Effects of SO_2 on Chlorophyll Content and Leaf Temperature on Leaves of Potato (Solanum Tuberosum L.) genotypes

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ABSTRACT

A field experiment was conducted during Rabi season 2013 and 2014 at Industrial area Jagdishpur (Amethi) and non-industrial area Kumarganj (Faizabad) of Uttar Pradesh. Three varieties of potato namely, Kufri Chandramukhi, Kufri Bahar and Kufri Anand were sown in sandy loam soil at three dates of sowing viz., 15th October, 1st November, 15th November in split plot design with four replications. Leaf temperature was measured on fortnightly basis with Tele-thermometer. Chlorophyll content was determined at 30, 45, 60 and 75 days after sowing (DAS). SO_2 in industrial area was measured using gas sampling device at quality lab of Indogulf Jagdishpur. It was found that Kufri Chandramukhi variety possess highest chlorophyll content at 45 DAS sown on 1st November of both industrial and non-industrial area, with the existing maximum concentration of sulphur dioxide (81.0 micro g/m3) at 750 meter distance from the point source of emission. The maximum chlorophyll in variety Kufri Chandramukhi sown on 1st November in industrial area was 2.0 as compared to 2.20 in non-industrial area. Variety Kufri Chandramukhi though possess highest chlorophyll content both in industrial and non-industrial areas, 10% reduction in chlorophyll was recorded in industrial as compared to non-industrial area due to pollutants exposure such as SO_2. 30°C leaf temperature possesses highest chlorophyll content (1.78 mg/g) in industrial whereas 28°C leaf temperature possesses highest chlorophyll content (1.96 mg/g) in non-industrial area. It is also revealed that leaf temperature of potato crop of industrial area is higher as compared to non-industrial area.

Keywords: *Chlorophyll, Air pollution, SO_2, Leaf temperature and potato.*

1. Introduction

Crop production is highly dependent upon environmental conditions among which air quality plays a central role. Deterioration of air quality in developing countries like India is due to urbanization, industrialization, economic growth as well as associated increase in energy demands. The major proportions for the gaseous and particulate emissions from industries and automobile are oxides of nitrogen and sulphur and fly-ash. Air pollution was earlier considered as a local problem around large point sources. But due to use of tall stacks and long range transport of pollutants, it has become a regional problem. The trans-boundary nature of pollutants was clearly evident in remote areas where sources of air pollution also showed higher concentrations of air pollutants. Uncontrolled use of fossil fuels in industries and transport sectors has led to the increase in concentrations of gaseous pollutants such as SO_2, NOx, etc. (Garg et al., 2001). Until 1980, air pollution was primarily the problem of urban and industrial regions in India. But in the last two decades, due to changes in pattern of air pollutant emissions, greater pollutant impacts have also been experienced even in rural and more remote areas (Garg et al., 2001).

Anthropogenic SO_2 emissions have been increasing by about 4% annually. This trend parallels with rise in global energy consumption. SO_2 emissions have reduced in most of the developed and developing countries due to stringent pollution control measures. Industrial sources, thermal power plants and transport sectors are identified as sole contributors for SO_2 emissions. Increase in SO_2 emissions are also linked with increase in motor vehicle population (Gurjar et al., 2004). Between 1970 and 1980, there was 66% increase in SO_2 emission, thereafter the increase declined due to introduction of natural gas as one

of the fuel source. The exposure of these pollutants results in reduction in the concentration of photosynthetic pigments viz., chlorophyll, which affects the plant productivity, germination of seeds, length of pedicles, and number of flowers inflorescence (Nithamani and Indir, 2005). The photosynthetic pigments are the most likely to be damaged by air pollution. Chlorophyll pigments exist in highly organized state and under stress they may undergo several photochemical reactions such as oxidation, reduction, pheophytinisation and reversible bleaching (Puckett, et al., 1973). Hence any alteration in total chlorophyll concentration may change the morphological, physiological and biochemical behaviour of the plant. Keeping in view the above information, urban air pollution may be a serious threat to agricultural productivity in areas around urban centers and there exist variations in pattern of pollutants due to interactions during transport. the present paper focuses the effect of SO^2 emissions and their effects on potato crops.

2. Data and Methodology

A field experiment was conducted during Rabi season 2013 and 2014 at Industrial area Jagdishpur & non Industrial area at Instructional Farm of Narendra Deva University of Agriculture & Technology, Kumarganj, Faizabad (U.P.), located at 25 km away from experimental site Jagdishpur Industrial area Jagdishpur is situated in Amethi district undivided Sultanpur district on the national highway No. 56 and 83.4 km from Lucknow towards east Location map of experimental site shown in Figure 1. It is densely populated and has heavy vehicular traffic. Jagdishpur industrial area consist of four main industries i.e. BHEL, SAIL, Arif Cements, Indogulf Fetilizers as well as many other small scale industries. Air pollution has increased tremendously that is affecting the proper growth of plants in its vicinity. The rapid addition of toxic substances to environment is responsible for altering the ecosystem (Niragau and Davidson, 1986). Plants growing in heavy trafficular area are thus exposed to variety of pollutants such as SO_2. Geographically Jagdishpur is situated at 260 75' N latitude, 800 56' E longitude and non- industrial site of Narendra Deva University of Agriculture & Technology is situated at 260 47' latitude, 820 12' E longitude and at an altitude of 113 meters above mean sea level in the north Indo-gangetic plain.

Three varieties of potato namely, Kufri Chandramukhi (V1), Kufri Bahar (V2) and Kufri Anand (V3) grown in silty/sandy loam soil in split plot design with four replications in gross plot size of 4x3 cm. For the measurement of chlorophyll 4th leaf from the top of potato crops were collected from both the sites of industrial and non-industrial area. Measurement of chlorophyll content was made at 30, 45, 60 and 75 days after sowing (DAS). The total chlorophyll content was estimated by the method of Arnon (1949) using Spectronic-20 spectrometer at 662 nm absorption maxima and expressed as mg g-1 fresh weight for each treatment. Leaf temperature of potato leaves of both the experimental sites was measured on fortnightly basis by Tele-thermometer. Measurement of SO_2 was made in quality lab of Indo-gulf Fertilizer industry using gas sampling device (RDS/HVS). The detailed procedure has been described in flow chart shown in fig 2. Average temperature of both the surface of leaves (upper and lower) through the contact sensor gives the measurement of leaf temperature. Leaf temperature was measured at 30, 45, 60 and 75 DAS during 2 p.m. in second date of sowing of variety Kufari Chandramukhi.

3. Results and Discussion

Average concentration of SO_2 of two years study 2013 & 2014 during crop period in industrial area at various distance and different wind speed has been shown in Table 1. SO_2 and other suspended particulate matters (SPM) emitted from point source distributes in the area depends upon the wind direction, wind speed and height of point source of emission. The concentration of SO_2 dispersed at different range was calculated using Gaussian Dispersion formula as described by Rao (2001). It is revealed from Table 1 that at 750 m distance from source, a significant reduction in total chlorophyll content. The results of this study indicated a decline in chlorophyll content in potato crop growing in industrial area. Leaves are most susceptible parts of a plant to acute injury due to their abundance of stomata, which permit the penetration of the pollutants into the sensitive tissues. The first barrier of gaseous air pollutant is boundary layer resistance which varies with wind speed and size, shape and orientation of leaves (Heath et al., 2009). At higher wind speed, boundary layer resistance declines allowing more pollutant entry into the leaf. The cells most exposed to air pollutant action are epidermal cells, but waxy cuticle is a potential barrier to most of the pollutant gases. Chlorophyll content may differ in different period of time under different conditions of pollution stress and different meteorological conditions.

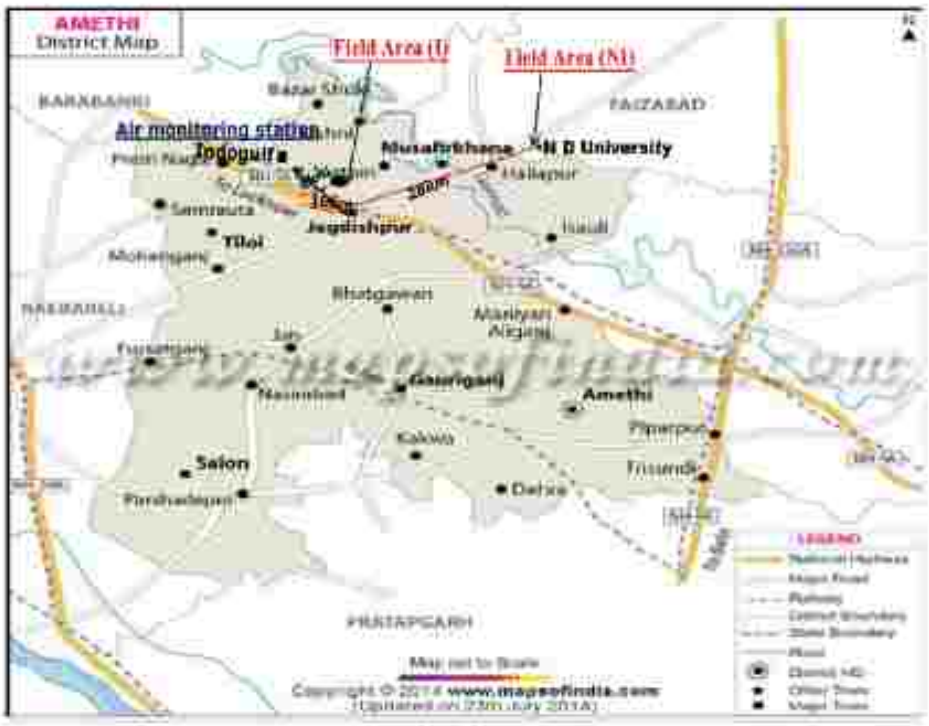

Fig.1 Location map of experimental site.

Placed 30 ml of absorbing media in an impinger

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Connected it to the gas-sampling manifold of gas sampling device (RDS/HVS)

↓

Drawn air at a sampling rate of 1 lpm for four hours

↓

Checked the volume of sample at the end of sampling and record it

↓

Transferred the exposed samples in storage bottle and preserve

↓

Prepared calibration graph as recommended in method

↓

Taken 10/20 ml. aliquot of sample in 25 ml. Vol. Flask

↓

Taken 10/20 ml. of unexposed sample in 25 ml. Vol. Flask (blank)

↓

Added 1 ml Sulphuric acid, Keep it 10 minutes

↓

Added 2 ml formaldehyde

↓

Added 2 ml working PRA

↓

Made up to mark (25 ml.) with distilled water.

↓

Kept it 30 minutes for reaction

↓

Set Zero of spectrophotometer with Distilled water

↓

Measured absorbance at 560 nm

↓

Calculated concentration using calibration graph

↓

Calculated concentration of Sulphur Dioxide in $\mu g/m^3$

Fig.2 Flow chart for measurement of Sulphur Dioxide.

Maximum concentration of SO_2 was recorded at all wind speed. Maximum concentration (81.00 ?) g/m3 was recorded at wind speed of 2 km/hr whereas concentration of SO_2 was decreased with different ranges successively followed by 71.50 ?g/m3at 1 km/hr wind speed (Table 1). Minimum concentration of SO_2 was recorded at 10,000 m at wind speed ranged 0.30 to 0.65. The response of stomata to SO_2 entry is largely dependent on leaf age, concentration and combination of pollutants (Pfanz et al., 1987) results in low concentration of SO2 stimulated stomatal conductance in potato crop within 15 minute of exposure, which persisted for several days (Black and Unsworth, 1980). This has been attributed to the destruction of epidermal cells adjacent to stomata and accumulation of sulphur within guard cells. Larger stomatal apertures not only allow ingress of the damaging pollutant, but also enhance water loss due to unrestricted transpiration. Once SO_2 enters through stomata, the route to the surface of a nearby subsidiary or epidermal cell is very short and therefore, the cells of the epidermis are more susceptible. The treatment combination of three varieties with three different dates of sowing revealed that D2V1 combination recorded highest chlorophyll content (2.00 mg/g) in non-industrial area at 45 DAS followed by (1.95 mg/g) 60 DAS. The next combination D2V3 recorded 1.94 mg/g chlorophyll content followed by D1V1 (1.87 mg/g) at 45 DAS (Table 2). It is obvious that there is no specific trend for leaf temperature with DAS may be due to variability in weather condition. But chlorophyll content increased up to 45 DAS then after slightly decreased in both industrial and non-industrial area. Maximum leaf temperature 300C was observed at 45 DAS in industrial and 280C in non-industrial area similarly lowest leaf temperature was recorded at 60 DAS as compared to other DAS in both experimental sites (industrial and non-industrial area).The detrimental effects of SO_2 occur due to reactions under liquid phases after their uptake in the plants. The result of this study showed that there is reduction in total chlorophyll content as compared to non-industrial area. In industrial area potato variety Kufari Chandramukhi has maximum chlorophyll content and over all the total chlorophyll was maximum in non-industrial area. Variation of total Chlorophyll content (mg/g) of potato crop as affected by genotypes and different dates of sowing (DAS) in non-industrial area has been shown in table 3. It is revealed that maximum chlorophyll content (2.09) was recorded in 2nd date of sowing (1st Nov) at 45 DAS. Variety Kufri Chandramukhi was recorded to possess highest chlorophyll (2.04) at 45 DAS and significantly differ with other varieties Kufri Bahar and Kufri Anand. Similarly, 2nd date of sowing (1st Nov) significantly differ with first date of sowing (15th October) and third date of sowing (15th November). The lowest chlorophyll content was recorded at 75 DAS as compared to 60 and 45 DAS but greater than 30 DAS in all the varieties and at all dates of sowing. The treatment combination of three varieties with three different dates of sowing revealed that Kufari Chandramukhi sown on 1st November recorded highest chlorophyll content (2.20 mg/g) in non-industrial area at 45 DAS followed by (2.15 mg/g) 60 DAS. The next combination Kufari Anand sown on 1st November recorded 2.13 mg/g chlorophyll content followed by Kufari Chandramukhi sown on 15th October (2.06 mg/g) at 45 DAS.

From the study it was also observed that chlorophyll content reduced in industrial area as compared to non-industrial area in all the varieties at all the dates of sowing. Third date of sowing (15th Nov) were recorded to possess the lowest value of chlorophyll content, may be due to more

TABLE 1

Average concentration of SO_2 (µg/m3) in industrial area at various distance and different wind speed (mean data of 2013 & 2014)

Distance (m)→ Wind ↓ Speed kmph	100	200	500	750	1000	2000	3000	5000	8000	10000
10	0.50 X10-6	1.21	48.85	34.28	14.08	1.30	0.87	0.63	0.33	0.30
05	0.70 X10-6	1.47	57.65	42.35	22.85	1.85	1.34	1.25	0.78	0.45
02	1.20 X10-6	2.20	68.50	81.00	64.10	4.25	2.65	1.85	1.20	0.65
01	1.10 X10-6	1.70	65.50	71.50	57.75	3.55	2.35	1.50	1.25	0.65

TABLE 2
Average leaf temperature and chlorophyll (mg/g) content of potato crop at different dates of sowing (DAS) in industrial and non-industrial area

DAS	Industrial Area		Non industrial area	
	Leaf temp(°C)	Chlorophyll (mg/g)	Leaf temp(°C)	Chlorophyll (mg/g)
30	29	1.73	25	1.90
45	30	1.78	28	1.96
60	24	1.66	22	1.83
75	29	1.35	26	1.49

TABLE 3
Variation of average total chlorophyll content (mg/g) of potato crop as affected by genotypes and different dates of sowing (DAS) in non-industrial area

Days → Treatments ↓	30	45	60	75
D_1V_1	1.65	2.06	2.00	1.70
D_1V_2	1.55	1.82	1.76	1.90
D_1V_3	1.50	2.00	1.95	1.88
D_2V_1	1.80	2.20	2.15	1.80
D_2V_2	1.70	1.94	1.88	2.06
D_2V_3	1.65	2.13	2.07	1.98
D_3V_1	1.66	1.85	1.80	1.52
D3V2	1.55	1.63	1.58	1.72
D3V3	1.51	1.80	1.76	1.69
SEm ±	0.056	0.064	0.062	0.061
CD at 5%	0.163	0.186	0.180	0.177
D1	1.57	1.96	1.90	1.83
D2	1.72	2.09	2.03	1.95
D3	1.57	1.76	1.71	1.64
SEm ±	0.041	0.056	0.050	0.054
CD at 5%	0.128	0.175	0.156	0.170
V1	1.70	2.04	1.98	1.67
V2	1.60	1.80	1.74	1.89
V3	1.55	1.98	1.93	1.85
SEm ±	0.032	0.037	0.036	0.035
CD at 5%	0.094	0.107	0.104	0.102

absorption/deposition of SO_2 and SPM at 45 DAS on account of calm wind hence less dispersion and more deposition. Variety Kufri Chandramukhi (V1) possesses highest chlorophyll content under SO_2 exposure as compared to other varieties. Variety Kufari Anand followed by Kufari Bahar showed better chlorophyll content at either dates of sowing except 30 DAS, hence, may response for better yield. Therefore, Kufri Chandramukhi seems to be more resistant to SO_2 or SPM for chlorophyll formation. Variation of average total Chlorophyll content (mg/g) of potato crop as affected by genotypes and different dates of sowing in industrial area has been shown in table 4. It is revealed from the data that maximum chlorophyll content (1.96 mg/g) was recorded in 2nd date of sowing (1st Nov) at 45 DAS. Variety Kufri Chandramukhi was recorded to possess highest chlorophyll (1.85 mg/g) at 45 DAS and significantly differ with other varieties Kufri Bahar and Kufri Anand. Similarly 2nd date of sowing (1st Nov) significantly differ with either 15th October on first date of sowing and 15th November on third date of sowing. The lowest chlorophyll content was recorded at 75 DAS as compared to 60 and 45 DAS but greater than 30 DAS in all the varieties and at all dates of sowing.

TABLE 4
Variation of average total chlorophyll content (mg/g) of potato crop as affected by genotypes and different dates of sowing (DAS) in industrial area

Days → / Treatments ↓	30	45	60	75
D_1V_1	1.50	1.87	1.81	1.54
D_1V_2	1.40	1.65	1.60	1.73
D_1V_3	1.36	1.82	1.77	1.70
D_2V_1	1.64	2.00	1.95	1.64
D_2V_2	1.54	1.76	1.71	1.87
D_2V_3	1.50	1.94	1.88	1.80
D_3V_1	1.51	1.68	1.63	1.38
D_3V_2	1.41	1.48	1.44	1.56
D_3V_3	1.37	1.64	1.60	1.54
SEm ±	0.049	0.055	0.056	0.053
CD at 5%	0.147	0.165	0.166	0.157
D_1	1.42	1.78	1.73	1.66
D_2	1.56	1.90	1.85	1.77
D_3	1.43	1.60	1.56	1.49
SEm ±	0.036	0.035	0.045	0.042
CD at 5%	0.126	0.122	0.156	0.146
V_1	1.55	1.85	1.80	1.52
V_2	1.45	1.63	1.58	1.72
V_3	1.41	1.80	1.75	1.68
SEm ±	0.029	0.032	0.032	0.030
CD at 5%	0.085	0.095	0.096	0.090

Graphical representation of total chlorophyll content with different treatment combination of potato varieties has been depicted from fig. 3 to 8. Variation of total chlorophyll content (mg/g) at 45 DAS of Kufri Chandramukhi variety of potato crop affected by different dates of sowing has been sown in fig 6 similarly for variety Kufari Bahar and Kufari Anand the variation of chlorophyll was depicted in fig 7 and 8, respectively. Likewise, graphical representations of total chlorophyll content with different treatment combinations of potato varieties at 45 DAS of different genotypes at first date of sowing (15th Oct) was shown in fig 3 and at second and third dates of sowing were shown in fig 4 & 5, respectively.

Maximum content of chlorophyll (2.0 mg/g) in industrial area and 2.20 mg/g in non-industrial area was observed in Kufari Chandramukhi sown on 1st November i.e., 10 % reduction of chlorophyll content in industrial area as compared to non-industrial area. Similarly, minimum chlorophyll content was recorded in Kufari Bahar sown on 15th November treatment combination in both experimental sites of industrial and non-industrial area.

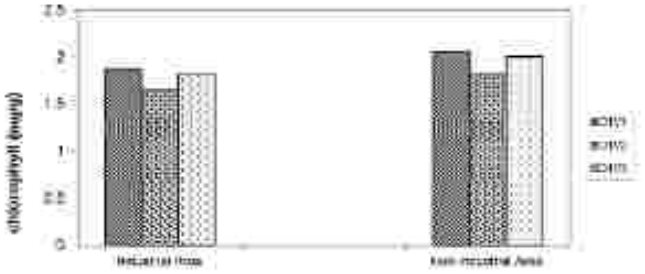

Fig.3 Variation of total chlorophyll content (mg/g) at 45 DAS of different genotypes of potato crop at first date of sowing (15th October).

Fig.4 Variation of total chlorophyll content (mg/g) at 45 DAS of different genotypes of potato crop at second date of sowing (1st November).

Fig.5 Variation of total chlorophyll content (mg/g) at 45 DAS of different genotypes of potato crop at third date of sowing (15th November).

Fig.6 Variation of total chlorophyll content (mg/g) at 45 DAS of Kufri Chandramukhi potato crop affected by different dates of sowing.

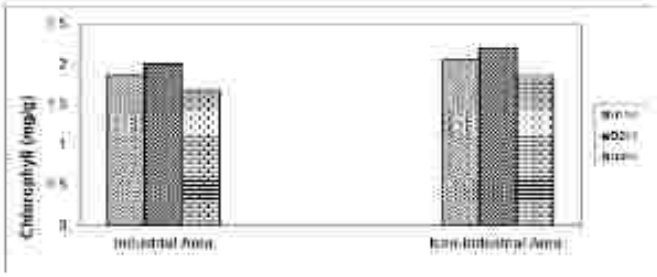

Fig.7 Variation of total chlorophyll content (mg/g) at 45 DAS of Kufri Bahar potato crop affected by different dates of sowing

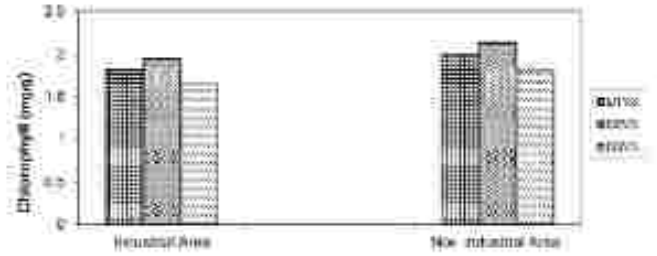

Fig.8 Variation of total chlorophyll content (mg/g) at 45 DAS of Kufri Anand potato crop affected by different dates of sowing

4. Conclusions

Changes in morphological characteristics, photosynthetic pigment and yield of potato crops directly corresponded to the levels of air pollution at different sites. The study elucidated that air pollution emitted from industry adversely affects the ambient air and agricultural production as well. The collected information based on field experiment concluded that air pollutants not only affect the vegetation near the point sources and urban centres, but depending upon the meteorology, specially wind pattern may spread in suburban and rural areas, affecting the crops also. Responses of plants vary between different species and their cultivars. Responses of plants to air pollutants also depend on type of pollutants, concentrations duration and its magnitude. There is a need to screen out sensitive and tolerant cultivars in India and establish the exposure indices of all the important crops to reduce the crop loss.

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