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Effect of varying levels of sulphur dioxide on growth parameters, chlorophyll and sulphur contents of mango (*Mangifera indica* L) and lime (*Citrus aurantifolia* Swingle)

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Abstract: Sulphur dioxide, emitting directly from the pollution source (mostly the industries), has been identified as one of the primary pollutants. This being potentially phytotoxic, adversely affects the plant health. Plant shoots form a sink for the atmospheric sulphur which can directly be absorbed by the foliage. However, plant species may differ to a great extent in respect of their sensitivity to sulphur dioxide. Under the circumstances, an experiment was carried out to study the impact of varying levels of sulphur dioxide (0.25, 0.5 and 1.0 ppm) fumigated for 1, 2 and 3 hours under simulated conditions on mango and lime. The results revealed that the important traits such as the leaf number, leaf area and chlorophyll content in leaves were adversely affected. However, sulphur dioxide at 1.0 ppm fumigated for 3 hours under simulated conditions was found to be more uninnocuous in this regards. No significant variation was observed amongst the treatments in respect of tissue dry weight when compared with that of control (ambient SO_2). On the other hand, sulphur content in tissues increase progressively with increasing levels of SO_2 and time of fumigation. Lime plants tolerated better than mango to sulphur dioxide exposure and hence, recommended for cultivation in the nearby areas of the captive plants, smelter and thermal power generating plants.

Keywords: SO_2 fumigation, mango and lime, growth, chlorophyll, sulphur content

INTRODUCTION

The continued expansion of industrial activity and urbanization worldwide are the main factor contributing to gaseous air pollution. Among the gaseous pollutant, SO_2 is the primary pollutant because it is directly emitted from the pollution source as a product of combustion or processing of raw material that contain sulphur. The principal sources of SO_2 are burning of coal and oil with high sulphur content and smelting of sulphide ores. The direct toxic effect of atmospheric pollutants, sulphur dioxide in particular, on plants has been well documented (Rajput *et al.*,1977, Winner *et al.*,1985 and Swain and Padhi, 2013) during the past two decades. It is essentially a potent phytotoxic gas and its toxicity to plant is manifested in typical chronic or acute foliar symptom injury. The relationship between foliar loss due to SO_2 exposure and yield reduction in various crops has also been studied by Barrett and Benedict (1970) and Irshad, *et al.* (2011). It has been known to cause injury in these crops by destroying chlorophyll, disrupting photosynthesis and reducing biomass production and productivity. Moreover, the extent of injury is species dependent and is likely to be influenced by the macro and micro-climate of that particular agro-ecosystem. The natural adaptability of a crop species to a particular ecosystem is determined taking into consideration the extent of injury and sustainability of that crop. The mode and extent of damage caused by this pollutant to the commercial fruit crops cultivated in Odisha state such as mango and lime has not been precisely and systematically studied. The

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present investigation is a modest attempt under simulating condition which aims at finding out the possible extent of adaptability of fruit species in SO_2 emission area of Odisha state.

MATERIALS AND METHODS

The investigation was carried out during 2016 and 2017 in the Horticulture Research Station, Orissa University of Agriculture and Technology, Bhubaneswar, Odisha, India. The plants were raised in 45 x 20 cm polythene bags filled with a mixture of soil (red lateritic having a pH 5.5), sand and manure(2:1:1). Sulphur dioxide for the study was prepared in the laboratory by heating copper turnings with conc. sulphuric acid. The gas is taken to the experimental plot where it is applied to the plants in the morning. The gas was brought in and applied to the chamber by keeping the volumetric flask upside down and opening the lid inside the chamber. Time to time stirring was done inside the chamber for uniform mixing of gas. The fumigation was given to the plants on the one and half year old seedlings. Sulphur dioxide gas was applied at three different concentrations i.e. at 0.25, 0.5 and 1.0 ppm for different duration i.e. for 1, 2 and 3 hours, by putting the plants in a specialized structure built in the dimension of 1x1x1m length, breadth and width covered with high density polythene strip. The treatments were replicated thrice and fitted into a factorial randomized block design. All the operations were performed on the same day. Observations on growth, flowering and fruiting were recorded seven days after the treatment. In general, SO_2 damage was assessed on the basis of its area affected. The damage exceeding more than 50 % of its total area was considered as completely affected and less than 50 % was considered as to be normal. The chlorophyll content was calculated by using the formula by Maclachlan and Zalik (1963) and the procedure for sulphur estimation was adopted from Patterson (1978).

RESULTS AND DISCUSSION

Number of leaf and leaf area

Data pertaining to various traits revealed that damage to leaf injury, which includes both leaf number and its area, increased progressively in both the fruit crops studied with increasing levels of SO_2 and time of fumigation (Table 1). However, the magnitude of damage was different in different crops. The percentage decrease in leaf number and leaf area in mango accounts for 73.6% and 30.0%, respectively, whereas in Lime it is only 8.0% and 12.0%. Moreover, the damage was highly significant at the highest level of SO_2 (1.0 ppm) when compared to that of control. The present study reveals that mango was more prone to SO_2 than the lime. Mango had the highest set back, while lime was the least affected. The injury manifested might be attributed to higher sulphur content in plant and as such the plant could not be capable of metabolizing and utilizing the SO_2 absorbed outwardly (Stratigakos and Ormorod, 1985 and Agrawal and Deepak, 2003). In contrast, lime, might be a sulphur loving plant, probably possess an efficient mechanism to metabolize the excess amount of sulphur resulting in minimum damage of leaf tissues as reported by Semeniuk and Heggested (1981) and Padhi *et al.* (1994). Such injury has been ascribed to the faster accumulation of SO_2 than its oxidation and assimilation in the plant tissues, exceeding threshold accumulation in the intercellular spaces of the leaf and causing cell injury (Thomas, 1961). Alternately, it has also been contemplated that SO_2 in combination with aldehydes and sugars forms secondary products which decompose slowly to release H_2SO_3 or H_2SO_4 into the plant cell, that becoming more uninnocuous to the system (Haselhoff and Lindau, 1903).

Table 1: Effect of varying level of So_2 simulation on leaf injury

SO_2 conc. with exposure time	*% leaf injury (No.)*		*% leaf area injury*	
	Mango	*Lime*	*Mango*	*Lime*
0.25 ppm				
1 hour	41.60	1.44	10.00	0
2 hour	42.80	1.63	15.00	0
3 hour	52.90	2.36	20.00	0
0.50 ppm				
1 hour	42.80	2.15	15.00	0
2 hour	46.60	2.34	20.00	0
3 hour	55.50	2.63	25.00	4.0
1.00 ppm				
1 hour	50.00	4.34	20.00	5.0
2 hour	66.60	6.95	25.00	9.0
3 hour	73.60	7.89	30.00	12.0
Control	0.00	0.00	0.00	0.00
LSD(0.05)	2.67	0.60	1.52	0.56

Dry matter content

The shoot, root dry matter and shoot to root ratio were more affected in mango where as lime is least affected (Table 2). The values obtained in respect of the above parameters seem to be inconsistent when compared with that of control. The treatment effect was not significant although there was a marked difference in the data pertaining to this parameter. Further, reduction in the dry matter was more manifested in shoot than in root of plants. The present findings are in agreement with the results of Mandal *et al.* (1980), Thompson *et al.* (1982) and Padhi *et al.* (2013).

Table 2: Effect of varying level of So_2 simulation on dry weight

SO_2 conc. with exposure time	*Dry weight(g)*					
	Mango			*Lime*		
	Shoot	*Root*	*Shoot: Root*	*Shoot*	*Root*	*Shoot: Root*
0.25 ppm						
1 hour	4.50	2.20	2.05	26.22	4.14	6.33
2 hour	4.80	2.00	2.40	23.18	3.66	6.33
3 hour	4.00	2.00	2.00	24.32	3.62	6.71
0.50 ppm						
1 hour	4.30	2.20	1.95	27.67	5.79	4.77
2 hour	4.50	2.50	1.80	24.32	4.70	5.17
3 hour	4.80	2.60	1.85	24.66	5.00	4.74
1.00 ppm						
1 hour	5.00	2.60	1.92	26.22	5.50	4.76
2 hour	4.90	2.80	1.75	28.88	6.20	4.65
3 hour	5.20	3.10	1.68	21.85	4.20	5.20
Control	4.30	2.00	2.15	32.00	5.50	5.81
LSD(0.05)	NS	NS	NS	NS	NS	NS

Chlorophyll content

Greater damage to the chloroplast machinery due to the SO_2 treatment is the main cause of decrease in chlorophyll content in the leaves. Among the fruit crops the chlorophyll content varied significantly, the most and least affected crops being mango and lime, respectively (Table 3). About 32% decrease in chlorophyll occurred in mango while in lime it is nearly 20.0%. In both the fruit crops chlorophyll content decreases with increase in SO_2 concentration and the effect is being more accentuated when the simulation period is increased. The decrease in chlorophyll content has been ascribed to the disruption of the chloroplast membrane due to phytotoxic nature of SO_2, (Winner *et al.* , 1985) resulting in leaching of pigments (Ray *et al.,* 1982; Olszyk *et al.,* 1990 and Rath *et al.,* 1996). Such interference of SO_2 is believed to promote secondary processes which breakdown chlorophyll and kills the cells. Increase in sulphur content of tissues with increasing levels of SO_2 is probably due to inability of plants to metabolize and assimilate the excess SO_2 at cellular level thus results in its accumulation to manifold. The basic cellular responses to SO_2 are the same for all species, but because of variations in their anatomy different species show variations in symptom.

Sulphur content

The results of the present study reveals that sulphur content in plant tissues of mango and lime increases with increasing SO_2 concentration. This is quite natural and is also evident from the earlier report of Mishra, 1980 and Rath *et al.* (1994). Amongst the crops, lime accumulated more sulphur in its tissues compared to mango (Table 3). The sulphur content lies in a sequence of 0.04 to 0.08 ppm in mango and in lime 0.06 to 0.11 ppm as the minimum and the maximum, respectively. The present finding suggests that despite higher accumulation of sulphur in lime, the adverse effect was not to that extent as it was thought to be observed in mango with low sulphur content (Karaca, 2012)). However, the tolerance of fruit crops under study to SO_2 exposure indicated that in an average there existed a sequence which is in the order of lime > mango. Apparently, SO_2 can cause some growth reduction in the absence of visible manifestation when a threshold concentration is exceeded. Under these conditions, it appears that H_2SO_3 or SO_4^{-2} can accumulate in the cells of the plants and inhibit photosynthesis without necessarily killing the cells. At sub-threshold concentrations, the sulphite is oxidized to the non-toxic sulphate as rapidly as it is absorbed, so that inhibition of photosynthesis does not occur. Similarly, at concentrations below those causing any visible symptoms, cause a reduction of photosynthesis, early senescence, an unthrifty appearance and reduction of growth.

Table 3. Effect of varying level of So_2 simulation on chlorophyll and sulphur contents in plant tissue

SO_2 conc. with exposure time	*Chlorophyll content(mg/g)*				*Sulphur content(ppm)*	
	Mango		*Lime*			
	Fresh leaf	*% of control*	*Fresh leaf*	*% of control*	*Mango*	*Lime*
0.25 ppm						
1 hour	8.88	96.0	8.73	97.0	0.04	0.06
2 hour	8.69	94.0	8.37	93.0	0.04	0.07
3 hour	8.66	93.0	8.19	91.0	0.04	0.07
0.50 ppm						
1 hour	8.41	91.0	8.28	92.0	0.04	0.07
2 hour	7.71	84.0	8.37	93.0	0.05	0.09
3 hour	7.95	86.0	8.28	92.0	0.06	0.10
1.00 ppm						
1 hour	7.58	82.0	7.92	88.0	0.06	0.10
2 hour	7.12	77.0	7.65	85.0	0.07	0.10
3 hour	6.29	68.0	7.20	80.0	0.08	0.11
Control	9.50	100.0	9.75	100.0	0.03	0.04
LSD(0.05)	0.71	---	0.28	---	0.03	0.03

CONCLUSION

Sulphur dioxide treatments irrespective of crop species were found to be uninnocuous even at lower dose and duration of exposure which increased gradually with increasing concentrations and durations. However, lower concentration i.e. at 0.25 ppm of SO_2, the injuries to various morpho-physiological parameters of mango and lime plant were subtle and insignificant. The different fruit plant species registered different levels of injury caused to different plant parts. The tolerance to SO_2 exposure in test fruit crops was in the order of lime > mango. It is suggested that the lowest concentration of SO_2 (0.25 ppm) used in this study is more than sufficient to bring about a significant changes in most of the parameters studied. The lime plant was found to be moderately tolerant which can be successfully grown in the nearby areas of the captive plants, smelter and thermal power generating plants. In the context of the present observations, it necessitates to go for further experimentation with varying levels of SO_2 simulation to ascertain its threshold value. However, basing on the present results it is hoped that this preliminary study would throw a light to the researchers and environmentalist from the view of increasing day to day global pollution and its effect on crop canopy as a whole. To explore and exploit the situation there is need for an integrated joint approach by various scientists working in different fields to combat against the threat caused due to toxic pollutants and to restore the life in the globe.

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