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Application of potassium iodide as a new agent for screening of drought tolerance upland rice genotypes at flowering stage

Ashok K. Singh[1*], Aasheesh Singh[1], Alok K. Singh[1], Md. Shamim[2], Prashant Vikram[2†], Sanjay Singh[3] and Ghanshyam Chaturvedi[1]

[1]Department of Crop Physiology, N.D. University of Agriculture and Technology, Kumarganj, Faizabad (U.P.) - 224 229, India
[2]Department of Plant Molecular Biology and Genetic Engineering, N.D. University of Agriculture and Technology, Kumarganj, Faizabad, 224 229, India
[†]Present address: Plant Breeding Genetics and Biotechnology Division, International Rice Research Institute, Manila, Philippines
[3]Division of Genetics, Indian Agriculture Research Institute, Pusa, New Delhi-110012, India

***Corresponding author: assinghkumar3@gmail.com**

Abstract

Selection of appropriate physiological criteria is still an impediment for the breeding of drought tolerant rice varieties. An experiment was conducted to analyze the effect of potassium iodide (KI) for it's suitability as a selection criterion to screen upland rice genotypes. Three different KI concentrations *vis*. 0.25%, 0.50% and 0.75% were applied on eight rice genotypes comprising four tolerant and four susceptible ones. Injuries in young tissues, reduction in yield, panicle length, panicle weight, grain number and grain weight were observed at the KI concentrations of 0.50 and 0.75%. However, 0.25% KI concentration did not showed significant injury effects on rice genotypes. The significant correlation of grain yield with apparent translocation rate ($R^2 = 0.54$) was also observed, indicating reduction in current assimilation during reproductive stage, under different KI treatments and tolerant rice genotypes induced an increase in stem reserve mobilization. SDS-PAGE profiling of KI treated rice leaves induced novel protein bands of 30 kDa, 50 kDa and 70 kDa in tolerant rice genotypes. The present study concluded that KI can be used as chemical desiccant for the screening of drought tolerant upland rice varieties at reproductive stage.

Keywords: Post anthesis, potassium iodide, panicle, grain filling.
Abbreviation: ACR, apparent contribution rate; ATR, apparent translocation rate.

Introduction

Rice is a primary food source for more than two third of the world's population that account for ~ 21% of global calorie intake (Maclean et al., 2002). Nearly 75% of the global rice production comes from irrigated ecosystem that covers around 55 % of the total cropped rice area. Rainfed upland and rainfed lowland contributed only 21% of the total production from 34 % of the cropped area. Frequent occurrence of abiotic stresses like drought and submergence are considered as the key factor for low productivity of rice in rainfed environments. In such areas drought is the single largest factor for yield reduction in rice. Drought stress during cropping season directly affects the grain yield; particularly the stress at reproductive stage is most devastating (Venuprasad et al., 2009a; Lanceras et al., 2004). It has been predicted that the water deficit would increase in future years and the intensity and frequency of drought would aggravate (Bates et al., 2008; Wassmann et al., 2009). The intensity, duration, and occurrence of water stress in relation to various phenological phases differ in the diverse rice ecosystems. Development of drought tolerant varieties and effective crop management strategies are required to maximize the production under such an unfavourable environment. Drought screening under field conditions depends on long dry spells which is based on intensity and frequency of rainfall. Alternatively, this could be done in controlled environments considering secondary traits as selection criteria. Availability of a feasible secondary trait as selection criteria is still an impediment. Breeders and physiologists have made efforts in past decades but could n't achieve satisfactory results. Important mechanisms of drought tolerance are osmotic adjustment, antioxidant capacity, and desiccation tolerance (Lenka et al., 2011). Drought stress at the anthesis stage accompanied by high temperatures reduces the duration and rate of grain filling thereby, reducing mean kernel weight. On the other hand it increases remobilization of assimilates from the vegetative tissues to the grains (Plaut et al., 2004). It is a well known fact that drought stress reduces the plant height, number of grains per spike, spike weight and grain yield per spike. Grain growth of cereals depends on current photosynthesis and previously accumulated assimilates. If current photosynthesis is limited by environmental stress such as water deficit (Marshell et al., 1980), low temperature or nutrient deficiency (Chatterton et al., 1972, Lenhert et al., 1979), then remobilization of previously accumulated assimilates is accelerated. Accumulated assimilates also enhance the recovery of plants after stress (Wardlaw and Eckhardt, 1987). Wide variability exists among genotypes on carbohydrate accumulation in the stems and subsequent organs. Desiccation tolerance is one of the important physiological mechanisms for drought tolerance in cereals like wheat (Blum 1983). Blum et al. (1983a) proposed the

use of chemical desiccation of the canopy after flowering as means for inhibiting current plant photosynthesis. Chemical desiccation of plant canopies at the onset of grain filling was developed as a tool for revealing genotypic differences in grain filling from stem reserves in the absence of current photosynthesis (Blum et al., 1983). The importance of desiccation tolerance mechanisms as secondary trait has been revealed by some other workers also (Bohnert et al., 2006). Potassium iodide (KI) is a chemical contact-desiccant used for assessing genotypic diversity in grain filling under drought stress (Tyagi et al., 2000). This technique is can be used in screening rice genotypes under the controlled condition. Earlier workers have revealed its importance in inducing desiccation at the post-anthesis stage. Desiccation could reduce the chlorophyll content, stomatal conductance, photosynthesis rate and transpiration of flag leaves (Farquhar and Sharkey, 1982). Plants could tolerate desiccation which is likely due to the sugars (Alpert and Oliver, 2002). Drying induces a major change in carbohydrate metabolism, which may be directly related to desiccation tolerance. Sucrose is the only free sugar available for cellular protection in fully desiccation-tolerant mosses, including *Tortula ruraliformis* and *Tortula ruralis* (Smirnoff 1992). Accumulation of the sugar is one of the last preparatory steps in the cell protection pathway when the cell is fully committed to a period of quiescence (Toldi et al., 2009). Accumulation of sucrose starts usually when relative water content is ranged in 20–60%. Objectives of present study were (1) to standardize the potassium iodide concentration, (2) Selection of the suitable drought tolerant rice genotypes and (3) to analyze changes in carbohydrate stem reserve in relation with drought stress created using chemical desiccant potassium iodide.

Results

Plant height (cm)

All three concentrations of KI significantly affected plant height of all rice genotypes as indicated by analysis of variance. Interaction was also found significant. Minimum per cent reduction (8.4-16.2 %) in plant height was obtained when plots were desiccated with 0.25% KI solution; further increase in KI concentration i.e. 0.50 and 0.75% drastically reduced the plant height of all rice genotypes (Table 1). Genotypic variability among rice genotypes were observed at different concentration of KI. Tolerant rice genotypes showed only 2.4 to 3.8% per cent reduction whereas at higher reduction in plant height over control was recorded from 8.28-15 % in susceptible rice genotypes.

Tiller number (plant^{-1})

The three concentrations of KI did not showed distinct injury effect on tiller numbers of rice genotypes. Interaction between chemical desiccation and tiller numbers was found to be non significant among various concentrations of KI. Minimum tiller mortality (%) was recorded with 0.25% KI. Maximum tiller production was observed in OS6 followed by TN1 and IR64.

Total soluble sugar in culm (µg/mg dry wt.)

Under non stress situation the maximum total soluble sugar (culm) was in OS6 (138.80) followed by susceptible rice genotypes Saita (128.71) and minimum was in IR64 (73.40) at harvesting stage. Under desiccation stress susceptible genotype Saita showed higher reduction in culm soluble sugar than tolerant genotypes (Table 2). Among various KI concentrations, minimum per cent reduction (8.42-9.43%) in total soluble sugar content of culm was measured in tolerant genotypes such as Moroberekkan followed by Browngora, OS6 and NDR 97 respectively when plants were desiccated with 0.25% potassium iodide solution. Similar patterns were also observed at other KI concentrations. Mild injury effect of chemical was noticed in all rice genotypes. However higher concentrations of KI (0.50 and 0.75%) reduced the soluble sugar of culm in all rice genotypes but statistically interaction effect was found to be non significant. Moreover extent of reduction was higher in susceptible rice genotypes at all KI concentrations.

Apparent translocation rate

Maximum apparent translocation rate (ATR) was measured in susceptible rice genotypes IR64 followed by NDR359 and Browngora in control plots. However ATR was significantly enhanced with substantial increase of KI concentrations in all tested rice genotypes. Maximum per cent increase over control was measured in tolerant rice genotypes Browngora (1380%) followed by OS6 (295%) and Moroberekkan (217%) at 0.75% KI treatment while tolerant rice genotype NDR97 showed minimum per cent increase with all KI concentrations (Table2). Similar genotypic response was observed with 0.25% KI concentration. Maximum per cent increase in ATR over control was recorded in tolerant rice genotypes Browngora (980%) fallowed by OS6 (177%) and Moroberekkan (127%). Interaction between chemical desiccation of KI and apparent translocation rate was significant.

Apparent contribution rate

Apparent contribution rate (ACR) was higher in susceptible rice genotypes like IR64 followed by NDR359 in control plots. Desiccation with potassium iodide significantly enhanced the ACR of all tested rice genotypes (Table2). In general, rice genotypes showed 2-3 fold increase in ACR when plants were desiccated with 0.25% KI solution. Further increase in KI concentration did not showed much increase in apparent contribution rate. Interaction between chemical desiccation of KI and ACR was non-significant. Significant correlation coefficient value (r=-0.40) was observed with grain yield.

Grain sterility %

Higher sterility was observed in susceptible rice genotypes. Maximum per cent sterility was recorded in susceptible rice genotypes Saita (30%) followed by NDR359 (21%) and minimum in Moroberekkan (10%), Browngora, OS 6 and NDR97 (less than 15%) under controlled condition. Data from table 3 revealed that chemical desiccant induced sterility in all rice genotypes (Table3). Susceptible rice genotypes showed higher percent sterility when rice plants were desiccated with various KI concentrations in the field. Effect of higher concentrations of KI was also found prejudicial. Maximum percent sterility was obtained in susceptible rice genotype Saita (40.33%) followed by IR64 (35.70%) and NDR359 (33.77%) at 0.75% KI concentration. Lower concentration (0.25%) of KI did not induced

Table 1. Effect of different concentrations of KI on plant height, tiller number, biological yield and panicle length

Genotypes	Plant height (cm)				Tiller no./plant				Biological yield/plant (g)				Panicle length (cm)			
	Control	0.25%	0.50%	0.75%	Control	0.25%	0.50%	0.75%	Control	0.25%	0.50%	0.75%	Control	0.25%	0.50%	0.75%
NDR 97	80.5 ^{b}	79.91 ^{b}	78.53 ^{b}	78.01 ^{b*}	7.51 ^{b}	5.28 ^{b}	5.21 ^{b}	5.13 ^{b}	5.51 ^{b}	5.28 ^{b}	5.21 ^{b}	5.13 ^{b}	23.03 ^{b}	20.9 ^{b}	20.2 ^{b}	19.6 ^{b}
Saita	130.62 ^{b}	126.41 ^{b*}	121.41 ^{b*}	111.25 ^{b*}	5.01 ^{b}	4.86 ^{b}	4.81 ^{b}	4.76 ^{b}	5.01 ^{b}	4.86 ^{b}	4.81 ^{b}	4.76 ^{b}	26.03 ^{b}	21.8 ^{b}	20.5 ^{b}	19.3 ^{b}
Moroberekan	90.09 ^{b}	89.51 ^{b}	88.39 ^{b}	87.99 ^{b*}	6.95 ^{b}	6.8 ^{b}	6.73 ^{b}	6.66 ^{b}	6.95 ^{b}	6.8 ^{b}	6.73 ^{b}	6.66 ^{b}	25.13 ^{b}	23.0 ^{b}	21.9 ^{b}	21.4 ^{b}
Browngora	82.88 ^{b}	81.56 ^{b}	80.31 ^{b*}	79.66 ^{b*}	8.17 ^{b}	8.12 ^{b}	7.88 ^{b}	7.8 ^{b}	7.17 ^{b}	7.12 ^{b}	6.88 ^{b}	6.8 ^{b}	18.57 ^{b}	16.9 ^{b}	16.0 ^{b}	15.6 ^{b}
Mean (tolerant Varieties)	96.02 ^{b}	94.34 ^{b}	92.16 ^{b*}	89.23 ^{b*}	6.91 ^{b}	6.25 ^{b}	6.16 ^{b}	6.09 ^{b}	6.16 ^{b}	6.01 ^{b}	5.90 ^{b}	5.87 ^{b}	23.19 ^{b}	20.65 ^{b}	19.65 ^{b}	18.98 ^{b}
TN1	134.72 ^{b}	128.03 ^{b*}	124.88 ^{b*}	123.56 ^{b*}	9.18 ^{b}	8.95 ^{b}	8.86 ^{b}	8.77 ^{b}	9.18 ^{b}	8.95 ^{b}	8.86 ^{b}	8.77 ^{b}	23.82 ^{b}	20.8 ^{b}	19.6 ^{b}	19.6 ^{b}
NDR359	101.68 ^{b}	99.54 ^{b}	97.69 ^{b*}	91.15 ^{b*}	7.22 ^{b}	7.08 ^{b}	7.01 ^{b}	6.94 ^{b}	7.22 ^{b}	7.08 ^{b}	7.01 ^{b}	6.94 ^{b}	29.33 ^{b}	25.2 ^{b}	24.25 ^{b}	22.9 ^{b}
IR64	85.2 ^{b}	81.72 ^{b*}	78.41 ^{b*}	73.25 ^{b*}	8.98 ^{b}	8.8 ^{b}	8.62 ^{b}	8.53 ^{b}	8.98 ^{b}	8.8 ^{b}	8.62 ^{b}	8.53 ^{b}	24.71 ^{b}	21.00 ^{b}	19.6 ^{b}	18.3 ^{b}
OS6	84.9 ^{b}	83.04 ^{b}	82.09 ^{b*}	81.82 ^{b*}	9.84 ^{b}	9.64 ^{b}	9.45 ^{b}	9.35 ^{b}	9.84 ^{b}	9.64 ^{b}	9.45 ^{b}	9.35 ^{b}	22.37 ^{b}	20.32 ^{b}	19.3 ^{b}	18.7 ^{b}
Mean (susc-eptible Varieties)	101.62 ^{b*}	98.08 ^{b*}	95.77 ^{b*}	92.45 ^{b*}	8.8 ^{b}	8.62 ^{b}	8.48 ^{b}	8.39 ^{b}	8.80 ^{b}	6.62 ^{b}	8.49 ^{b}	8.39 ^{b}	25.06 ^{b}	21.84 ^{b}	20.69 ^{b}	19.88 ^{b}

b The differences among the means of genotypes were significant at P≤0.05, a The differences among the means of genotypes were significant at P≤0.01, b* significant

Table 2. Effect of different concentration total soluble sugar, starch content of culm, apparent translocation rate and apparent contribution rate

Genotypes	Total soluble sugar of culm (µg/mg dry wt)				starch content of culm (µg/mg dry wt)				Apparent Translocation Rate				Apparent Contribution Rate			
	Control	0.25%	0.50%	0.75%	Control	0.25%	0.50%	0.75%	Control	0.25%	0.50%	0.75%	Control	0.25%	0.50%	0.75%
NDR 97	120.01 ^{b}	108.69 ^{b}	105.33 ^{b}	101.97 ^{b}	117.59 ^{b}	106.50 ^{b}	103.21 ^{b}	99.91 ^{b}	0.05 ^{b}	0.07 ^{b}	0.07 ^{b*}	0.08 ^{b*}	14.41 ^{b}	34.09 ^{b}	34.79 ^{b}	38.34 ^{b}
OS6	138.8 ^{b}	125.95 ^{b}	119.59 ^{b}	115.78 ^{b}	141.03 ^{b}	127.97 ^{b}	121.51 ^{b}	117.6 ^{b} 3	0.02 ^{b}	0.06 ^{b*}	0.07 ^{b*}	0.09 ^{b*}	13.99 ^{b}	35.16 ^{b}	35.89 ^{b}	39.55 ^{b}
Moroberekan	83.81 ^{b}	76. 75 ^{b}	72.88 ^{b}	71.33 ^{b}	119.05 ^{b}	109.02 ^{b}	103.52 ^{b}	101.32 ^{b}	0.03 ^{b}	0.07 ^{b*}	0.07 ^{b*}	0.09 ^{b*}	17.55 ^{b}	37.02 ^{b}	37.78 ^{b}	37.78 ^{b}
Browngora	81.44 ^{b}	74.24 ^{b}	70.49 ^{b}	68.24 ^{b}	107.32 ^{b}	97.84 ^{b}	92.90 ^{b}	89.93 ^{b}	0.05 ^{b}	0.06 ^{b}	0.07 ^{b*}	0.07 ^{b*}	11.03 ^{b}	29.72 ^{b}	30.33 ^{b}	33.43 ^{b}
Mean (tolerant Varieties)	106.01 ^{b}	96.40 ^{b}	92.07 ^{b}	89.33 ^{b}	121.24 ^{b}	110.34 ^{b}	105.28 ^{b}	102.19 ^{b}	0.037 ^{b*}	0.065 ^{b*}	0.07 ^{b*}	0.08 ^{b*}	14.25 ^{b}	34.00 ^{b}	34.70	37.28 ^{b}
TN1	108.28 ^{b}	94.87 ^{b}	89.12 ^{b}	88.16 ^{b}	115.22 ^{b}	100.94 ^{b}	94.82 ^{b}	93.80 ^{b}	0.04 ^{b}	0.07 ^{b*}	0.08 ^{b*}	0.10 ^{b*}	13.04 ^{b}	27.49 ^{b}	28.06 ^{b}	30.92 ^{b}
NDR359	113.69 ^{b}	97.87 ^{b}	93.92 ^{b}	88.97 ^{b}	119.05 ^{b}	102.48 ^{b}	98.34 ^{b}	93.17 ^{b}	0.06 ^{b}	0.10 ^{b*}	0.13 ^{b*}	0.19 ^{b*}	14.65 ^{b}	30.89 ^{b}	31.52 ^{b}	34.74 ^{b}
Saita	128.71 ^{b}	107.81 ^{b}	101.21 ^{b}	95.71 ^{b}	137.40 ^{b}	115.08 ^{b}	108.04 ^{b}	102.17 ^{b}	0.03 ^{b}	0.07 ^{b*}	0.07 ^{b*}	0.10 ^{b*}	13.02 ^{b}	35.09 ^{b}	35.81 ^{b}	39.46 ^{b}
IR64	73.4 ^{b}	62.64 ^{b}	58.21 ^{b}	54.42 ^{b}	91.73 ^{b}	78.29 ^{b}	72.75 ^{b}	68.01 ^{b}	0.06 ^{b}	0.10 ^{b*}	0.12 ^{b*}	0.14 ^{b*}	16.24 ^{b}	33.10 ^{b}	33.78 ^{b}	37.23 ^{b}
Mean (susceptible Varieties)	106.02 ^{b}	90.80 ^{b*}	85.61 ^{b*}	81.81 ^{b*}	115.85 ^{b*}	99.19 ^{b*}	93.58 ^{b*}	89.28 ^{b*}	0.0475 ^{b*}	0.085 ^{b*}	0.10 ^{b*}	0.132 ^{b*}	14.23 ^{b}	31.85 ^{b}	32.30 ^{b}	35.59 ^{b}

b The differences among the means of genotypes were significant at P≤0.05, a The differences among the means of genotypes were significant at P≤0.01, b* significant

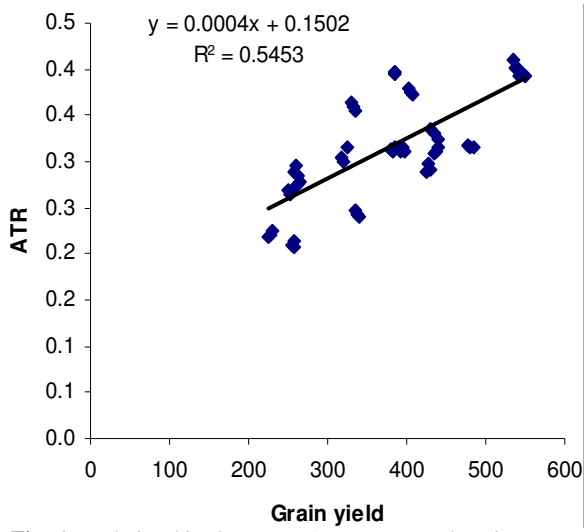

Fig 1. Relationship between Apparent translocation rate (ATR) and yield after chemical desiccation.

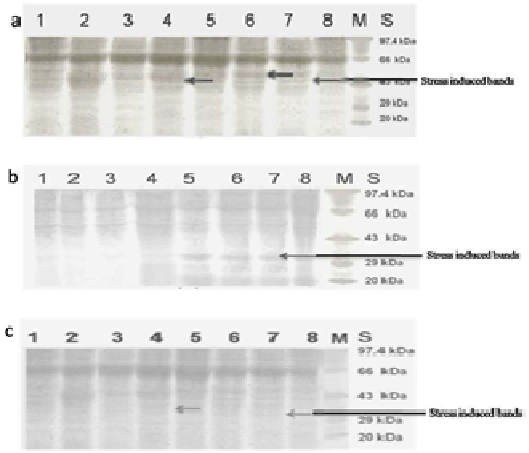

Fig 2. SDS-PAGE profiling of the different rice cultivars, showing the banding pattern on 12% gel. (a) chemical desiccation of 0.25%, (b) chemical desiccation of 0.50%, (c) chemical desiccation of 0.75%, 1. TN1, 2. NDR 359, 3. Saita , 4. IR64, 5-NDR 97, 6. OS6, 7. Morobroken, 8-Browngora, M. Molecular weight marker and S. Size of the weight marker

significant grain sterility in tested rice genotypes. Interaction effect was found non significant.

Biological yield (g)

Higher biological yield was recorded in NDR97 followed by Browngora and minimum in IR64 under controlled condition. Higher concentration of KI significantly reduced the biological yield of all rice genotypes. Adverse effect of higher concentration of KI was more pronounced in susceptible rice genotypes. Maximum per cent reduction was observed in IR64 followed by Saita and NDR359 respectively. Tolerant rice genotypes OS6, NDR97 and Moroberekkan did not showed much reduction in biological yield (Table3). Interaction effect was found non significant.

Test weight (g)

In control plots, higher test weight (g) was recorded in Browngora (24.25) followed by OS6 (23.94) and minimum was in TN1 (21.57). Genotypic variability in test weight of grain was also observed among genotypes in response to various concentration of KI. Browngora, TN 1 and Moroberekkan showed substantial increase in test weight up to the 0.75% of KI concentration. However, 0.50 and 0.75% KI concentrations significantly reduced the test weight of other rice genotypes. Moreover, test weight of rice genotypes did not affected much when plants were desiccated with lower concentration (0.25%) of KI (Table3). Interaction effect was non significant

Protein profiling

The second leaves of exposed plants at flowering stage were used for the analysis. Samples were taken from control and desiccation stress treatment for protein profiling of rice varieties. The lower molecular weight proteins (30±2kDa) were induced in the comparatively tolerant varieties at 0.25% KI treatment and vice-versa for the susceptible ones. (Fig. 2a.). Analysis with samples exposed to 0.50% KI treatment showed induction of protein bands of 30±2kDa and 50±2kDa in tolerant varieties NDR97, OS6, Moroberekkan and Browngora, where as in the varieties TN1, NDR359, Saita and IR64 such bands were absent (Fig. 2b.). Specific bands of molecular weight of 70±2kDa and 30±2kDa were induced after 0.75% of KI treatment in the tolerant varieties NDR97, OS6, Moroberekkan and Browngora, where as in the susceptible varieties TN1, NDR359, Saita and IR64 these bands were absent. Thus the chemical desiccation induced specific band of low molecular protein bands in the tolerant varieties. The susceptible rice varieties also showed some medium molecular weight protein bands disappearance after chemical desiccation (Fig. 2c).

Discussion

Drought screening of rice cultivars under natural field condition solely depends on environmental factors. This is one of the major causes for slow progress in drought breeding programmes. Selection through secondary traits under controlled condition is an alternative approach. Numerous secondary traits have been suggested for drought screening including root traits and osmotic adjustment. Use of chemical desiccants could be an alternative. Chemical desiccants such as potassium iodide (KI) have been studied in cereals like wheat by earlier workers. KI treatment has been used to identify wheat lines maintaining stable kernel weight and higher stem reserves during drought (Blum 1983; Blum 1998). One of the advantages of this technique is that rice plants could be brought under a situation comparable to water stress situation. The purpose of the present study was to ascertain whether potassium iodide treatment evokes qualitatively similar physiological and biochemical effects as that water stress. Effects of KI on plant height, tiller number, ATR, ACR, grain yield components and biochemical composition were observed.

Effect of KI on crop growth parameters

Among all KI concentrations, 0.25% KI concentration did not reduce plant height of tested rice genotypes significantly. The interaction effect was found non significant. However, higher concentration of KI (0.50 and 0.75%) drastically reduced the

plant height of tolerant (54-59%) and susceptible (66-81%) rice genotypes over control. It is likely that desiccation through higher concentration of KI could have caused injury in young growing tissues that limited the cell division and cell expansion of panicle. While, higher concentrations of KI had no significant adverse effects on tiller number plant^{-1} in all rice genotypes (Table1). Plant height showed positive correlation with grain number per panicle (r=0.52), reserve soluble sugar (r=0.54) and starch (r=0.57) of culm at post anthesis. It could be attributed to the fact that the contribution of culm reserve to grain yield was greater in tall genotypes in non-desiccated plants suggesting that taller genotypes lacked in current assimilation in comparison to semi dwarf rice genotypes.

KI in relation to ATR and ACR

Present study clearly indicated that chemical desiccation through KI stimulates the ATR and ACR of tolerant and susceptible rice genotypes. Regression coefficient (R^2 = 0.54) between ATR and grain yield explains the ability of genotypes to translocate the reserve carbohydrate of culm. It is likely that this reserve is utilized in grain development when plant canopy is desiccated with KI (Fig.1). Chaturvedi and Ingram (1988) suggested that carbohydrate and its remobilization is a key component of drought recovery specially for flowering stage drought stress. ATR and ACR is an indirect measurement of translocatory behaviour of stem reserve to panicle growth. In general, ATR and ACR were increased in KI desiccated plants in both tolerant and susceptible genotypes in comparison to non desiccated plants. Somewhat similar observations have been reported by Reyniers et al. (1982). Present study also indicated that desiccation through KI enhanced many fold increase in inherent capacity of remobilization (ATR) and utilization (ACR) of culm reserve carbohydrate of all tested rice genotypes (Table3). In spite of higher value of ATR an ACR when plants were desiccated with higher (0.50 and 0.75%) concentration of KI, grain number per panicle was reduced in both tolerant and susceptible rice genotypes mainly due to suppression of exertion of new emerging panicles and formation of grains. Desiccation with lower concentration (0.25%) of KI showed distinct genotypic variability in re-translocation and utilization efficiency of reserve assimilate at post-anthesis but significant difference between control and desiccated plants was not observed. The value of ATR was relatively higher in tolerant genotypes than rest of the genotypes in both conditions (Table3). Strong negative relationship between fertile grain number per panicle and re-translocation (r=-0.47) and utilization (r=-44) were obtained. Similar trends have been reported by earlier workers (Chaturvedi and Ingram 1988; Hossain et al., 1990).

Effect of KI on yield components

A small reduction in grain weight in response to KI treatment indicated higher degree of compensation for the loss of leaf photosynthesis and is most likely due to a high contribution of stem reserves to grain filling. Consequently the existence of a KI induced increase in grain weight which strongly suggests that a high contribution of stem reserves to grain filling is an important character when irreversible increase in leaf area was induced by drought. Chemical desiccation increased ACR in comparison to control condition. Treatment effects on ACR bear similar in 0.25% and 0.75% KI concentrations. Some genotypes like Moroberekkan, Browngora and NDR359 showed linear increase in test weight with increase in KI concentration. This could be due to faster hydrolysis of reserve CHO of Culm as result of KI induction. It seems that some genotypes (e.g. Moroberekkan, Browngora and NDR359) had large storage that helps in sustaining test weight at higher concentration of KI. Another possibility was that the higher concentration KI reduced grain number per panicle thus there is less competition for assimilates during grain filling. Strong positive relation was obtained with culm soluble sugar before desiccation with test weight (r= 0.70) and grain yield (r= 0.66). This result indicates that like drought condition grain growth depended on previously accumulated assimilates (Chaturvedi et al. 2006). Similar trends were also reported by Wastgate and Boyer (1985). Grain yield was positively correlated(r=0.72) with CHO in culm after chemical desiccation suggesting the fact that culm is greatest source of translocated CHO for grain growth and supported by ACR.

KI treatment and protein profiling

The effect of KI treatment was significantly associated with the biochemical compositions as revealed by sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE) analysis. Several investigators have reported positive relationship between stress protein accumulations in leaves with drought tolerance in rice. Some proteins specific to desiccation also have a major role in cellular protection and recovery in vascular plants. Differential expressions of these proteins were observed in plants grown under drought conditions (Farrant et al., 1993). Plants exposed to drought conditions exhibited a characteristic set of cellular and metabolic response, including a decrease or increase in the synthesis of protein (Elumalai et al., 2000). Increase in stress protein accumulation in the tolerant varieties under chemical desiccation may be considered as important adaptive characteristics. The tolerant varieties accumulated 30kDa, 50kDa and 70kDa after KI treatments in our study (Fig.2). Also, it was found that 30kDa and 50kDa protein bands were more prominent in desiccated plants with 0.75% KI compared to the ones in controlled conditions. Distinction in protein levels of tolerant and susceptible cultivars after KI treatment also indicated differential expression of genes resulting in levels of protein profiles. These proteins are likely to be involved in drought tolerance mechanisms and further investigation may provide interesting conclusions.

Materials and methods

The present investigation was carried out in Kharif season, during 2006 and 2007 at the Instructional Farm of Department of Crop Physiology, N.D. University of Agriculture and Technology, Kumarganj, Faizabad (U.P.) India. Eight contrasting rice genotypes namely TN-1 (Taichung Native-1), Saita, NDR359 and IR64, Moroberekkan, OS6, Browngora and NDR97 were used for the study. Nitrogen, phosphorus and potash were applied in the field @ 60:40:40 kg ha-^{1}. Planting materials for chemical desiccation were grown in three row plots of with spacing of 15x30 cm. Three replications were laid in randomized completely block design. Screenings with three different KI concentrations (0.25%, 0.50% and 0.75% of KI) were carried for simulation of drought at flowering stage. Planting materials were 0.5m apart from each treatment. Irrigation was provided three days before the KI treatment. KI was manually sprayed (using Back-sprayer) over canopy of the plants at heading stage (Blum et al., 1983).

Table 3. Effect of different KI concentration on sterility percentage, grain number, test weight and grain weight.

Genotypes	Sterility percentage				Grain number / panicle				Test weight (1000 seeds)				Grain weight / panicle			
	Control	0.25%	0.50%	0.75%	Control	0.25%	0.50%	0.75%	Control	0.25%	0.50%	0.75%	Control	0.25%	0.50%	0.75%
NDR 97	15.21 [b]	16.69 [b]	20.62 [b]	20.67 [b]	158.08 [b]	148.73 [b]	147.20 [b]	145.66 [b]	22.87 [b]	22.78 [b]	22.66 [b]	22.11 [b]	3.90 [b]	3.83 [b]	3.75 [b]	3.46 [b]
OS6	14.39 [b]	17.53 [b]	19.28 [b]	20.19 [b]	142.24 [b]	133.99 [b]	127.22 [b]	125.87 [b]	23.94 [b]	23.84 [b]	23.61 [b]	23.17 [b]	3.45 [b]	3.42 [b]	3.31 [b]	3.12 [b]
Moroberekan	10.30 [b]	16.14 [b]	20.66 [b]	22.20 [b]	164.62 [b]	159.62 [b]	158.01 [b]	153.17 [b]	23.68 [b]	23.76 [b]	23.89 [b]	23.63 [b]	3.60 [b]	3.53 [b]	3.47 [b]	3.19 [b]
Browngora	14.26 [b]	15.21 [b]	16.69 [b]	18.21 [b]	130.97 [b]	125.16 [b]	121.36 [b]	120.10 [b]	24.25 [b]	25.29 [b]	24.63 [b]	24.39 [b]	3.41 [b]	3.30 [b]	3.27 [b]	2.98 [b]
Mean (tolerant Varieties)	13.54 [b]	16.39 [b]	19.31 [b]	20.32 [b]	148.97 [b]	141.87 [b]	138.44 [b]	136.2 [b]	23.68 [b]	23.91 [b]	23.69 [b]	23.32 [b]	3.59 [b]	3.52 [b]	3.45 [b]	3.18 [b]
TN1	14.39 [b]	17.53 [b]	20.69 [b]	28.38 [b]	160.12 [b]	153.91 [b]	144.58 [b]	143.02 [b]	21.57 [b]	21.67 [b]	21.70 [b]	21.91 [b]	3.22 [b]	2.91 [b]	3.09 [b]	3.18 [b]
NDR359	21.34 [b]	29.84 [b]	30.50 [b]	33.77 [b]	178.05 [b]	157.70 [b]	152.61 [b]	152.61 [b]	23.97 [b]	23.97 [b]	23.87 [b]	23.55 [b]	3.55 [b]	3.45 [b]	3.42 [b]	3.18 [b]
Saita	30.79 [b]	32.16 [b]	34.07 [b]	40.33 [b]	167.52 [b]	153.43 [b]	144.04 [b]	140.90 [b]	23.75 [b]	23.28 [b]	23.05 [b]	22.83 [b]	3.04 [b]	2.98 [b]	2.92 [b]	2.75 [b]
IR64	20.84 [b]	29.12 [b]	29.23 [b]	35.70 [b]	160.41 [b]	149.82 [b]	139.22 [b]	136.20 [b]	22.17 [b]	21.11 [b]	22.00 [b]	21.79 [b]	3.49 [b]	3.42 [b]	3.35 [b]	3.12 [b]
Mean (susceptible Varieties)	21.84 [b*]	27.16 [b*]	28.62 [b*]	34.54 [b*]	166.52 [b*]	153.71 [b*]	145.11 [b*]	143.18 [b*]	22.86 [b]	22.50 [b]	22.65 [b]	22.52 [b]	3.32 [b]	3.18 [b]	3.19 [b]	3.05 [b]

b The differences among the means of genotypes were significant at P≤0.05, a The differences among the means of genotypes were significant at P≤0.01, b* significant

Measurement of growth parameters

Plant height and Tiller number were recorded before treatment and at maturity. Dry weight of culm and panicle were recorded before stress i.e. at the end of stress and at maturity. Three plants from each treatment were separated to their respective culm and panicle. The separated culm and panicle were oven dried initially $70^0 \pm 1^0$C for 1 hrs and thereafter the temperature was raised to $90^0 \pm 1^0$C till weight become constant. Samples were weighed using electronic balance. ATR was determined at the post anthesis stage. The decreases in culm dry weight relative to increase in panicle dry weight was calculated using formula of Reyniess et al. (1982). ACR estimation was done with the procedure described by Yoshida and Ahn (1968).

Measurements for grain yield and biological yield

Total number of seeds per panicle were counted and categorized into sterile (unfilled grain) and fertile (filled grain) seed per plant to calculate sterility %. Samples were taken from the middle row of each plot. Biological yield was sampled by harvesting total biomass above ground in one meter length in each plot. Biomass samples were sun dried then oven-dried and weighed. Grain weight/panicle and test weight (1000 seed) were measured.

Biochemical analysis

Total soluble sugar (mg g^{-1} dry weight) was determined according to the method described by Yemm and Willis (1954). Starch content estimation (mg g^{-1} dry weight) was carried out as described by McCready et al. (1950).

Protein profiling

Control and KI desiccant treated leaves of different rice genotypes were collected and washed with the doubled distilled water. Total soluble proteins from the leaves were isolated in 0.25M phosphate buffer (pH 7.5).The homogenated samples were centrifuged at 10,000g for 15 minutes. After centrifugation the supernatant was collected and protein concentration in each samples were measured (Lowry et al., 1951). Protein samples (10µg) were separated on 12% SDS-PAGE as described by Laemmli et al. (1970).

Statistical analysis

Experiments were set up in a factorial randomized block design. Three replicates per treatment with 10 explants for each replicate were used. Data of two year were pooled and subjected to Analysis of Variance (ANOVA) for testing the differences among treatments using method described by Panse and Sukhatme (1967).

Conclusions

Potassium iodide was analyzed for its suitability in imparting water stress in rice genotypes. Three concentrations of KI *viz.* 0.25%, 0.50% and 0.75% were used for the screening of drought resistance. The 0.50 and 0.75% KI concentration significantly reduced the plant height of rice genotypes by 52 -81% over control. However, 0.25% KI concentration did not showed any deleterious effect on grain growth. This concentration could be considered as a suitable criterion in screening rice genotypes for drought stress at flowering stage. Effect of KI on grain yield component traits, ATR, ACR as well as biochemical composition of plants reveals its importance as selection criteria for drought tolerance. The efficiency of remobilizing reserve carbohydrates and their utilization during grain growth showed significant genotypic variation among tolerant and susceptible rice genotypes.

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