# Influence of simulated post-anthesis water stress induced by foliar application of potassium iodide on stem dry matter remobilization, yield and yield components in rice varieties.

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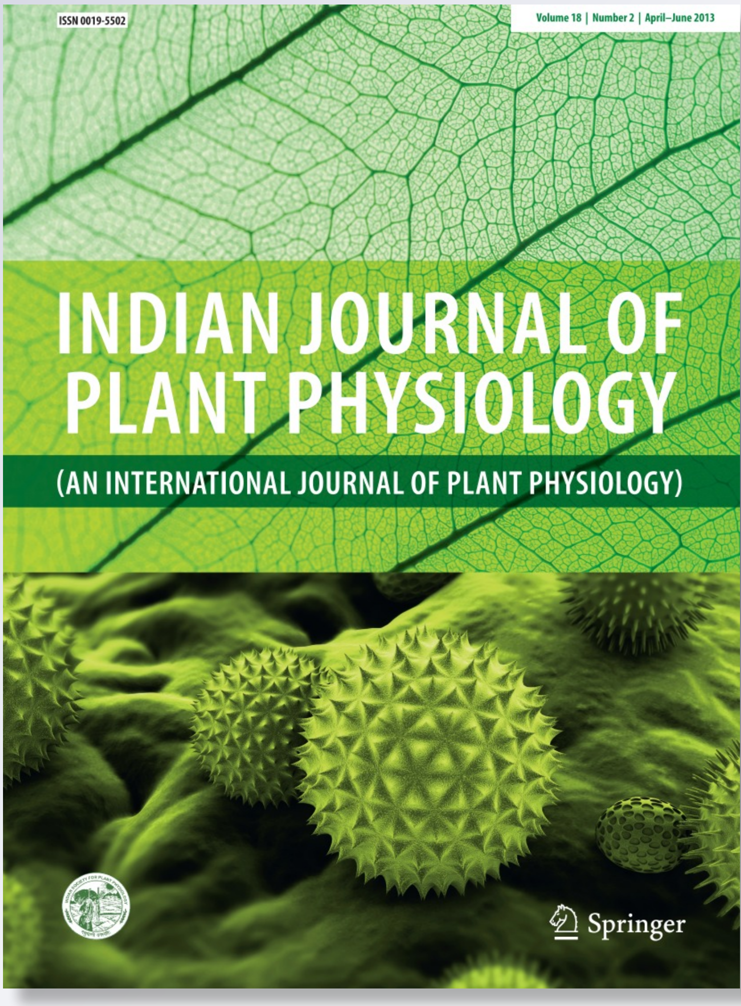


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SHORT COMMUNICATION

# Influence of simulated post-anthesis water stress on stem dry matter remobilization, yield and its components in rice

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**Abstract** A field study was conducted to investigate the influence of foliar application of potassium iodide (KI) to simulate post-anthesis water stress on stem dry matter remobilization and yield. KI treatment had significantly reduced total chlorophyll content in all tested varieties and significant varietal differences were observed. KI application had no significant influence on number of spikelets per panicle or number of spikelets. However, the interaction between treatment and variety was found significant. The number of grains/panicle were reduced by KI spray and varietal difference was significant. Maximum number of grains/panicle was recorded in WGL-4 under control followed by DRR Dhan-39 under KI treatment. KI application had resulted in significant reduction in mean grain yield and the reduction was highest in PA-6129, Swarna and Akshayadhan and the reduction was comparatively less in Sampada, WGL-14, PA-6201 and PA-6444 indicating better carbon remobilization in these varieties. The mean remobilization efficiency was increased by KI application. The increase in remobilization efficiency was higher in WGL-14, PA-6201, Sampada and PA-6444 which incidentally produced higher yields under KI treatment due to increased remobilization of carbon from the vegetative organs which replenished the carbon lost due to impaired photosynthesis. Our findings suggest that KI application can be effectively used to identify rice varieties with high remobilization capacity and yield stability under post-anthesis water stress.

**Keywords** Chlorophylls · Dry matter remobilization · Post-anthesis water stress · Potassium iodide · Yield

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Drought is a world-spread problem seriously influencing grain production and quality and with increasing population and global climate change making the situation more serious (Shao et al. 2008). Rice (*Oryza sativa* L.) as a paddy field crop is particularly susceptible to water stress (Yang et al. 2008). It is estimated that 50 % of the world rice production is affected more or less by drought (Bouman et al. 2005). Selection of rice genotypes combining enhanced water use efficiency (WUE) and drought resistance have become priority target traits for genetic improvement. Water stress that reduces plant water status and photosynthesis during grain filling and induces the conversion of stem reserves into soluble sugars and the mobilization of sugars into the grains (Blum 2005).

Screening of crop germplasm for drought tolerance under field conditions is a pre-requisite for identifying tolerant donors which necessitate creating water stress conditions in normal growing season to avoid possible interaction of genotype and season. However, imposing water stress under field conditions is difficult which demands precise control of irrigation and require costly rain-out shelters for maintaining stress treatments. Use of chemical desiccants and senescence agents such as potassium iodide was reported as a cost effective method of simulating water stress in field. Application of chemical desiccants induce senescence and due to inhibition of photosynthesis and stimulates translocation of reserve carbohydrates from stems to developing grains (Roya and Blanco 1998). Herrett et al. (1962) reported that potassium iodide (KI) was one of the best desiccant for field use due its low toxicity and efficacy to induce senescence. Reduction in kernel weight due to desiccation induced by KI spray under irrigated conditions was correlated with the reduction in kernel weight under post-anthesis drought in the absence of severe drought stress before anthesis (Nicolas and Turner 1993). KI application causes early senescence due to impairment of photosynthesis which shortens the grain filling period and reduces grain weight (Meng et al. 2011). Chemical desiccants have been successfully used to simulate post-anthesis drought in many cereal crops (Ramazanzadeh and Asgharipour 2011). However, information on use of such chemicals in rice crop is scarce. The objective of this study was to investigate the influence of KI application after anthesis on yield, yield components and remobilization of carbon reserves from the stems in field grown rice varieties to identify suitable variety with higher remobilization capacity and yield stability under simulated water stress conditions.

A field trial was conducted during Rabi-2011 season at Directorate of Rice Research, Hyderabad, experimental farm with 15 rice varieties (Akshayadhan Varadhan, Rasi, Vandana, Swarna, PA-6129, PA-6201, PA-6444, PHB-71, Jaya, Sampada, NDR-359, Shanthi, DRR Dhan-38, and WGL-14). The experiment was conducted in split-plot design with treatments as main plots and varieties as sub-plots with three replications. The Plot size was 3.3 × 0.6 m with a spacing of 20 × 10 cm and NPK (100:60:60 kg/ha) was applied. All package of practices recommended for irrigated transplanted rice were followed. The treatments were Control (normal irrigation) and KI spray @ 0.3 %. KI (0.3 %) containing a wetting agent (Tween-20) was hand sprayed 1 week after anthesis ensuring full wetting of leaves and ears at a rate of 280 ml/m$^2$. Chlorophyll content of the leaves was estimated 6 days after KI spray after extraction with 80 % Acetone according to the method of Lichtenthaler and Wellburn (1983). Grain yield (kg/m$^2$), TDM (kg/m$^2$) and yield components were measured after harvest. Stem dry weight at anthesis and at harvest was estimated by harvesting three plants per treatment per variety and after dissecting the plants into different parts, stem dry weight was measured after drying in a hot air oven. Dry matter remobilization was estimated by subtracting the stem dry weight recorded at harvest from the stem dry weights recorded at anthesis. The dry matter remobilization efficiency (%) was computed as (dry matter remobilization)/(dry matter at anthesis) × 100. The data on yield and yield components was analyzed as per split-plot design using Satistix 8.1 for Windows Analytical for software.

Application of KI had resulted in visible yellowing of the rice leaves clearly noticeable after 6 days of the foliar spray. Significant variation was found in total chlorophyll content, determined 6 days after the spray, among the 15 rice varieties. KI sprays had significantly (45 % reduction) reduced mean total chlorophyll content. Significant differences were observed amongst the varieties (Fig. 1). Maximum reduction in total chlorophyll content was recorded in Vandana followed by Rasi, Sampada and Jaya. Minimum reduction was noticed in PA-6129 followed by NDR-359 and Shanti (Fig. 1). KI was applied to simulate post-anthesis drought in our study. Chemical desiccants have been successfully used to simulate post-anthesis drought in many cereal crops (Ramazanzadeh and Asgharipour 2011; Meng et al. 2011). Reduction in chlorophyll content following KI application was reported earlier (Sawhney and Singh 2001) in wheat. Varietal differences in the reduction in chlorophyll content was attributed the differences in the drought tolerance potential of the varieties.

KI spray had no significant influence on number of spikelets per panicle or number of spikelets/m$^2$ (Table 1).

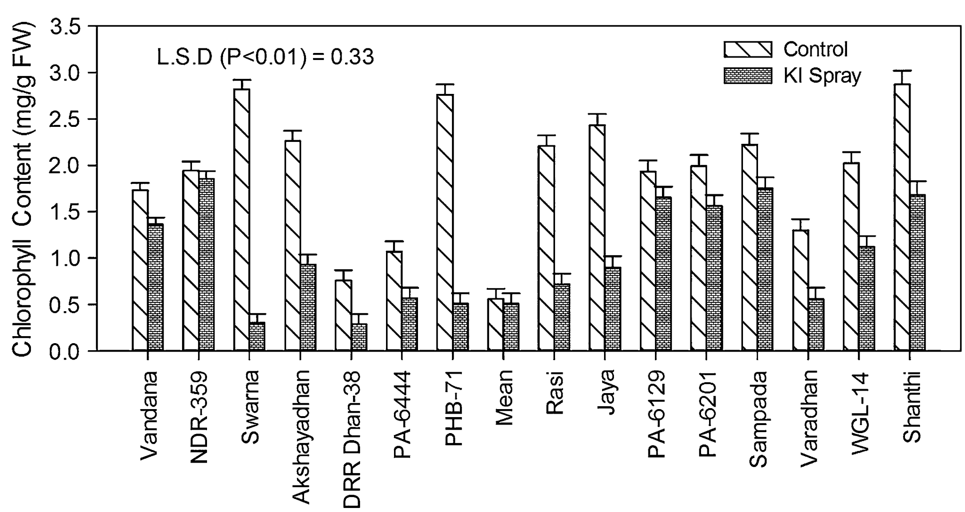


**Fig. 1** Influence of KI application on leaf chlorophyll content in different rice varieties. The chlorophyll content was estimated 6 days after the KI (@ 0.3 %) spray. Each value represents mean of three replication ± SD

**Table 1** Influence of potassium iodide (KI) application on number of spikelets and number of panicles in different rice varieties

| Varieties | Number of spikelets/panicle | | Number of spikelet/m$^2$ ($\times 10^3$) | | Number of panicles/m$^2$ | |
|---|---|---|---|---|---|---|
| | Control | KI spray | Control | KI spray | Control | KI spray |
| Akshayadhan | 125.8 | 123.9 | 41.7 | 35.2 | 293 | 312 |
| DRR Dhan-38 | 169.3 | 148.6 | 59.4 | 47.1 | 353 | 320 |
| Jaya | 114.0 | 109.0 | 31.9 | 31.9 | 303 | 283 |
| NDR-359 | 109.6 | 101.0 | 27.8 | 25.7 | 250 | 240 |
| PA-6129 | 157.3 | 141.0 | 44.4 | 35.0 | 293 | 316 |
| PA-6201 | 184.8 | 164.3 | 55.2 | 50.2 | 340 | 306 |
| PA-6444 | 171.4 | 165.0 | 55.6 | 52.1 | 323 | 340 |
| PHB-71 | 196.0 | 181.0 | 55.6 | 53.0 | 286 | 293 |
| Rasi | 103.8 | 109.0 | 34.2 | 37.1 | 330 | 313 |
| Sampada | 166.8 | 159.0 | 55.8 | 45.9 | 340 | 353 |
| Shanti | 192.0 | 189.0 | 55.9 | 43.9 | 290 | 286 |
| Swarna | 132.0 | 121.0 | 48.6 | 46.8 | 400 | 389 |
| Vandana | 88.0 | 87.3 | 37.9 | 36.2 | 430 | 416 |
| Varadhan | 115.4 | 114.0 | 39.3 | 36.9 | 289 | 280 |
| WGL-14 | 192.9 | 191.0 | 62.5 | 53.7 | 276 | 290 |
| **Mean** | **147.9** | **140.3** | **47.1** | **42.0** | **320** | **316** |
| LSD (treatment) | NS | | NS | | NS | |
| LSD (variety) | 25.9 | | 9.6 | | 55.03 | |
| LSD (T $\times$ V) | 41.4 | | 15.6 | | 95.32 | |
| C V (%) | 11.2 | | 23.1 | | 14.65 | |

Each value represents the mean of three replications

Significant variation in number of spikelets/panicle was reported among genotypes. The interaction between treatment and variety was found to be significant ($P < 0.01$). The reduction in spikelet number per panicle was >10 % in DRR-Dhan-38, PA-6201 and PA-6129. Rasi recorded a marginal increase (5 % increase) in number of kernels per panicle. Similarly, the number of spikelets/m$^2$ was reduced by KI spray. However, the effect was non-significant. Significant variation was observed in the response of varieties to KI application (Table 1). Similarly, KI application had not resulted in significant reduction in the number of panicles/m$^2$. Significant differences were noticed amongst the tested varieties. The interaction between treatment and variety was also found to be significant. Vandana recorded maximum number of panicles both under control and KI treatment. NDR-359 recorded lowest number of panicles/m$^2$ under both control and KI treatment (Table 1).

The number of grains/panicle was reduced by KI spray. Varietal difference was significant and ranged between 162.9 (WGL-4) to 53.2 (Vandana). Maximum no. of grains/panicle was recorded by WGL-4 (162.9) under control followed by DRR Dhan-39 (149.5) in KI spray (Table 2). Significant differences in the mean number of grains/m$^2$ were observed among the treatments. The no. of grains/m$^2$ was reduced by KI spray (31 % reduction). The difference amongst the varieties was significant and the interaction between the treatment and varieties was also found to be significant ($P < 0.01$). Maximum reduction was noticed in DRR-Dhan-38 followed by Varadhan, Vandana and Jaya. Rasi was found to be tolerant as no significant change in number of grains/m$^2$ was noticed (Table 2).

A non-significant reduction was noticed in the mean 1,000 grain weight by KI application. However, the differences amongst the varieties and the interaction between treatment and varieties was also found to be significant ($P < 0.05$). NDR-359 recorded highest test weight under KI treatment followed by Akshayadhan, PA-6201, Shanti, Varadhan and Sampada. The reduction in test weight by KI spray was highest in PHB-71 followed by Vandana and Jaya. The total dry matter recorded at harvest was also significantly (19.7 % reduction) reduced by the KI application. The TDM (kg/m$^2$) varied between 2.04 (PA-6444) and 1.35 (Vandana) with mean of 1.65 (kg/m$^2$). The TDM was reduced by KI application and maximum TDM was recorded in PA-6444, followed by Akshayadhan and Sampada. The reduction in TDM was highest in Varadhan followed by Jaya (Table 3). Similarly KI application had resulted in significant reduction (27 % over control) in mean grain yield (kg/m$^2$). DRR-Dhan-38 recorded highest grain yield under control condition. PA-6129, PA-6201, Akskhayadhan, varadhan, PA-6444 are the other varieties

**Table 2** Influence of potassium iodide (KI) application on number of grains per panicle and test weight in different rice varieties

| Varieties | Number of grains/panicle | | Number of grains/m$^2$ ($\times 10^3$) | | 1,000 grain weight (g) | |
|---|---|---|---|---|---|---|
| | Control | KI spray | Control | KI spray | Control | KI spray |
| Akshayadhan | 103.2 | 76.6 | 30.0 | 24.9 | 27.9 | 25.6 |
| DRR Dhan-38 | 121.8 | 52.8 | 42.8 | 16.8 | 20.6 | 18.5 |
| Jaya | 80.8 | 43.3 | 24.6 | 12.2 | 28.1 | 23.5 |
| NDR-359 | 76.3 | 33.6 | 19.2 | 11.4 | 31.3 | 32.2 |
| PA-6129 | 122.0 | 69.4 | 35.6 | 23.3 | 25.2 | 22.5 |
| PA-6201 | 116.6 | 64.7 | 39.2 | 19.8 | 23.1 | 24.0 |
| PA-6444 | 121.6 | 96.8 | 39.3 | 32.0 | 23.3 | 23.0 |
| PHB-71 | 101.4 | 84.0 | 29.0 | 24.6 | 24.4 | 19.5 |
| Rasi | 89.5 | 90.0 | 29.4 | 30.4 | 22.5 | 22.1 |
| Sampada | 113.6 | 80.0 | 38.1 | 28.2 | 22.1 | 23.3 |
| Shanti | 90.4 | 88.0 | 26.2 | 24.0 | 23.9 | 23.8 |
| Swarna | 104.7 | 80.8 | 42.0 | 29.3 | 18.2 | 15.6 |
| Vandana | 66.4 | 31.5 | 28.6 | 13.3 | 25.3 | 21.0 |
| Varadhan | 91.5 | 46.1 | 31.1 | 12.7 | 26.1 | 23.4 |
| WGL-14 | 162.9 | 130.9 | 44.7 | 37.7 | 16.2 | 13.5 |
| **Mean** | **104.2** | **71.2** | **33.3** | **22.7** | **23.9** | **22.1** |
| LSD (treatment) | 13.7 | | 4.6 | | NS | |
| LSD (variety) | 16.3 | | 4.5 | | 2.3 | |
| LSD (T × V) | 28.2 | | 7.9 | | 4.0 | |
| C V (%) | 16.7 | | 20.9 | | 9.7 | |

Each value represents the mean of three replications

**Table 3** Influence of potassium iodide (KI) application on total dry matter (TDM), grain yield and harvest index in different rice varieties

| Varieties | Grain yield (kg/m$^2$) | | TDM (kg/m$^2$) | | Harvest index (%) | |
|---|---|---|---|---|---|---|
| | Control | KI spray | Control | KI spray | Control | KI spray |
| Akshayadhan | 0.84 | 0.51 | 1.76 | 1.58 | 47.6 | 40.2 |
| DRR Dhan-38 | 0.88 | 0.64 | 1.91 | 1.41 | 46.4 | 22.4 |
| Jaya | 0.72 | 0.51 | 1.49 | 0.99 | 46.4 | 28.2 |
| NDR-359 | 0.60 | 0.37 | 1.70 | 1.21 | 34.9 | 30.3 |
| PA-6129 | 0.86 | 0.52 | 1.67 | 1.22 | 48.3 | 43.6 |
| PA-6201 | 0.85 | 0.68 | 1.64 | 1.28 | 49.8 | 37.0 |
| PA-6444 | 0.81 | 0.68 | 2.04 | 1.60 | 45.1 | 45.6 |
| PHB-71 | 0.76 | 0.48 | 1.47 | 1.40 | 48.6 | 34.4 |
| Rasi | 0.59 | 0.47 | 1.38 | 1.32 | 47.9 | 44.6 |
| Sampada | 0.69 | 0.66 | 1.90 | 1.54 | 41.3 | 42.9 |
| Shanti | 0.74 | 0.54 | 1.56 | 1.40 | 35.8 | 32.1 |
| Swarna | 0.76 | 0.46 | 1.56 | 1.23 | 48.8 | 36.8 |
| Vandana | 0.69 | 0.49 | 1.35 | 1.22 | 41.1 | 36.6 |
| Varadhan | 0.81 | 0.62 | 1.71 | 1.02 | 47.3 | 29.2 |
| WGL-14 | 0.72 | 0.59 | 1.62 | 1.34 | 44.7 | 38.5 |
| **Mean** | **0.75** | **0.55** | **1.65** | **1.32** | **44.9** | **36.2** |
| LSD (treatment) | 0.13 | | 0.23 | | 2.9 | |
| LSD (variety) | 0.09 | | 0.21 | | 4.2 | |
| LSD (T × V) | 0.16 | | 0.36 | | 7.3 | |
| C V (%) | 0.13 | | 20.2 | | 7.6 | |

Each value represents the mean of three replications

which produced higher yields. The reduction in grain yield was highest in PA-6129, Swarna and Akshayadhan (Table 3). The reduction in grain yield as a result of KI application was comparatively less in Sampada, WGL-14, PA-6201 and PA-6444 indicating better carbon remobilization from the stems.

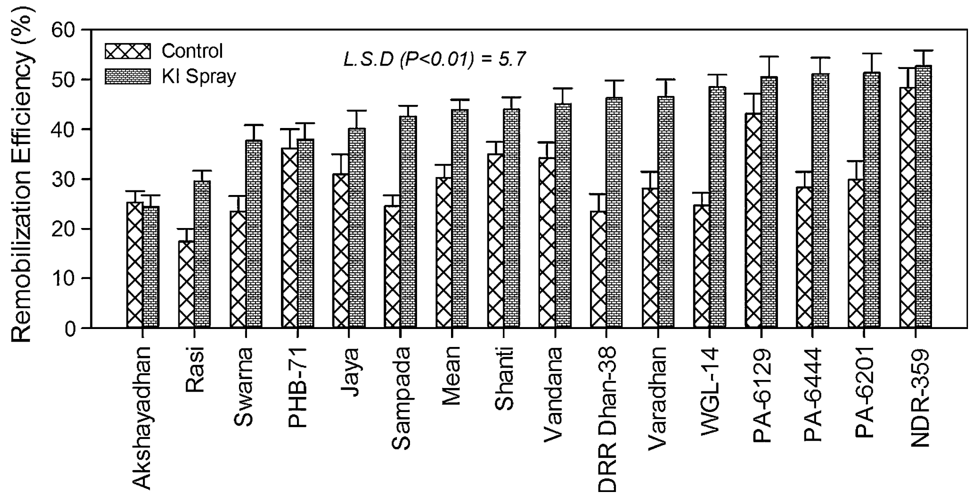


**Fig. 2** Influence of KI application on the dry matter remobilization from the stems of different rice varieties. Each value represents the mean of three replications ± SD

The remobilization of carbon reserves from the stems was estimated from the stem dry weight measured at anthesis and at maturity and remobilization of carbon and nitrogen from the stems was expressed as the remobilization efficiency. Significant differences were noticed among the tested varieties (Fig. 2) in remobilization efficiency both under control and KI treated treatments. In varieties like NDR-359, PA-6129 and PHB-71, the remobilization efficiency was higher under controlled condition than in other tested varieties. The mean remobilization efficiency for all the tested varieties was increased by KI application. The increase in remobilization efficiency was higher in WGL-14, PA-6201, Sampada and PA-6444 which incidentally produced higher yields under KI treatment due to increased remobilization of carbon from the vegetative organs which replenished the carbon lost due to impaired photosynthesis.

Our results clearly show that KI application had significantly reduced leaf chlorophyll content, grain yield caused due to reduction in number of grains. Reduction in grain yield due to reduction in grain number and grain size by KI treatment was reported (Ramazanzadeh and Asgharipour 2011). Roya and Blanco (1998) reported that the effect of KI was similar to that of post-anthesis drought effect on yield and yield components. Grain-filling in cereals depends on carbon derived from current photosynthesis and carbon redistributed from vegetative tissues such as stems. In rice plants around 30 % of the final yield depending on cultivar and environmental conditions are from the contribution of reserved assimilates in culms and leaf sheaths (Takai et al. 2005). Remobilization of carbon reserves from vegetative organs (stem and leaf sheath) to developing grain is critical for grain yield if the plants are subjected to water stress during grain filling. It is well known that among pre-anthesis assimilates help in yield stability during terminal drought stress. Senescing agents like KI induce early senescence caused by impaired photosynthesis through dehydration of leaves shortens grain filling period and reduces grain yield (Meng et al. 2011).

In conclusion our results indicate that for field screening of rice germplasm for drought tolerance, chemical desiccants like KI are very useful. Based on the response of varieties to KI application, WGL-14, PA-6201, Sampada and PA-6444 can be identified as relatively drought tolerant due to increased remobilization of stem reserves which replenished the carbon lost due to impaired photosynthesis. Selection of genotypes with higher remobilization capacity under drought condition was desirable to develop drought tolerant varieties.

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