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*Full Length Research Paper*

# Influences of nitrogen and potassium top dressing on yield and yield components as well as their accumulation in rice (*Oryza sativa*)

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**This research was conducted to investigate the effects of different rates of nitrogen (N) and potassium (K) top dressing on grain yield and yield components of rice (*Oryza sativa* cv. Tarrom) and to investigate N and K content of upper leaves analyzed at ten different times. A pot experiment was carried out on a completely randomized design with seven replications under greenhouse conditions at the Experiment Station of Sari Agricultural Sciences and Natural Resources University, Iran, during the growing season in 2008. Nitrogen was applied in the form of urea (46% N) at the rates of 0, 23 and 46 kg N $ha^{-1}$ and potassium in the form of potassium chloride (60% $K_2O$) at the rates of 0, 30 and 60 kg $K_2O$ $ha^{-1}$. Results indicated that panicle length, plant height, number of tiller, number of grain per panicle, hollow grain percentage, grain and biological yield were significantly affected by N and K fertilization. Maximum grain yield (75.46 g $pot^{-1}$) occurred at 23 kg N $ha^{-1}$ and 30 kg $K_2O$ $ha^{-1}$. At flowering stage, K content of stems were higher than leaves, and N content in flag leaves was higher than other plant parts.**

**Key words:** Leaf potassium concentration, potassium chloride, rice, top-dressing fertilization, urea and yield.

## INTRODUCTION

Increase in rice production in Asia in the 1960s and 1970s brought about by improved germplasm was associated with increased use of nitrogen (N) fertilizers, but without a corresponding increase in the use of potassium (K) fertilizers. As a result, most irrigated rice production systems were conducted under negative K balances (Wihardjaka et al., 1999). K is the most abundant nutrient in plants including rice plant. This is especially true for improved cultivars that uptake K considerably upto four-fold higher than native cultivars (Dobbermann et al., 1998). It is also one of the most important factors influencing crop metabolism, growth, development and yield. K plays a number of indispensable roles in a wide range of functions: photosynthesis, enzyme activation, protein synthesis, osmotic potential and as a counter ion to inorganic ions and organic biopolymers (Marschner, 1995). K deficiency resulted in a decrease in net photosynthetic rate and dramatic decrease in crop yield (Ding et al., 2006).

De Datta and Gumez (1985) showed that K has additive influence on filled grain percentage per panicle and its deficiency cause sterility of pollen seeds at the reproductive stage and result in decreased number of filled grains. Qiangsheng et al. (2004) reported that K uptake by rice population is maximized in the growth season of elongation stage to heading stage. Non-fertilizer and/or excessive fertilizer application enhanced plant K uptake before the elongation stage, but reduced effective panicles. Also, with one-time application of K as basal dressing compared to one-time application as top-dressing, K application as panicle fertilizer caused increases in plant K uptake and proportion from elongation stage to heading stage as well as number of filled grain. Combined application of K and N had a remarkable positive reciprocal effect on crops, and was an important approach in improving K use efficiency (Li et al., 2009). Kavitha et al. (2008) revealed that application of N and K in four equal splits at active tillering, panicle initiation,

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booting and flowering recorded higher yield of 7484 kg/ha in kharif seasons for hybrid rice.

Nitrogen is one of the most important plant nutrients and plays a vital role in plant photosynthesis and biomass production. Several studies showed that when there is a slight N deficit within plants, the demands for $NO_3^-$-N, free amino acid and free amino N increase quickly, without necessarily a simultaneous marked change in total nitrogen (Wang et al., 2005). Increasing panicle numbers in per unit area is the main factor of yield increment as result of nitrogen application (Bindra et al., 2000). Zhou and Wang (2003) indicated that in tillering stage, the ratio of protein-N to non-protein-N were not considerably different between the upper leaf and the lower leaf. Sulok et al. (2007) reported that urea and potassium chloride application significantly increased soil N, K, magnesium (Mg), and sodium (Na) concentrations. Potassium concentration in stems and N in roots were significantly higher under fertilized condition (0.52 g N and 0.60 g $K_2O$ per pot) than under unfertilized condition. Due to N and K fertilization, there was significant increase in plant height and number of panicles under fertilized condition compared to under unfertilized condition. Nitrogen, K, Na and Mg uptake in stem were significantly higher for fertilized condition than under unfertilized condition.

The main objectives of the present study are to consider the effects of compound of urea and potassium chloride with different proportion in two stages as top-dressing, on variation of nitrogen and potassium concentration during growth season, yield and yield components of rice (landrace rice cultivar) and to determine the best compound for top-dressing.

## MATERIALS AND METHODS

The experiment was a pot study conducted in a glasshouse at the Experiment Station of Sari Agricultural Sciences and Natural Resources University during the growing seasons in 2008. Three N rates of 0 ($N_0$), 23 ($N_1$) and 46 ($N_2$) kg N $ha^{-1}$ and three K rates of 0 ($K_0$), 30 ($K_1$) and 60 ($K_2$) kg $K_2O$ $ha^{-1}$ were established in the experiment. The form of N fertilizer was urea with N content of 46% and K fertilizer was potassium chloride with $K_2O$ content of 60%. These fertilizers were applied in two splits: 50% at mid of tillering (15 days after transplanting) and 50% at panicle initiation (35 days after transplanting) as top-dressing per pots. Plastic pots with 15 l volume were filled up to 15 kg paddy soil (0 - 30 cm $A_p$ horizon) and then submerged to balance chemical reactions in the flooded soil for two weeks. The experimental soil type was Gleyed paddy soil with pH 7.2, total N of 12.7 g $kg^{-1}$, available K of 175 mg $kg^{-1}$ and available phosphorous of 9 mg $kg^{-1}$. 50 kg superphosphate and 50 kg urea $ha^{-1}$ were added to pots as basal dressing, based on soil testing results. After preparation of seed, sowing was done on the 22$^{nd}$ of May and transplanting on the 25$^{th}$ of June. Planting density was 20 × 20 cm with four plants per pots. Upper fully expanded leaves were sampled during the growth period at 14, 17, 19, 25, 31, 34, 36, 43, 50 and 95 days after transplanting, to determine N and K concentration. Total plant N was determined by Kjeldahl method and K extracted by 1 M HCl and measured by a flame spectrophotometer (Page et al., 1982).

At maturity, straw and grain weight were measured in a 12-hill sample (three pots) dried at 75°C to constant weight. Hills included all above ground plant material. Panicle length, number of grains per panicle, hollow grain percentage, plant height, length of flag leaves, 1000 grain weight, tiller number, biological yield and harvest index were determined (Esfehani et al., 2005). Harvest index was calculated as the ratio of grain dry weight to the total aboveground dry weight at maturity.

The experimental design was completely randomized design (CRD) with seven replications. Data was analyzed statistically to detect treatment effect. The statistical software used was the statistical analysis system (SAS) and means compared with Duncan's multiple range tests.

## RESULTS AND DISCUSSION

### Effects of different rates of N and K top dressing on grain yield and yield components

Mean squares from the analyses of variance (Table 1) showed that N treatment effects for grain yield and yield components, except for 1000 grain weight, was significant ($p < 0.01$) while potassium treatment effects were significant for number of grains per panicle, hollow grain percentage, biological yield and harvest index. Interaction effect of N and K was significant for number of grains per panicle, hollow grain percentage, biological yield and harvest index ($p < 0.01$).

Panicle length was significantly influenced by nitrogen treatment (Table 1). Increasing N and K fertilizers caused an increase in panicle length from 22.1 cm in ($N_0K_0$) to 26.8 cm in $N_1K_2$, but panicle length decreased with higher rates of N ($N_2$ treatments). This showed that stimulating vegetative plant growth and increasing tiller numbers by nitrogen could cause a decrease of panicle length (Shen et al., 2003).

Plant height was significantly influenced by nitrogen treatment (Table 1). The highest plant height (181 cm) was found in $N_1K_1$ which was similar to $N_1K_0$ (179 cm) and $N_1K_2$ (178 cm) treatments, while the lowest plant height (150 cm) was recorded for $N_0K_0$ treatment (Table 2). These results are similar to those obtained by Rahman et al. (2007).

Length of flag leaves from 33.3 to 43.3 cm in $N_2K_2$ and number of tillers from 10.2 to 15.9 in $N_2K_1$ were increased. Length of flag leaves and number of tiller increased with increasing N and K amounts, which could be attributed to the influence of N on leaf development, tiller production and increasing leaf photosynthetic activity (Ntanson and Koutroubas, 2002). However, this necessarily did not result in cause yield increase, because net photosynthesis of canopy, total dry matter production and grain yield could decrease with increase in leaf development and tiller number (Ohnishi et al., 1999).

Number of grains per panicle increased with increasing N and K from 80.8 ($N_0K_2$) to 108.4 in $N_1K_2$ and hollow grain percentage from 6.2% in $N_0K_1$ to 38.6% in $N_2K_1$. Number of grains per panicle increased with increasing N and K rates (Table 2), and treatment combinations of $N_2K_0$ and $N_2K_1$ (46 Kg N $ha^{-1}$ with 0 or 30 kg $K_2O$ $ha^{-1}$) increased hollow grain percentage. It seems that the

**Table 1.** Variance analysis of rice grain yield and yield components (MS).

| S.O.V. | df | MS Mean squares) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Panicle length | Plant height | Length of flag leaves | Number of tiller | Number of grains per panicle | Hollow grain (%) | 1000 grain weight | Grain yield per pot | Biological yield per pot | Harvest index per pot |
| Nitrogen | 2 | 15.8** | 1641** | 189** | 47.5** | 1009** | 1402** | $2.7^{ns}$ | 421** | 2247** | 793** |
| Potassium | 2 | $5.4^{ns}$ | $25^{ns}$ | $3.5^{ns}$ | 1.5 | 202** | 15* | $2.4^{ns}$ | 1.9 | 21.4* | 20** |
| N × K | 4 | $3.6^{ns}$ | $16^{ns}$ | $6.6^{ns}$ | 0.4 | 193** | 90** | $0.6^{ns}$ | 18.1* | 16.3* | 23** |
| Error | 18 | 1.8 | 14 | 2.5 | 1.6 | 15 | 2.6 | 1.9 | 15.2 | 3.8 | 3.2 |
| CV (%) | | 5.6 | 2.3 | 4.2 | 9.7 | 4.2 | 7.1 | 7.24 | 5.8 | 3.32 | 5.3 |

CV = Coefficient of variation, ** = ($p < 0.01$) * = ($p < 0.05$) ns = not significant.

**Table 2.** Means comparison of rice yield and yield component.

| Treatments | Panicle length (cm) | Plant height (cm) | Length of flag leaves (cm) | Number of tiller | Number of grains per panicle | Hollow grain (%) | 1000 grain weight (g) | Grain yield (g $pot^{-1}$) | Biological yield per pot (g) | Harvest index per pot |
|---|---|---|---|---|---|---|---|---|---|---|
| $N_0K_0$ | 23.1b | 150d | 33.3c | 10.9d | 86.2b | 8.5e | 18.6a | 61.6e | 44.2d | 43.1ab |
| $N_0K_1$ | 22.7b | 156cd | 33.4c | 10.2cd | 89.2b | 6.2e | 18.8a | 59.1e | 41.1d | 45.2a |
| $N_0K_2$ | 23.3ab | 151d | 33.5c | 11.1bcd | 80.8b | 14.6d | 18.5a | 58.8e | 43.0d | 41.9ab |
| $N_1K_0$ | 26.0ab | 179a | 42.1ab | 12.8abcd | 105.0a | 19.0c | 20.8a | 71.6b | 64.6b | 31.5c |
| $N_1K_1$ | 24.3ab | 181a | 41.1ab | 13.4abc | 105.7a | 25.5b | 19.5a | 75.5a | 57.5c | 39.6b |
| $N_1K_2$ | 26.8a | 178a | 41.2ab | 13.7ab | 108.4a | 27.6b | 19.0a | 73.7ab | 63.1b | 23.7c |
| $N_2K_0$ | 26.0ab | 168b | 38.8ab | 14.6a | 107.0a | 35.4a | 20.1a | 66.8cd | 74.6a | 24.1d |
| $N_2K_1$ | 23.5ab | 165bc | 41.9ab | 15.9a | 90.0b | 38.6a | 19.0a | 65.2d | 75.3a | 23.1d |
| $N_2K_2$ | 22.6b | 163bc | 43.3a | 15.3a | 81.0b | 28.5b | 18.8a | 70.2bc | 72.7a | 26.4d |

$N_0$: Without N; $N_1$: 23 kg N per hectare; $N_2$: 46 kg N per hectare; $K_0$: without K; $K_1$: 30 kg $K_2O$ per hectare; $K_2$: 60 kg $K_2O$ per hectare; *each row with same letters was not significantly different ($p< 0.01$).

cause of increase in grain number per panicle at high N level caused severe competition for carbohydrates, which resulted in increased hollow grain percentage. In lower nitrogen levels, insufficient nutrients for filling of grains led to diminished grain number per panicle;thus in this state, lower competition is the cause of decreased hallow grain percentage in panicle. Esfehani et al. (2005) and Mondal et al. (1987) showed that potassium fertilizer has positive effect on filled grains in rice while its deficiency caused pollen sterility and decreased rice filled grains number. Weight of 1000-grains was not significantly affected by fertilizer treatments, it is a genetical character fixed by an individual variety (Wilson et al., 1996).

Grain yield was significantly influenced by top dressing application of fertilizers especially of nitrogen. The highest grain yield (75.5g per pot) observed from $N_1K_1$ treatment, was statistically similar to $N_1K_2$ treatment (Table 2). The lowest grain yield recorded was with $N_0$ treatments. Application of 46 kg N $ha^{-1}$ at two stages of top-dressing ($N_2$ treatments) produced maximum straw yield (Figure 1); this could be a lodging agent and could eventually lead to decrease in yield. Nitrogen increased straw yield with effect on plant vegetative growth by increasing tiller number and plant height. Rahman et al. (2007) also showed that maximum straw yield (6.98 ton $ha^{-1}$) was obtained with the highest dose of N level (46

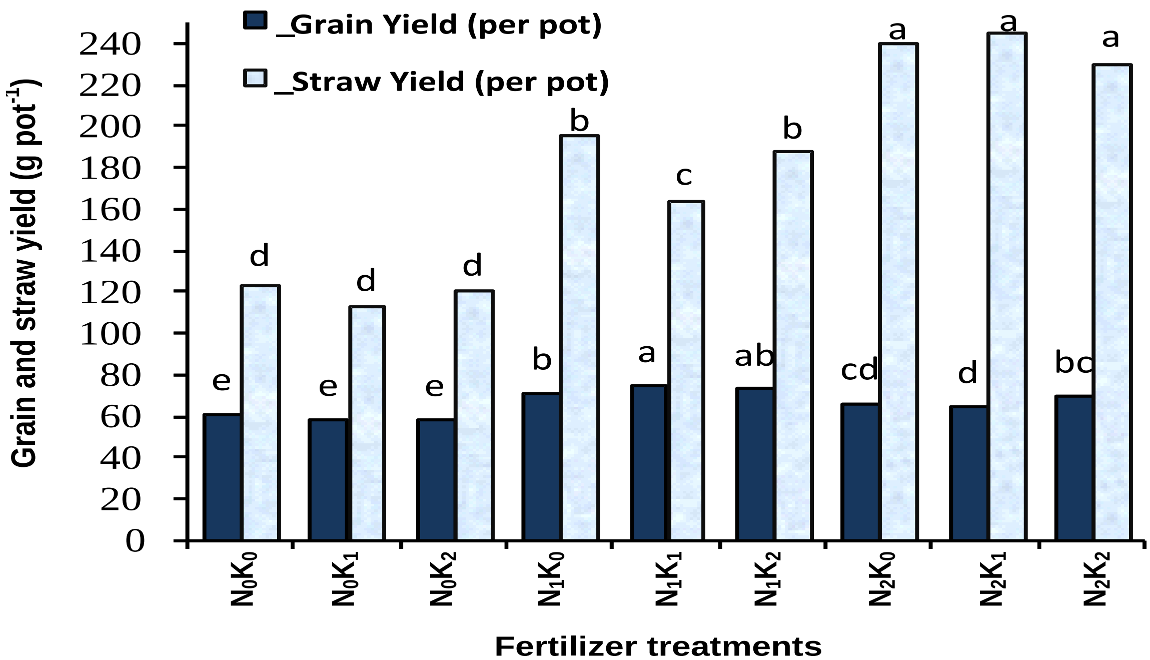


**Figure 1.** Grain and straw yields per pot affected by N and K treatments. $N_0$: Without N, $N_1$: 23 Kg N $ha^{-1}$, $N_2$: 46 Kg N $ha^{-1}$. $K_0$: without K, $K_1$: 30 Kg $K_2O$ $ha^{-1}$, $K_2$: 60 Kg $K_2O$ $ha^{-1}$.

Kg N $ha^{-1}$). With increment of nitrogen fertilizer, grain yield increased relatively, but further increase in nitrogen level produced higher straw yield that ultimately gave the lower harvest index. This result was supported by Qiangsheng et al. (2004) and Kanda and Dixit (1996).

DeDatta and Gumez (1985) showed that the effect of nitrogen on grain yield significantly affected the response to potassium presence; when nitrogen fertilizers are not utilized, rice do not react to potassium fertilizer. In this research, increasing grain yield in fertilizer treatments led to increase in straw and dry matter yield (Figure 1) while reducing harvest index in high fertilizer levels (Table 2).

## Accumulation of N and K in plant

Nitrogen and potassium concentration changed in upper development leaves, during growth stage, after two stages of top-dressing (Figure 2). Nitrogen content in upper leaves did not increased considerably, after top-dressing fertilization (Figures 2a, b and c), but nitrogen levels of upper fully extended leaves was high in $N_2$ treatment (46 Kg N $ha^{-1}$) especially, in terminal growth stage. The concentration of K in leaves increased after top-dressing in each stage (Figures 2d, e and f). Potassium concentration decreased with initiation of natal stage (30 days after transplanting) and further increase of leaf potassium was observed after second top-dressing stage (40 days after transplanting). Generally, potassium content in upper fully expanded leaves in $N_2$ (46 Kg N $ha^{-1}$) treatments was more than $N_1$ (23 Kg N $ha^{-1}$) and $N_0$ (control) treatments. Slaton et al. (2004) reported similar results which showed that the upper and middle leaves have higher K concentration than the lower leaves, and this concentration gradient is most pronounced in K deficient rice plants (from 0.15 to 0.80%). Maximum potassium concentration was observed between 1 and 5 weeks after flooding, before panicle differentiation.

Nitrogen and potassium distribution of rice shoot in fertilizer treatments at flowering stage are shown in Figure 3. In the flowering stage, flag leaves proportion in plant nitrogen content was more than that observed for rest leaves and significantly higher than in the stems. The highest nitrogen content in flag leaves was 3.8% in $N_2K_0$, while in rest leaves and stems, it was 3.5 and 1.9% in $N_2K_1$, respectively. Potassium content in stems proportion was higher than flag leaves and rest leaves. This could be attributed to K role in material transportation by plant xylem and phloem. The maximum K content concentrated in stems, flag leaves and rest leaves were 4.2, 2.0 and 1.7% in $N_2K_1$, $N_2K_2$ and $N_1K_2$, respectively. The treatments also received high amount of N ($N_2$). The flag leaves had more K than stems.

Slaton et al. (2004) also showed that rice stems represent the majority of plant biomass and contain 50 to 75% of the aboveground K, and K concentrations in mature rice stem are usually >1.0% when K availability is not growth- or yield-limiting. Sulok et al. (2007) reported same results with application of urea and potassium chloride. These researchers showed that the highest K concentration was in stem and N in roots under fertilizer treatments. Due to N and K fertilization, there was

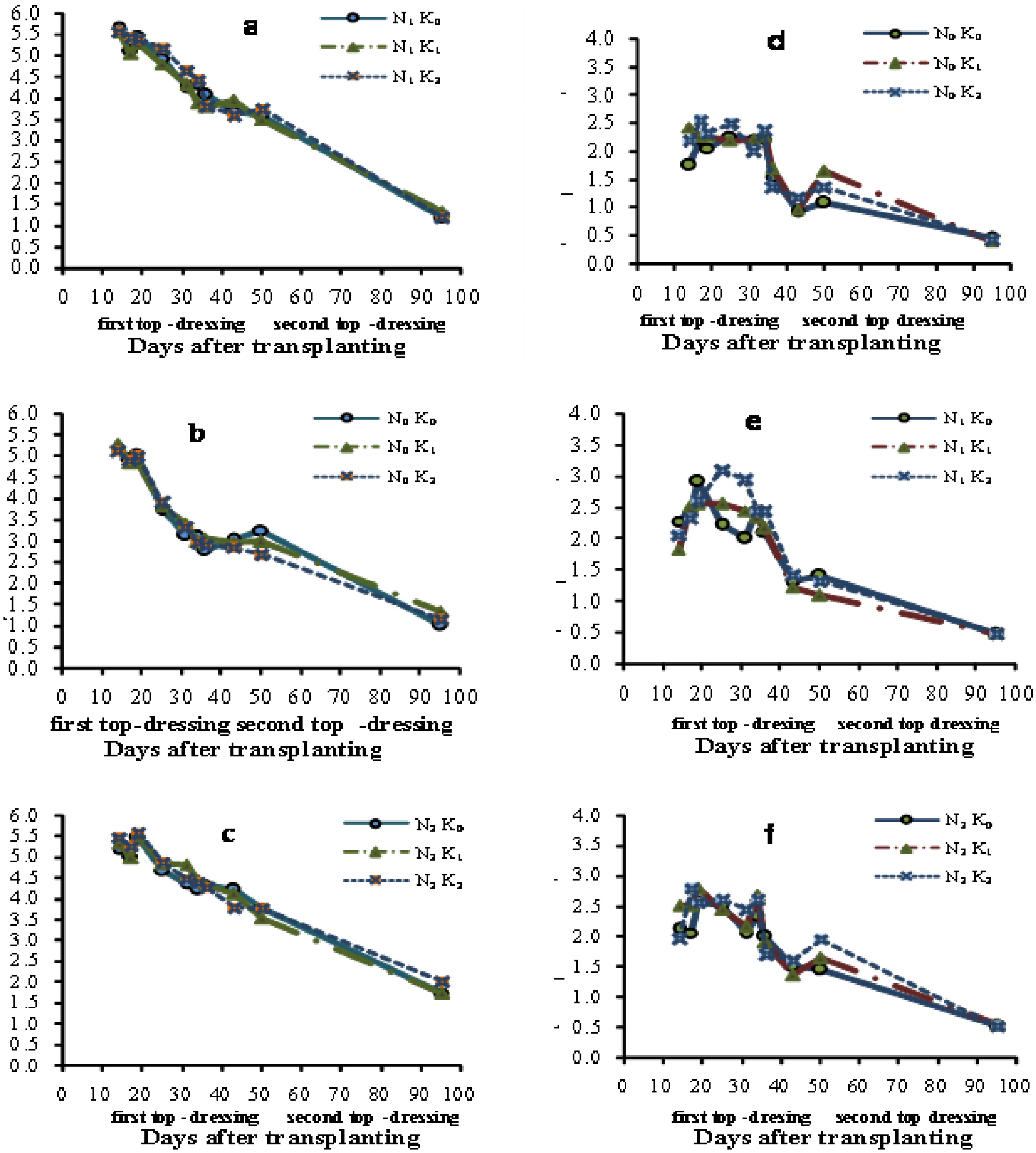


**Figure 2.** N and K concentration changes during growth stage in upper development leaves at first and second top-dressing. $N_0$: Without N; $N_1$: 23 Kg N $ha^{-1}$; N2: 46 Kg N $ha^{-1;}$ $K_0$: without $K_2O$; $K_1$: 30 Kg $K_2O$ $ha^{-1}$; $K_2$: 60 Kg $K_2O$ $ha^{-1}$.

significant increase in plant height and number of panicles under fertilizer treatment, and N, K, Na, and Mg uptake in stem were significantly high.

## Conclusion

Potassium application as top-dressing together with nitrogen increased potassium content of plant, grain number in panicle and straw yield. Nitrogen concentration of upper development leaves decreased during growth stage. After first top-dressing, leaves potassium amount significantly increased and then decreased with initiation of natal stage of rice (30 days after transplanting). In flowering stage, the K concentration in stems were more than leaves, and N content of flag leaves (3.8% dry matter) was higher than other leaves and stems. Due to higher grain yield, decrease in the plant lodging and nutrient balance, application of 23 Kg N and 30 Kg $K_2O$

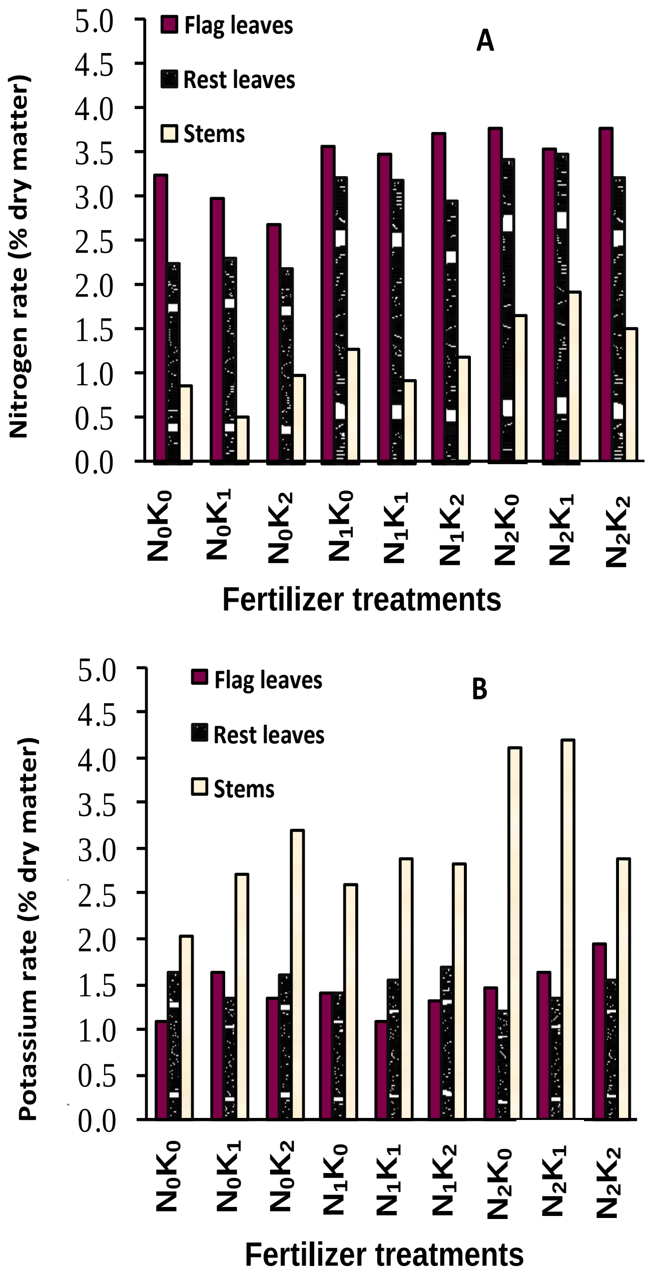


**Figure 3.** Nitrogen and potassium concentration in rice shoot at flowering stage. $N_0$: Without N; $N_1$: 23 Kg N $ha^{-1}$; $N_2$: 46 Kg N $ha^{-1;}$ $K_0$: without $K_2O$; $K_1$: 30 Kg $K_2O$ $ha^{-1}$; $K_2$: 60 Kg $K_2O$ $ha^{-1}$.

$ha^{-1}$ as top-dressing in mid-tillering stage (15 days after transplanting) and panicle initiation stage (35 days after transplanting) were suitable for rice, especially Tarrom variety.

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