Assessing the growth, yield, nutrient use efficiency and profitability of drought tolerant rice varieties in dry season under varied N application rates

Abstract

Field experiments were carried out at ICAR- Indian Institute of Rice Research, Hyderabad (ICAR-IIRR), Hyderabad during the dry season of 2015/16 and 2016/17 to study the influence of Nitrogen rates and Varieties on yield attributes, yield, nitrogen use efficiency and economics of puddled direct sown rice with an aim to assess the performance under direct sown conditions to identify suitable varieties for direct sown conditions during the dry season. Treatments comprised of four rates of nitrogen- 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 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 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} was not observed. When compared with DRR Dhan 42 or IR 64, DRR Dhan 44 and 46 accumulated greater shoot biomass, tillers m^{-2} and higher leaf area. 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 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 2015/16 (r^2=0.98) but quadratic positive relationship was observed in 2016/17 r^2=0.93) and also showed a high degree of correlation. Grain yields from N_{140} plots was significantly increased by 39.65% and 41.5% compared to N_0 during 2015/16 and 2016/17. 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 as nitrogen economising varieties. However, with increasing the N rates, use efficiency of applied nitrogen 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 recommended as a suitable variety for Telangana zone, adapted to drought prone situations during the dry season.

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

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Introduction

Rice (*Oryza sativa* L.) is the major 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 rice area and second in production after China. The common method of rice cultivation is transplanting and this system requires large amount of energy, labour (Bhushan, et al., 2007) and also consumes about 80% of total irrigated water used in Asia (Bouman and Tuong, 2001) and 34–43% of the world's irrigation water (Bouman et al., 2007) and 14.6% of the world's fertilizer (Heffer, 2009). Therefore, there is a need to explore rice production technologies that will eliminate puddling, save labour for transplanting as well as maintain rice yield potential and is sustainable (Thind et al. 2017). A shift from transplanted to 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 (Flinn and Mandac, 1986). Among the different resources, nitrogen play an important role in enhancing rice yield. Nitrogen losses and the resulting pollution is becoming a serious global concern and has necessitated for the development of nutrient responsive varieties.

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The productivity of direct seeded rice is very low due to inadequate and imbalanced use of nitrogen fertilizers by the farmers. Nitrogen (N) is an important nutrient for rice production (Ju et al., 2009) and is required in larger 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 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 important for enhancing crop productivity and maintaining environmental sustainability.

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Variety has a large influence on the grain yield of 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 nitrogen fertilizer and enhance Nitrogen use efficient varieties are important 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 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 and varieties for drought tolerant 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 is still lacking and needs the focus of the researchers. 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 N rates influence on different 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 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 2016/17 during the dry season at experimental farm of Indian Institute of rice research, 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 experimental field at the start of the experiment had 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 the establishment of the experiment, the site had been under rice-rice cropping system for several years.

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2.2 Experimental design, layout and crop management

The experiment was laid out in split-plot design with Nitrogen (N) rates as main plot and varieties as sub plot with three replications for two years. Four nitrogen 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 pest and disease resistance. 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 dwarf variety with long slender grain type. The rice crop was sown on 06 Jan 2016 in first year and 17 Jan 2017 in second year. The plot size for each treatment was 20 m^2 (5 m x 4m). The land was prepared by ploughing once with mould board plough, followed by harrowing prior to establishment of the experiment. Nitrogen fertilizer (Urea) was applied in three split doses, 50% at sowing, 25% at maximum tillering stage and 25% at panicle initiation stage. The P fertiliser (DAP) was applied entirely as a basal dose at 60 kg ha^{-1} and K fertiliser (muriate of potash) at 40 kg ha^{-1} was used as a source of potash fertiliser. 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 area index of five individual representative hills was recorded with a digital plant canopy imager to measure the leaf area index. 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 produce 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 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 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 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

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

2.4 Nitrogen use efficiencies

The dried samples were ground and N content in grain and straw was determined by kjeldahl method (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 use efficiency (ANUE) and RE were computed according to the method described by Xue et al., 2013.

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

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= $(N_f\text{-}N_u/N_a)$ X 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). Expressed in %.

The cost of production incurred in each treatment was worked out 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 of cultivation from the gross monetary return. Different values were determined for each treatment as per details given below:

Gross monetary returns = Cost of grain + cost of straw

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

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

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2.5 Statistical analyses

The data was subjected to analysis of variance to determine the influence of treatments (Gomez and Gomez, 1984). Data was analysed using analysis of variance (ANOVA) to evaluate the differences among the treatments. The statistical model used included sources of variation due to replication, Nitrogen rates, varieties and interaction effect of nitrogen rates x varieties. Differences due to treatments were judged by least significant difference (LSD) at 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 rice growth season of both years was measured at a 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 2015/16 and 71.6 mm in 2016/17. The rainfall was more in May of 2015/16 (157.4 mm) than in May of 2016/17 (61.8 mm). Monthly mean maximum and minimum temperatures did not vary greatly in the two years during the rice seasons except in the month of March of 2016/17 which recorded higher mean temperature (27.0 ◦C) compared to 2015/16 (21.5◦C). Maximum temperatures in all the month from Jan-May of 2015/16 were higher compared to 2016/17 except in March where lower maximum temperature of 32.5◦C was noted in 2015/16 as compared to 35.7 ◦C in 2016/17. Average maximum temperature during the rice season (Jan-May) ranged from 32.5-42.5◦C in 2015/16 and from 29.3-39.9 ◦C in 2016/17, while the average minimum temperature ranged from 10.5-20.0 ◦C in 2015/16 and from 12.2-24.6 ◦C in 2016/17. The mean daily sunshine hours in February (8.8), March (8.0), and May (8.50) in 2015/16 were lower than in February (9.6), March (8.4) and May (9.3) of 2016/17. Higher mean evaporation was noted in the months of Jan-April of 2015/16 compared to 2016/17. Maximum RH ranged from 84-100% and from 60.9-86.9% whereas minimum RH ranged from 14.0-20.0 in 2015/16 and 22.5-33.4 in 2016/17 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} 2015/16 and from 103.63 to 128.49 g m^{-2} in 2015/16 and 2016/17 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 shoot in both the years. At FL stage also, DRR Dhan 44 produced the highest shoot dry matter accumulation, with a range of 486.7-636.5 g m^{-2} in 2015/16 and 491.4-650.2 g m^{-2} in 2016/17 respectively. DRR Dhan 46 yielded shoot dry matter ranging from 412.77-571.01 g m^{-2} in 2015/16 and 467.9-595.7 g m^{-2} in 2016/17. At all the N application rates, shoot biomass of DRR Dhan 44 and DRR Dhan 46 showed no significant difference. Herein, our 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 fold during both the years. Biomass accumulation in 2016/17 was slightly higher compared to 2015/16 during the TL and FL stages respectively. Non-significant 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 noted in different varieties. A consistent trend for increase in tiller density was observed with increasing nitrogen application rates during both the years with more number of tillers in DRR Dhan 44. At 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, at FL stage, tiller density ranged from 355 to 467 and 377 to 492 tillers m^{-2} in DRR Dhan 44 during 2015/16 and 2016/17 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 effect between varieties and N rates was non-significant during flowering stage but the individual effect of varieties and nitrogen levels was found to be significant. Higher tiller density was observed in 2016/17 than in 2015/16.

3.4 LAI

In consistence with the results on 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 variety DRR Dhan 44 at all the N rates (Fig 3). Identical 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 2015/16 and 4.5-5.53 at TL and FL in 2016/17. LAI in 2016/17 was slightly higher than in 2015/16 Interaction between N rates and varieties was significant at TL and FL stages during both the years.

3.5 Yield attributes and yield

In general, the grain and straw yield were marginally higher in second year in all the varieties (Table). Panicles m^{-2}, Panicle weight, grain weight, filled grain percentage increased with the application of nitrogen, reaching maximum at N_{140}. All the yield attributes increased significantly up to a nitrogen level of N_{120} and 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 2015/16, while the increase was 29.0% and 25.6%% during 2016/17 respectively. Filled grain percentage ranged from the lowest of 79.11 to the highest of 96.45% and from 70.41-93.02% during the first and second year. Grain weight of all the varieties was higher in 2016/17 than in 2015/16 and ranged from 2.26-2.62 and 1.87-2.43 in 2015/16 and 2016/17. Mean grain yield of all the varieties increased significantly upto N_{120} kg N/ha and thereafter remained statistically 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 N_0 treatment that received no application of N in all the cultivars. The results indicated that N_{120} was superior and increased

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the total yield of rice by 20.28% in 2015/16 and 25.41 % in 2016/17 respectively, when compared to zero N 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%. When compared to N_0 treatments, mean grain yield in N_{140} increased by 39.65 % in 2015/16 and 41.56% in 2016/17 respectively.

Grain yield differed significantly in varieties in both the years. Of the four promising varieties studied, difference in yield attributes and yield was significant and different varieties exhibited 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 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 2015/16 and 2016/17 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 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 2015/16 and 3.16-7.03 t ha^{-1} in 2016/17 respectively. Lowest yield was recorded in IR 64 ranging from 3.38-5.30 t ha^{-1} in first year and 3.31-5.44 t ha^{-1} in 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 higher number of panicles per square meter or higher filled grain percentage. In both the years, the interaction between varieties and N rates on grain yield was not significant (Table 3). Straw yield followed a similar trend as that of grain yield during both the years and DRR Dhan 44 recorded 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

N fertilization significantly affected the nitrogen uptake by different Varieties (grain + straw) during 2015/16 and 2016/17. The interactions between N rates and Varieties were significant for grain and total N uptake (Fig.4 i & ii). Results indicated that nitrogen uptake clearly followed yield pattern. Grain and total N uptake increased with the application of N rates in all the Varieties except at N_0. Total nitrogen 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

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uptake was with variety DRR Dhan 44 and was closely followed by DRR Dhan 46. Similar to grain yield and total nitrogen uptake, ANUE and RE was significantly higher for both DRR Dhan 44 and DRR Dhan 46 at all the 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 2015/16 and 2016/17 respectively (Table 4 i & ii). At all the N rates, DRR Dhan had higher RE 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 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 and 0.94 for 2016/17 respectively (fig 4 i). Similarly, co-relation between total N uptake and grain yield also exhibited a significant positive relationship with a high degree of correlation with r^2 value of 0.98 for the first year and 0.93 for the second year demonstrating that the grain yield increased with increase in nitrogen rates upto 140 kg/ha (fig 4 ii). However, the relationship between total N uptake and grain yield was linear for the first year whereas 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 second year with quadratic response (fig 4 iii).

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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 as well as B:C ratio which was 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 and 2.30 for 2016/17 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 labour requirement and economises water (Kumar and Ladha, 2011). Significant variation was reported among rice varieties with respect to growth, yield attributes, yield and nitrogen use efficiency parameters and is in consistence with the previous works (Ju et al., 2015; Zhang Ya-Li et al, 2009). Difference in growth and yield attributes is mainly due to the difference in genetic constitution of the variety. Of the four promising varieties studied, DRR Dhan 44 had higher panicle weight, which remained close to DRR Dhan 46 and is in agreement with the researches carried out at different locations (DRR Annual report, 2015/16). N_{140} registered 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 in yield during both the year can be attributed to variation in environmental situations during both the years (Fageria, 1992). N_{120} has contributed to higher grain yield of DRR Dhan 44 (DRR Annual report 2015-16). 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 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, DRR Progress report, 2015 reported that DSR responded to fertilizer N upto 140 kg N ha^{-1}. Yield differences with each incremental N rates has 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 Grain N uptake was similar to grain yield, thus total N uptake was significantly influenced by grain N uptake resulting in 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.

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 and 2016/17 respectively which is in consistence with the prior reports (Peng et al., 2002). It has been found that the agronomic efficiency in farmers 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 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 fertiliser (Fageria, 1992). The agronomic use efficiency of N applied in fertiliser always 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 al., 2008; Wu et al., 2016). Samonte et al., 2006 and Wu et al., 2016 also observed quadratic relationship between grain yield and agronomic nitrogen 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 related 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 sown conditions can be reached under proper Nitrogen 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 contributors to higher grain yield and thereby increase the N uptake and utilisation efficiency. Our findings suggest that optimum rice yields for direct-seeded rice can be obtained by selection of suitable variety with the use of optimum N rates which will greatly facilitate the wide adoption of this technology in Southern India. Results from this study indicate that genotype differences in NUE existed among different drought tolerant rice varieties; therefore, NUE of different cultivars could be a useful 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 2015/16 and 2016/17*

Month	2015/16								2016/17							
	Rainfall (mm)	Temperature (^0C)			Relative humidity		Evaporation (mm)	Sunshine (hrs)	Rainfall (mm)	Temperature (^0C)			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 growing season of (A) 2015/16 (B) 2016/17 in Hyderabad, Telangana, India. Rainfall, Sunshine hours are monthly totals whereas temperature data is monthly averages.*

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

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 tolerant varieties on yield attributes of rice for the year 2016/17

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 tolerant varieties on yield and harvest index of rice for the year 2015/16

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 Nitrogen levels and short duration drought tolerant varieties on yield and harvest index of rice for the year 2016/17

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				

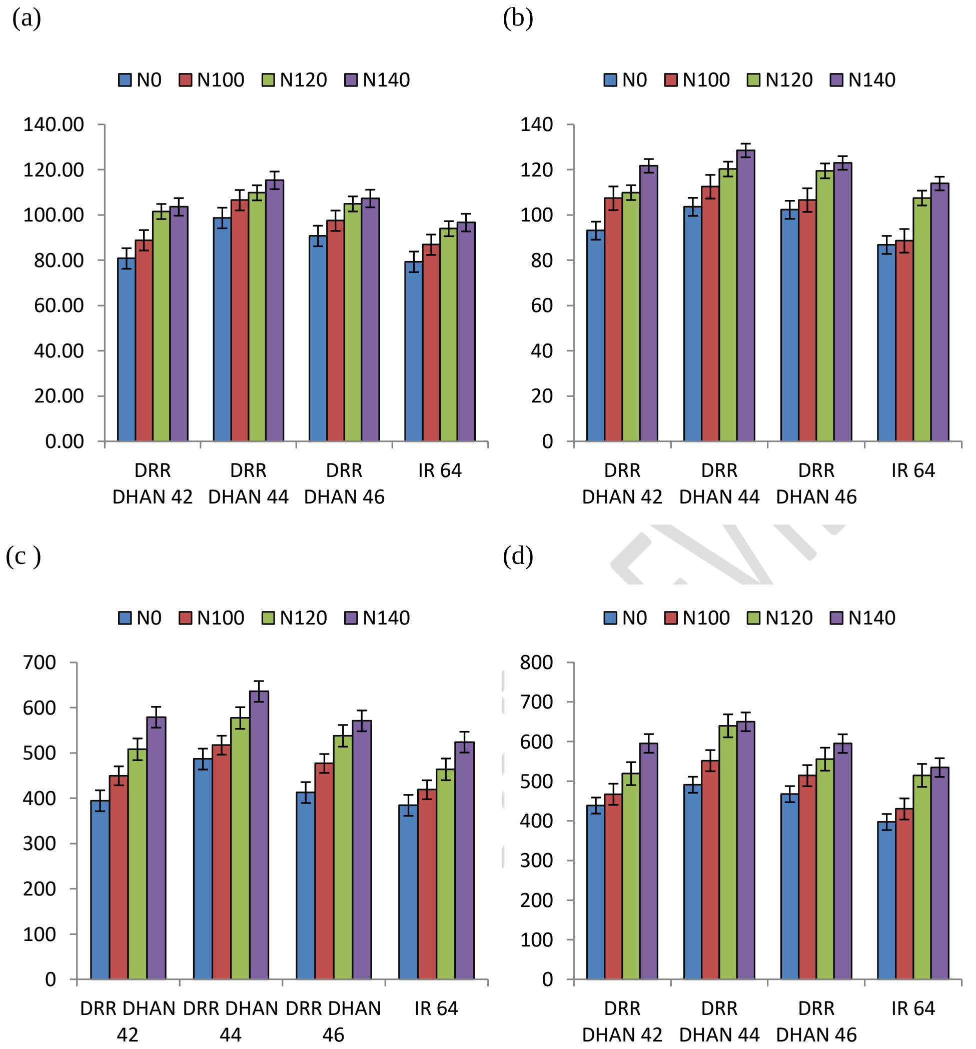
Table 4 (i): Influence of short duration drought tolerant varieties and Nitrogen levels on Physiological and Nitrogen use indices of rice 2015/16

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 tolerant varieties and Nitrogen levels on Physiological and Nitrogen use indices of rice 2016/17

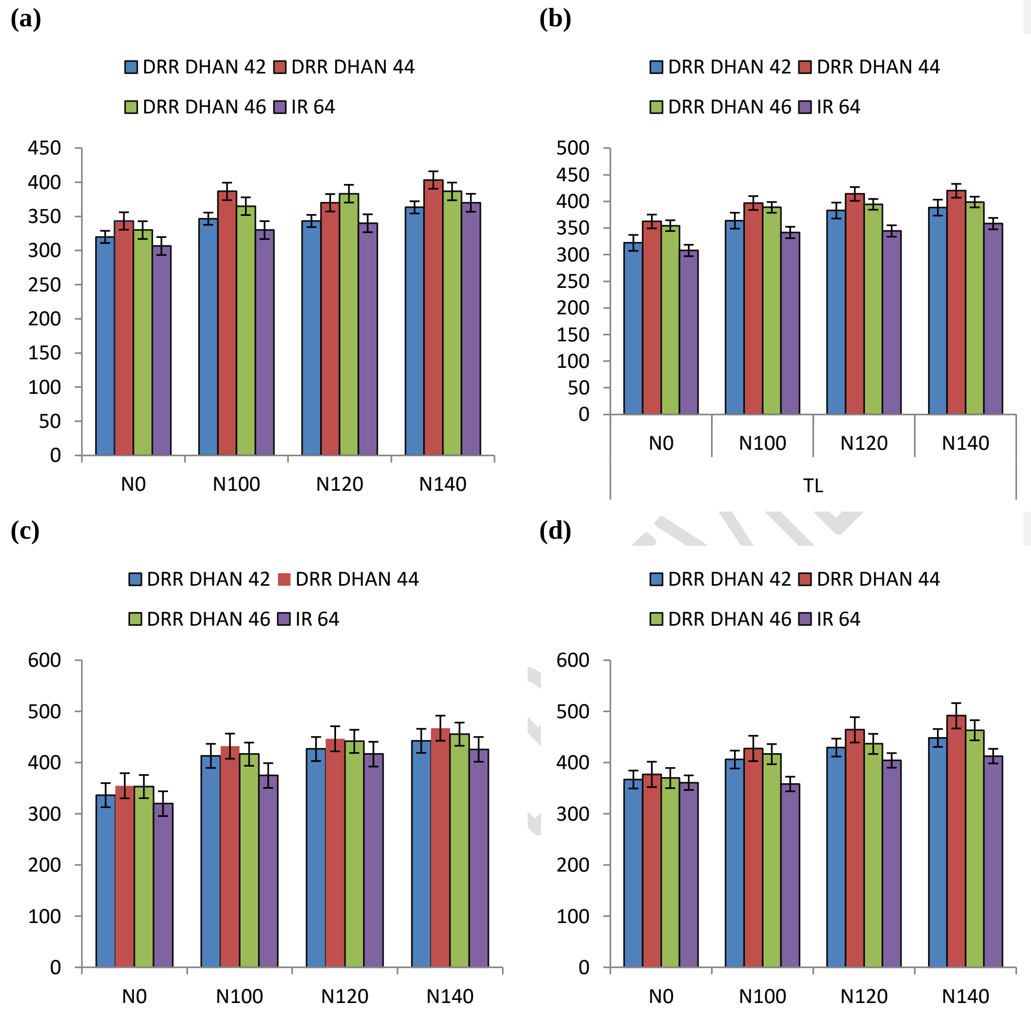
Treatments	Total nitrogen uptake (kg ha^{-1})					RE (%)*					ANUE (kg grain kg^{-1})*				
	N-Levels					N-Levels					N-Levels				
	N0	N100	N120	N140	Mean	N0	N100	N120	N140	Mean	N0	N100	N120	N140	Mean
DRR-Dhan 42	84.6	117.9	125.7	130.0	114.55b	-	33.32	34.25	32.44	33.34	-	20.56	19.47	18.11	19.38
DRR-Dhan 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



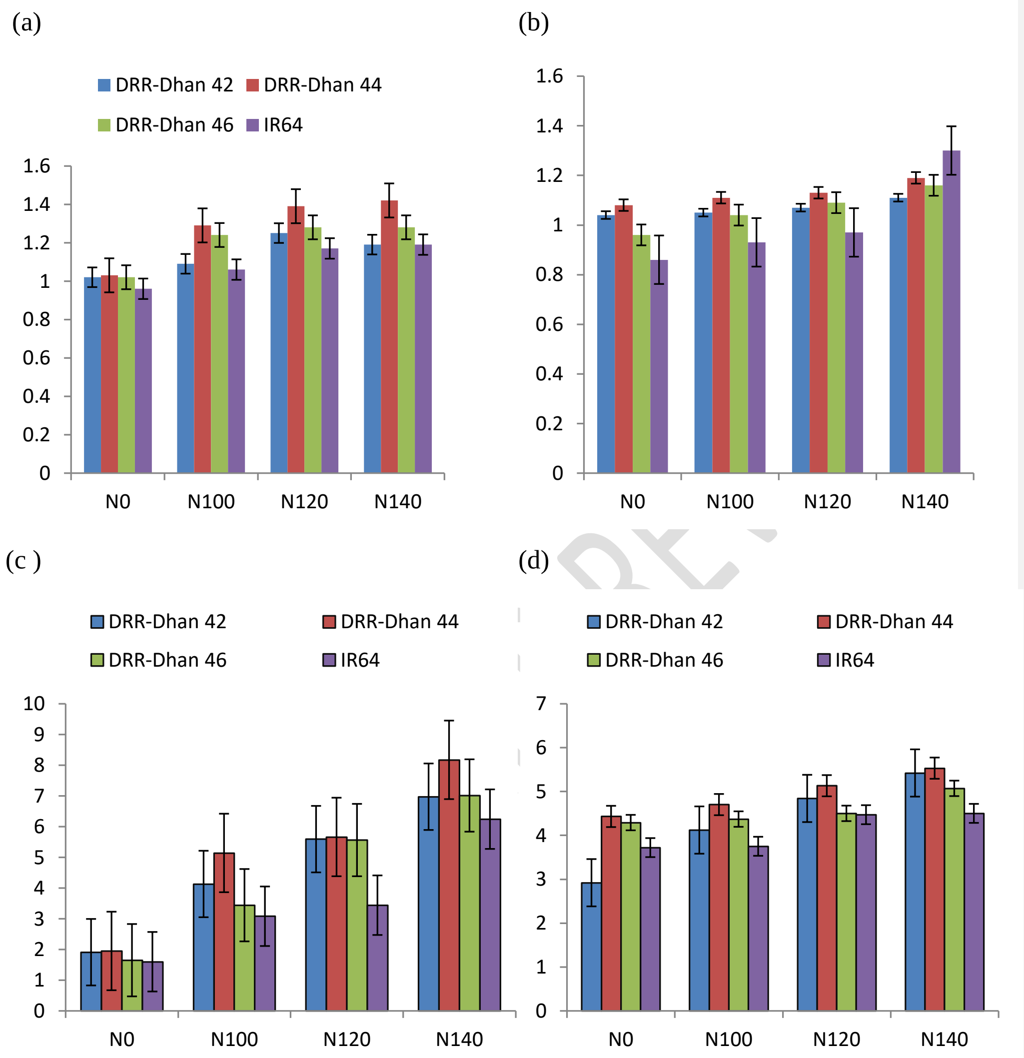
	2015/16				2016/17		
	stage	**N rates**	**Variety**	**N X V**	**N rates**	**Variety**	**NX V**
Shoot dry biomass m^{-2}	TL	4.71***	5.92***	NS	3.63***	4.26***	*
	FL	58.34***	41.71**	NS	28.50***	22.27***	NS

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



		2015/16			2016/17		
	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) 2015/16 Tillering stage (b) 2016/17 Tillering stage (c) 2015/16 Flowering stage (d) 2016/17 Flowering stage. ***** significant at p=0.05, *p*=** 0.001 *and p*=*** at <0.001



	2015/16				2016/17		
	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 Tillering stage (b) 2016/17 Tillering stage (c) 2015/16 Flowering stage (d) 2016/17 Flowering stage. Vertical bars represent the standard error of means at 5% level of probability. ***** significant at p=0.05, *p=*** 0.001 *and p=**** at <0.001

(a) (b)

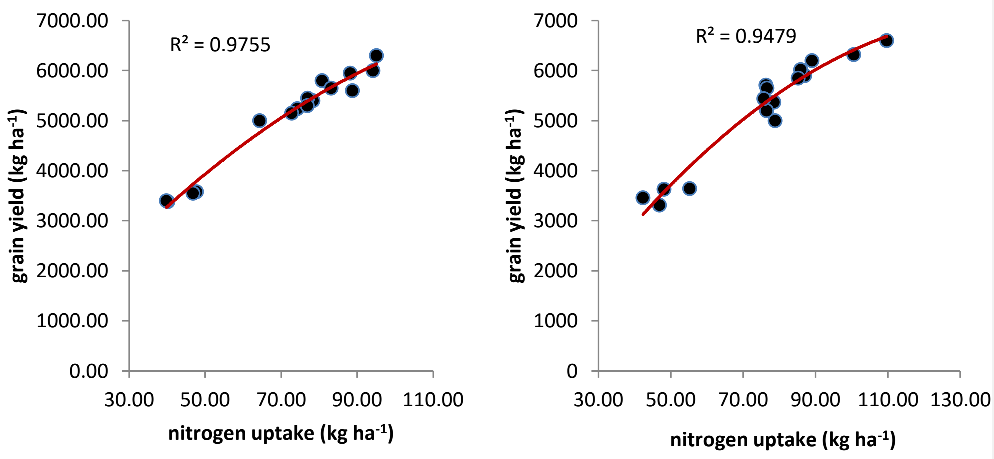


Fig 4 (i): Relationship between N uptake by grain and grain yield of four rice varieties (a) 2015/16 (b) 2016/17

(a) **(b)**

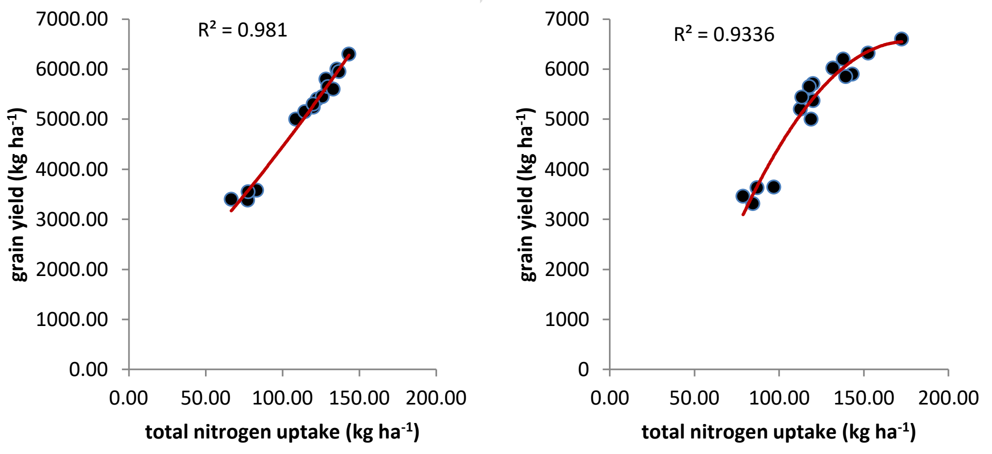


Fig 4 (ii): Relationship between Total N uptake and grain yield of four rice varieties (a) 2015/16 (b) 2016/17

(a) (b)

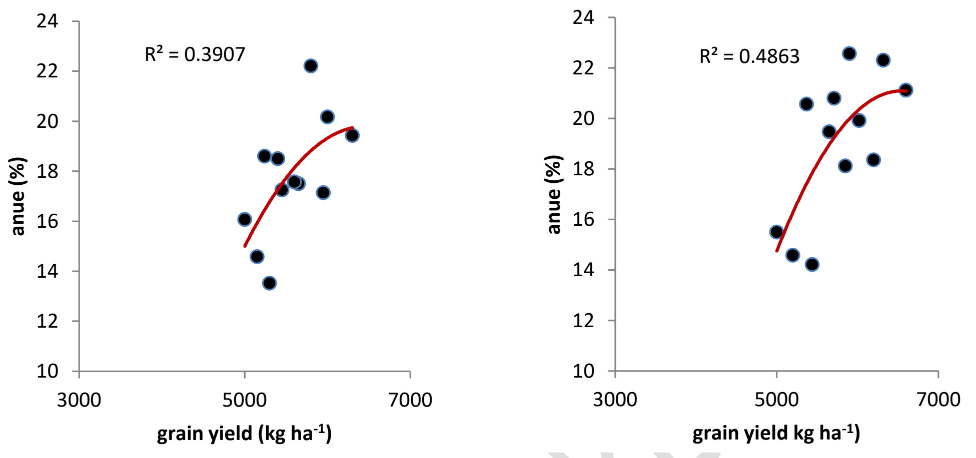


Fig 4 (iii): Relationship between grain yield and agronomic nitrogen use efficiency (n=12)(a) 2015/16 (b) 2016/17

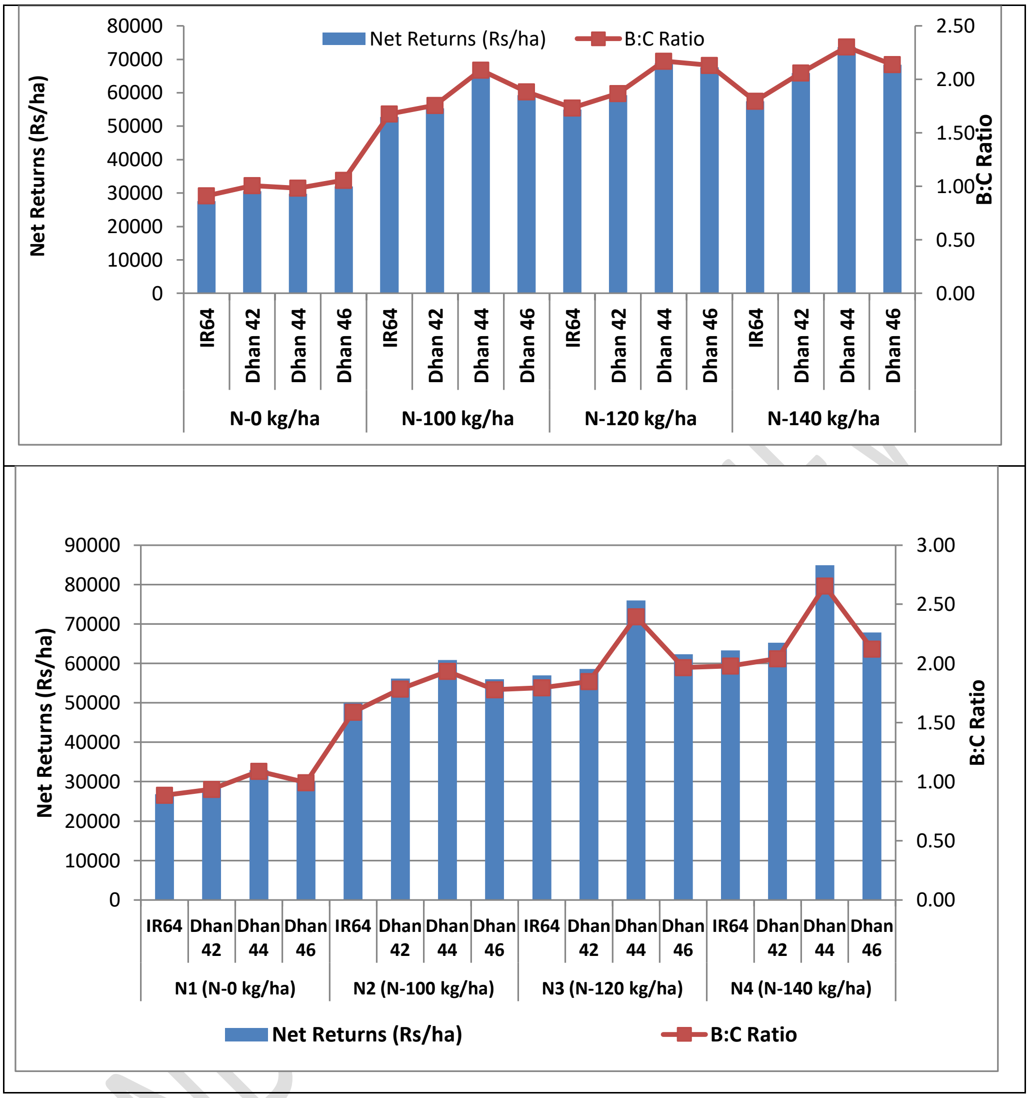


Fig 5: Gross returns, net returns and B:C ratio of different varieties at varying nitrogen rates (a) 2015/16 (b) 2016/17