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DETERMINATION OF STRESS RESPONSE INDEX & RECOVERY INDEX OF WHEAT CULTIVARS AGAINST SO_2 EXPOSURE

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Air pollutants including the gaseous and particulate matters are accountable for poor consequences on health of living beings at local, regional and global level. Sulfur dioxide (SO_2) is one of the most common harmful air pollutants in relation to its negative effect on the variety of living beings including plant growth and productivity.Leaves of the plants are the primary receptors of air pollutant gases viz. SO_2, NO_X, CO_2, O_3 etc. As soon as pollutant gases enters through stomata, plants have the ability to absorb and assimilate these gases in its natural metabolic pathway. Generally, the assimilatory pathways are common in almost all higher plant life forms. However, the rate of response to variety of air pollutant gases may differ and governed by certain external and internal factors. The phytotoxicity of SO_2 depends on multiple factors including genetic factors, environmental factors, age of plants, growth factors, concentration of pollutants, and exposure time**.** Based on the response towards exposure, the plants can be categorized as "sensitive" and "tolerant" species. Sensitive species are early indicators of pollution, and the tolerant species help in reducing the overall pollution load. The study reports the effect of exposure of SO_2 gas on a range of physiological parameters of the selected wheat cultivars exposed to SO_2. Stress Response Index (SRI) and Recovery Index (RI) of wheat cultivars were calculated in order to judge the tolerance and resilience nature of different cultivars.

Key words: Gaseous Pollutants, OTC, Sulphur dioxide, Sensitive and tolerant species

Atmospheric pollutants have a negative effect on the plants; directly by entry through leaf surface and produce noxious effects, or indirectly by changing soil pH followed by solubilization of toxic salts, heavy metals etc. Air pollution receives one of the prime concerns in India, primarily due to rapid economic growth, industrialization and urbanization with associated increase in energy demands (Gupta 2016).

Unrestrained use of fossil fuels in industries and transport sectors has led to the increase in concentrations of gaseous pollutants such as SO_2 and NO_x etc. (Frederica 2018, Polavarapu *et al.* 2013). Sulfur oxides arise during combustion from oxidation of sulfur in sulfur containing fuels (some coals and some petroleum-based products). SO_2 emissions from India's thermal power plants have gone up by a whopping 71% from what it was in 2005 (Pallavi, 2015). The rapid rise in demand of power and the absence of regulations are seen as the reasons behind the drastic rise in SO_2 emission.

Different plant species, varieties and even individuals of the same species are varying considerably in their sensitivity to sulfur dioxide. These variations occur because of the differences in metabolic pathway, geographical location, and climatic condition, stages of growth and maturation of the plant species (Brahmachari and Kundu 2017, Long and Huilan 2012).

Screening of crop species and cultivars are always useful in order to prepare inventory of indicators of air pollutants. There are varieties of crops plants, which are generally considered susceptible to sulfur dioxide: alfalfa, barley, buckwheat, clover, oats, pumpkin, radish, rhubarb, spinach, squash, Swiss chard and tobacco. Resistant crop plants include asparagus, cabbage, celery, corn, onion and potato (Griffiths 2003).

In present paper, the effect of exposure of SO_2 was analyzed on different cultivars of wheat by assessing the various physiological parameters. Stress Response Index (SRI) and Recovery Index (RI) of wheat cultivars have

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also been calculated so as to evaluate the tolerance and resilience of different cultivars.

MATERIALS AND METHODS

Seeds of three cultivars of wheat *viz.* Sujata, Lok-1 and WH 147 were obtained from IARI Regional Station Indore (MP). One-month old plants of three cultivars of wheat were subjected to 300 μgm^{-3} SO_2 exposure in $1*1*1m^3$ open-top chamber at the rate 3hrs/day for 7 days. The chamber was fitted with perforated Teflon tubing and small fan from inside in order to ensure the uniform distribution of gas. The concentration of SO_2 inside the chamber was measured with Toxic Gas Monitor 555 (TGM 555 CEA Instruments).

Plant samples were assessed for following physiological parameters such as (a) Total chlorophyll content by Bates (1949), Nitrate Reductase (NR) activity by Shrivastava and Mathur (1980), Free proline content by Bates *et al.*, (1973) and Foliar Protein Content by Lowry *et al*., (1951). The analysis of samples were carried out at the Laboratory of IEMPS Ujjain India.

Plant samples were analyzed for total Chlorophyll Content, Free Proline Content, Total Protein Content and Nitrate Reductase Activity at 38 and 48 days of plant age, in order to assess the effect of SO_2 on crops and further potential of crop to mitigate SO_2 induced effects. Quantify values further used for calculating Stress response index (SRI) and Recover index (RI) respectively using following formula -

$$\text{Stress response index (SRI)} = \frac{\text{\% Changes over their controls (A)}}{\text{SO2 concentration (B)}}$$

A -The percentage change in parameters over its value in control plants

B -The SO_2 dose given to a plant was calculated by multiplying So_2 concentration with the exposure time in hours.

$$\text{Recovery index (RI)} = \frac{\text{\% change over SO2 stressed condition (C)}}{\text{Time taken in hrs. for the above (D)}}$$

C. The percentage of recovery in a given parameters from the time of termination of SO_2 stress

D. The time of recovery measurement

Statistical Analysis: In order to test the existing significance between the means of treated and their respective controls, the data were subjected to student t' test.

RESULT AND DISCUSSION

Table 1 reveals the changes in different parameters over their respective control due to the action of SO_2 fumigation. Magnitude of percentage induced in different physiological activities in cultivars of wheat has been given in parenthesis. Quantitative analysis reveals remarkable changes in comparison to their respective controls. Amount of photosynthetic pigment was dropped by 16 to 20% in all the three cultivars of wheat. Decrease in pigment concentration can be attributed to pigment destruction, denaturation or reduced biosynthesis process (Katiyar and Dubey 2005, Katiyar 2014).

Proline has been recognized as a multi-functional molecule, which accumulates in high concentrations in response to a variety of abiotic stresses (Polavarapu *et al.* 2013, Yasis, 2015). In this study, level of free proline content was increased in treated wheat cultivars from 12.55 to 15.8% over their respective controls. Proline is a catabolic amino acid, which accumulate due to the protein degradation in stressed leaves (Raggi, 1994). Protein synthesis is also an important biological process. Quantitative induced in contents of plant protein affect the productivity and yield of crops (Muneer *et al.* 2014; Brahmachari and Kundu 2017). In this study, a decline in total plant protein content was observed in same fashion as observed in case of pigment concentration. It declined by 6-8% in all cultivars after 7 day's exposure.

Nitrate reductase (NR) is one of the important enzymes in the assimilation of exogenous nitrate. It provides a good estimate of nitrogen status of the plant and could be correlated with the plant growth (Kumawat 1990, Katiyar, 2014). Reduction in NR activity was noticed in all three wheat cultivars in response to SO_2. Maximum decline in content of NR activity

Table 1: Effect of SO_2 Exposure on different parameters of Wheat Cultivars (38 days of plant age)

S. No.	Parameter	Cultivars	Control	Exposed Plants
1.	Total chlorophyll content (mg g^{-1}fr. wt.)	Sujata	2.42±0.14	1.92 ^{NS}±0.17 (20.61)
		Lok-1	2.27±0.10	1.85*±0.08 (18.78)
		WH147	1.50±0.06	1.25*±0.12 (16.46)
2.	Free proline content (µmol g^{-1} fr. wt)	Sujata	8.10±0.60	9.38 ^{NS}±1.18 (15.8)
		Lok-1	6.98±0.70	7.91 ^{NS}±0.79 (13.32)
		WH147	7.33±0.77	8.25 ^{NS}±0.79 (11.15)
3.	. Total plant protein (mg g^{-1} fr. wt.)	Sujata	146.13±5.27	138.33*±4.13 (8.75)
		Lok-1	135.86±4.69	125.6 ^{NS}±5.88 (7.55)
		WH147	90.93±6.66	84.8 ^{NS}±1.35 (6.55)
4.	Nitrate reductase activity (µmol g^{-1} h^{-1} fr. wt.)	Sujata	8.62±0.39	7.59*±0.29 (11.95)
		Lok-1	10.9±0.37	9.61*±0.35 (11.83)
		WH147	10.08±0.37	8.98*±0.36 (10.91)

± =Standard deviation, NS = Not significant, *='t' Score significant at 5% level, Values in parenthesis is % changes over controls

Table 2: Mitigation of SO_2 Stress in wheat cultivars (48 days of plant age).

S. No.	Parameter	Cultivars	Control	Exposed Plants
1.	Total chlorophyll content (mg g^{-1} fr.wt.)	Sujata	1.98±0.07	1.62 ^{NS}±0.17 (2.26)
		Lok-1	1.74±0.08	1.51*±0.14 (5.63)
		WH147	1.53±0.10	1.32*1±0.06 (3.16)
2.	Free proline content (µmol g^{-1} fr.wt)	Sujata	8.08±0.92	9.09 ^{NS} ±1.55 (4.30)
		Lok-1	6.73±0.76	8.28 ^{NS} ±0.84 (5.15)
		WH147	7.45±0.76	7.93 ^{NS} ±0.75 (4.67)
3.	. Total plant protein (mg g^{-1} fr. wt.)	Sujata	135.62±4.48	125.84 ^{NS} ±3.26 (1.54)
		Lok-1	140.88±4.09	133.14*±4.02 (2.06)
		WH147	83.38±4.99	79.19^{NS}±2.78 (1.72)
4.	Nitrate reductase activity (µmol g^{-1} h^{-1} fr. wt.)	Sujata	7.50±0.31	8.71 ^{NS} ±0.31 (3.64)
		Lok-1	10.5±0.30	9.75*±0.30 (4.69)
		WH147	10.71±0.42	9.88*±0.42 (3.17)

± =Standard deviation, NS = Not significant, *='t' Score significant at 5% level, Values in parenthesis is % changes over controls

Table 3: Indicator Parameters

In min (Fast)	In hrs. (Medium)	In days (Slow)S
1) Ru5PK	1) Ascorbic acid	1) Leaf pH
2) Fbpase	2) Ethane	2) Sulphur content
3) NADP-GAPD	3) Transpiration rate	3) Pigments
4) Photosynthesis	4) Ethylene	4) Ascorbic acid
5) Thylakoid		5) Carbohydrates
6) Electron Transport		6) Proteins
		7) Calorific value
		8) Net P.P.
		9) Phytomass

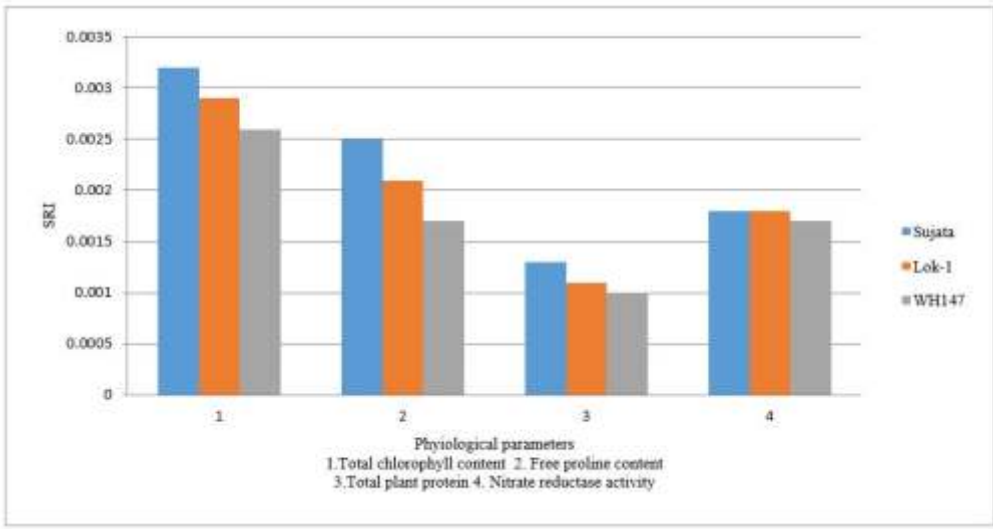

Figure 1: Stress Response Index (SRI) in different Wheat Cultivars

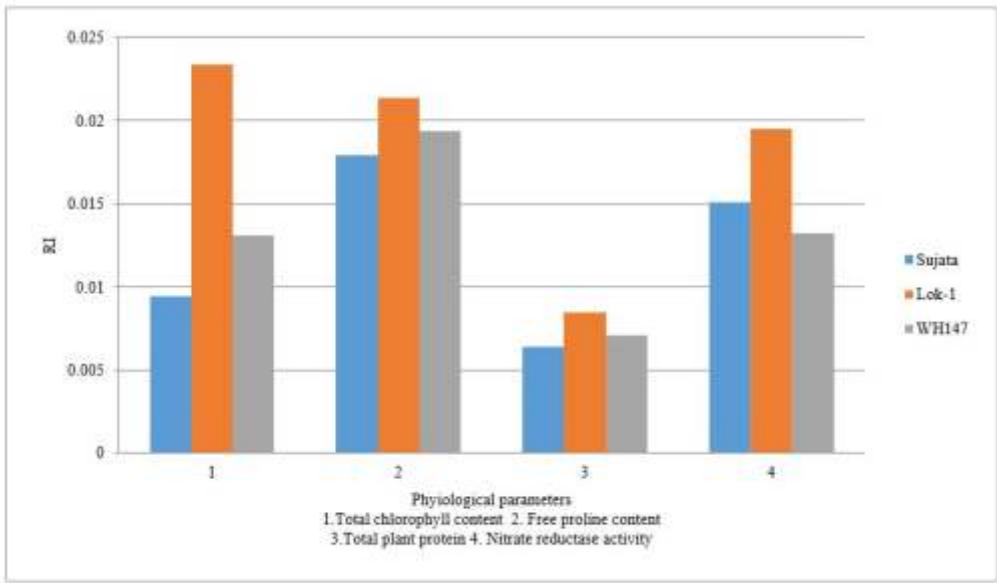

Figure 2: Recovery Index (RI) in different Wheat Cultivars

was observed in Sujata followed by Lok-1 and WH147. Similar results were reported by Katiyar and Dubey (2001), Katiyar (2014).

The cultivar Sujata was found to be more susceptible to SO_2 as compared to Lok-1 and WH147. An intermediary response was depicted by cultivar Lok-1, while WH147 expressed considerable tolerance to SO_2 exposure.

Table 2 illustrates the amelioration of SO_2 stress and magnitude of restoration of various physiological processes in cultivars of wheat. Percentage values revealed that cultivars Sujata has restore the contents of its various physiological processes (7.21 to 18.35%) followed by WH147 (4.83 to 13.30%) and Lok-1 (5.49 to 13.15%) respectively.

Stress Response Index (SRI) and Recovery Index (RI)

The response of different plant parameters to SO_2 stress depends considerably on the time taken by a particular parameter to respond the SO_2 exposure. The parameters studied for

evaluating SO_2 response can be grouped into three categories *viz*. slow, medium and fast responding. These parameters are used as indicator parameters for evaluating the extent of plant response to SO_2 exposure (Mitra, 1994).

SRI facilitates the comparison strength and weakness of various plant parameters in respect of SO_2 sensitivity; comparison of response of plant species to air pollution stresses and dose-response analysis in respect of different parameters (Mitra, 1994).

A wide range of time durations has been employed in different studies in order to study the recovery (Brahmachari and Kundu, 2017). Consequently, direct comparison of the results is difficult. To overcome the constraint and to get a meaningful result, calculation of SRI becomes important. Stress response index indicates that cultivars Sujata has responded to SO_2 at higher side followed by Lok 1 and WH147 (Fig. 1). However, the rate of response to various parameters have been varied.

RI may be one of the bases of comparing a wide range of different parameters, which are used in assessing the mitigation of SO_2 induced injuries in plants. The SRI and RI of plant may differ from each other. Low SRI value indicates tolerant species and low RI means that the quantum changes in content of a parameter during recovery regime is not large. In this study LOK-1 showed signs of high recovery followed by Wh147 and Sujata, respectively (Fig 2).

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