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Field efficacy of exogenously applied putrescine in wheat (*Triticum aestivum*) under water-stress conditions

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ABSTRACT

A field experiment was conducted during winter (*rabi*) season of 2005–06 and 2006–07 taking wheat (*Triticum aestivum* L. emend Fiori. & Paol.) genotype ‘HD 2329’ to investigate the efficacy of putrescine under water stress condition. Putrescine (0.01, 0.1 and 1.0 mM concentrations) was applied as seed treatment, one or two foliar sprays. For water stress treatment, the number of irrigations was reduced to three as compared to six in control. Putrescine application enhanced plant height, leaf area, grain number, grain weight, grain yield and biological yield under non-stress as well as under water stress conditions. Exogenous application of 0.1 mM putrescine was found the best in most of the observations. Among mode of applications, two foliar sprays of putrescine at the time of anthesis and post anthesis performed best over seed treatment and one foliar spray of putrescine.

Key words: Putrescine, Seed treatment, Spray, Water stress, Wheat, Yield

Polyamines including spermidine, spermine and putrescine are small ubiquitous nitrogenous compounds which are involved in several plant growth and developmental processes (Farooq *et al.* 2009). They are the recent additions to the class of plant growth regulators, and also considered as a secondary messenger in signalling pathways (Kusano *et al.* 2008). Polyamines are involved in abiotic stress tolerance in plants (Nayyar *et al.* 2005). Increased polyamines level in stressed plants are of adaptive significance because of their involvement in regulation of cellular ionic environment, maintenance of membrane integrity, prevention of chlorophyll loss, and stimulation of protein, nucleic acid and protective alkaloids (Sharma 1999). Interaction of polyamines with membrane phospholipids implicates membrane stability under stress conditions (Roberts *et al.* 1986). Polyamines also protect the membranes from oxidative damages as they act as free radical scavengers (Besford *et al.* 1993). Transgenic plant with over production of polyamines are reported to display better stress tolerance than their wild counterparts (Kusano *et al.* 2008).

Exogenous application of polyamines improved tolerance against several abiotic stresses (Basra *et al.* 1997). Positive response of exogenously applied polyamines has been reported in olive, rice, and soybean (Yang *et al.* 1997, Sharma 1999). Polyamines were found to enhance productivity in wheat under water stress conditions in pots (Gupta *et al.* 2003). Nayyar *et al.* (2005) found that exogenous application of putrescine and spermidine substantially improved the drought tolerance in soybean. Seed priming with polyamines was effective in improving the emergence and seedling growth in rice (Farooq *et al.* 2009).

Despite many reports available on the role of endogenous polyamines and application of polyamines as seed treatment or spray, much headway could not be made to translate the experimental information into a tensible blue print of technology. Therefore, present investigation has been taken to find out the effect of exogenously applied putrescine in imparting drought tolerance in wheat under field conditions.

MATERIALS AND METHODS

Experiment was conducted at Swami Keshwanand Rajasthan Agricultural University, Campus Jobner in two consecutive winter (*rabi*) seasons of 2005–06 and 2006–07. Climate of this zone is typically semi-arid characterised by wide range of temperatures, both in winter (–2 to 10ºC) and in summer (30 to 48ºC). The normal rainfall of this zone varies between 400 and 500 mm, most of which comes from south-west monsoon during July-September. The soil used for experimentation was sandy loam having bulk density of 1.5 g/cm^3.

The experiment was laid out in randomized block design with five replications under non-stress and water stress

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conditions. Wheat genotype ‘HD 2329’ was taken for study. Treatments consisted of control, seed treatment (1.0 mM, 0.1 mM and 0.01 mM putrescine), one foliar spray (1.0 mM, 0.1 mM and 0.01 mM putrescine) and two foliar sprays (1.0 mM, 0.1 mM and 0.01 mM putrescine). The plot size was 3 m × 2 m. Field was initially ploughed by disc plough, followed by cross harrowing and planking to bring the field into good tilth. A pre-sowing irrigation was given for proper germination and establishment of the seedlings. For fertilizer application, a uniform basal dose of 90 kg N/ha through urea, 30 kg P_2O_5/ha through single super phosphate and 30 kg K_2O/ ha through muriate of potash was drilled prior to sowing. The remaining nitrogen was top-dressed through urea.

For seed soaking treatment, the seeds were soaked in above mentioned concentrations of putrescine dihydrochloride for six hours, followed by air-drying prior to sowing. These seeds were then sown at about 5 cm depth in rows of 25 cm apart. For one spray treatment, putrescine was sprayed at anthesis stage, whereas for two spray treatment, putrescine was sprayed at anthesis and post-anthesis stages. About 250 ml solution of each concentration was used in each plot and the control plants were sprayed with distilled water.

Plants were harvested separately in non-stress and water-stressed plots. The harvested material of each plot was tied up in bundles and kept on threshing floor for drying. Threshing and winnowing was done manually for each plot and yield/plot was measured. Observations on plant height, leaf area/plant, number of grains/ear, grain yield, biological yield, test weight and harvest index were taken at harvest in control and putrescine-treated plants.

RESULTS AND DISCUSSION

Effect of exogenously applied polyamines on physiological processes of plants, growth and yield attributes is well documented (Gupta *et al.* 2003, Farooq *et al.* 2009). In present investigation, exogenous application of putrescine has enhanced the grain yield in wheat genotype ‘HD 2329’ (Table 1). Putrescine concentration also affected the grain yield and it increased with increased putrescine concentration, but the differences between 0.1 mM and 1.0 mM putrescine treatments were not significant. Response of putrescine was more pronounced under water-stress conditions. It increased the grain yield regardless of the mode of application, but the effect was more pronounced with two foliar sprays of putrescine (Table 1). In another study, the significant response of different modes of putrescine application on grain yield has been observed. Maximum yield was observed with a combination of seed treatment plus one spray of putrescine (Gupta *et al.* 2003).

Biological yield also enhanced by putrescine application. Its maximum values have been recorded with 1.0 mM concentration of putrescine, but the differences were not significant above 0.1 mM concentration (Table 1). Harvest index is an important parameter to understand the source sink relationship. In our study, putrescine treatment altered harvest index, but the differences among the treatments were not significant (Table 1). It is evident that a concomitant increase in biological yield along with grain yield resulted in non-significant variations in harvest index. It has been reported that the physiological functions of putrescine are comparable to cytokinin (Gupta *et al.* 2003). Improvement in yield of tomato by putrescine application has been reported (Cohen *et al.* 1982).

Table 1 Effect of putrescine on yield attributes and yield in wheat under non-stress and water-stress conditions (pooled data)

Treatment	Grain yield (tonnes/ha)		Biological yield (tonnes/ha)		Test weight (g)		Harvest index (%)	
	Non-stress	Water stress	Non - stress	Water stress	Non - stress	Water stress	Non-stress	Water stress
Mode of treatment								
Seed treatment	3.89	2.49	10.59	7.13	37.78	34.32	36.76	34.95
One spray	4.02	2.61	10.86	7.41	38.23	34.52	36.93	35.22
Two sprays	4.13	2.72	11.16	7.65	39.58	35.94	36.99	35.53
CD (*P*=0.05)	0.07	0.07	0.17	0.15	0.91	0.84	NS	NS
Concentration								
0.01 mM Put	3.93	2.51	10.61	7.07	37.21	33.61	37.01	35.52
0.1 mM Put	4.03	2.63	10.91	7.47	38.98	35.08	36.96	35.25
1 mM Put	4.07	2.67	11.09	7.66	39.39	36.09	36.72	34.92
CD (*P*=0.05)	0.07	0.07	0.17	0.15	0.91	0.84	NS	NS
Control	3.65	22.35	10.03	6.61	35.27	31.89	36.32	33.80
Rest	4.01	26.04	10.87	7.40	38.52	34.92	36.89	34.22
CD (*P*=0.05)	0.29	0.29	0.42	0.41	1.17	1.08	NS	NS

Author: Convert all readings in q/ha to tonnes/ha in Tables and Text.

Table 2 Effect of putrescine on plant height, leaf area, number of grains and grain weight in wheat under non-stress and water-stress conditions (pooled data)

Treatment	Plant height (cm)		Leaf area (cm^2)		Grains/ear	
	Non-stress	Water-stress	Non-stress	Water-stress	Non-stress	Water-stress
Mode of treatment						
Seed treatment	75.1	73.3	123.7	100.0	49.09	44.65
One spray	76.1	75.2	130.6	108.5	51.23	46.48
Two spray	79.4	77.9	137.2	116.8	51.94	47.47
CD (P=0.05)	NS	2.93	3.22	2.82	1.57	1.23
Concentration						
0.01 mM Put	76.2	75.2	126.1	104.8	49.64	45.08
0.1 mM Put	76.8	75.8	131.8	108.9	50.84	46.40
1 mM Put	77.8	75.3	133.6	111.5	51.78	47.12
CD (P=0.05)	NS	NS	3.22	2.82	1.57	NS
Control	72.5	69.5	116.1	98.9	47.34	42.00
Rest	76.8	77.4	130.5	108.4	50.75	46.19
CD (P=0.05)	3.16	3.78	4.18	3.55	2.03	1.60

Grain weight and grain number are two most important yield components of wheat. A critical evaluation of the yield data in present investigation revealed that the effect of putrescine was more perceptible in grain weight as compared to grain number. The mode of application affected both grain weight and grain number significantly but the effect of putrescine concentration on grain number was found non-significant (Table 1). Significant effect of mode of putrescine application on grain number suggests its role in grain setting. The role of exogenously applied cytokinin on grain weight without affecting grain number has been reported in our previous studies. The response of cytokinin was more pronounced in younger grain of wheat than older grains (Gupta *et al*. 2000).

The effect of exogenous application of putrescine has also been observed in other growth and yield-contributing parameters. Putrescine application significantly increased leaf area/plant, but plant height did not change significantly (Table 2). Putrescine induced increase in chlorophyll content, water status, photosynthesis, membrane properties have been reported in rice (Farooq *et al.* 2009). It is inferred that the enhanced leaf area in present investigation might have helped in fulfilling the enhanced demand of developing sink, particularly under water-stress conditions. Liu *et al.* (2000) suggested that polyamines target KAT 1 like inward K^+ channel in guard cell and modulate stomatal movement, providing a link between stress conditions, polyamine levels and stomatal regulation. This property may be linked to the increased transpiration rate and stomatal conductance caused by polyamine application in wheat. In soybean, foliar spray of 10^{-3} M polyamines at 50% flowering stage increased number of pod/plant, 100-seed weight, seed and oil yield (Sharma 1999).

In present investigation, different concentrations of putrescine increased the yield significantly over control. The effect was noticeable under stress as well as non-stress conditions. Comparatively, the productivity of wheat increased more under stress conditions. It clearly indicated that the benefit of applying putrescine was more under water-stress conditions. This finding has valuable implication for the wheat growers of semi-arid region. Further, economic analysis of data shows that albeit maximum grain yield was recorded with 0.1 mM concentration with two mode of applications, the maximum net returns were obtained with 0.01 mM at two mode of application (Table 3). This may be due to high cost of putrescine. The cost of treatment may also be deterrent to farmers. Yet, an economically viable preposition can increase their profit by using putrescine. This finding calls for further research to cut down the cost of

Table 3 Relative economics of different treatments of putrescine under non-stress and water-stress conditions (pooled data)

Treatment	Gross returns (₹/ha)		Cost of cultivation (₹/ha)		Net returns (₹/ha)		B:C ratio	
	Non-stress	Water-stress	Non-stress	Water-stress	Non-stress	Water-stress	Non-stress	Water-stress
Seed treatment								
0.01 mM Put	33 757	23 874	11 451	10 251	22 506	11 103	2.97	2.33
0.1 mM Put	34 630	22 830	12 000	10 738	22 630	12 093	2.89	2.13
1 mM Put	35 028	23 205	17 530	16 268	17 498	6 937	2.00	1.43
One spray								
0.01 mM Put	34 722	22 629	11 512	10 312	23 210	12 317	3.02	2.19
0.1 mM Put	35 801	23 848	12 610	11 410	23 191	12 437	2.84	2.09
1 mM Put	36 173	24 429	3 670	22 470	12 503	1 959	1.53	1.09
Two sprays								
0.01 mM Put	35 622	23 379	11 716	10 516	24 048	12 863	3.07	2.22
0.1 mM Put	36 778	24 871	13 912	12 712	24 106	12 160	2.64	1.95
1 mM Put	37 275	25 288	36 046	34 847	13 544	–9 559	1.03	0.72
Control	32 574	20 645	11 328	10 128	21 246	10 517	2.88	2.04

putrescine or evaluating commercial formulation of polyamines for inducing drought tolerance.

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