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MITIGATION OF LEAD STRESS IN *TRITICUM AESTIVUM* L. SEEDLINGS BY TREATING WITH SALICYLIC ACID

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Abstract

Heavy metal pollution is a serious issue for the large parts of world especially with respect to agriculture. This study was undertaken to investigate the effect of different concentrations of salicylic acid (0, 0.1 and 0.5 mM) on biochemical attributes in three wheat varieties (Millat-2011, Aas-2011 and FSD-2008) under lead stress (0, 0.5, 1, 1.5 mM). The experiment was designed in completely randomized design (CRD) with five replicates. Increasing lead (Pb) concentration from 0 to 1.5 mM caused several disruptions in wheat varieties, reflected by reduction in chlorophyll, carotenoids, protein and soluble sugar contents but amount of proline increased with rise in Pb levels. However, the applications of salicylic acid (SA) significantly lowered the effect of Pb and enhanced the amount of biochemical attributes of *T. aestivum* L. cultivars. Maximum improvement was perceived at 0.5 mM SA concentration. In conclusion, the application of SA is proved to be suitable to minimize the effect of Pb in wheat.

Key words: Salicylic acid; Biochemical attributes; Wheat; lead; CRD.

Introduction

Wheat (*Triticum aestivum* L.) belongs to tribe “Triticeae” in the grass family (Poaceae) (Briggle & Reitz, 1963). It is an appetizing grain and one of the oldest cereal crops which is grown under variety of climatic conditions. Wheat is best acclimated to temperate areas which received annual rainfall between 30 and 90 cm. It is used more than any other grain in the world (Singh & Singh, 2007). It is grown every year all over the world (Poehlman & Sleper, 1995). It assumes approximately 25 percent of the whole worldwide area dedicated to cereal yields and estimated commercial production is 650.9 million metric tons in 2010, gathered from 217.0 million hectares; it is cultivated on about 4 percent of the earth’s agrarian land (Anon., 2012). The calculated worldwide demand for wheat in 2020 differs among 840 and 1050 Mt. Global wheat production can be achieved by increasing 2.5 percent per year (Kronstad, 1998).

It is a staple food of Pakistani people and contributes about 80 percent of total nutritional intake and more than 60 percent of the total protein and calorie needs (Bostan & Naeem, 2002). Pakistan is an agricultural country with high population growth. To meet high demand for food production soils are intensively cropped. Due to high cost, lack of chemical fertilizers and acute water shortage, industrial, municipal and agricultural waste disposals are used as a low-cost and richest home of organic matter, nutrients and alternatives of irrigation by agrarians in Pakistan (Younas & Shahzad, 1998). Industrial effluents bring different types of contaminants besides of nutrients. Between these pollutants, heavy metals (Pb, Cd, As, Se, Ni and Hg) are posing serious threat to animals, plants and human beings (Baath, 1989). In Pakistan, 0.033 million hectares area takes industrial waste (Ensink *et al.*, 2004) and its continual use might create metal problems in soil (Ahmad *et al.*, 2007). Lead, zinc and copper are the most reported heavy metals in agricultural soils amended with wastes (Jamal *et al.*, 2002).

Lead is a main anthropogenic toxin that has been stored in various water and global ecosystems since the industrial uprising. It is generally circulated heavy metal that is very damaging to plants and hard to control (Verma & Dubey, 2003). Lead in soil not simply changes the soil microbe actions but also caused potency drop in soil (Majer *et al.*, 2002). Soil can lost its productivity due to elevated level of lead in soil. Moreover, a very low amount of lead in soil can also obstruct some vigorous plant processes (Patra *et al.*, 2004).

Salicylic acid (SA) is made as a result of metabolism of phenylalanine in plant digestion and reflected as a key signaling particle and endogenous growing controller with various physiological roles (Senaratna *et al.*, 2000). SA can increase plants syndrome-resistance, decrease transpiration and improve the stress effects of several heavy metal components for a range of crops. SA is involved in creating local and organized disease confrontation reactions of plants when pathogen attacks (Alvarez, 2000). Other than biotic pressures, a huge organization of studies (Shah, 2003) describe the participation of salicylic acid in reactions to some abiotic pressures e.g. UV light, water scarcity, salt, chilling and temperature; it arbitrates certain supportive acclimation reactions to abiotic pressure elements, such as low temperatures, herbicides, salinity and heavy metals (Metwally *et al.*, 2003). The current study is aimed to study the physiological and biochemical mechanisms for lead prompted stress and ameliorative effect of salicylic acid to reduce lead stress in wheat seedlings. This study is also aimed to evaluate wheat varieties through high tolerance or resistance to heavy metal (lead) ions.

Materials and Methods

The seeds of three varieties of *Triticum aestivum* L. (Millat-2011, Aas-2011 and FSD-2008) were gotten from National Agriculture Research Center (NARC), Islamabad and used to study the effect of salicylic acid under lead stress. SA (Merck, Germany) and lead nitrate

(BDH Laboratory Supplies, England) were used as test chemicals in the present study. Four different concentrations of lead nitrate solution (0, 0.5, 1 and 1.5 mM) were prepared by dissolving lead nitrate in dH_2O and pH was fixed to 5.5 with nitric acid. Similarly, 3 concentrations of SA (0, 0.1 and 0.5 mM) in distilled water were formed and used. Fresh and healthy wheat seeds of uniform size were selected. Before sowing, seeds were soaked in 5 percent sodium hypochlorite for 10 min and washed thrice by distilled water. The experiment was performed in laboratory conditions in Department of Botany, University of Azad Jammu and Kashmir, Muzaffarabad. The seeds were germinated for ten days at room temperature with alternate exposure to light and dark periods of 12 hours. Seeds were placed on blotting papers in sterilized petri dishes. Fifteen seeds per variety were positioned at equidistance in each petri dish for each replicate. The blotting paper was moisturized with 8 mL of test chemical concentration regularly in each petri dish. The roots and shoots of ten days old seedlings were taken for biochemical investigation.

Extraction of photosynthetic pigments was done by standardizing 0.1 g of fresh leaf tissue in 10 mL of 80 percent acetone. Leaf homogenate was cleaned by Whatman filter paper and the remainder was collected in a test tube. Lichtenthaler’s formulae were used to convert absorbance readings for determination of chlorophyll and carotenoid as follows:

Chl_a (mg/g) = [(12.25 x $A_{663.2}$) - (2.79 x $A_{646.8}$)] × ml acetone / mg leaf tissue
Chl_b (mg/g) = [(21.50 x $A_{646.8}$) - (5.10 x $A_{663.2}$)] × ml acetone / mg leaf tissue
Total Chl = Chl_a + Chl_b
Carotenoids (mg/g) = (1000 A_{470}–1.8Chl_a – 85. 02 Chl_b) /198,
(x = xanthophylls and carotenes) (Lichtenthaler, 1987).

Accumulation of extra proline was found by following the process of Bates (Bates *et al.*, 1973). Soluble protein content in fresh leaves was quantified by the process described by Bradford (1976). Soluble sugar content was measured by using phenol-sulphuric acid method of Dubois *et al*., (1956). All the data recorded for all parameters were analyzed by using MSTAT-C software and the means were compared by using Duncan’s Multiple Range Test (Steel *et al.,* 1997).

Results and Discussion

Heavy metal pollution is a global environmental issue due to its irreversible and long term toxic effects (Sharma *et al*., 2020). Salicylic acid is one of the most important groups of the plant phenolics; distributed in vast range of plant kingdom (Hayat *et al.,* 2007). It is directly involved in plant physiobiochemical processes (Yusuf *et al.*, 2013). Protective role of SA against heavy metals has been reported in various plants (Drazic & Mihailovic, 2005). In present study, all parameters were reduced with increasing Pb concentrations except proline that showed maximum accumulation at high lead concentrations. SA significantly affected biochemical parameters and showed maximum performance at 0.5 mM concentration followed by 0.1 and 0 mM SA concentrations. Proline was reduced at high SA concentrations which indicated release of lead stress severity in wheat seedlings due to SA applications. Wheat variety Aas-2011 withstand excess Pb and showed best up regulation of protective mechanism followed by FSD-2008 and Millat-2011.

Impaired development of chlorophyll has been reported under heavy metal stress which may be the result of interference of heavy metals with protein synthesis; the integral structural parts of chloroplast. In recent study, highest chlorophyll content was found in Aas-2011 followed by FSD-2008 and Millat-2011. Pb showed inhibitory effects on photosynthetic pigment i.e., chlorophyll and carotenoid content. Significant reduction in chlorophyll content was resulted at 1.5 mM Pb concentration in case of Millat-2011. However, chlorophyll content remained highest at 0 mM Pb concentration in Aas-2011 (Table 1). Reduction in chlorophyll content is due Pb which avoids incorporation of Fe ion in chlorophyll molecule as integral part of phytoporphyrin ring of chlorophyll (Jaleel *et al.*, 2009)

SA have beneficial role in maintenance of physiological mechanisms of plants (Sihag *et al.,* 2019). During this study, SA significantly increased chlorophyll content with and without Pb interactions. SA was more effective at 0.5 mM concentration than 0 and 0.1 mM SA concentrations. It enhanced chlorophyll content in interaction with 0, 0.1 and 0. 5 mM lead concentrations but effect of 0.5 mM SA under these Pb stress levels was more pronounced for Aas-2011 than other SA concentrations. Lowest chlorophyll content was observed at 0 mM SA x 1.5 mM lead concentrations in case of Millat-2011. Role of SA in alleviating chlorophyll content under Pb stress has been reported in *T. aestivum* L. (Song *et al.*, 2012). It enhanced photosynthetic contents of *T. aestivum* L. under stress condition (Kaydan *et al.*, 2007). Many heavy metals including Pb may inhibit biosynthesis of carotenoid content and caused retardation of pigment incorporation into photosystem (Shu *et al.,* 2012). In recent research, carotenoid content was found to be highest in FSD-2008 and Aas-2011 at 0 and 0.5 mM lead concentrations respectively. In contrast, it was found to be lowest at 1.5 mM lead concentrations in case of Millat-2011.

Reduction in photosynthetic pigments under heavy metal stress such as Pb may result of regulation of any of two pathways: either enhanced biodegradation of photosynthetic pigments or reduction in their biosynthesis. These findings were similar to another study which showed reduction in carotenoid content under Pb stress in urd (*Vigna mungo* L.) seedlings (Singh *et al.,* 2012). During this study, SA showed lowest carotenoid content at its 0 mM concentration but highest carotenoid content was observed at 0.5 mM SA concentration. Carotenoid content was reduced at 0 mM SA x 1.5 mM Pb interactions in case of Millat-2011 but it was enhanced at 0.5 mM SA x 0.5 mM lead interactions in Aas-2011 (Table 2). SA alleviated carotenoid contents in wheat under abiotic stress (Turkyilmaz, 2012). It enhanced carotenoid content in maize under abiotic stress (Fahad & Bano, 2012).

Table 1. Effect of SA concentrations on chlorophyll content (mg g^{-1} fw) of wheat varieties under lead stress.

Varieties	Lead concentrations (mM)				Means
	0	0.5	1	1.5	
Millat-2011	0.769 c*	0.771 c	0.709 d	0.674 e	0.731 C*
Aas-2011	0.862 a	0.844 ab	0.817 b	0.691 de	0.803 A
FSD-2008	0.824 b	0.783 c	0.82 b	0.698 de	0.781 B
SA (mM)					
0	0.780c*	0.728 de	0.698 e	0.612 f	0.705 C*
0.1	0.817 b	0.792 bc	0.781 c	0.703 e	0.773 B
0.5	0.858 a	0.878 a	0.863 a	0.748 d	0.837 A
Interactions					
Millat-2011 x 0 SA	0.737 j..n*	0.683 no	0.643 op	0.583 q	0.662^{NS}
Millat-2011 x 0.1 SA	0.763 h..m	0.790 e..j	0.677 no	0.713 lmn	0.736
Millat-2011 x 0.5 SA	0.807 d..i	0.840 b..e	0.807 d..i	0.727 k..n	0.795
Aas-2011 x 0 SA	0.833 b..f	0.774 f..l	0.730 j..n	0.620 pq	0.739
Aas-2011 x 0.1 SA	0.865 bcd	0.803 e..i	0.827 c..g	0.690 no	0.796
Aas-2011 x 0.5 SA	0.887 b	0.953 a	0.893 b	0.763 h..m	0.874
FSD-2008 x 0 SA	0.770 g..l	0.727 k..n	0.720 lmn	0.633 opq	0.713
FSD-2008 x 0.1 SA	0.823 c..h	0.783 e..k	0.840 b..e	0.707 mn	0.788
FSD-2008 x 0.5 SA	0.880 bc	0.840 b..e	0.890 b	0.753 i..m	0.841
Means	**0.818 A***	**0.799 B**	**0.781 C**	**0.688 D**	

Key: NS= Non-significant

*= The means in a row or column carry same letter (s) are non-significant at *P*=0.05 by Duncan's multiple range test

Table 2. Effect of SA concentrations on carotenoid content (mg g^{-1} fw) of wheat varieties under lead stress.

Varieties	Lead concentrations (mM)				
	0	0.5	1	1.5	Means
Millat-2011	0.168 abc*	0.153 bc	0.117 de	0.100 e	0.135 B*
Aas-2011	0.186 ab	0.194 a	0.167 abc	0.138 cd	0.171 A
FSD-2008	0.196 a	0.189 ab	0.172 ab	0.163 abc	0.180 A
SA (mM)					
0	0.168 b..e*	0.149 d..g	0.140 efg	0.122 g	0.145 C*
0.1	0.184 abc	0.180 a..d	0.154 c..g	0.133 fg	0.163 B
0.5	0.197 ab	0. 207 a	0.161 c..f	0.146 efg	0.188 A
Interactions					
Millat-2011 x 0 SA	0.151 c..j*	0.130 e..j	0.113 hij	0.097 j	0.123 E*
Millat-2011 x 0.1 SA	0.173 b..h	0.160 b..i	0.120 g..j	0.107 ij	0.137 DE
Millat-2011 x 0.5 SA	0.180 b..g	0.170 b..i	0.117 g..j	0.107 ij	0.143 CDE
Aas-2011 x 0 SA	0.180 b..g	0.163 b..i	0.160 b..i	0.127 f..j	0.158 CD
Aas-2011 x 0.1 SA	0.187 a..f	0.177 b..g	0.163 b..i	0.137 e..j	0.166 BC
Aas-2011 x 0.5 SA	0.190 a..f	0.241 a	0.177 b..g	0.150 c..j	0.190 AB
FSD-2008 x 0 SA	0.173 b..h	0.153 c..j	0.147 c..j	0.143 d..j	0.154 CD
FSD-2008 x 0.1 SA	0.193 a..e	0.203 a..d	0.180 b..g	0.167 b..i	0.186 AB
FSD-2008 x 0.5 SA	0.220 ab	0.210 abc	0.190 a..f	0.180 b..j	0.200 A
Means	**0.183 A***	**0.179 A**	**0.152 B**	**0.134 C**	

Key: NS= Non-significant

*= The means in a row or column carry same letter (s) are non-significant at *P*=0.05 by Duncan's multiple range test

Proline, an amino acid is reported as most frequently accumulating amino acid among all amino acids in plant tissues in response to various abiotic stress conditions. Accumulation of proline in plants is indication of plant's tolerance or resistance to unfavorable growth conditions and high proline content in plants is sign of weak tolerance or resistance to adverse conditions (Cao *et al.,* 2011). In these findings, proline content in wheat varieties was significant at all tested concentrations of Pb. In Aas-2011, proline concentration was highest at 1.5 mM Pb concentration and lowest at 0 mM Pb concentration (Table 3). Environmental stress causes accumulation of proline (Oncel *et al.,* 2000). The higher concentration of proline accumulated during stress condition is due to reciprocal regulation of the pathways which either enhance expression of various synthetic enzymes of proline or repressed proline degradation activity (Peng *et al.,* 1996). Maximum enzyme activity was observed in wheat seeds treated with 0.1 mM SA along with foliar spray (Murtaza & Asghar, 2013). In present study, SA concentrations reduced the amount of proline content at 0.1 and 0.5 mM concentrations. SA proved to be most effective at 0.5 mM concentration in this regard but showed minimum value of proline at 0 mM concentration. In FSD-2008, lowest proline content accumulated at 0.5 mM SA x 0 mM Pb and highest proline content was observed for Aas-2011 at 0 mM SA x 1.5 mM lead. Reduction of leaf proline content in wheat is due to role of SA as a stimulator of stress response of plants (Shakirova *et al.,* 2003).

Table 3. Effect of SA concentrations on proline content (µmol/g fw) of wheat varieties under lead stress.

Varieties	Lead concentrations (mM)				
	0	**0.5**	**1**	**1.5**	**Means**
Millat-2011	22.0 ef*	23.1 ef	38.1 c	49.3 b	33.1 B*
Aas-2011	10.8 g	26.5 de	45.0 b	76.2 a	39.6 A
FSD-2008	5.8 h	20.5 f	29.8 d	37.8 c	23.5 C
SA (mM)					
0	19.6 e*	33.9 c	49.6 b	72.8 a	44.0 A*
0.1	12.4 f	23.6 de	36.0 c	52.2 b	31.0 B
0.5	6.7 g	12.6 f	27.3 d	38.4 c	21.2 C
Interactions					
Millat-2011 x 0 SA	28.7 i..l*	38.0 e..h	50.7 d	86.6 a	51.0 A*
Millat-2011 x 0.1 SA	21.3 lm	22.3 lm	36.7 f..j	44.0 def	31.1 C
Millat-2011 x 0.5 SA	16.0 mn	8.9 nop	27.0 kl	17.3 mn	17.3 DE
Aas-2011 x 0 SA	20.3 lm	36 f..k	59.6 c	85 a	50.2 A
Aas-2011 x 0.1 SA	9.8 nop	28 jkl	42.3 def	75 b	38.8 B
Aas-2011 x 0.5 SA	2.4 p	15 mn	33 g..k	68.7 b	29.9 C
FSD-2008 x 0 SA	9.8 nop	27.6 jkl	38.7 efg	46.7 de	30.7 C
FSD-2008 x 0.1 SA	6.2 op	20.6 lm	29.0 h..l	37.7 e..i	23.4 D
FSD-2008 x 0.5 SA	1.5 pq	13.3 mno	22.0 lm	29.3 h..l	16.5 E
Means	**12.9 D***	**23.4 C**	**37.7 B**	**54.5A**	

Key: NS= Non-significant

*= The means in a row or column carry same letter (s) are non-significant at *P*=0.05 by Duncan's multiple range test

Table 4. Effect of SA concentrations on protein content (mg g^{-1} fw) of wheat varieties under lead stress.

Varieties	Lead concentrations (mM)				
	0	**0.5**	**1**	**1.5**	**Means**
Millat-2011	5.57 f*	3.82 h	2.12 j	1.51 kl	3.26 C*
Aas-2011	9.83 a	9.21 b	7.71 c	2.73 i	7.37 A
FSD-2008	7.04 d	6.11 e	5.10 g	1.15 k	4.85 B
SA (mM)					
0	6.77 b*	5.87 c	4.74 e	1.93 f	4.83 B*
0.1	7.20 b	6.27 c	4.78 e	1.75 f	5.00 B
0.5	8.49 a	7.01 b	5.41 d	1.71 f	5.65 A
Interactions					
Millat-2011 x 0 SA	4.60 lm*	2.73 op	2.86 o	1.33 rs	2.88 F*
Millat-2011 x 0.1 SA	5.40 jkl	3.76 n	1.70 qrs	1.50 rs	3.09 F
Millat-2011 x 0.5 SA	6.73 ghi	4.96 klm	1.80 qrs	1.70 qrs	3.80 E
Aas-2011 x 0 SA	9.10 bc	9.10 bc	7.16 efg	2.50 opq	6.97 B
Aas-2011 x 0.1 SA	9.40 b	9.10 bc	7.56 ef	2.80 o	7.21 B
Aas-2011 x 0.5 SA	11.0 a	9.43 b	8.40 cd	2.90 o	7.93 A
FSD-2008 x 0 SA	6.60 ghi	5.77 jk	4.20 mn	1.97 pqr	4.63 D
FSD-2008 x 0.1 SA	6.80 fgh	5.93 ij	5.06 kl	0.97 st	4.69 D
FSD-2008 x 0.5 SA	7.73 de	6.63 ghi	6.03 hij	0.53 t	5.23 C
Means	**7.48 A***	**6.38 B**	**4.97 C**	**1.80 D**	

Key: NS= Non-significant

*= The means in a row or column carry same letter (s) are non-significant at *P*=0.05 by Duncan's multiple range test

The accumulation of protein in plants is their response to both biotic and abiotic stress conditions. Phytohormone such as SA is an agent to induce many of these proteins which support plant defense mechanism against stress circumstances (Hyos & Zhang, 2000). In this experiment, highest protein content was observed in Aas-2011 followed by FSD-2008 and Millat-2011. Accumulation of protein was lowest in Millat-2011 at 1.5 mM Pb concentration than Aas-2011 which showed lowest protein content 0 mM Pb concentration (Table 4). Negative correlation was observed between increase in heavy metal concentration and decrease in soluble protein content in *Hydrilla* plants and *Lemna minor* L. (Das *et al.*, 2013). Reduction in protein content under Pb stress may be caused by either enhanced protein degradation process due to increased activity of protease (Palma *et al.*, 2002) or catalytic activity of Pb (Bhattacharyya & Choudhuri, 1997). During this study, SA was found to be significant at all tested concentrations and showed maximum protein content at 0.5 mM concentration and lowest protein content was resulted at 0 mM concentration. Interactions between varieties, SA and Pb were also found to be significant in case of protein content. FSD-2008 showed lowest protein content at 0.5 mM SA x 1.5 mM Pb concentrations as compared to Aas-2011 which showed highest protein content at 0.5 mM SA x 0 mM lead interaction. SA improved soluble protein content in spring wheat under abiotic stress (Aldesuquy *et al.,* 2012).

Table 5. Effect of SA concentrations on soluble sugar content (mg g^{-1} fw) of wheat varieties under lead stress.

Varieties	Lead concentrations (mM)				
	0	0.5	1	1.5	Means
Millat-2011	1.31 c*	1.27 c	0.80 f	0.46 g	0.96 C*
Aas-2011	1.71 ab	1.66 b	1.35 c	0.86 f	1.40 A
FSD-2008	1.76 a	1.16 d	1.16 d	1.07 e	1.29 B
SA (mM)					
0	1.45 bc*	1.17 e	0.85 g	0.57 h	1.01 C*
0.1	1.52 b	1.42 c	1.17 e	0.78 g	1.22 B
0.5	1.81 a	1.51 b	1.28 d	1.04 f	1.41 A
Interactions					
Millat-2011 x 0 SA	1.23 l..0*	1.10 op	0.60 uv	0.20 w	0.78 F*
Millat-2011 x 0.1 SA	1.30 j..m	1.33 i..m	0.90 qr	0.46 v	1.0 E
Millat-2011 x 0.5 SA	1.40 h..k	1.40 h..k	0.90 qr	0.73 stu	1.10 D
Aas-2011 x 0 SA	1.56 efg	1.40 h..k	1.13 nop	0.70 tu	1.20 C
Aas-2011 x 0.1 SA	1.66 de	1.73 cd	1.43 g..j	0.86 rs	1.42 B
Aas-2011 x 0.5 SA	1.90 b	1.86 bc	1.50 fgh	1.03 pq	1.57 A
FSD-2008 x 0 SA	1.56 efg	1.03 pq	0.83 rst	0.83 rst	1.06 DE
FSD-2008 x 0.1 SA	1.60 def	1.20 mno	1.20 mno	1.03 pq	1.25 C
FSD-2008 x 0.5 SA	2.13 a	1.26 k..n	1.46 f..i	1.36 h..l	1.55 A
Means	1.59 A*	1.37 B	1.10 C	0.80 D	

Key: NS= Non-significant

*= The means in a row or column carry same letter (s) are non-significant at *P*=0.05 by Duncan's multiple range test

In present study, soluble sugar content was significantly affected by lead in Millat-2011 at 1.5 mM Pb concentration and it remained highest in FSD-2008 at 0 mM Pb concentration. Thus, soluble sugar content reduced with increasing lead concentrations from 0 to 1.5 mM (Table 5). These results coincided with findings of many researchers. Heavy metal stressed *Hydrilla* plant was reported to contain low sugar content (Das *et al.*, 2013). The toxic effects of heavy metals on metabolic process of carbon are due to possible interaction of heavy metals with reaction center of ribulose bisphosphate carboxylase. Decrease in soluble sugar content in recent research may be due to low photosynthetic activity or high respiration rate in wheat seedlings. Soluble sugar content was lowest 0 mM SA in Millat-2011 and it was highest in FSD-2008 at 0.5 mM SA concentration. Interactions between wheat varieties, SA and Pb were also found to be significant. Sugar content was lowest in Millat-2011 at 0 mM SA x 1.5 mM lead and highest in FSD-2008 at 0.5 mM SA x 0 mM Pb interactions. SA decreased toxic effects of Pb on soluble sugar content in *T. aestivum* L. varieties (Song *et al.*, 2012).

Conclusion

Heavy metals, mainly Pb, are a lethal factors for restrictive crop production. As such, reform of heavy metal stresses is vital. In this research, the role of SA was examined to delimit the effect of Pb stress in wheat varieties and it was found that it could inhibit the damaging effects of Pb.

References

Ahmad, M.S.A., M. Hussain, R. Saddiq and A.K. Alvi. 2007. Mungbean: A nickel indicator, accumulator or excluder. *Bull. Environ. Contam. Toxicol*., 78: 319-24.

Aldesuquy, H.S., S.A. Abo-Hamed, M.A. Abbas and A.H. El-Hakem. 2012. Role of glycine betaine and salicylic acid in improving growth vigor and physiological aspects of drought wheat cultivars. *J. Stress Physiol. Biochem*., 8(1): 149-71.

Alvarez, M.E. 2000. Salicylic acid in the machinery of hypersensitive cell death and disease resistance. *Plant Mol. Biol*., 44(3): 429-42.

Anonymous. 2012. *Statistical database from food and agriculture division of the United Nations*.

Baath, E. 1989. Effects of heavy metals in soil on microbial processes and populations (a review). *Water Air Soil Poll*., 47: 335-79.

Bates, L.S., R.P. Waldren and I.D. Teare. 1973. Rapid determination of the free proline for water stress studies. *Plant Soil*, 39: 205-07.

Bhattacharyya, M. and M.A. Chouduri. 1999. Effect of Pb and Cd on the biochemical changes in the leaves of terrestrial (*Vigna*) and aquatic (*Hydrilla*) plants under solution culture. *Ind. J. Plant Physiol*., 32: 99-103.

Bostan, N. and M. Naeem. 2002. Evaluation of resistance in some wheat cultivars to *Tribolium castaneum* L. under laboratory conditions. *Asian J. Plant Sci*., 1: 95-98.

Bradford, M.M. 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. *Anal Biochem*., 72: 248-54.

Briggle, L.W. and L.P. Reitz. 1963. *Classification of Triticum species and of wheat varieties grown in the United States. Technical bulletin 1278*. United States Department of Agriculture.

Cao, H.X., C.X. Sun, H.B. Shao and X.T. Lei. 2011. Effects of low temperature and drought on the physiological and growth changes in oil palm seedlings. *Afr. J. Biotechnol*., 10: 2630-37.

Das, G.C., K.B. Kumar and B.K. Mohantay. 2013. Effect of mercury and cadmium on the biochemical parameters of *Hydrilla* plant. *Environ. Biol*., 3(2): 58-67.

Dat, J.F., D.H. Lopez C.H., Foyer and I.M. Scott. 1998. Parallel changes in H_2O_2 and catalase during thermotolerance induced by salicylic acid or heat acclimation in mustard seedlings. *Plant Physiol*., 116: 1351-57.

Drazic, G. and N. Mihailovic. 2005. Modification of cadmium toxicity in soybean seedlings by salicylic acid. *Plant Sci*., 168: 511-517.

Dubois, M., K.A. Gilles, J.K. Hamilton, P.A. Rebers and F. Smith. 1956. Colorimetric method for determination of sugars and related substances. *Anal. Chem*., 38: 350-56.

Ensink, J.H.J, R.W. Simmons and W.V. Hoek. 2004. Wastewater use in Pakistan: The cases of Haroonabad and Faisalabad. In: "*Wastewater use in irrigated agriculture*", (Ed.): Scott, C.A., N.I. Faruqui and L.R. Sally. CAB International, Wallingford, UK, p. 91-99.

Fahad, S. and A. Bano. 2012. Effect of salicylic acid on physiological and biochemical characterization of maize grown in saline area. *Pak. J. Bot*., 44(4): 1433-38.

Hayat, S., B. Ali and A. Ahmad. 2007. Salicylic acid: Biosynthesis, metabolism and physiological role in plants. In: "*salicylic acid: a plant hormone*". Springer, Dordrecht, pp. 1-14.

Hyos, M.E. and S.Q. Zhang. 2000. Calcium-independent activation of salicylic acid induced protein kinase and a 40 kilodalton protein kinase by hyperosmotic stress. *Plant Physiol*., 122: 1355-63.

Jaleel, C.A., K. Jayakumar, Z. Chang-Xing and M. Iqbal. 2009. Low concentration of cobalt increases growth, biochemical constituents, mineral status and yield in *Zea mays*. *J. Sci. Res*., 1: 128-137.

Jamal, A., N. Ayub, M. Usman and A.G. Khan. 2002. *Arbuscular mycorrhizal* fungi enhance Zn and Ni uptake from contaminated soil by soybean and lentil. *Int. J. Phytoremed*., 4: 205-21.

Kaydan, D., M. Yagmur and N. Okut. 2007. Effects of salicylic acid on the growth and some physiological characters in salt stressed wheat (*Triticum aestivum* L.). *Terim. Biliml. Derg*., 13(2): 114-19.

Kronstad, W.E. 1998. Agricultural development and wheat breeding in the 20th century. Wheat: Prospects for global improvement. Proc. of the 5th Int. Wheat Conf., Ankara, Turkey. Developments in Plant Breeding, Kluwer Academic Publishers. Dordrecht. 6: 1-10.

Lichtenthaler, H.K. 1987. Chlorophylls and carotenoids: Pigments of photosynthetic biomembranes. *Methods Enzymol*., 148: 350-82.

Majer, B.J., D. Tscherko and A. Paschke. 2002. Effects of heavy metal contamination of soils micronucleus induction in *Tradescantia* and on microbial enzyme activities: a comparative investigation. *Mutation Res*., 515: 111-24.

Metwally, A., I. Finkermeier, M. Georgi and K.J. Dietz. 2003. Salicylic acid alleviates the cadmium toxicity in barley seedlings. *Plant Physiol*., 132: 272- 81.

Murtaza, G. and R. Asghar. 2013. Effect of salicylic acid on acid phosphatase activity during seed development and germination in pea (*Pisum sativum* L.). *Int. J. Agri. Biol*., 15: 493-98.

Oncel, I., Y. Keles and A.S. Ustun. 2000. Interactive effects of temperature and heavy metal stress on the growth and some biochemical compounds in wheat seedlings. *Environ. Poll*., 107: 315-20.

Palma, J.M., L.M. Sandalio, F.J. Corpas, M.C. Romero-Puertas, I. Mccarthy and L.A.D. Rio. 2002. Plant proteases, protein degradation, and oxidative stress: role of peroxisomes. *Plant Physiol. Biochem*., 40: 521-30.

Patra, M., N. Bhowmik, B. Bandopadhyay and A. Sharma. 2004. Comparison of mercury, lead and arsenic with respect to genotoxic effects on plant systems and the development of genetic tolerance. *Environ. Exp. Bot*., 52(3): 199-223.

Peng, Z., Q. Lu and D.P.S. Verma. 1996. Reciprocal regulation of 1- pyrroline-5-carboxylate synthetase and proline dehydrogenase genes controls proline levels during and after osmotic stress in plants. *Mol. Genet. Genom*., 253: 334-41.

Poehlman, J.M. and D.A. Sleper. 1995. Breeding Field Crops. 4 ed. Iowa State University Press 259-62, 274 -77.

Senaratna, T., D. Touchell, T. Bunn and K. Dixon. 2000. Acetyl salicylic acid (Aspirin) and salicylic acid induce multiple stress tolerance in bean and tomato plants. *Plant Growth Reg*., 30: 157-61.

Shah, J. 2003. The salicylic acid loop in plant defense. *Curr. Opinion Plant Biol*., 6: 365-71.

Shakirova, F.M., A.R. Sakhabutdinova, M.V. Bezrukova, R.A. Fatkhutdinova and D.R. Fatkhutdinova. 2003. Changes in the hormonal status of wheat seedlings induced by salicylic acid and salinity. *Plant Sci*., 164: 317-22.

Sharma, A., G.P.S. Sidhu, F. Araniti, A.S. Bali, B. Shahzad, D.K. Tripathi, M. Brestic, M. Skalicky and M. Landi. 2020. The role of salicylic acid in plants exposed to heavy metals. *Molecules*, 25(3): 540.

Shu, X., L. Yin, Q. Zhang and W. Wang. 2012. Effect of Pb toxicity on leaf growth, antioxidant enzyme activities, and photosynthesis in cuttings and seedlings of *Jatropha curcas* L. *Environ. Sci. Poll. Res*., 19(3): 893-902.

Sihag, S., B. Brar, U. Joshi. 2019. Salicylic acid induces amelioration of chromium toxicity and affects antioxidant enzyme activity in *Sorghum bicolor* L. *Int. J. Phytorem*., 21: 293-304.

Singh, G., R.K. Agnihotri, R.S. Reshma and M. Ahmad. 2012. Effect of lead and nickel toxicity on chlorophyll and proline content of Urd (*Vigna mungo* L.) seedlings. *Int. J. Plant Physiol. Biochem*., 4(6): 136-41.

Singh, H. and A.K. Singh. 2007. Energy consumption pattern of wheat production in India. *Energy*, 32: 1848-54.

Song, W., A. Zheng, H. Shao, L. Chu, M. Brestic and Z. Zhang. 2012. The alleviative effect of salicylic acid on the physiological indices of the seedling leaves in six different wheat genotypes under lead stress. *Plants Omi. J*., 5(5): 486-93.

Steel, R.G.D., J.H. Torrie and D.A. Deekey. 1997. *Principles and procedures of statistics: A Biometrical Approach*. 3rd ed. McGraw Hill Book Co. Inc. New York, 428 p.

Turkyilmaz, B. 2012. Effects of salicylic and gibberellic acids on wheat (*Triticum aestivum* L.) under salinity stress. *Bang. J. Bot*., 41(1): 29-34.

Verma, A.D. and R.S. Dubey. 2003. Lead toxicity induces lipid peroxidation and alters the activities of antioxidant enzymes in growing rice plants. *Plant Sci*., 164: 447-53.

Younas, M. and F. Shahzad. 1998. Assessment of Cd, Ni, Cu, and Pb pollution in Lahore, Pakistan. *Environ. Int*., 24: 761-66.

Yusuf, M., S. Hayat, M.N. Alyemeni, Q. Fariduddin and A. Ahmad. 2013. Salicylic Acid: Physiological Roles in Plants. In: *Salicylic acid plant growth and development*. Springer, Dordrecht, pp. 15-30.

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