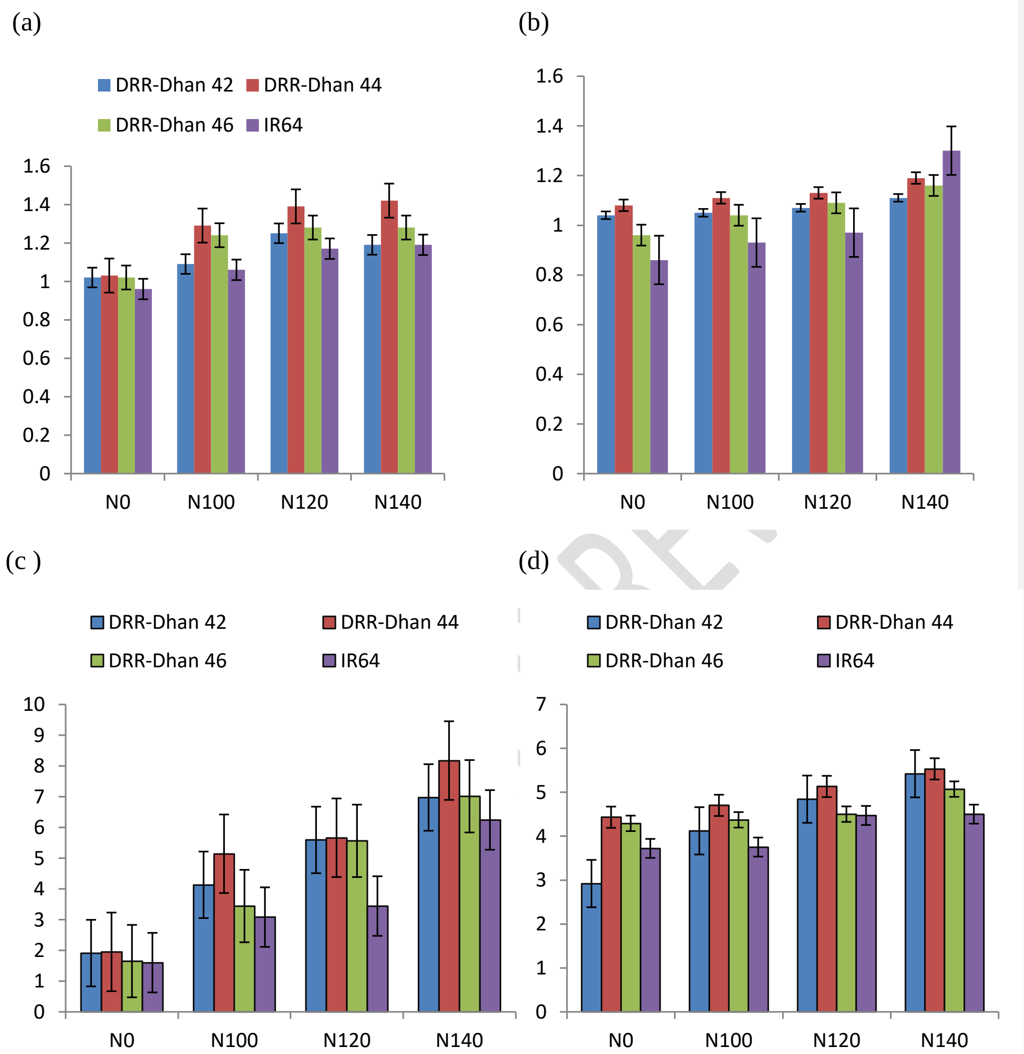
	2015/~~16~~2016				2016/~~17~~2017		
	stage	**N rates**	**Variety**	**N X V**	**N rates**	**Variety**	**NX V**
Shoot dry biomass m^{-2}	TL	4.71***	5.92***	NS	3.63***	4.26***	*
	FL	58.34***	41.71**	NS	28.50***	22.27***	NS

Fig 1: Interaction effect of N rates and varieties on shoot biomass accumulation at tillering (TL) and flowering stage (FL) respectively (a) 2015/~~16~~2016 Tillering stage (b) 2016/~~17~~2017 Tillering stage (c) 2015-~~16~~2016 Flowering stage (c) 2016/~~17~~2017 Flowering stage . ***** significant at p=0.05 ** p=0.001 and *** p <0.0001



		2015/~~16~~2016			2016/~~17~~2017		
	stage	N rates	Variety	NX V	N rates	Variety	NX V
Tillers m^{-2}	TL	24.71**	16.28***	NS	21.45*	14.724*	*
	FL	23.58***	20.46 ***	NS	15.45***	14.40***	NS

Fig 2: Interaction effect of N rates and varieties on number of tillers m^{-2} at tillering (TL) and flowering stage (FL)respectively (a) 2015/2016 Tillering stage (b) 2016/~~17~~2017 Tillering stage (c) 2015/~~16~~2016 Flowering stage (d) 2016/~~17~~2017 Flowering stage. ***** significant at p=0.05, *p=*** 0.001 *and p=**** at <0.001



		2015/2016			2016/~~17~~2017		
	stage	N rates	Variety	NX V	N rates	Variety	NX V
Leaf area Index	TL	0.185**	0.094*	**	0.023***	0.021***	***
	FL	0.64***	0.72**	**	0.187***	0.132***	***

Fig 3: Interaction effect of N rate and varieties on leaf area index at tillering (TL) and flowering (FL) stages (a) 2015/~~16~~2016 Tillering stage (b) 2016/~~17~~2017 Tillering stage (c) 2015/~~16~~2016 Flowering stage (d) 2016/~~17~~2017 Flowering stage. Vertical bars represent the

standard error of means at a 5% ~~level of probability~~probability level. * significant at p=0.05, *p=*** 0.001 *and p=**** at <0.001

(a) (b)

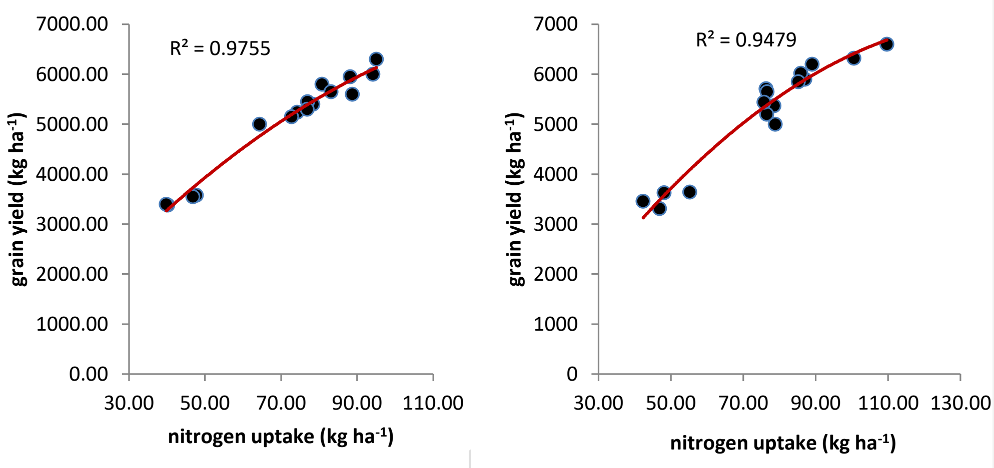


Fig 4 (i): Relationship between N uptake by grain and grain yield of four rice varieties (a) 2015/~~16~~2016 (b) 2016/~~17~~2017

(a) **(b)**

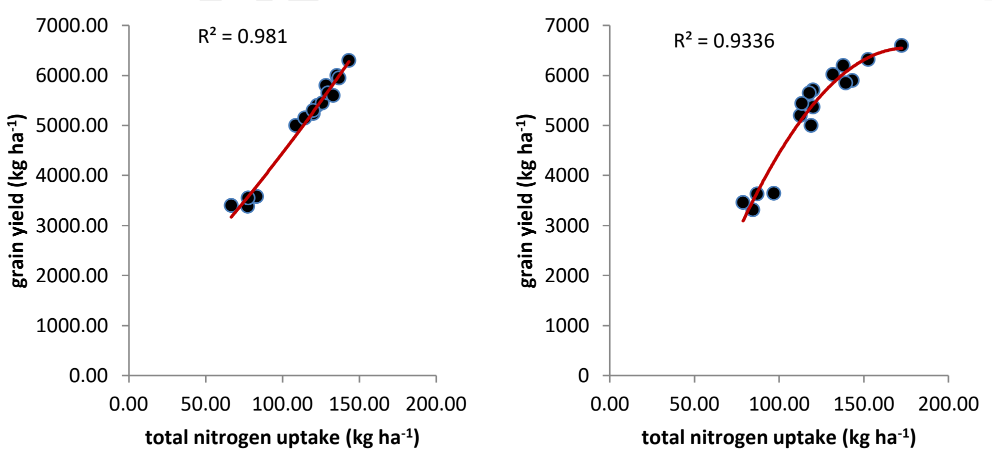


Fig 4 (ii): Relationship between Total N uptake and grain yield of four rice varieties (a) 2015/~~16~~2016 (b) 2016/~~17~~2017

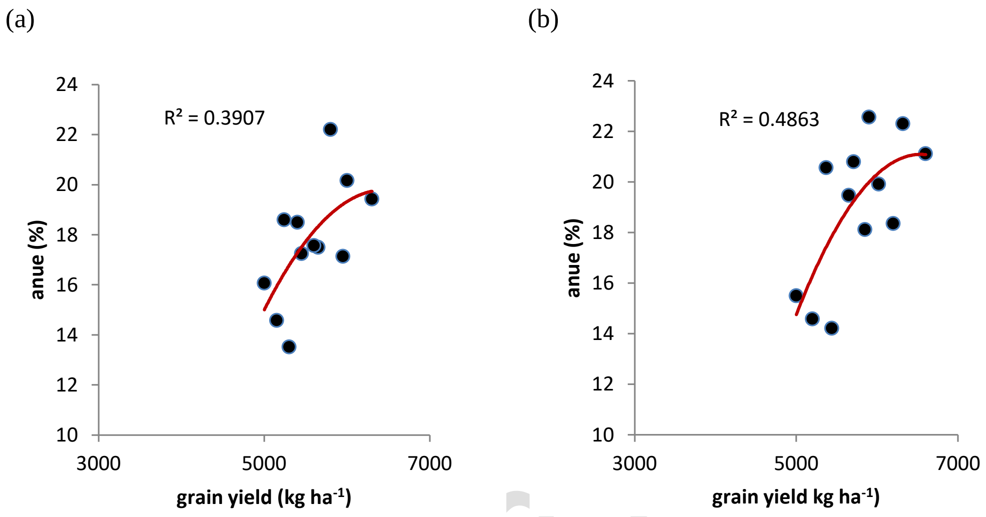


Fig 4 (iii): Relationship between grain yield and agronomic nitrogen use efficiency (n=12)(a) 2015/~~16~~2016 (b) 2016/~~17~~2017

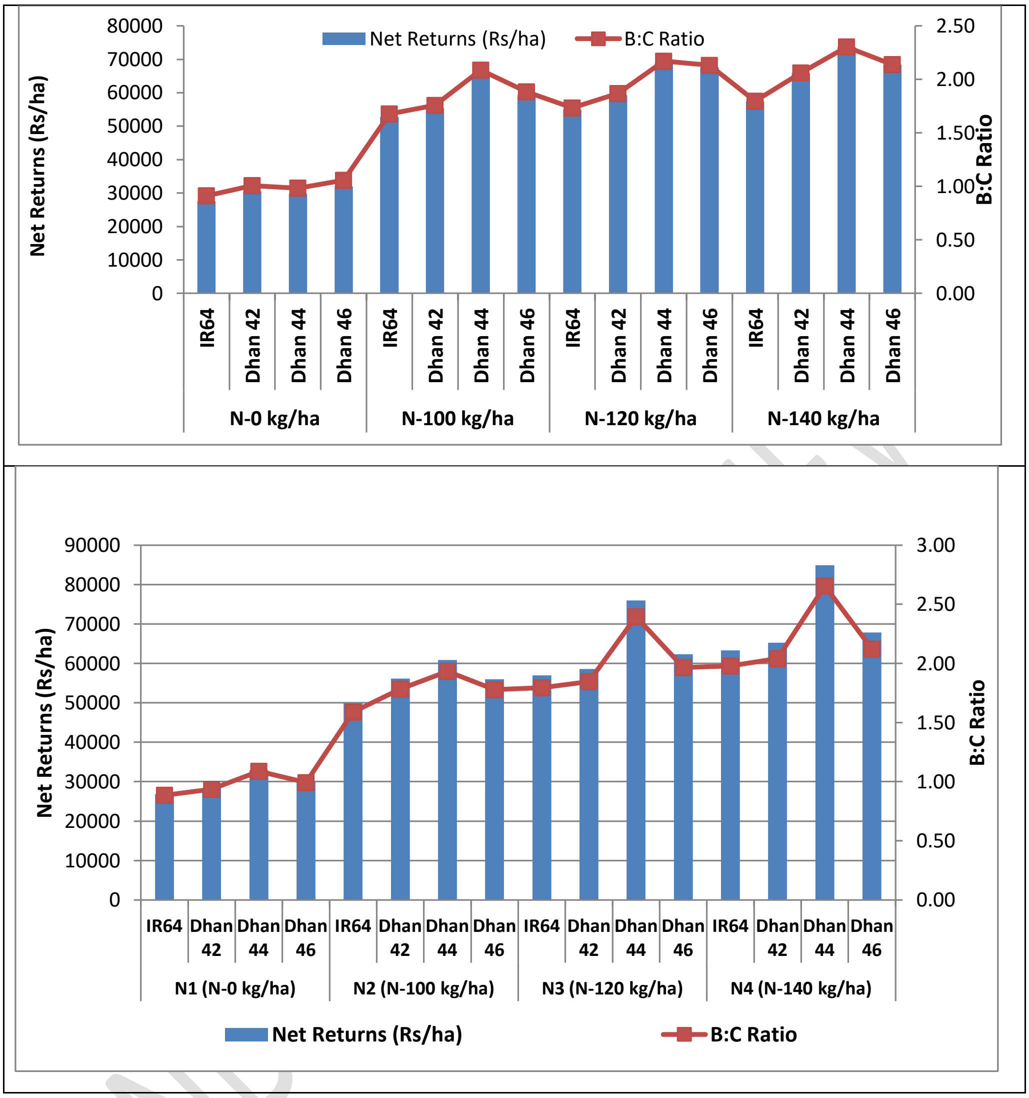


Fig 5: Gross returns, net returns, and B:C ratio of different varieties at varying nitrogen rates (a) 2015/~~16~~2016 (b) 2016/~~17~~2017