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Response of paddy (*Oryza sativa*) to exogenous application of bio-regulators in soils irrigated with alkali groundwater

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ABSTRACT

Exogenous applications of plant bio-regulators (PBRs) were evaluated during *kharif* of 2017 and 2018 for their efficiency to facilitate growth and production processes in paddy (*Oryza sativa* L.) grown in loam soils undergoing sodification (pH_s 8.5 & 8.3; ESP 37 & 13) with alkali groundwater irrigation (RSC 3.4 meq L^{-1} at site-I during both the years and RSC 4.4 & 3.7 meq l^{-1} at site-II during 2017 and 2018, respectively). The PBRs included gibberellic acid (GA, 25 ppm), potassium nitrate (PN, 15 g l^{-1}), salicylic acid (SA, 10uM), sodium benzoate (SB, 150 mg l^{-1}; 2017 only) and thio-urea (TU, 500 ppm). These were sprayed at three stages, i.e. seedling establishment and tillering (30-40 days after transplanting), booting and maximum growth (50-60 DAT) and flowering and grain formation (80-90 DAT). PBRs promoted growth and improved yields and contributing attributes like tillers, panicle length and filled grains. The increase in grain yield equaled 20, 16, 2, 16 and 24% with application of GA, PN, SA, SB and TU, respectively at Site-I during 2017 and the counter values at Site-II were 4, 24, 2, 17 and 21%. Similarly, during 2018, the improvements in yield equaled 3, 15, 4 and 20% with GA, PN, SA and TU at Site-I and nil, 14, 8 and 7% at Site-II, respectively. The Na:K ratio was lower especially with PN while grain quality monitored in terms of protein and gluten contents remained unaffected. On the basis of consistency, it emerges that the use of thio-urea and potassium nitrate is a viable option for alleviating sodicity stress in paddy under alkali groundwater irrigated conditions.

Key words: Abiotic stress, Alkali water, Bio-regulators, Paddy, Sodic soil

With surge in groundwater irrigation to enhance and stabilize food production, even the poor quality waters are being increasingly extracted especially the alkali waters to raise paddy (*Oryza sativa* L.)-wheat in north-west states (Minhas and Bajwa 2001). Because of high water requirements of the system, sodication of the irrigated soils is much more (about 1.8 times) than that of rotations like millet/maize-wheat (Minhas and Sharma 2006). Therefore specialized soil-water-crop management practices are required for sustaining crop yields; the main being recurring needs for amendments like gypsum to maintain soil's sodicity within tolerance levels. Recently several plant treatment options have been put forward to alleviate salinity and other abiotic stresses (Farooq *et al.* 2009; Srivastva *et al.* 2016; Ratna-Kumar *et al.* 2017). These include priming at seeding stage, application of non-enzymatic anti-oxidants, plant bio-regulators (PBRs) or other compatible solutes and foliar applications of nutrients. The objective is to stimulate plant growth and productivity when applied, even in small quantities at appropriate plant growth stages. Though tested mainly for drought, heat/cold stresses, positive responses for gibberellic acid (Vettakkorumakankav *et al.* 1999); salicylic acid (Fayez and Bazaid, 2014); sodium benzoate (Beltrano *et al.* 1999); thio-urea (Wakchaure *et al.* 2016) and potassium nitrate (Gimeno *et al.* 2014) have also been demonstrated for their effectiveness in pot-culture and controlled saline conditions. However, their usefulness to alleviate salinity/sodicty impacts under field conditions needs elaborative and critical evaluation. Keeping above in view, field experiments were conducted during 2017 and 2018 to evaluate some of the low cost PBRs for their viability in sodic soils irrigated with alkali groundwater.

MATERIALS AND METHODS

The experiments were conducted during *kharif* seasons of 2017 and 2018 at two of the farmers' fields' (one acre each) at Jodhpur village, Patiala district, Punjab. The loam soils (sand, silt and clay 33, 45 and 23%, respectively) belonging to *Typic Ustochrepts* and were being sodicated (surface 0.15 soil pH_s 8.5 and 8.3; ECe 2.8 and 2.4 dS m^{-1}; ESP 37 and 13) with the alkali water irrigation (RSC, EC and SAR as 3.4 meq l^{-1}, 0.90 dS m^{-1} and 8.2 at site-I for both years, while, values obtained were 4.4 meq l^{-1}, 0.82 dS m^{-1} and 12.8 in 2017 and 3.7 meq l^{-1}, 0.74 dS m^{-1} and

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4.8 in 2018 at site-II, respectively) to paddy-wheat crops. The experiments were laid out in a randomized block design with 6 treatments using four and three replications at site-II and site-I, respectively in 2017 and 5 treatments with four replications in 2018 at both sites. Treatments consisted of foliar application of PBRs namely gibberellic acid (GA, 25 ppm), potassium nitrate (PN, 15 g l^{-1}), salicylic acid (SA, 10uM), sodium benzoate (SB, 150 mg l^{-1}) and thiourea (TU, 500ppm), along with control (no PBR) during 2017 and the SB was excluded during 2018. Requisite concentrations of different PBRs were sprayed after seedling establishment and tillering (30-40 days after transplanting), booting and maximum growth (50-60 DAT) and flowering and grain formation (80-90 DAT). Paddy varieties; CSR-30 Basmati (long duration) and PR-126 (short duration) were cultivated in 2017 and 2018, respectively at site-I, while, Pusa-1121 (long duration) variety was grown during both the years at site-II. Recommended doses of fertilizers and other agronomic practices were followed to raise respective varieties of paddy. The plant height at maturity, number of tillers per square meter, panicle length and number of filled grains were measured from the randomly selected 5 plants for each subplot. The biological yield from each plot was monitored after manual harvesting of paddy from two representative locations (meter quadrant) at physiological maturity. After taking the fresh weight, plants were air dried and then thrashed. Sub-samples of grains were drawn and dried in hot air oven at 60 ˚C to constant weight. Grain yield was then adjusted at 14 % moisture content. Starch and protein content of grains were analyzed using InfraTec Grain Analyser (InfraTec 124) while standard procedures were followed for digestion and analysis for Na and K in grains and straw.

RESULTS AND DISCUSSION

The data on growth, grain yield and its attributing parameters are included in Table 1. The growth of paddy was promoted by PBRs especially GA, PN and TU, e.g. plants were 0.01-0.09 and 0.03-0.07m taller at site-I during year 2017 and 2018, respectively. Similarly the plants attained 0.03 and 0.03-0.09m more height at site-II during both the years. The yield attributing parameters monitored in terms of tillers, panicle length and filled grains were also enhanced by the use of PBRs. Tillers increased by 45-78 and 9-23 during 2017 and 2018 at site-I while the increase of 23 was observed with PN only during 2017 and 6-16 by TU and PN during 2018 at site-II. Panicle length also got improved with PN, GA and TU at site-I during both the years, while slight improvement was shown with SA in 2017 and improvement with all the PBRs over control was observed in 2018 at site-II. Grain-filling was considerably enhanced with SB, GA and TU by 4-12 panicle^{-1} and with SA, PN and TU by 9-26 panicle^{-1} at site-I during both the years. The filled grains per panicle also got slightly improved by 3-5 with PN, SB and TU at site-II during 2017 and by 9-12 with TU, GA, SA and PN in 2018. The improvement in growth and yield attributing parameters were also translated in terms of grain yields at both the sites. The application of GA, PN, SA, SB and TU improved yields by 20, 16, 2, 16 and 24% over control (No PBR) at Site-I during 2017 and the counter values for Site-II were 4, 24, 2, 17 and 21 per cent though the latter were statistically non-significant. Similarly, during 2018 the improvements with GA, PN, SA and TU equalled 3,

Table 1 Paddy growth, yield attributes, grain yield and quality as affected by the plant bioregulators (PBR)

PBR	Plant height (m)		Effective tillers (No. m^{-2})		Panicle length (cm)		Filled grains (No. panicle^{-1})		Grain yield (Mg ha^{-1})		Na:K ratio		Protein (%)	Starch (%)
											Grain	Straw		
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2018	2018	2017	2017
Site-1														
GA	1.43	0.89	244	178	24.5	23.3	50	71	2.24	3.05	0.19	2.40	10.2	58.0
PN	1.37	0.90	252	192	23.7	23.6	48	94	2.15	3.41	0.14	1.59	10.4	58.4
SA	1.27	0.88	234	180	23.0	22.9	47	77	1.89	3.08	0.21	2.37	10.4	58.2
SB	1.30	--	251	--	22.7	--	54	--	2.16	--	--	--	10.2	59.1
TU	1.41	0.93	267	192	25.2	23.6	58	94	2.31	3.57	0.20	2.36	9.9	58.9
No PBR	1.34	0.86	189	169	23.0	22.3	46	68	1.86	2.97	0.23	2.83	10.1	58.6
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	17	0.28	0.28	0.05	0.58	NS	NS
Site-II														
GA	1.53	1.26	252	195	29.9	27.2	67	67	3.64	3.41	0.10	0.26	9.0	66.1
PN	1.44	1.34	301	213	29.1	28.0	71	70	4.34	3.92	0.09	0.17	9.2	65.4
SA	1.43	1.28	227	212	30.0	28.5	66	67	3.55	3.71	0.10	0.25	9.4	66.3
SB	1.46	--	262	--	29.1	--	70	--	4.08	--	--	--	9.0	64.1
TU	1.53	1.28	278	203	29.3	27.1	72	67	4.23	3.68	0.10	0.25	9.1	65.0
No PBR	1.50	1.25	278	197	29.3	26.8	67	58	3.49	3.44	0.11	0.31	9.1	64.3
LSD (P=0.05)	0.08	0.05	NS	NS	NS	NS	NS	7	NS	NS	NS	NS	NS	NS

15, 4, and 20% at Site-I and nil, 14, 8 and 7% at site-II, respectively. PBRs have been documented to increase the rate of cell division and stimulation of vegetative growth and increased leaf area leading to higher rate of photosynthesis (Ratna-Kumar *et al.* 2016). These regulate the root growth for improving plant water/nutrient uptake, photosynthetic efficiency and source-sink relationship. Metabolic activities of cells supported by –SH group increases photosynthetic efficiency and delays leaf senescence (Sahu 2017), while GA increase the rate of cell division and stimulation of vegetative growth (Ratna-Kumar *et al.* 2017). Growth parameters are supposed to improve with the application of K (PN here) counteracting the deleterious effects of sodium (lower Na:K ratio; Table 1) and also through activation of enzymes, osmotic regulation, loading and unloading of sugars in phloem (Ratna-Kumar *et al.* 2017). SA is linked to enhanced activity of photosynthetic pigments like Chl a & b, carotenoids, induction of flowering and retardation of petal senescence but the judicious application and concentration of SA has to be considered as higher concentrations may lead to decline in yield (Tiwari *et al.* 2017). Recently several reports on PBRs to enhance the growth and crop yields under stress environments have appeared in other crops too, e.g. in wheat under water stress with SB (Beltrano *et al.*1999), in Brassica under salt stress with TU (Pandey *et al.* 2013), chickpea under salinity stress with KNO_3 (Abdolahpour and Lotfi 2014). Though the role of PBRs to enhance growth and improve yield was established here, the impact was less on the site-II where gypsum is being regularly applied to neutralize alkalinity. Also no impact of PBRs was observed on grain quality, i.e. protein and starch content (Table 1).

It is concluded that application of plant bio regulators (PBRs) helped to obviate sodicity stress induced by alkali groundwater irrigation and improved the growth and yield of paddy though these were not as effective under lower stress with gypsum application. Thio-urea and potassium nitrate with improvements in the grain yield by 12-24% indicate their viability towards alleviating sodicity stress.

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