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Exogenous application of glycine betaine and potassium nitrate for improving growth and yield of rice (*Oryza sativa* L.) under drought at flowering stage

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Abstract

This investigation was carried out in the rainout shelter at Student Instructional Farm (SIF), Narendra Deva University of Agriculture & Technology, Kumarganj, Faizabad (U.P.) during *Kharif* (wet season) 2015 and 2016 to find out response of glycine betaine and potassium nitrate in improving growth and yield of rice under drought at flowering stage. Experiments were laid out in randomized block design with 3 replications, one variety *i.e.* Swarna *Sub 1* and nine foliar treatments. Rice plants were exposed to drought at 60 DAT for 15 days by holding irrigation during drought treatment. During drought treatment soil moisture tension of the field was ranged from 60-80 kPa. Foliar application of different concentrations of glycine betaine (100 & 200 ppm) applied at 60 DAT and different concentrations of KNO_3 (2 & 3%) applied at 30 DAT & at 60 DAT as well as their combination was given. Data regarding various growth and yield parameters of rice were recorded using standard procedures. The data so collected were analyzed statistically by using the Fisher's analysis of variance technique and LSD at 5% probability was used to compare the differences among treatment. Drought at flowering stage hampered the growth and yield of rice but exogenous application of glycine betaine and potassium nitrate will helps to ameliorate the detrimental effect of drought. All the foliar treatment improved the growth and yield of rice however maximum improvement in growth and yield can be observed when glycine betaine and potassium nitrate were applied in combination.

Keywords: Rice, growth, yield, drought, glycine betaine and potassium nitrate

Introduction

Rice (*Oryza sativa*) is the most important cereal crop and belonging to the grass family (Poaceae). It has the second largest area under production following maize worldwide. The tremendous growth of human population worldwide has increased the demand for rice production (Liang *et al*., 2010) [18], requiring an improvement of 50% by the year 2025 (Khush, 2001) [16]. Rainfed ecosystems contribute to only 25% of the total water supply, thereby making rice more vulnerable to increased frequency of drought stress under the ensuing threat of global climate change. Rice, being a water-loving crop, is severely affected by drought stress that depresses yield by 15–50% depending on the vigour and period of stress (Kumar *et al*., 2008; Srividhya *et al*., 2011) [17, 29]. Rice is especially sensitive to drought stress during reproductive growth and even moderate stress can result in drastic reduction in grain yield (GY) (Venuprasad *et al*., 2008) [31].

Glycine betaine (Gly Bet), a member of quaternary ammonium compounds, is an osmolyte that is pre-dominant in higher plants subjected to drought condition (Chaitanya *et al*., 2009) [8]. GlyBet has been reported to protect photosynthetic machinery, stabilize the structure of Rubisco (ribulose-1, 5-bisphosphate carboxylase/ oxygenase), and act as oxygen radical scavenger under drought (Anjum *et al*., 2012; Rezaei *et al*., 2012) [4, 27]. It has been argued that exogenous GlyBet application could be a promising way to directly maintain and enhance the growth and yield in monocot crops such as rice (Farooq *et al*., 2008) [12], wheat (Ma *et al*., 2006) [19] and maize (Anjum *et al*., 2011) [3]. Previous studies have reported that foliar spray of GlyBet significantly improves growth performances of fine grain aromatic rice seedlings subjected to drought stress (Farooq *et al*., 2010) [12].

Potassium plays a foremost role in translocation of carbohydrates, photosynthesis, water relations, resistance against insects and diseases and sustain balance between monovalent and divalent cations (Brar and Tiwari, 2004) [6] and involved in several biochemical and physiological processes that is considered very crucial for plant growth and yield (Marschner, 1995) [20]. Additionally potassium also plays a significant role in photophosphorylation, turgor maintenance, photoassimilate transport from source tissues via phloem to sink tissues, stress tolerance and enzyme activation in plants (Usherwood, 2000) [30]. Potassium is considered to be a key osmoticum in plants as it provides water relations for plants making them to survive under drought stress. Potassium enhances water uptake of a plant to keep hold of cell turgor required for development and growth of a crop when it accumulates in growth of a plant and stomatal opening and potassium is considered to be mobile in plant and can be translocated against strong electrical and chemical gradients (Brar and Tiwari 2004) [6]. Potassium plays a remarkable role in transpiration, stomatal opening and closing and osmoregulation (Cakmak 2005) [7]. El-Ashry *et al.* (2005) [10] reported that negative effects of drought on wheat growth can be diminished by foliar application of potassium. Plants translocate the potassium to all parts of plant and in turn yield per plant is increased. To maximize yield of cotton crop foliar application of potassium may be used to supplement soil application (Pettigrew, 2008; Sawan *et al.*, 2008) [24, 28].

Materials and Methods

The present investigation was carried out in the rainout shelter (25 m length and 7.5 m width) of the Student Instructional Farm (SIF), Narendra Deva University of Agriculture & Technology, Kumarganj, Faizabad (U.P.) during *Kharif* (wet season) 2015 and 2016. Experiments were laid out in randomized block design with three replication and one variety *i.e.* Swarna *Sub 1*. Twenty five days old seedlings were transplanted in the rainout shelter. At 60 DAT plants were exposed to drought by holding irrigation for 15 days and rainout shelter was properly covered with the polythene to avoid the rainwater during the drought treatment. During 15 days of drought treatment soil moisture tension was measured and it was ranged from 60-80 kPa, after 15 days of drought treatment field was reirrigated to release drought. The treatments comprised of T_1 (Control- Distilled water spray), T_2 (foliar spray of KNO_3 @ 2% at 30 DAT), T_3 (foliar spray of KNO_3 @ 3% at 30 DAT), T_4 (foliar spray of KNO_3 @ 2% at 60 DAT), T_5 (foliar spray of KNO_3 @ 3% at 60 DAT), T_6 (foliar spray of glycine betaine @ 100 ppm at 60 DAT), T_7 (foliar spray of glycine betaine @ 200 ppm at 60 DAT), T_8 (foliar spray of KNO_3 @ 2% at 30 DAT & glycine betaine @ 100 ppm at 60 DAT) and T_9 (foliar spray of KNO_3 @ 2% at 30 DAT & glycine betaine @ 200 ppm at 60 DAT). Data were recorded on various growth and yield parameters like plant height, number of tillers plant^{-1}, panicle length, and number of sterile and fertile grains at maturity. Plant height and panicle length was measured with the help of meter scale while number of tillers plant^{-1}, number of sterile and fertile grains was counted from the samples of each treatment.

Result and Discussion

Data pertaining to plant height as influenced by foliar spray of different concentrations of glycine betaine and KNO_3 (Osmoprotectants) alone as well as their combination applied at different stages on rice plants exposed to drought stress at flowering stage (60 DAT) have been presented in Table-1. Maximum significant effect of treatments on plant height was found in T_5 (81.57 and 82.72 cm) followed by T_4 (80.63 and 82.00 cm), T_7 (79.72 and 81.86 cm) and T_6 (78.56 and 80.96 cm) while other treatments *i.e.* T_2 (76.73 and 77.86 cm), T_3 (77.62 and 78.82 cm), T_8 (75.61 and 77.45 cm) and T_9 (76.71 and 78.00 cm) showed non-significant effect over T_1 (72.69 and 73.91 cm) in respective year 2015-16 & 2016-17. Reduced plant height under drought stress is may be due to dehydration of protoplasm; decrease in relative turgidity associated with turgor loss and decreased cell expansion and cell division (Hussain *et al.*, 2008) [14] and exogenous application of compatible solutes like glycine betaine and potassium increased plant height *via* different mechanism such as osmotic adjustment, maintaining the activity of aquaporin's and hence water uptake, cell elongation, promotion of root growth, cell membrane stability, stomatal regulation as well as detoxification of reactive oxygen species and thereby increasing the availability of water to the plants (Wang *et al.*, 2013) [32]. Similar results were also observed by Raza *et al.*, (2014) [26] who reported that the highest plant height was obtained when glycine betaine and potassium were applied in combination at 100 mM and 1.5%. Ahanger *et al.*, (2015) [1] also found that exogenous application of potassium increases the root/shoot length.

Data regarding number of tillers plant^{-1} as influenced by foliar spray of different concentrations of glycine betaine and KNO_3 (Osmoprotectants) alone as well as their combination applied at different stages on rice plants exposed to drought stress at flowering stage (60 DAT) have been presented in Table-2. The data show that T_3 recoded maximum number of tillers plant^{-1} *i.e.* 10.44 and 10.67 followed by T_9 (10.22 and 10.56), T_2 (10.11 and 10.22) and T_8 (10.00 and 10.22) in year 2015-16 & 2016-17 respectively which is found significant over T_1 (7.44 and 8.00) while rest of the treatments *viz.*, T_4 (8.00 and 8.11), T_5 (8.11 and 8.67), T_6 (8.00 and 8.11) and T_7 (8.22 and 8.78) showed non-significant effect over T_1 (7.44 and 8.00) in year 2015-16 & 2016-17 respectively. Increase in tiller number plant^{-1} with foliar spray of compatible solutes is might be due to the role of osmolytes in osmotic adjustment that maintains the activity of aquaporin's and hence water uptake therefore cell elongation, cell division and maintaining cell membrane stability. The results are in agreement with Ahanger *et al.*, 2015 [1]; Raza *et al.*, 2014 [26] who reported an increase in number of tillers plant^{-1} with exogenous application of glycine betaine and potassium nitrate.

It is evident from the data presented in Table-3 that panicle length increased with the foliar spray of different concentrations of glycine betaine and KNO_3 (Osmoprotectants) alone as well as their combination applied at different stages on rice plants exposed to drought stress at flowering stage (60 DAT) but the result was found non-significant. However among the treatments, maximum panicle length was found in T_5 (23.86 and 24.44 cm) followed by T_4 (23.37 and 24.12 cm), T_3 (23.21 and 23.91 cm), T_2 (23.16 and 23.79 cm), T_9 (23.14 and 23.56 cm) , T_8 (23.04 and 23.33 cm), T_7 (22.97 and 23.27 cm), T_6 (22.84 and 23.02 cm) while minimum was noted in T_1 (21.92 and 22.23 cm) in year 2015-16 & 2016-17 respectively. Raza *et al.*, 2014 [26] also reported that foliar application of glycine betaine increased panicle length and spikelets number per spike in addition to number of grains per spike and seed weight in wheat genotypes under stress. Glycine betaine and potassium nitrate treatment might have improved yield performance of rice under drought stress possibly by better net photosynthetic assimilation (Gupta and

Thind, 2015; Kausar *et al.*, 2014) [13, 15], enhanced photo-inhibition tolerance of PSII (Ma *et al.*, 2006; Cha-um *et al.*, 2013) [19, 9].

The perusal of the data presented in Table-4 reveal that foliar spray of different concentrations of glycine betaine and KNO_3 (Osmoprotectants) alone as well as their combination applied at different stages on rice plants exposed to drought stress at flowering stage (60 DAT) significantly increase number of fertile grains panicle^{-1}. However in year 2015-16 among the treatments, maximum number of fertile grains panicle^{-1} was found in T_9 (104.33) followed by T_8, T_7, T_6, T_5, T_4 and T_3 *i.e.* 101.00, 100.17, 99.33, 97.00, 93.67 and 95.83 respectively while T_2 (90.83) was found non-significant over T_1 (87.17). Likewise in 2016-17 among the treatments, maximum number of fertile grains panicle^{-1} was found in T_9 (108.33) followed by T_8, T_7, T_6, T_5 and T_4 *i.e.* 105.89, 102.44, 101.11, 99.44 and 99.11 respectively while T_3 and T_2 *i.e.* 96.22 and 94.89 respectively was found non-significant over T_1 (89.89). Glycine betaine application has been demonstrated to improve yield components in maize (Miri and Armin, 2013) [22], rice (Cha-um *et al.*, 2013) [9]. Accumulation of these compounds endure the plants to retain water within cells and protect cellular compartments from injury caused by dehydration and thus balancing turgor pressure, during drought stress (Bohnert *et al.*, 1995) [5]. It has also been used to enhance the drought tolerance of some crop species like wheat (Allard *et al.* 1998) [2] rice (Rahman *et al.*, 2002) [25]. Moreover, potassium application has demonstrated increase in number of fertile tillers (Mehdi *et al.*, 2001) [21].

Data presented in table-5 shows significant reduction in number of sterile grains panicle^{-1} in all the foliar treatments during both the years (2015-16 & 2016-17). However in year 2015-16, among the treatments minimum number of sterile grains panicle^{-1} was noted in T_9 (23.89) followed by T_8, T_6 , T_7, T_5, T_4, T_3 and T_2 *i.e.* 24.44, 26.11, 26.89, 27.44, 28.44, 29.44 and 30.11 respectively while maximum number of sterile grains panicle^{-1} was noted in T_1 (32.89). Similarly in 2016-17, among the treatments minimum number of sterile grains panicle^{-1} was noted in T_9 (20.78) followed by T_8 , T_7, T_6, T_5, T_4, T_3 and T_2 *i.e.* 21.11, 23.67, 24.00, 25.33, 26.00, 27.67 and 28.11 respectively while maximum number of sterile grains panicle^{-1} was noted in T_1 (30.11). . Plant growth is restrained under drought stress due to osmotic and ionic effects; however, plants have the ability to develop certain mechanisms to cope up with stress conditions (Munns 2002) [23]. Foliar spray of glycine betaine and KNO_3 increased the yield and yield components and reduced the sterility number of grains by osmoprotective roles of glycine betaine and potassium nitrate which could results in reducing sterile number of grains. Both the chemicals showed positive effect in modifying assimilates translocation which may be predicted to be responsible for reducing number of sterile grains panicle^{-1}.

Table 1: Effect of foliar spray of glycine betaine and KNO_3 on plant height (cm) of rice plants exposed to 60-80 kPa drought stress at 60 DAT

Stage → **Treatments ↓**	**Year →**	**At Maturity**	
		2015-16	**2016-17**
T_1	Untreated	72.69	73.91
T_2	Foliar spray of KNO_3 @ 2% at 30 DAT	76.73	77.86
T_3	Foliar spray of KNO_3 @ 3% at 30 DAT	77.62	78.82
T_4	Foliar spray of KNO_3 @ 2% at 60 DAT	80.63	82.00
T_5	Foliar spray of KNO_3 @ 3% at 60 DAT	81.57	82.72
T_6	Foliar spray of glycine betaine @ 100 ppm at 60 DAT	78.56	80.96
T_7	Foliar spray of glycine betaine @ 200 ppm at 60 DAT	79.72	81.86
T_8	Foliar spray of KNO_3 @ 2% at 30 DAT & glycine betaine @ 100 ppm at 60 DAT	75.61	77.45
T_9	Foliar spray of KNO_3 @ 2% at 30 DAT & glycine betaine @ 200 ppm at 60 DAT	76.71	78.00
SEm±		1.63	1.67
CD at 5%		5.87	5.00

Table 2: Effect of foliar spray of glycine betaine and KNO_3 on number of tillers plant^{-1} of rice plants exposed to 60-80 kPa drought stress at 60 DAT

Stage → **Treatments ↓**	**Year →**	**At Maturity**	
		2015-16	**2016-17**
T_1	Untreated	7.44	8.00
T_2	Foliar spray of KNO_3 @ 2% at 30 DAT	10.11	10.22
T_3	Foliar spray of KNO_3 @ 3% at 30 DAT	10.44	10.67
T_4	Foliar spray of KNO_3 @ 2% at 60 DAT	8.00	8.11
T_5	Foliar spray of KNO_3 @ 3% at 60 DAT	8.11	8.67
T_6	Foliar spray of glycine betaine @ 100 ppm at 60 DAT	8.00	8.11
T_7	Foliar spray of glycine betaine @ 200 ppm at 60 DAT	8.22	8.78
T_8	Foliar spray of KNO_3 @ 2% at 30 DAT & glycine betaine @ 100 ppm at 60 DAT	10.00	10.22
T_9	Foliar spray of KNO_3 @ 2% at 30 DAT & glycine betaine @ 200 ppm at 60 DAT	10.22	10.56
SEm±		0.19	0.20
CD at 5%		0.57	0.59

Table 3: Effect of foliar spray of glycine betaine and KNO$_3$ on Panicle length (cm) of rice plants exposed to 60-80 kPa drought stress at 60 DAT

Treatments ↓ Year →		**Panicle length (cm)**	
		2015-16	**2016-17**
T$_1$	**Untreated**	21.92	22.23
T$_2$	Foliar spray of KNO$_3$ @ 2% at 30 DAT	23.16	23.79
T$_3$	Foliar spray of KNO$_3$ @ 3% at 30 DAT	23.21	23.91
T$_4$	Foliar spray of KNO$_3$ @ 2% at 60 DAT	23.37	24.12
T$_5$	Foliar spray of KNO$_3$ @ 3% at 60 DAT	23.86	24.44
T$_6$	Foliar spray of glycine betaine @ 100 ppm at 60 DAT	22.84	23.02
T$_7$	Foliar spray of glycine betaine @ 200 ppm at 60 DAT	22.97	23.27
T$_8$	Foliar spray of KNO$_3$ @ 2% at 30 DAT & glycine betaine @ 100 ppm at 60 DAT	23.04	23.33
T$_9$	Foliar spray of KNO$_3$ @ 2% at 30 DAT & glycine betaine @ 200 ppm at 60 DAT	23.14	23.56
SEm±		0.47	0.48
CD at 5%		NS	NS

Table 4: Effect of foliar spray of glycine betaine and KNO$_3$ on number of fertile grains panicle^{-1} in rice plants exposed to 60-80 kPa drought stress at 60 DAT

Treatments ↓ Year →		**Number of fertile grains panicle^{-1}**	
		2015-16	**2016-17**
T$_1$	**Untreated**	87.17	89.89
T$_2$	Foliar spray of KNO$_3$ @ 2% at 30 DAT	90.83	94.89
T$_3$	Foliar spray of KNO$_3$ @ 3% at 30 DAT	95.83	96.22
T$_4$	Foliar spray of KNO$_3$ @ 2% at 60 DAT	93.67	99.11
T$_5$	Foliar spray of KNO$_3$ @ 3% at 60 DAT	97.00	99.44
T$_6$	Foliar spray of glycine betaine @ 100 ppm at 60 DAT	99.33	101.11
T$_7$	Foliar spray of glycine betaine @ 200 ppm at 60 DAT	100.17	102.44
T$_8$	Foliar spray of KNO$_3$ @ 2% at 30 DAT & glycine betaine @ 100 ppm at 60 DAT	101.00	105.89
T$_9$	Foliar spray of KNO$_3$ @ 2% at 30 DAT & glycine betaine @ 200 ppm at 60 DAT	104.33	108.33
SEm±		2.09	2.17
CD at 5%		6.26	6.51

Table 5: Effect of foliar spray of glycine betaine and KNO$_3$ on number of sterile grains panicle^{-1} in rice plants exposed to 60-80 kPa drought stress at 60 DAT

Treatments ↓ Year →		**Number of sterile grains panicle^{-}**	
		2015-16	**2016-17**
T$_1$	**Untreated**	32.89	30.11
T$_2$	Foliar spray of KNO$_3$ @ 2% at 30 DAT	30.11	28.11
T$_3$	Foliar spray of KNO$_3$ @ 3% at 30 DAT	29.44	27.67
T$_4$	Foliar spray of KNO$_3$ @ 2% at 60 DAT	28.44	26.00
T$_5$	Foliar spray of KNO$_3$ @ 3% at 60 DAT	27.44	25.33
T$_6$	Foliar spray of glycine betaine @ 100 ppm at 60 DAT	26.11	24.00
T$_7$	Foliar spray of glycine betaine @ 200 ppm at 60 DAT	26.89	23.67
T$_8$	Foliar spray of KNO$_3$ @ 2% at 30 DAT & glycine betaine @ 100 ppm at 60 DAT	24.44	21.11
T$_9$	Foliar spray of KNO$_3$ @ 2% at 30 DAT & glycine betaine @ 200 ppm at 60 DAT	23.89	20.78
SEm±		0.54	0.48
CD at 5%		1.62	1.45

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