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Effect of Plant Bioregulators and Their Combinations on Growth and Yield of Wheat Under Sodicity Stress Induced by Alkali Water Irrigation

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Abstract

Exogenous applications of plant bio-regulators (PBRs) were evaluated during *rabi* of 2017-18 and 2018-19 for their efficiency to modulate growth and production processes in wheat grown in soils undergoing sodification. The PBRs included three sprays with either of gibberellic acid (GA, 25ppm), potassium nitrate (PN, 15g L^{-1}), salicylic acid (SA, 10uM), thio-urea (TU, 500ppm), or in sequence of TU-PN-TU, GA-TU-PN and a mixture of TU+PN. These were sprayed at three stages i.e. tillering (30-40 days after sowing, DAS), jointing (60-70 DAS) and heading and spike emergence (90-100 DAS). The increase in grain yield equaled 20, 17, 11 and 9% with the application of TU-PN-TU, SA, PN, TU+PN mixture, respectively at site II while the crop responded (7-11%) to only TU and TU-PN-TU at Site-I. Similarly during 2018, the improvements in yield equaled 18, 12, 9, and 6% with SA, GA, GA-TU-PN and PN at Site I and 8-10% with SA, TU+PN mixture and TU at site II while the effects of other treatments were non-significant. On the basis of consistency, it emerges that the use of potassium nitrate, salicyclic acid and thio-urea alone or in combination is a viable option for alleviating sodicity stress in wheat under alkali water irrigated conditions.

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

Introduction

Soil structure deterioration with the development of sodicity causes anoxic conditions in alkali water irrigated soils. Therefore, sparse germination and stunted growth especially of *kharif* crops are common. Adverse impact is further observed on crop productivity in terms of smaller and lesser grains in the spikes. Rice-wheat, though a high water requiring cropping system has become popular in areas underlain with alkali ground waters in the absence of any other remunerative upland crops (Minhas and Bajwa, 2001). These soils have recurring need for amendments like gypsum, but recently several plant treatment options have been put forward to alleviate abiotic stresses (Farooq *et al*., 2009; Srivastva *et al*., 2016; Ratna-Kumar *et al*., 2017). The objective is to stimulate plant growth in terms of better growth parameters viz., plant height, effective tillers and better plant biomass when applied, even in small quantities at appropriate plant growth stages.

PBRs even applied in small doses at appropriate time stimulate plant growth by triggering enzymatic activation and by providing essential nutrients in foliar form at the most needed stage (Sahu, 2017). PBRs have shown 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) and their effectiveness to alleviate salinity/sodicty needs elaborative and critical evaluation. Keeping above in view, field experiments were conducted with wheat during 2017 and 2018 to evaluate some of the low cost PBR' for their viability in sodic soils irrigated with alkali waters.

Material and Methods

The experiments were conducted during *rabi* seasons of 2017-18 and 2018-19 at two of the farmers' fields' (one acre each) at Jodhpur and Patti Jhungia villages, Patiala district, Punjab. The

Table 1. Physico-chemical properties of initial soils

Properties	2017-2018		2018-2019	
	Site-1	Site-II	Site-1	Site-II
pH_2	9.1	8.8	9.0	8.7
EC_2 (dS m^{-1})	1.4	0.65	1.3	0.85
Organic Carbon (%)	0.38	0.42	0.40	0.44
Available Nitrogen (kg ha^{-1})	135.4	155.8	145.2	160.8
Available Phosphorous (kg ha^{-1})	17.6	21.9	16.2	22.6
Available Potassium (kg ha^{-1})	265.8	305.6	280.5	310.5
Fe (mg kg^{-1})	16.18	19.44	18.53	17.65
Mn (mg kg^{-1})	7.84	11.60	6.85	10.40
Zn (mg kg^{-1})	0.80	1.40	0.75	1.30
Cu (mg kg^{-1})	0.32	0.45	0.40	0.52

loam soils at Site-I during both years and loam soil during 2017-18 and clay loam during 2018-19 at Site-II belong to *Typic Ustochrepts* and were being sodificated (ESP 24.5 at Site-I during both years, ESP 15.2 and 14.1 at Site-II during 2017-18 and 2018-19, respectively) with the alkali water irrigation to wheat crop. The RSC, EC and SAR of irrigation water at site I was 4.2 meq L^{-1}, 0.92 dS m^{-1} and 8.2, respectively for both years, while values obtained were 3.7 meq L^{-1}, 0.74 dS m^{-1} and 4.76 in 2017-18 and 4.8 meq L^{-1}, 1.13 dS m^{-1} and 8.77 in 2018-19 at site-II. The initial physico-chemical properties of soils are included in Table 1.

The experiments were laid out in a randomized block design with 8 treatments using three replications at all sites. Treatments consisted of foliar application of PBR's either gibberellic acid (GA, 25ppm), potassium nitrate (PN, 15 g L^{-1}), salicylic acid (SA, 10uM), thio-urea (TU, 500ppm) for all the three spays or sequential application of TU-PN-TU, GA-TU-PN and a mixture of TU+PN along with control (no PBR) during both the years. Requisite concentrations of different PBRs were sprayed after the initial crop establishment i.e. tillering (30-40 days after sowing, DAS), jointing (60-70 DAS) and heading and spike emergence (90-100 DAS) stages. Wheat varieties; KRL 210 (long duration) and Badbad (short duration) were cultivated in 2017-18 and 2018-19, respectively at site-I, while, HD 2967 (long duration) variety was grown during both the years at site-II.

Recommended doses of fertilizers and other agronomic practices were followed to raise wheat. The plant height at maturity, number of tillers per square meter, spike length, number of grains per spike, number of filled and unfilled grains were measured from the randomly selected plants for each subplot. The biological yield from each plot was monitored after manual harvesting of wheat from two representative locations (meter quadrant) at physiological maturity. After taking the fresh weight, plants were air dried and then thrashed. Biological yield was calculated on thrashing air weight basis. For experimentation, Site-I remained same for both years while, Site-II location was different in both years. Standard procedures were followed for digestion and analysis for Na and K in grains. The statistical analysis of data and derived variables from the experiment was performed using SAS (Ver. 9.4) in randomized block design and analysis of variance (ANOVA) was generated.

Results and Discussion

The data on growth, grain yield and its attributing parameters are included in Table 2. The growth of wheat was promoted by PBRs especially GA-TU-PN, GA and TU e.g. plants were 0.1 to 1.9 cm and 0.9-1.9 cm taller at site-I during year 2017-18 and 2018-19, respectively. Similarly, the plants attained 0.3-7.6 cm more height at site-II during 2017-18. The yield attributing parameters monitored in terms of effective tillers, panicle length and filled grains were also improved by the use of PBRs. Tillers increased by 12-60 and 10-28 during 2017-18 and 2018-19 at site-I while a increase i.e. 2-7 and 28-128 was observed during 2017-18 and 2018-19 at site-II. Spike length was improved by 0.1-0.4 cm by all the PBRs treatments except GA during 2017-18 and 0.3-1.3 cm with all the treatments over No PBR during 2018-19 at Site-I. Number of grains per spike got slight increment of 2 by PN during 2017-18 and 3-7 during 2018-19 at Site-I while, the values range between 1-7 and 2-12 during 2018-19 at Site-II.

The improvement in growth and yield attributing parameters were also translated in terms of grain yields at both the sites. The application of TU and TU-PN-TU improved yields by 7-11% at Site-I during 2017 and the improved yields for Site-II were 8.57, 11.4, 17.1, 20 and 8.57% by TU, PN, SA, TU-PN-TU and mix of TU+PN, respectively. Similarly during 2018-19, the increase in yield ranged between 3-18% at Site-I. The maximum yield was obtained with SA followed by GA, GA-TU-PN and PN. At Site-II also, highest improvement yields was obtained with SA that equaled with mix of TU+PN followed by TU, GA and with PN. However, at Site-II during 2017, GA performed below No PBR and a significant reduction in grain yield has been obtained. During 2017-18, biomass improvement has been reported with the application of TU, GA, PN and GA-TU-PN by 21.5, 10, 7 and 2% at Site-I, while, an improvement of 21.1, 10.1 and 3.91% has been obtained with TU+PN, TU-PN-TU and GA-TU-PN at Site-II. During 2018-19, TU and SA improved biomass by 6.80 and 3.88% at Site-I and for Site-II, all treatments except No PBR excelled biomass production.

Several reports have recently appeared (Daei *et al.*, 2009; Farooq *et al.*, 2015) where PBRs have been documented to stimulate redox signaling under abiotic stress conditions by inhibiting high uptake of Na and Cl and their transport to plant-shoots and by increasing enzymatic antioxidant defense system (SOD and CAT). They promote plant growth by increasing rate of cell division and enhance vegetative growth, increase leaf area thereby leading to higher rate of photosynthesis (Ratna-Kumar *et al.*, 2016). PBRs enhance the efficiency of antioxidant system, upgrade osmolytes and enhance the expression of stress-responsive genes in plants (Srivastava *et al.*, 2016). Especially TU and SA have been tested to enhance plant stress tolerance as these enhance the activity of photosynthetic pigments like Chl a & b, carotenoids, induce flowering and retards petal senescence (Ratna-Kumar *et al.*, 2017). TU has thiol containing 2 –SH group which stimulates carbon dioxide assimilation in the dark up to five-folds and thus improves storage capacity by improving yield attributes of the plants (Werdan *et al.*, 1975). GA increases the rate of cell division, increases intermodal elongation and stimulates vegetative growth. K plays an important role in the form of enzyme activation, osmotic regulation, loading and unloading of sugars in phloem, thereby, counteracting the deleterious effects of sodium (Ratna-Kumar *et al.,* 2017).

A lower Na:K ratio was also monitored with application of PN compared with No PBR (Table 2). PBR's are known to enhance the growth and crop yields under stress environments in wheat under water stress with Sodium Benzoate (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). TU as a thiol compound improves the metabolic transport of sucrose to grains in the form of phloem loading, improves storage capacity, increase canopy rate and photosynthesis and increases grain filling in wheat, SA enhance the rate of deep oxidation, improves the capacity of osmotic adjustment by maintaining low (Malonbialdehyde) MDA contents and decreases Na/K ratio in wheat (Ratna-Kumar *et al.,* 2017). Though the role of PBRs to enhance growth and improve yield was established here, the impact was less on the site-I during 2017-18 where the sodicity stress was severe.

Conclusions

It is concluded that application of plant bio regulators (PBR's) helped to obviate sodicity stress induced by alkali water irrigation and improved the growth and yield of wheat. Salicyclic acid and sequential application of thio-urea, potassium nitrate and thio-urea were more effective with an

Table 2. Growth, yield and its attributing parameters of wheat as affected by different plant bio-regulators and their combinations.

PBR	Plant height (cm)		Eff. tillers (No.m^{-2})		Spike length (cm)		Spikelets (No.spike^{-1})		No. of (grains spike^{-1})		Grain yield (q ha^{-1})		Biological yield (qha^{-1})		Na:K ratio Grain	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Site-1																
GA	93.4	84.8	325	281	10.3	10.6	10.3	15.1	45	52	27	37	97	91	0.044	0.055
PN	92.7	80.5	345	275	10.8	9.7	10.8	15.2	51	44	26	35	95	95	0.034	0.059
SA	92.5	82.2	349	284	10.7	10.1	10.7	13.8	47	45	26	39	89	107	0.036	0.060
TU	93.1	85.8	344	290	11.0	10.5	11.0	16.2	49	48	30	34	107	110	0.048	0.059
TU-PN-TU	91.6	81.8	337	243	10.7	10.3	10.7	16.3	42	48	29	34	88	96	0.041	0.058
GA-TU-PN	95.2	80.8	357	251	11.0	10.7	11.0	15.8	49	51	28	36	90	97	0.044	0.062
TU+PN Mix	90.5	81.0	385	272	10.9	10.5	10.9	14.9	43	48	27	34	88	102	0.029	0.061
No PBR	93.3	83.9	325	262	10.6	9.4	10.6	15.4	49	45	27	33	88	103	0.052	0.064
LSD(p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Site-II																
GA	94.5	94	318	294	12.7	9.3	20.6	18.3	51	56	27	42	101	117	0.029	0.060
PN	96.3	96	300	266	12.7	9.8	19.0	18.8	53	51	39	41	123	118	0.032	0.066
SA	100.2	98	292	365	13.1	9.0	18.8	18.5	54	56	41	44	120	128	0.030	0.059
TU	98.9	95	308	380	12.5	9.3	19.0	19.5	52	59	38	43	100	131	0.035	0.063
TU-PN-TU	101.7	96	313	304	12.2	9.8	19.0	20.5	57	61	42	41	141	118	0.028	0.065
GA-TU-PN	99.0	98	258	394	12.4	8.9	19.8	18.5	51	52	32	40	133	124	0.034	0.061
TU+PN Mix	94.4	97	290	261	13.3	9.6	18.0	19.5	55	55	38	44	155	122	0.023	0.065
No PBR	94.1	101	311	266	12.4	9.2	18.3	19.0	50	49	35	40	128	116	0.047	0.070
LSD(p=0.05)	5.02	NS	NS	30.8	NS	NS	NS	NS	NS	NS	7.77	NS	NS	NS	NS	NS

GA= Gibberelic acid, PN = Potassium nitrate, SA = Salicyclic acid, TU = Thiourea, q=100 kg improvement of 10-20% in grain yield, while, application of thio-urea and potassium nitrates alone was also quite effective (3-11% grain yield improvement) which signifies the viability of PBRs in alleviating sodicity stress.

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