



## Seedling age and nitrogen application affect on dry matter accumulation, partitioning and nutrient status of rice under temperate conditions

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**Abstract:** Rice is the most important crop at the global level, as it used as a staple food in most of the countries of the world. Transplanting aged seedlings of paddy has a detrimental effect on the crop performance, which needs to be overcome for sustaining the productivity. Leaf colour chart based nitrogen application is an efficient and economical tool for enhancing the rice productivity and nitrogen use efficiency. With this in mind, a field experiment was conducted during *kharif* 2011, at the Research Farm of SKUAST-K, Shalimar, Srinagar (Kashmir) to optimize the seedling age of rice (*Oryza sativa* L.) under late transplanting conditions and to assess the suitability of using leaf colour chart as a nitrogen management tool to improve the performance of rice. The experiment was established in Randomized Block Design, with three replicates, 3 seedling ages and 6 nitrogen application treatments. The analyses of data revealed that 35 days old seedling recorded significantly higher total dry matter accumulation and dry matter partitioning to panicle (8.2 t ha<sup>-1</sup>) and leaf (2.4 t ha<sup>-1</sup>); grain yield (7.4 t ha<sup>-1</sup>); N, P and K uptake (11.6, 3.1 and 11.3 kg ha<sup>-1</sup>, respectively) (p<0.05). Among nitrogen application treatments significantly higher dry matter accumulation; yield (8.6 t ha<sup>-1</sup>) and N, P and K uptake (14.1, 3.6 and 12.7 kg ha<sup>-1</sup>, respectively) was found in ½ N as basal and remaining at LCC <4 @20 kg ha<sup>-1</sup> (p<0.05). Age of seedling and time of nitrogen application did not affect N, P, K and protein content of grain and straw significantly (p>0.05). It is concluded that the yield of rice can be improved by transplanting 35-days old seedling under late transplanted conditions in temperate regions and by following LCC guided nitrogen management.

**Keywords:** Dry matter, Nitrogen, Phosphorus, Potassium, Rice and seedling age

### INTRODUCTION

Rice is the staple food for more than 50% of world's population (Zhao *et al.*, 2011), and thus holds the key to world food security (Dass and Chandra, 2013). The geometric growth of population and the arithmetic increase in rice production leave a vast gap in the food supply (Rajendran and Ganesa, 2014). The world demand for rice is projected to increase by 70% over the next 30 years (Patra and Haque, 2011) to maintain the present per capita supply, assuming the productivity of existing farmland does not decline. This demand can only be met by maintaining a steady increase in production by proper use of different factors of production. Among the various factors responsible for realizing potential yield of rice, age of seedlings at the time of transplanting and timely nutrition are the important non-monetary inputs, manipulation of which can lead to optimization of growth and yield.

Age of seedlings at transplanting is considered important for influencing grain yield in rice production systems, primarily by affecting dry matter accumulation

and laying the foundation for determining the number of panicles at harvest (Rajendran and Ganesa, 2014). Transplanting seedlings at an appropriate age is of primary importance for uniform stand and seedling establishment, as "half of the success of rice cultivation depends upon the seedling" (Padalia, 1981). Constraints like scarcity of agricultural labour and non availability of inputs and financial constraints during peak periods of transplanting compel the farmers to resort to planting of aged seedlings (Rasool *et al.*, 2015). Transplanting seedlings at a proper age can provide appropriate ground for achieving potential production by reducing the death of tillers and providing the optimum period for completion of growing cycle of paddy. When the seedlings are left for a longer period of time in the nursery, these are subjected to an increased competition within the nursery leading to exhaustion of intrinsic nutrients in the seedlings, which contributes to the poor performance of older seedlings after transplanting (Pasuquin *et al.*, 2008).

Nitrogen, the key nutrient of rice production accounts

for 67 % of total nutrients applied to rice (Jayanthi *et al.*, 2007). Although the nitrogen supply drives productivity, but the crop recovery of applied nitrogen is only 20 to 35 % due to losses in several ways. The development and promotion of more efficient practices for nitrogen fertilizer management in rice consequently remain a high priority for increasing profitability of rice farming while protecting the environment (Buresh *et al.*, 2004). Regulation of nitrogen supply to rice crop is dependent upon the interaction of a number of factors of which the timing of nitrogen application is usually most important. Application of nitrogen at proper time avoids periods of significant loss and provides adequate nitrogen when the crop needs it most. Synchronization between the crop nitrogen demand and supply from soil and applied fertilizer can be achieved by monitoring the plant nitrogen status (Cassman *et al.*, 1994). Adopting need based variable rates of nitrogen application and using portable decision aids like LCC to improve nutrient management are the approaches to increase nitrogen use efficiency. LCC is a simple, easy-to-use and inexpensive (US\$1 a piece) diagnostic tool that can help farmers determine the right time of nitrogen application to rice crop by measuring leaf color intensity which is related to leaf N status (Alam *et al.*, 2005). Whenever the leaf colour falls below the critical LCC value, a prescribed amount of nitrogen is applied which helps in maintaining the optimum concentration of leaf nitrogen. Keeping these facts in view, the present study was carried out to assess the effect of seedling age on dry matter accumulation and partitioning and nutrient status of rice under late transplanting conditions and to find the optimum time of nitrogen application to overcome the reduction in yield due to transplanting of aged seedlings.

## MATERIALS AND METHODS

A field experiment was carried out at the Research Farm of SKUAST-Kashmir, Shalimar, Srinagar in *kharif* 2011. The site is situated 15 km towards the North of Srinagar (34°05' N latitude and 74°89' E longitude, 1587 m above mean sea level). Soil of the experimental field was silty clay loam, low in available nitrogen (253.6 kg ha<sup>-1</sup>), medium in available phosphorus (14.3 kg ha<sup>-1</sup>), and medium in available potassium (248 kg ha<sup>-1</sup>) with a pH = 6.90, electrical conductivity (EC) = 0.13 dSm<sup>-1</sup> and organic carbon (OC) = 0.52 %. The experiment was laid out in randomized complete block design with three replications having 18 treatment combinations including 3 levels of seedling age viz., 25, 35 and 45 days old seedling and 6 levels of time of nitrogen application; control, recommended practice, 1/4 N as basal and 3/4 in 3 equal splits at 14 days interval, 1/4 N as basal and 3/4 in 2 equal splits at 14 days interval, 1/2 N as basal and 1/2 in 2 equal splits at 14 days interval, 1/2 N as basal and remaining at LCC <4 @20 kg ha<sup>-1</sup> per application. Plot size was 4m × 3m with a spacing of 15 x 15 cm. Diammonium phosphate (DAP) and muriate of potash (MOP) were applied as basal dose to

each plot at the rate of 60 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> and 30 kg K<sub>2</sub>O ha<sup>-1</sup>, respectively before transplanting. Nitrogen was applied @ 120 kg ha<sup>-1</sup> as per treatment in the form of urea. In case of LCC based treatments top dressing of urea was done only at LCC <4 @ 20 kg ha<sup>-1</sup> application<sup>-1</sup>. Transplanting of seedlings of all the three ages was done on 21<sup>st</sup> June. Recommended cultural practices were followed for raising the crop. A sample of six randomly selected hills from penultimate row in each plot was collected at 15 days interval after transplanting till harvest. At 15, 30, 45 and 60 days after transplanting (DAT) the samples were sun dried for one day and then oven dried at 60 to 65 °C till constant weight reached. From 75 DAT onwards the plants were first separated into stem, leaf and panicle and then dried in the similar way as above. Dry weight of component fractions (stem, leaf and panicle) of six hills was determined. Total dry matter accumulation was obtained by adding weight of all the components of each plot. Both weights were then converted into q ha<sup>-1</sup>. Yield was determined from net harvest area of 7.4 m<sup>2</sup> after excluding border rows. Plant samples collected at harvest were sun dried followed by oven drying at 60 to 65 °C till a constant weight reached. Grain and straw samples were separately ground and used for chemical analyses. Nitrogen content was estimated by modified Kjeldhal method (Jackson, 1973) after digesting 0.5 g of plant sample (grain and straw) with 10 mL conc. sulphuric acid and digestion mixture. Phosphorus was estimated by Vanado-molybdo phosphoric yellow method using spectrophotometer after digestion of the samples in diacid mixture (HNO<sub>3</sub>:HClO<sub>4</sub>; 9:4). Potassium was estimated by flame photometer after triple acid digestion of the samples. Nitrogen, phosphorus and potassium uptake was calculated by multiplying grain and straw yield by respective percentages of nitrogen, phosphorus and potassium and then expressed in kg ha<sup>-1</sup>. Protein content in grain and straw was determined by multiplying nitrogen content of grain and straw by a factor 5.95 (Souza *et al.*, 1999). Data were statistically analyzed by the method described by Cochran and Cox (1963). The significance of 'F' was tested at 5 % probability.

## RESULTS AND DISCUSSION

**Dry matter accumulation:** Dry matter accumulation reflects growth and metabolic efficiency of a plant, which ultimately influences the economic yield. Dry matter accumulation showed an increasing trend up from 15 days after transplanting up to harvest. 35 days and 25 days old seedling produced similar quantities of dry matter but were significantly superior to 45 days old seedling (p<0.05) (Table 1). Higher dry matter accumulation of 35 days old seedling under late transplanted conditions is attributed to the production of healthy plants. Mandal *et al.* (1984) also observed that successive delay in transplanting results in concomitant reduction in dry matter production of 25 days old seedling and longer stay of 45 days old seedling

**Table 1.** Dry matter accumulation ( $q\ ha^{-1}$ ) as influenced by age of seedling and time of nitrogen application.

Treatment	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	At harvest
Age of seedling (days)							
45	3.4	10.8	37.8	55.3	95.0	128.79	131.3
35	4.1	15.6	46.2	59.7	102.8	150.70	158.4
25	3.8	15.1	42.4	55.4	97.6	139.65	141.2
CD <sub>0.05</sub>	0.3	2.9	4.3	4.2	5.8	7.1	5.2
Time of nitrogen application							
Control	2.6	5.2	31.1	40.5	64.8	94.73	97.3
Recommended practice	4.4	17.6	47.7	60.9	106.9	154.04	161.9
1/4 basal; 3/4 in 3 equal splits at 14 day interval	3.6	12.3	39.9	58.9	104.9	151.68	157.5
N <sub>3</sub> = 1/4 basal; 3/4 in 2 equal splits at 14 day interval	3.5	12.5	40.0	57.3	92.8	134.31	134.9
1/2 basal; 1/2 in 2 equal splits at 14 days interval	4.4	18.4	47.9	57.5	96.6	137.03	138.8
1/2 basal; remaining at LCC <4 @20 kg ha <sup>-1</sup> per application	4.2	17.2	46.1	66.0	124.7	176.48	178.4
CD <sub>0.05</sub>	0.4	4.0	6.1	5.9	8.2	10.0	7.3

DAT= Days after transplanting

**Table 2.** Dry matter partitioning ( $q\ ha^{-1}$ ) as influenced by age of seedling and time of nitrogen application at 75, 90 DAT and at harvest.

Treatment	DMP at 75 DAT			DMP at 90 DAT			DMP at harvest		
	Leaf	Stem	Panicle	Leaf	Stem	Panicle	Leaf	Stem	Panicle
Age of seedling									
45 Days old seedling	15.0	52.2	27.7	15.4	52.9	58.5	15.4	52.8	63.1
35 Days old seedling	21.4	49.1	32.3	23.9	50.7	76.2	23.9	50.6	82.9
25 Days old seedling	20.5	46.7	30.4	22.9	48.2	68.6	22.9	48.1	70.2
CD (p=0.05)	1.6	4.2	2.7	1.9	3.5	5.6	1.9	3.5	3.2
Time of nitrogen application									
Control	12.7	33.4	18.6	14.9	33.8	45.8	14.9	33.8	48.6
Recommended practice	21.6	53.3	32.1	24.1	55.0	75.2	24.1	55.1	82.6
1/4 basal and 3/4 in 3 equal splits at 14 days interval	21.1	52.2	31.5	23.4	54.1	74.5	23.4	54.2	79.9
N <sub>3</sub> = 1/4 basal and 3/4 in 2 equal splits at 14 days interval	16.7	48.0	28.0	19.0	50.0	65.6	19.0	49.4	66.5
1/2 basal and 1/2 in 2 equal splits at 14 days interval	16.9	49.6	30.2	19.3	51.2	65.8	19.3	51.4	68.1
1/2 basal and remaining at LCC <4 @20 kg ha <sup>-1</sup> per application	24.7	59.5	40.5	27.4	61.3	87.6	27.4	61.3	92.6
CD (p=0.05)	2.2	6.0	3.8	2.7	5.0	7.9	2.7	4.9	4.5

DAT= Days after transplanting, DMP= Dry matter partitioning

in the nursery affects seedling growth pattern in response to high seedling competition. Also the transplanting shock received during transplanting at advanced stage resulted in poor growth of 45 days old seedling, which might have hindered the dry weight accumulation. Depressed seedling vigour after transplanting due to the impairment of root growth in nursery has been reported earlier (Ros *et al.*, 2003). Significantly higher dry matter production of paddy with 35 days old seedlings as compared to 25 and 45 days old seedlings has been previously reported by Padmaja and Reddy (1998). Sahoo and Rout (2004) reported that planting of four weeks old seedlings recorded greater shoot dry matter than that of five and six week old seedlings.

The nitrogen application as 1/2 N basal and remaining at LCC <4 @ 20 kg ha<sup>-1</sup> application<sup>-1</sup>), accumulated significantly higher quantity of dry matter from 75

DAT onwards than all other treatments (p<0.05). Lowest quantity of dry matter was recorded in control (Table 1). This could be due to the fact that LCC guided nitrogen management provided specific amounts of nitrogen as per crop requirement throughout the growing season and reduced the leaching of nitrate (NO<sub>3</sub><sup>-</sup>) in the soil. The result was the higher photosynthetic area, better interception of solar radiation and presence of photosynthetically active leaves for longer time. Jayanthi *et al.* (2007) reported significantly highest dry matter accumulation with nitrogen application in more number of splits (4 or 5) @ 20 kg N ha<sup>-1</sup> or 30 kg ha<sup>-1</sup> on the basis of LCC readings at weekly and bi-weekly interval.

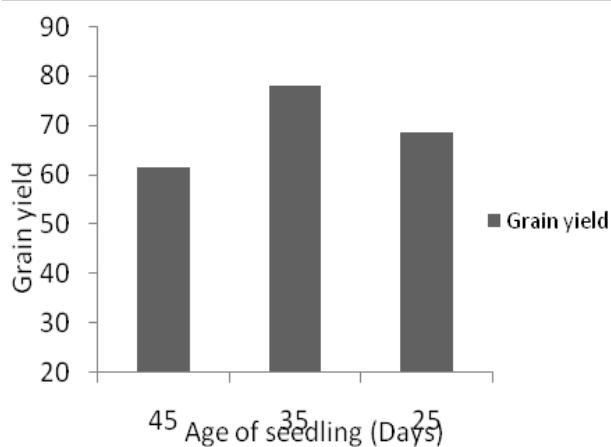
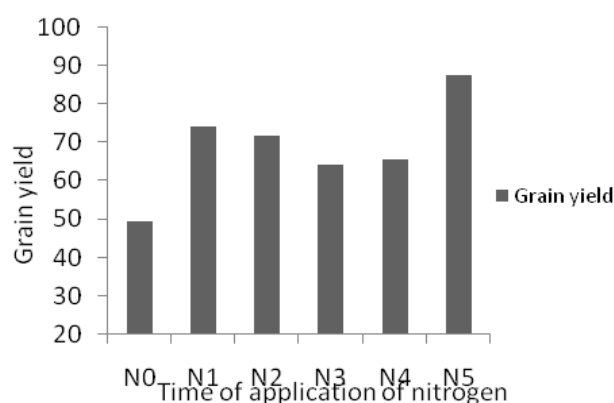
**Dry matter partitioning:** The manner in which dry matter is distributed among different parts of the plant, determines the magnitude of economic yield. At 75 days after transplanting (DAT) most of the dry matter

**Table 3.** N, P, K and protein content (%) of grain and straw as influenced by age of seedling and time of nitrogen application.

Treatment	N content		P content		K content		Protein Content	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
<b>Age of seedling</b>								
45 Days old seedling	1.019	0.461	0.204	0.171	0.346	1.00	6.06	2.79
35 Days old seedling	1.020	0.465	0.215	0.174	0.349	1.01	6.07	2.81
25 Days old seedling	1.10	0.479	0.219	0.175	0.349	1.03	6.55	2.89
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
<b>Time of nitrogen application</b>								
Control	0.993	0.461	0.203	0.169	0.345	1.00	5.91	2.74
Recommended practice	1.066	0.473	0.217	0.176	0.349	1.018	6.34	2.82
1/4 basal and 3/4 in 3 equal splits at 14 days interval	1.078	0.488	0.217	0.177	0.347	1.017	6.41	2.90
N <sub>3</sub> = 1/4 basal and 3/4 in 2 equal splits at 14 days interval	1.029	0.471	0.216	0.173	0.350	1.019	6.12	2.80
1/2 basal and 1/2 in 2 equal splits at 14 days interval	1.014	0.471	0.212	0.169	0.350	1.031	6.03	2.80
1/2 basal and remaining at LCC <4 @20 kg ha <sup>-1</sup> per application	1.200	0.488	0.225	0.178	0.346	1.016	7.55	2.90
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

**Table 4.** N, P, K uptake (kg ha<sup>-1</sup>) by grain and straw as influenced by age of seedling and time of nitrogen application.

Treatment	N uptake		P uptake		K uptake	
	Grain	Straw	Grain	Straw	Grain	Straw
<b>Age of seedling</b>						
45 Days old seedling	59.3	36.1	11.9	13.4	20.1	78.4
35 Days old seedling	75.7	40.6	15.9	15.2	25.9	88.3
25 Days old seedling	70.9	39.8	14.1	14.5	22.5	85.6
CD (p=0.05)	9.3	2.3	1.3	0.9	1.7	4.2
<b>Time of nitrogen application</b>						
Control	27.6	32.1	5.6	11.8	9.6	69.7
Recommended practice	78.9	42.3	16.1	15.7	25.8	91.1
1/4 basal and 3/4 in 3 equal splits at 14 days interval	78.1	42.1	15.7	15.2	25.1	87.7
N <sub>3</sub> = 1/4 basal and 3/4 in 2 equal splits at 14 days interval	65.8	38.7	14.2	14.2	22.4	83.7
1/2 basal and 1/2 in 2 equal splits at 14 days interval	67.9	38.7	14.2	13.9	23.4	85.1
1/2 basal and remaining at LCC <4 @20 kg ha <sup>-1</sup> per application	95.4	46.8	19.5	17.1	30.1	97.4
CD (p=0.05)	13.1	3.2	1.9	1.2	2.4	5.9

**Fig. 1.** Effect of age of seedling on grain yield (q ha<sup>-1</sup>)**Fig. 2.** Effect of time of nitrogen application on grain yield (q ha<sup>-1</sup>).

N<sub>0</sub>= Control, N<sub>1</sub>= Recommended practice, N<sub>2</sub>= 1/4 basal and 3/4 in 3 equal splits at 14 days interval, N<sub>3</sub>= 1/4 basal and 3/4 in 2 equal splits at 14 days interval, N<sub>4</sub>= 1/2 basal and 1/2 in 2 equal splits at 14 days interval, N<sub>5</sub>= 1/2 basal and remaining at LCC <4 @20 kg ha<sup>-1</sup> per application

was partitioned to stem followed by leaf and panicle. At 90 DAT there was an increase in dry matter partitioning to panicle and was followed by stem and leaf. Similar trend was observed at harvest (Table 2). Increased dry matter partitioning to panicle is attributed to the fact that apart from accumulation of photosynthates in panicle (sink) resulting from flag leaf photosynthesis, mobile carbohydrates, proteins and mineral nutrients from other parts (stem, leaf etc.) also moved to panicle during the grain filling stage and the plant gradually became senescent. San-oh *et al.* (2004) also considered the effectiveness of assimilate remobilization from non-productive tillers towards reproductive ones. Thirty five days old seedling while remaining at par with 25 days old seedling recorded significantly higher quantity of dry matter in panicle and leaf as compared to 45 days old seedling ( $p < 0.05$ ). As regards dry matter partitioning to stem, 45 and 35 days old seedling remained at par with each other and recorded significantly higher quantity of dry matter than 25 days old seedling ( $p < 0.05$ ). Higher partitioning of dry matter to panicle of 35 days old seedling is due to the balance in partitioning of assimilates between the sink and source, owing to its better growth characters. Limited dry matter production caused by low photosynthetic rate and early senescence of leaves during grain filling period, or relatively low ratio of source to sink resulting in poor grain filling of rice has been studied previously (Lu *et al.*, 1994; Yuan, 1994).

Among different nitrogen treatments,  $N_5$  ( $\frac{1}{2}$  N as basal, remaining at LCC  $< 4 @ 20 \text{ kg ha}^{-1}$  application $^{-1}$ ) recorded higher dry matter partitioning to panicle. It may be due to the efficient translocation of photosynthates to sink, resulting from LCC guided nitrogen management. Higher nitrogen rates, primarily increased the chlorophyll concentration in leaves and thereby higher photosynthetic rate made plenty of photosynthates available during grain development (Mahzoor *et al.*, 2006). Chowdhury *et al.* (2011) also observed the increase in mobilization of photosynthates to rice panicle at higher rate of nitrogen in comparison to lower rates of application.

**Yield:** Yield is an important component of the crop which reflects the resultant impact of all crop growth parameters that are affected by various input treatments. 35 days old seedling gave significantly more grain yield ( $74.19 \text{ q ha}^{-1}$ ) and straw yield ( $87.4 \text{ q ha}^{-1}$ ) than 25 days old seedling and 45 days old seedling ( $p < 0.05$ ) (Fig. 1). Bali *et al.* (1995) also found that planting five week old seedlings gave higher grain yield than seven week old seedling with 6.3% increase over the latter. Amin and Haque (2009) and Faghani *et al.* (2011) concluded that 35-days old seedling was better than those of relatively younger (15- and 25-day old) and older (45- day old) seedlings. In fact the healthy crop plants which had undergone normal physiological growth and field duration contributed to the higher yield of 35 days old seedling. Twenty-five days old seedlings were subjected to comparatively

lower environmental elements in terms of temperature and sunshine hours which hindered them to exploit their potential. While as, Rajesh and Thanunathan (2003) attributed the reduction in yield with planting of older seedlings (50 days old seedling) to minimum dry matter production in these seedlings compared to 30 days old seedling.

Regarding nitrogen application treatments,  $N_5$  ( $\frac{1}{2}$  basal, remaining at LCC  $< 4 @ 20 \text{ kg ha}^{-1}$  application $^{-1}$ ) recorded highest grain yield ( $86.69 \text{ q ha}^{-1}$ ) and  $N_0$  (control) resulted in lowest yield ( $p < 0.05$ ) (Fig. 2). This is attributed to the fact that crop performance depends not only on the absolute amount of nitrogen but also upon the nitrogen supply pattern and uptake process at each growth stage for respective yield components. Leaf colour chart based fractional application of nitrogen (synchronizing with the crop demand) was effective in maintaining optimal leaf nitrogen during critical stages of plant growth, which led to conducive translocation of higher amounts of carbohydrates to the sink. The critical LCC value of 4 with 25 and 35 kg N  $\text{ha}^{-1}$  was found to be suitable for guiding nitrogen application to achieve the highest grain yield by Houshmandfar and Kimaro (2011).

**Nutrient and protein content:** Nitrogen and phosphorus content of grain was higher than that of straw but the trend was reverse for potassium content. Age of seedling and time of nitrogen application could not make any significant difference in nutrient and protein content of grain and straw ( $p > 0.05$ ) (Table 3). This is attributed to the fact, that uptake of nutrients is accompanied by increase in growth (biomass production) of plant. Thus the increased absorption of nutrients well buffered by increased dry matter production failed to show any significant change in nutrient content of grain and straw. Dingkuhn *et al.*, (1991a, b) reported that the production of high leaf area led to low foliage nitrogen concentration because of nitrogen dilution. Since protein content is obtained by multiplying nitrogen content by a constant factor, 5.95 for rice (Souza *et al.*, 1999), therefore it couldn't show any significant difference due to age of seedling and time of application of nitrogen ( $p > 0.05$ ).

**Nutrient uptake:** Age of seedling created significant variation in N, P and K uptake by grain and straw. 35 days old seedling registered the highest N ( $75.67 \text{ kg ha}^{-1}$ ), P ( $15.92 \text{ kg ha}^{-1}$ ) and K ( $25.89 \text{ kg ha}^{-1}$ ) uptake in grain followed by 25 days old seedling ( $p < 0.05$ ). N, P, K uptake was also highest in straw of 35 days old seedling which was at par with 25 days old seedling (Table 4). This is attributed to higher yield of 35 days old seedling compared to other two ages of seedling. Regarding time of application of nitrogen,  $N_5$  ( $\frac{1}{2}$  basal, remaining at LCC  $< 4 @ 20 \text{ kg ha}^{-1}$  application $^{-1}$ ), showed highest nutrient uptake, other treatments except  $N_0$  (control) remained at par ( $p < 0.05$ ) (Table 4). This is because of the fact that additional supply of nitrogen during maximum growth phase favors higher nitrogen uptake of the crop. Increased stimulation of phosphorous

and potassium uptake by nitrogen was due to specific influence of nitrogen on the physiological activity of the roots that control nutrient absorption and transfer into the symplast. Houshmandfar and Kimaro (2011) found that total nitrogen uptake was higher for LCC based nitrogen treatments than for fixed schedule recommended nitrogen application. Nitrogen uptake in grain and straw increased with increment of nitrogen levels up to 100 kg/ha (Mannan *et al.*, 2010).

## Conclusion

It was concluded that transplanting aged seedlings lead to a poor crop performance. Maintaining of optimum leaf nitrogen status through LCC guided nitrogen management helps in supplying photosynthates in adequate quantities for proper crop growth and development. Thus, the yield of rice can be improved by transplanting 35-day old seedlings under late transplanted conditions and by following LCC guided nitrogen management.

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