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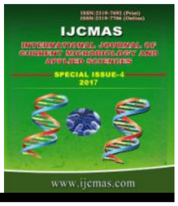

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Original Research Article

Accumulation of Nutrients (NPK) at Different Growth Stages of Machine Transplanted Rice (*Oryza sativa* L.) Under Different Levels of Nitrogen and Split Schedules

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ABSTRACT

Keywords

Accumulation of nutrients, growth stages, levels of nitrogen

A field experiment was conducted at Agriculture Research Institute (ARI), Rajendranagar, Hyderabad, Telangana on a clay loam soil during the *kharif* seasons of 2014 and 2015 to study the "Accumulation of nutrients (NPK) at different growth stages of machine transplanted rice (*Oryza sativa* L.) under different levels of nitrogen and split schedules". The experiment was taken up in a split plot design with three nitrogen levels (120, 160 and 200 kg N ha^{-1}) were kept as main plot treatments and three split schedules (2 equal splits at active tillering and panicle initiation, 3 equal splits at initial tillering, active tillering and panicle initiation and 4 equal splits at initial tillering, active tillering, tillering and panicle initiation) as sub plot treatments with three replications using the long duration variety BPT 5204. Application of 200 kg N ha^{-1}in 3 equal splits recorded maximum dry matter production, nitrogen, phosphorus and potassium uptake at all growth stages. The maximum uptake of nitrogen was from panicle initiation to flowering stages (39.1%) then followed by active tillering to panicle initiation (33.7%). Phosphorus was largely taken up at active tillering to panicle initiation (43.4%), while for potassium it was at active tillering to panicle initiation (36.5%), and then followed at panicle initiation to flowering (31.1%).

Introduction

Rice (*Oryza sativa* L.) is the most important staple food for more than half of the world's population. In Asia, more than two billion people are getting 60-70 per cent of their energy requirement from rice and its derived products, a major source of dietary protein for most people in tropical Asia (Juliano, 1993). In India, it is grown on an area of

44.1 m ha with a production of 106.7 mt with a productivity of 2.42 t ha^{-1}. In Telangana state, rice is also the principal food crop cultivated throughout the state. The crop is cultivated in an area of about 2.01 m ha with an annual production of 6.62 m t and productivity of 3.29 t ha^{-1} (Statistical Year Book, 2015). At the current population growth rate (1.5%), the rice requirement of India by 2025 would have to be around 125 m t (Kumar *et al.,* 2009). In India, area under rice is expected to be reduced from 44.1 to about 40.0 m ha in the next 15-20 years and most of this reduction is attributed to water shortage and rapid urbanization. Plateauing of rice yield coupled with restriction on area expansion, shortage of water, labour (Zheng *et al.,* 2004) and the need to achieve projected targets of about 125 m t by 2025 are the major challenges facing Indian researchers. To safeguard and sustain the food security in India, it is quite important to increase the productivity of rice under limited resources, especially land and water. Hence, the major challenges are to produce more rice per unit amount of natural resource. Among nutrients, nitrogen is the most important limiting element in rice growth and it is required in large amount (Jayanthi *et al.,* 2007). Additionally, rice production has heavy system losses of nitrogen when applied as inorganic sources in puddled field (Fillery *et al.,* 1984). Yield increase in magnitude of 70-80% of field rice could be obtained by the application of nitrogen fertilizer (IFC, 1982), a prime nutrient for protein and carbohydrate synthesis, growth and development of plant body. Mohammadin (2002) noted that limitation of nitrogen in any growth phase of the plant growth causes reduction in yield. Optimum dose of nitrogen fertilization plays a vital role in growth and development of rice plant, thus lower dose of nitrogen seriously hampered its growth which drastically reduces yield. Synchrony of nitrogen supply with crop demand is essential in order to ensure adequate quantity of uptake and utilization and optimum yield, therefore rate and timing of nitrogen application are critical in terms of their effects on yield and are important crop management practices for improving nitrogen use efficiency and crop yields (Fageria and Baligar, 2005). Therefore, the present study was undertaken to evolve the best combination of nitrogen level and split schedules on higher productivity under machine transplanted rice cultivation.

Materials and Methods

The experiment was conducted during *kharif* season of 2014 and 2015 at Rice Section experimental site of the Agricultural Research Institute (ARI), Rajendranagar, Hyderabad located at 17°32’ N latitude, 78° 40’ E longitude and at an altitude of 542.3 m above mean sea level. The soil was clay loam in texture, moderately alkaline in reaction with mean pH (8.1), organic carbon (1.37%) and electrical conductivity (1.42 dsm^{-1}) with low available nitrogen (230 kg ha^{-1}), high available phosphorus (41.5 kg ha^{-1}) and potassium (532.5 kg ha^{-1}). The experiment was laid out in a split plot design where main plot treatments consisted of three N levels: N_1=120, N_2=160 and N_3=200 kg ha^{-1} and sub plot treatments were split schedules: S_1=2 equal splits at active tillering (AT) and panicle initiation (PI), S_2=3 equal splits at initial tillering (IT), active tillering (AT) and panicle initiation (PI) and S_3=4 equal splits at initial tillering, (IT), active tillering (AT), tillering (T) and panicle initiation (PI) with three replications. Nitrogen was applied as urea while, 60 kg P_2O_5 kg ha^{-1} as single super phosphate (SSP) and potassium @ 40 kg K_2O ha^{-1} as muriate of potash (MOP) was applied to all the treatments uniformly as basal. The long duration (150 days) variety BPT 5204 was used in the experiment and was machine transplanted using 15 days old seedlings spaced at 30 x 16 cm. Individual plots were 7.2 m x 3.0 m and borders were made 30 cm high and wide using soil bunds to avoid N contamination between plots. Data collected were statistically analysed and presented in pooled means.

Results and Discussion

Dry matter production

Maximum dry matter was produced with the application of 200 kg N ha^{-1} at all growth stages and was at par with application of 160 kg N ha^{-1} (Table 1). It was significantly higher than application of 120 kg N ha^{-1} at all growth stages. The increase on dry matter was 27.0 % at active tillering, 20.5 % at panicle initiation, 13.6 % at flowering and 9.4% at maturity with application of 200 kg N ha^{-1} over 120 kg N ha^{-1}. Application of 200 kg N ha^{-1} also increased the dry matter production by 7.5% at active tillering, 11.5% at panicle initiation, 4.7% at maturity. Increased nitrogen availability at higher level of N might have been responsible for profuse tillering and plant height and hence higher dry matter accumulation. Significantly lowest dry matter was produced with application of 120 kg N ha^{-1} at all stages of growth in both years and in pooled means. Similar results were obtained by Meena*et al.*, (2003) and Babu*et al.*, (2013).

Maximum dry matter production was recorded with 3 equal split applications at all stages. The increase in dry matter production with 3 and 4 equal splits over 2 equal splits was 23.9 % and 22.3 % at active tillering, 16.5% and 12.5 % at panicle initiation, 14.7% and 14.5% at flowering and 3.2% and 1.4% at maturity. This might be due to favourable vegetative growth and development as they received adequate supply of nitrogen at the critical stages. This resulted in higher plant height, number of tillers, leaf area index and crop growth rate which contributed to higher dry matter production through increased photosynthetic activity of leaves. Youseftabar *et al.*, (2012) and Postmasari*et al.*, (2007) found similar results were 3 equal split recorded highest dry matter production.

Nitrogen uptake (kg ha^{-1})

Nitrogen uptake of the crop was significantly influenced by nitrogen levels and stages of application. Nitrogen uptake increased rapidly from active tillering to flowering then it continued to increase to maturity at a decreasing rate. Highest N uptake was observed at maturity stage. Increase in N application level showed increased in N uptake at all growth stages (Table 1).

Maximum N uptake (31.2 kg ha^{-1} at active tillering, 82.4 kg ha^{-1} at panicle initiation, 134.0 kg ha^{-1}at flowering and 144.2 kg ha^{-1} at maturity) was observed with the application of 200 kg N ha^{-1} and was at par with the application of 160 kg N ha^{-1} (123.5 kg ha^{-1}) at flowering only.

Application of 200 kg N ha^{-1} recorded significantly higher N uptake as compared to application of 160 kg N ha^{-1} at active tillering, panicle initiation and maturity (3.5, 9.8 and 9.4 kg ha^{-1}respectively) and 120 kg N ha^{-1} at active tillering, panicle initiation, flowering and maturity (6.0, 18.0, 25.1 and 21.4 kg N ha^{-1}respectively). The uptake being the product of nutrient content and dry mass accumulation, the increase in nutrient uptake by crop at higher dose of nitrogen might be due to increased availability of nutrients and higher grain and straw yields.

Similarly, Meena*et al.*, (2002) and Panday*et al.*, (2007) observed highest N uptake with application of 200 kg N ha^{-1}. Fageria and Baligar (2001) also reported that nitrogen uptake increased with the advancement of the crop growth age up to the flowering stage and thereafter decreased. Lowest N uptake was recorded with application of 120 kg N ha^{-1} at all growth stages and was at par with application of 160 kg N ha^{-1} at active tillering and flowering.

Three equal split applications recorded maximum N uptake, that is, 31.1 kg ha^{-1} at active tillering, 79.2 kg ha^{-1} at panicle initiation, 130.6 kg ha^{-1} at flowering and 136.4 kg ha^{-1} at harvest. Both 3 and 4 equal split applications recorded significantly higher N uptake as compared to 2 equal splits at all growth stages. Three equal splits recorded 7.7 kg ha^{-1} at active tillering, 13.7 kg ha^{-1} at panicle initiation, 21.6 kg ha^{-1} at flowering and 6.6 kg ha^{-1} at harvest more N uptake as compared to 2 equal splits. These results are similar to those found by Mahajan and Sekhar (2010), Chaudhary *et al.*, (2013) and Tari and Amiri (2015). The interactive effect of nitrogen levels and stages of application were found to be non-significant on N uptake at all growth stages.

The average nitrogen absorption levels in the rice plants were 28.0, 45.1, 52.3 and 8.5 kg ha^{-1} at periods from transplanting to active tillering, active tillering to panicle initiation, panicle initiation to flowering and flowering to maturity respectively (Table 2).

Across the whole growth period, the highest amount of nitrogen was accumulated from panicle initiation to flowering (39.1%), then followed by active tillering to panicle initiation stages (33.7%), transplanting to active tillering (20.9%) and lowest nitrogen accumulation was from flowering to maturity (6.3%).

Additionally, highest nitrogen accumulation was observed when highest nitrogen application rate of 200 kg N ha^{-1} was used and was at par with application of 160 kg N ha^{-1} but significantly higher as compared to 120 kg N ha^{-1} at transplanting to active tillering and from active tillering to panicle initiation. In terms of stages of application, maximum nitrogen accumulation was observed with 3 equal splits at initial tillering, active tillering and panicle initiation stages at early stages that is, transplanting to active tillering and from active tillering to panicle initiation. From flowering to maturity, 2 equal splits recorded highest nitrogen accumulation which must be due to higher proportion of nitrogen applied at panicle initiation stage as compared to 3 and 4 equal splits.

Phosphorus uptake (kg ha^{-1})

Phosphorus uptake of the crop was significantly influenced by nitrogen levels and stages of application at all growth stages. Phosphorus uptake increased rapidly from active tillering to panicle initiation, and then it continues to increase at a decreasing rate to flowering. The P uptake rate from flowering to maturity was lower as compared to the previous stage (Table 1).

Highest and significant P uptake (7.6 kg ha^{-1} at active tillering, 23.4 kg ha^{-1} at panicle initiation, 32.5 kg ha^{-1} at flowering and 35.0 kg ha^{-1} at harvest) was recorded when 200 kg N ha^{-1} was applied and was at par with application of 160 kg N ha^{-1} at panicle initiation, flowering and at harvesting.. The increase in P uptake with application of 200 kg N ha^{-1} as compared to application of 120 kg N ha^{-1}at active tillering is 1.4 kg ha^{-1}. Application of 160 kg N ha^{-1} recorded on par P uptake with application of 120 kg N ha^{-1} at active tillering, panicle initiation and at harvest but was significantly higher (6.0

kg P ha^{-1}) at flowering. Majumdar *et al.*, (2005) explained that nitrogen had a complimentary effect on availability of P, thus enhanced uptake of N resulted in enhancement in the uptake of P. Application of 120 kg N ha^{-1} recorded lowest P uptake at all growth stages.

Three equal split applications recorded maximum phosphorus uptake (6.6, 21.6, 28.8 and 32.8 kg P ha^{-1} at active tillering, panicle initiation, flowering and at harvest) and was at par with 4 equal splits. The 3 equal split recorded significantly higher phosphorus uptake as compared to 2 equal splits, a difference of 2.4, 6.3, 9.0 and 9.1 kg P ha^{-1} at active tillering, panicle initiation, flowering and at harvest, respectively. The interactive effect of nitrogen levels and split schedules were found to be non-significant on P uptake at all growth stages.

Average phosphorus uptake was 6.3, 13.5, 8.3 and 3.0 kg ha^{-1} at periods from transplanting to active tillering, active tillering to panicle initiation, panicle initiation to flowering and flowering to maturity respectively (Table 3). Unlike nitrogen uptake, maximum phosphorus uptake was observed at active tillering to panicle initiation (43.4%), followed by panicle initiation to flowering (26.7%), transplanting to active tillering (20.6%) and least at flowering to maturity (9.6%). Generally, it could be concluded that phosphorus uptake increased with increase nitrogen application rate. Three equal split applications at initial tillering, active tillering and panicle initiation provide best environment for maximum phosphorus uptake.

Fig.1 Correlation between grain yield and total uptake of nitrogen, phosphorus and potassium in response to nitrogen levels (top) and stages of application (bottom) in machine transplanted rice

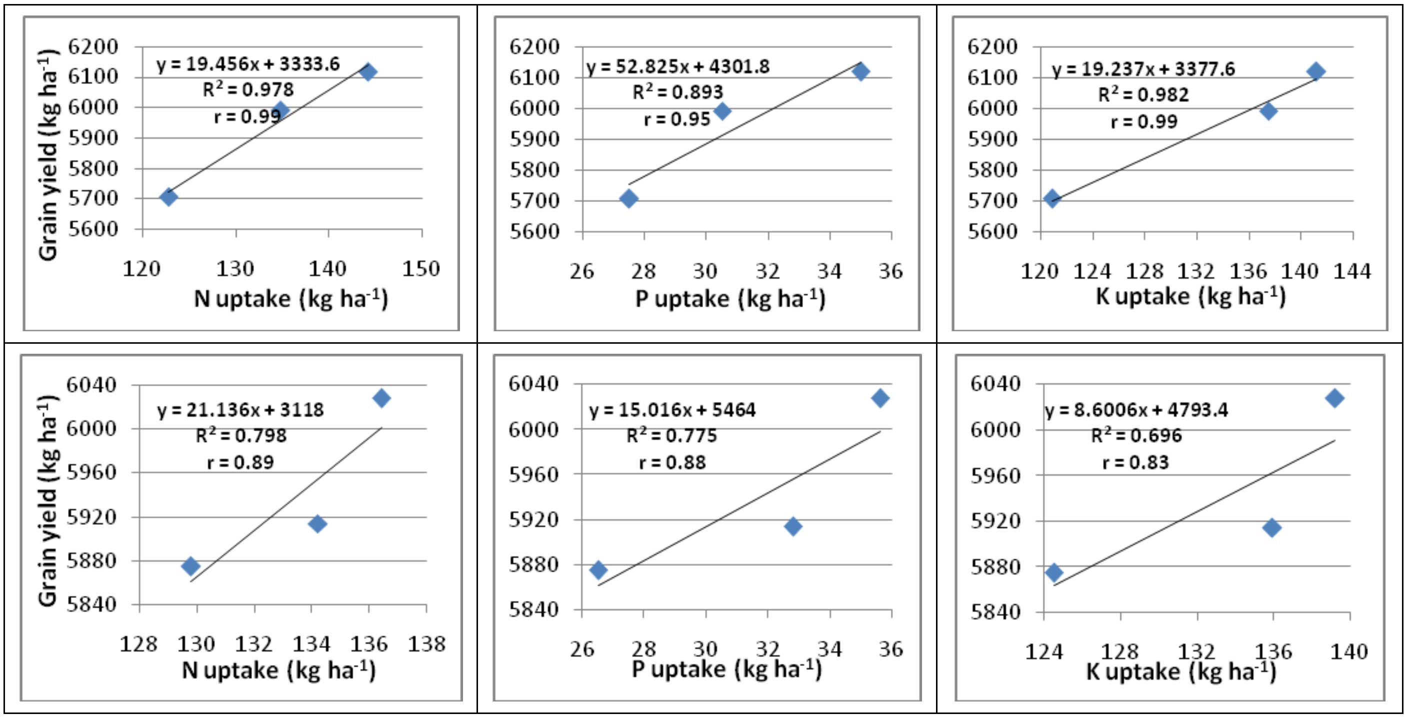

Table.1 NPK uptake at different growth stages as influenced by different nitrogen levels and split schedules in machine transplanted rice (pooled means)

Treatments	Dry matter production (kg m^{-2})				Nutrient uptake (kg ha^{-1})											
					Nitrogen				Phosphorus				Potassium			
	AT	PI	FL	Mat	AT	PI	FL	Mat	AT	PI	FL	Mat	AT	PI	FL	Mat
Nitrogen levels (kg ha^{-1})																
N_1 – 120	0.13	0.62	1.43	1.33	25.2	64.4	118.9	122.8	5.0	16.6	22.8	27.5	22.1	65.6	111.2	120.8
N_2 – 160	0.15	0.66	1.55	1.40	27.7	72.6	123.5	134.8	6.2	19.3	28.8	30.5	26.7	74.6	118.1	137.5
N_3 – 200	0.16	0.73	1.62	1.47	31.2	82.4	134.0	144.2	7.6	23.4	32.5	35.0	30.1	87.3	125.8	141.2
SEM±	0.03	0.13	0.06	0.07	1.2	2.8	2.8	2.7	0.5	1.6	1.7	1.6	1.5	3.6	3.2	1.7
CD (p=0.05)	0.08	0.36	0.17	0.10	3.3	7.8	7.7	7.5	1.4	4.2	4.5	5.0	4.1	10.0	7.7	4.4
Stages of application																
S_1 - 2 equal split	0.13	0.61	1.40	1.38	23.4	65.5	119.0	129.8	5.0	16.0	23.1	26.5	20.5	69.1	116.1	124.5
S_2 - 3 equal splits	0.16	0.71	1.60	1.42	31.1	79.2	130.6	136.4	7.4	23.3	32.1	35.6	30.9	82.8	122.4	139.2
S_3 - 4 equal splits	0.15	0.69	1.60	1.40	29.2	75.1	129.6	134.2	6.6	21.6	28.8	32.8	27.7	75.6	117.6	135.9
SEM±	0.03	0.19	0.04	0.01	1.2	3.3	3.1	1.5	0.8	0.8	1.9	1.7	1.5	3.1	1.7	2.8
CD (p=0.05)	0.06	0.42	0.09	0.02	2.7	7.1	6.7	3.3	2.3	2.1	4.8	5.2	3.5	7.9	3.8	NS
N x S SEM±	0.04	0.33	0.07	0.01	2.1	5.6	5.3	2.6	0.2	0.4	0.3	0.4	2.0	3.0	3.0	4.6
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x N SEM±	0.05	0.30	0.09	0.01	2.1	5.4	7.4	3.5	0.3	0.3	0.3	0.5	2.2	2.5	4.9	3.9
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

AT = active tillering, PI = panicle initiation, FL = flowering, Mat = maturity

Table.2 Effect of nitrogen levels and stages of application on nitrogen uptake (kg ha^{-1}) by machine transplanted rice at different growth stages

Treatments	Transplanting to active tillering	Active tillering to panicle initiation	Panicle initiation to flowering	Flowering to maturity
Nitrogen levels (kg ha^{-1})				
N_1 – 120	25.2	39.2	54.5	3.9
N_2 – 160	27.7	44.9	50.9	11.3
N_3 – 200	31.2	51.2	51.6	10.2
SEM±	1.2	3.9	1.7	1.3
CD (p=0.05)	3.3	8.7	NS	2.6
Stages of application				
S_1 - 2 equal split at AT and PI	23.4	42.1	53.5	10.8
S_2 - 3 equal splits at IT, AT and PI	31.1	48.1	51.4	5.8
S_3 - 4 equal splits at It, AT, T and PI	29.2	45.9	54.5	4.6
SEM±	1.2	3.5	2.4	2.5
CD (p=0.05)	2.7	NS	NS	5.1

AT = active tillering, PI = panicle initiation, FL = flowering, Mat = maturity

Table.3 Effect of nitrogen levels and stages of application on phosphorus uptake (kg ha^{-1}) by machine transplanted rice at different growth stages

Treatments	Transplanting to active tillering	Active tillering to panicle initiation	Panicle initiation to flowering	Flowering to maturity
Nitrogen levels (kg ha^{-1})				
N_1 – 120	5.0	11.6	6.2	4.7
N_2 – 160	6.2	13.1	9.5	1.7
N_3 – 200	7.6	15.8	9.1	2.5
SEM±	0.2	0.9	1.2	0.5
CD (p=0.05)	0.4	2.2	2.9	1.3
Stages of application				
S_1 - 2 equal split at AT and PI	5.0	11.0	7.1	3.4
S_2 - 3 equal splits at IT, AT and PI	7.4	15.9	8.8	3.5
S_3 - 4 equal splits at It, AT, T and PI	6.6	15.0	7.2	4.0
SEM±	0.1	1.3	0.3	0.4
CD (p=0.05)	0.3	3.0	0.7	NS

AT = active tillering, PI = panicle initiation, FL = flowering, Mat = maturity

Table.4 Effect of nitrogen levels and stages of application on potassium uptake (kg ha^{-1}) by machine transplanted rice at different growth stages

Treatments	Transplanting to active tillering	Active tillering to panicle initiation	Panicle initiation to flowering	Flowering to maturity
Nitrogen levels (kg ha^{-1})				
N_1 – 120	22.1	43.5	45.6	19.6
N_2 – 160	26.7	47.9	43.5	19.4
N_3 – 200	30.1	57.2	38.5	15.4
SEM±	1.5	1.7	2.2	3.3
CD (p=0.05)	4.1	4.8	NS	NS
Stages of application				
S_1 - 2 equal split at AT and PI	20.5	48.6	47.0	18.4
S_2 - 3 equal splits at IT, AT and PI	30.9	51.9	39.6	16.8
S_3 - 4 equal splits at It, AT, T and PI	27.7	47.9	42.0	18.3
SEM±	2.2	2.4	2.0	3.2
CD (p=0.05)	4.5	NS	4.4	NS

AT = active tillering, PI = panicle initiation, FL = flowering, Mat = maturity

Potassium uptake (kg ha^{-1})

Potassium uptake of the crop was significantly influenced by nitrogen levels and stages of application. Potassium uptake was rapid from active tillering to flowering then it continues to increase at a decreasing rate to maturity (Table 1).

Maximum K uptake (30.1 kg ha^{-1} at active tillering, 87.3 kg ha^{-1} at panicle initiation, 125.8 kg ha^{-1} at flowering and 141.2 kg ha^{-1} at harvest) was observed with the application of 200 kg N ha^{-1} and was at par with the application of 160 kg N ha^{-1} at active tillering and at harvest except at panicle initiation and flowering. Potassium uptake with application of 200 kg N ha^{-1} was significantly higher as compared to application of 120 kg N ha^{-1} by 8.0 kg ha^{-1} at active tillering, 21.7 kg ha^{-1} at panicle initiation, 24.6 kg ha^{-1} at flowering and 10.4 kg ha^{-1} at harvest. Application of 160 kg N ha^{-1} recorded 4.6 kg ha^{-1} increase in K uptake at active tillering and 6.7 kg ha^{-1} at harvesting over application of 120 kg N ha^{-1}. Majumdar *et al.,* (2005) explained that nitrogen had a complimentary effect on availability of K, thus enhanced uptake of N resulted in enhancement in the uptake of K. Lowest K uptake was observed with application of 120 kg N ha^{-1} at all growth stages.

Regarding split schedules, 3 equal split observed highest K uptake (30.9, 82.8 and 122.4 kg ha^{-1}) at active tillering, panicle initiation and at flowering, respectively, and was non-significant at harvest. The increase in K uptake with 3 equal splits over 2 equal splits were 10.4 kg ha^{-1} at active tillering, 13.7 kg ha^{-1} at panicle initiation and 16.3 kg ha^{-1} at flowering. The interactive effect of nitrogen levels and split schedules were found to be non-significant on K uptake at all growth stages.

Average potassium uptake was 26.3, 49.5, 42.5 and 18.1 kg ha^{-1} at periods from transplanting to active tillering, active tillering to panicle initiation, panicle initiation to flowering and flowering to maturity respectively (Table 4). Maximum potassium uptake was observed at active tillering to panicle initiation (36.5%), followed by panicle initiation to flowering (31.1%), transplanting to active tillering (19.4%) and least at flowering to maturity (13.0%). Generally, it could be seen that potassium uptake increased with increase nitrogen application rate. Three equal split applications observed highest uptake at transplanting to active tillering and from active tillering to panicle initiation, then followed by 2 equal splits from panicle initiation to flowering and to maturity.

Relationship between total nutrient uptake and grain yield

Significant correlations existed between grain yield and total nitrogen, phosphorus and potassium uptake amounts. These correlation coefficients were 0.99, 0.95 and 0.99 as influenced by nitrogen levels and 0.89, 0.88 and 0.83 as influenced by stages of application for nitrogen, phosphorus and potassium respectively (Fig. 1).

Application of 200 kg N ha^{-1} in three equal splits at initial tillering, active tillering and panicle initiation enabled the crop to produced significantly highest dry matter production which resulted in recording highest total nitrogen, phosphorus and potassium uptake. Maximum nitrogen uptake was recorded at panicle initiation to flowering stages while phosphorus and potassium uptakes were highest at active tillering to panicle initiation stage. These results are important in making sound fertilizer recommendations regarding the application of nitrogen, phosphorus and potassium at the optimum levels and time of application.

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