Research Article

Dry Matter Accumulation, Partitioning and Nitrogen Uptake of Transplanted Rice under Varied Plant Densities and Nitrogen Levels

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Abstract

An experiment was conducted at Agriculture Research Institute, Rajendranagar, Hyderabad to study the dry matter partitioning and nutrient uptake potential of transplanted rice in response to plant densities (farmers practice 28 hills m^{-2}, 44.44 hills m^{-2}, and 16 hills m^{-2} and nitrogen levels. (120 kg ha^{-1}, 180 kg ha^{-1}, 240 kg ha^{-1} and 300 kg ha^{-1}). Crop raised using 44.44 hills m^{-2} recorded more dry matter production and dry matter partitioning to grain and nitrogen uptake over 28 and 16 hills m^{-2}. In similar way, application of nitrogen up to 180 kg ha^{-1} showed significant increase in dry matter production, partitioning to grain and nitrogen uptake. Rice yield was positively correlated with dry matter production and nitrogen uptake.

Keywords: Dry matter, Nitrogen uptake, Plant densities, partitioning, Rice

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Introduction

Rice is particularly important in Asia that accounts for 90% of world's rice production and consumption. India ought to add 1.7 million tonnes of additional rice every year to ensure national food security [1]. Thus demand can only be met by maintaining a steady increase in production by proper agronomic management practices like optimum plant population and nitrogen nutrition (non-monetary inputs).

The productivity of cereals depends not only on the accumulation of dry matter, but also on effective partitioning of the dry matter to economically important plant parts; this is key to yield stability [2, 3]. Plant density affects the partitioning of assimilates to grain and nutrient uptake. Optimum plant density ensures plants to grow properly both in their aerial and underground parts by proper utilization of radiant energy, nutrients and water [4]. Dense planting may have the limitations in the maximum availability of solar radiation and nutrients and lead to production of more straw instead of grain. While the sparse planting may produce insufficient tiller, keeping space and nutrients unutilized resulting in less number of panicles per unit area, and ultimately poor yield [5]. Optimum plant population utilizes resources more effectively and leads better dry matter production and remobilization of reserves to grain which reflects in yield of crop [6]. In estimation, it was found that 24% increase in Asian rice was attributed to use of fertilizers, mainly nitrogen. It has been observed that the rice crop needs a higher amount of nitrogen (greater than 120 kg N/ha) to achieve a good yield. Being key nutrient for rice production nitrogen accounts for 67 % of total nutrients applied to rice [7, 8]. Nitrogen being an integral part of structural and functional proteins, chlorophyll and nucleic acid affects plant growth and development pattern by changing canopy size and structure, ultimately altering resource use efficiency [9,10] and is required throughout the crop growth period from vegetative stage to subsequent harvesting [11,12].

So, optimum plant density and N application are the most important factors for increasing total dry matter accumulation and partitioning greater amounts into panicles, thereby increasing yield. Keeping these facts in view, the present study was carried out to assess the effect of plant density and nitrogen application on dry matter accumulation and partitioning and nitrogen uptake of rice.

Materials and Method

The experiment was conducted at Agricultural Research Institute, Professor Jayasankar Telangana State Agricultural University, Rajendranagar, Hyderabad during *kharif* 2012. The soil of the experimental site was sandy loam in texture, alkaline in reaction, low in available nitrogen, phosphorus and high in available potassium. The experiment was laid out in a factorial randomized complete block design with three replications. The treatments comprised of three plant densities (farmers practice : 26 hills m^{-2}, 15x15cm : 44.44 hills $m^{-2}$and 25x25 cm: 16 hills m^{-2}) and four nitrogen levels (120, 180, 240 and 300 kg ha^{-1}). Rice var. MTU 1010 was used in the experiment. Recommended dose of P, K and Zn @ 60, 40 and 50 kg ha^{-1} through single super phosphate (SSP), muriate of potash (MOP) and zinc sulphate as basal dose. Nitrogen was applied as per the treatments in the form of urea (46% N) in three equal splits at planting, 20 days after planting (DAP) and at panicle initiation (PI) stage. Plant samples of rice were collected for dry matter estimation at tillering, panicle initiation, heading, dough and physiological maturity stages from different treatments. Dry weight per plant was calculated as sum of the dry weights of the plant components. The collected data was statistically analyzed and mean differences were compared using SAS. Total N uptake was determined using following formulae

$$\text{Nitrogen uptake by grain (kg ha-1)} = \frac{\text{\% N in grain} \times \text{grain yield (kg ha}^{-1})}{100}$$

$$\text{Nitrogen uptake by stover (kg ha}^{-1}) = \frac{\text{\% N in stover} \times \text{straw yield (kg ha}^{-1})}{100}$$

Results and Discussion

Total Dry Matter Production

Dry matter accumulation reflects growth and metabolic efficiency of a plant, which ultimately influences the economic yield. Dry matter production by rice plants increased progressively with the advancement of growth stages and reached peak at maturity (**Table 1**). Total dry matter production (TDM) increased progressively with the progressive increase in planting densities and N-levels. Maintaining 44.44 hills m^{-2} showed significantly more dry matter accumulation over 16 hills m^{-2} and 28 hills m^{-2}. The percent increase in dry matter production with 44.44 hills m^{-2} over 28 and 16 hills m^{-2} was 6% and 11% respectively. This rapid dry matter production under closer spacing could be attributed to vertical growth of rice plants at closer spacing as compared to horizontal tillering in wider spacing [13].

Table 1 Dry matter production (g m^{-2}) of rice at different phenophases as influenced by plant densities and nitrogen levels

Treatments	Tillering	Panicle initiation	Heading	Dough	Physiological maturity
Plant densities (PD) (hills m^{-2})					
Farmers practice (28)(PD_1)	46^b	271^b	883^b	1251^b	1447^b
15×15cm (44.44) (PD_2)	70^a	369^a	963^a	1318^a	1537^a
25×25cm (16) (PD_3)	30^c	228^c	824^c	1168^c	1384^c
SEd±	2	14	20	11	14
CD (P=0.05)	5	28	40	23	30
Nitrogen (N) (kg ha^{-1})					
120 (N_1)	41^b	221^b	746^b	1061^b	1250^b
180 (N_2)	50^a	293^a	925^a	1299^a	1509^a
240 (N_3)	51^a	319^a	942^a	1307^a	1525^a
300 (N_4)	53^a	324^a	948^a	1316^a	1540^a
SEd±	3	16	22	13	17
CD (P=0.05)	5	33	46	27	35
Interaction (PD×N)					
SEd±	5	27	39	22	29
CD (P=0.05)	NS	NS	NS	NS	NS

Considering the nitrogen fertilization, the highest dry matter was obtained when rice plants were fertilized with 300 kg N ha^{-1} which was on par with 240 and 180 kg N ha^{-1} and were significantly superior to 120 kg N ha^{-1}. Elevated nitrogen supply can boost dry matter content through production of photo-assimilates via leaves which is the center of plant growth during vegetative stage and later distribution of assimilates to the reproductive organs [14]. Furthermore, dry matter production in rice is significantly related to intercept photosynthetically active radiation. Low N concentrations in plant leaves have been described as a limiting factor for reducing radiation use efficiency and biomass productivity resulting lower dry matter production of rice [15].

Dry matter partitioning at physiological maturity

Dry matter partitioning towards leaf, stem and grain varies significantly with plant densities and graded levels of nitrogen **(Table 2).** The dry matter partitioning to grain at physiological maturity ranged from 55% to 56% with different plant densities. Significantly higher leaf and grain partitioning was noticed with 44.44 hills m^{-2} and was superior to 28 hills m^{-2} and 16 hills m^{-2}, which in turn recorded the lowest leaf and grain partitioning. Plant densities did not influence the stem partitioning significantly.

Table 2 Dry matter (g m^{-2}) partitioning at maturity stage of rice as influenced by plant densities and nitrogen levels

Treatments	Stem	Leaf	Grain	Total dry matter
Plant densities (PD) (hills m^{-2})				
Farmers practice (28) (PD_1)	334	306^b	807^b	1447^b
15×15cm (44.44) (PD_2)	345	341^a	849^a	1537^a
25×25cm (16) (PD_3)	329	285^c	770^c	1384^c
SEd±	9.85	8.89	10.77	14.44
CD (P=0.05)	NS	18.4	22.30	29.90
Nitrogen (N) (kg ha^{-1})				
120 (N_1)	284^b	250^b	716^b	1250^b
180 (N_2)	346^a	328^a	835^a	1509^a
240 (N_3)	353^a	331^a	841^a	1525^a
300 (N_4)	363^a	334^a	843^a	1540^a
SEd±	11.40	10.29	12.42	16.67
CD (P=0.05)	23.60	21.3	25.70	34.50
Interaction (PD×N)				
SEd±	19.76	17.84	21.51	28.84
CD (P=0.05)	NS	NS	NS	NS

The dry matter partitioning to grain at physiological maturity ranged from 54% to 57%, with graded levels of nitrogen application. Of all the N levels tested, the highest stem, leaf and grain accrual was observed with 300 kg ha^{-1} and was comparable with 240 kg ha^{-1}, 180 kg ha^{-1} and distinctly superior to 120 kg N ha^{-1}, which in turn recorded the lowest accrual of stem, leaf and grain partitioning at physiological maturity. The higher stem weight resulted from greater partitioning of assimilates to stem because when the N in root zone is more, the root to shoot ratio increases. The grain yield depends on the partitioning of dry matter into its economical portion and its conversion into grain [16].

Nitrogen uptake

Nitrogen uptake significantly increased with increasing plant densities and nitrogen levels. Maximum nitrogen uptake at PI, heading and in leaf, stem and grain samples at physiological maturity was observed with 44.44 hills $m^{-2}$and was significantly superior to 28 hills $m^{-2}$and 16 hills m^{-2} which in turn recorded the lowest nitrogen uptake (**Table 3**). This might be due to higher biomass production under higher plant densities [17]. This outcome was confirmed with research results, where high density planting recorded more nitrogen uptake than low density due to higher biomass production [18].

Nitrogen uptake at all crop growth stages, increased with increasing the N rate from 120 kg N ha^{-1} to 300 kg N ha^{-1} but the significant increase was observed only upto 180 kg N ha^{-1}. The highest nitrogen uptake was recorded at PI, heading and physiological maturity stage with 300 kg ha^{-1} and was comparable with 240 kg ha^{-1} and 180 kg ha^{-1} and significantly superior to 120 kg ha^{-1}, which in turn recorded the lowest nitrogen uptake. Nitrogen content in grain significantly depends on the applied nitrogen level and with the increase in nitrogen dose, its content in the grain increased. Further, [19] reported that increased N application led to over-growth of above ground biomass and consequently, increase of leaves and stems dry weight, so, it increased nitrogen uptake.

Correlation studies between dry matter accumulation and nitrogen uptake with yield

Dry matter accumulation and nitrogen uptake showed a significant positive correlation with grain yield of rice (**Table 4**). Further the regression analysis revealed that 84% of the variation in grain yield was attributed to nitrogen uptake at physiological maturity stage (**Figure 1**). This indicates that nitrogen levels and plant densities affect the rice yield through its effect on dry matter production and nitrogen uptake.

Table 3 Nitrogen uptake (kg ha^{-1}) by rice during different growth phases as influenced by plant densities and nitrogen levels

Treatments	Panicle initiation	Heading	Physiological maturity			
			Stem	Leaf	Grain	Total
Plant densities (PD) (hills m^{-2})						
Farmers practice (28)(PD_1)	29^b	120^b	27^b	24^b	84^b	135^b
15×15cm (44.44) (PD_2)	40^a	134^a	32^a	30^a	101^a	163^a
25×25cm (16) (PD_3)	19^c	103^c	23^c	21^c	68^c	112^c
SEd±	2	5	1	1	3	3
CD (P=0.05)	5	10	3	2	6	7
Nitrogen (N) (kg ha^{-1})						
120 (N_1)	18^b	82^b	22^b	20^b	68^b	110^b
180 (N_2)	31^a	126^a	28^a	25^a	89^a	142^a
240 (N_3)	33^a	131^a	29^a	27^a	90^a	146^a
300 (N_4)	35^a	137^a	30^a	28^a	91^a	149^a
SEd±	3	6	2	1	3	4
CD (P=0.05)	6	12	3	3	7	8
Interaction (PD×N)						
SEd±	5	10	3	2	6	6
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table 4 Correlation coefficients between growth parameters and grain yield of rice

Growth parameter	Correlation coefficients
Dry matter at panicle initiation stage	0.89**
Dry matter at heading stage	0.99**
Dry matter at physiological maturity	0.99**
Nitrogen uptake at physiological maturity	0.92**

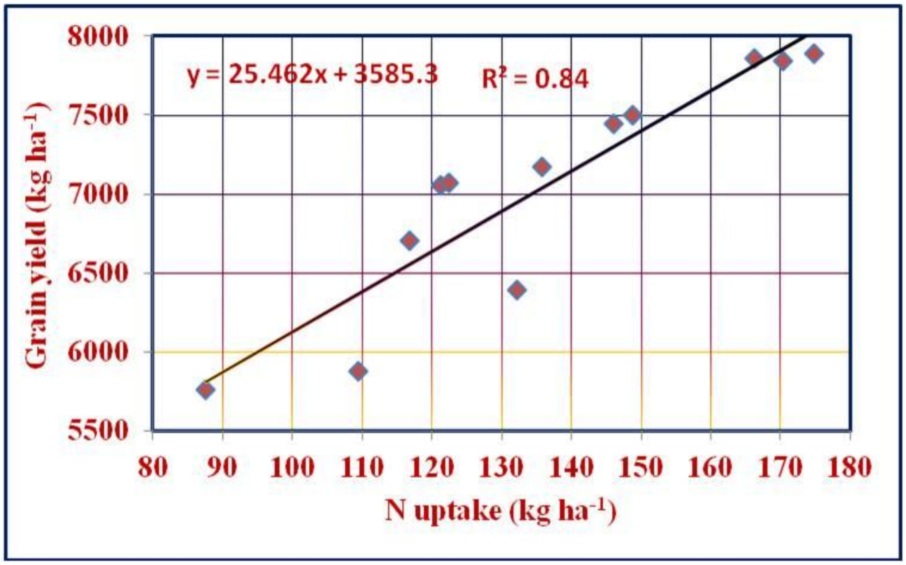

Figure 1 Relationship between N uptake at maturity and grain yield of transplanted rice

Conclusion

The results of this study confirmed that increase in plant density and N levels were more beneficial in terms higher DM accumulation and partitioning greater amounts into panicles in transplanted rice. It is, therefore, recommended that plant density of 44.44 hills m^{-2} along with application of 180 kg N ha^{-1} should be considered optimum to improving growth performance and increased nitrogen uptake of transplanted rice in South Telangana region of Telangana State.

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Publication History

Received 15th Aug 2017
Revised 28th Aug 2017
Accepted 05th Sep 2017
Online 30th Sep 2017