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Greenhouse effect and its relevance to abiotic stress in Horticultural Crops: A review

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Abstract
Global warming, caused by the increase in concentration of greenhouse gases (GHGs) in the atmosphere, has emerged as the most prominent environmental issue all over the world. These GHGs *viz.* carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) trap the outgoing infrared radiations from the earth's surface and thus raise the atmospheric temperature. As a result, the temperature of atmosphere and oceans is going up, snow and ice are fast melting and sea level is rising. This global climate change will have considerable impact on the Horticultural crops, soils, livestock, fisheries and pests. Horticulture is crucial for ensuring food, nutritional and livelihood security of India. It engages workforce in gainful employment and accounts for a significant share in India's Agricultural gross domestic product (GDP). Several industries depend on horticultural production for their requirement of raw materials. Thus, the purpose of this review paper to summarize all the factors that affect horticultural production like fruits, Vegetables and plantation crops by the greenhouse gases and methane emission. So here, we review information on how horticultural crops face redox imbalance and problems caused by abiotic stresses through greenhouse gases and methane emission.

Keywords: Global warming, Climate change, Horticultural Crops, greenhouse gases (GHGs)

Introduction
Climate change is a change of climate over comparable period of time that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere. The global mean temperature of the earth's surface has increased by about 0.74°Cover last hundred years. The variation in surface temperature indicated that 1990's decade has been the warmest in the past millennium and 1998 was the warmest year. The rise in temperature is attributed to alarming increase in the atmospheric concentration of greenhouse gases *viz*., CO_2, CH_4, N_2O and chlorofluorocarbons mainly due to accelerated rate of industrialization. The expected carbon dioxide concentration in 2100 is estimated to be 100% higher than the one observed at the pre-industrial era. With global temperatures expected to rise by up to 6°C by the end of the 21st century compared to pre-industrial levels; it is unlikely that this Agro-climatic metric will remain stable (Singh, 2010) [8]. An orchard is characterized by an environment composed of light, temperature, water, humidity, wind, various atmospheric gases, soil nutrients and other conditions of the rhizosphere. During the growth of plants different climatic and stress factors are effective at the same time for the crop, i.e., drought, heat, UV light, etc. Climatic factor alone can decide the physiological staging, for example, photosynthesis depends not only on radiation, but also on temperature, Carbon dioxide, water and nutritional elements. As shown by these authors, planting a crop in an eco-physiologically unfit place increases the costs of production and, thus, reduces the chance of high economic success. Taking into account environmental factors, at a given site, growing conditions decide on the size of the plant, the duration of phenological stages, the time and volume of the harvest.

Greenhouse effect occurs in the troposphere (the lower atmosphere layer), where life and weather occur. In the absence of greenhouse effect, the average temperature on Earth's surface is estimated around -19°C, instead of the current average of 14°C (Le Treut *et al.*, 2007) [4]. Greenhouse effect is produced by greenhouse gasses (GHG). GHG are those gaseous constituents of the atmosphere that absorb and emit radiation in the thermal infrared range (IPCC, 2014) [2]. Traces of GHG, both natural and anthropogenic, are present in the troposphere. The most abundant GHG in increasing order of importance are: water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxides (NxO) and ozone (O_3) (Kiehl and

Trenberth, 1997) [3]. GHG percentages vary daily, seasonally, and annually. Methane (CH_4) is the main atmospheric organic trace gas. CH_4 is the primary component of natural gas, a worldwide fuel source. Significant emissions of CH_4 result from cattle farming and agriculture, but mainly as a consequence of fossil fuel use. Concentrations of CH_4 were multiplied by two since the pre-industrial era. The present worldwide-averaged concentration is of 1.8 $\mu mol.mol^{-1}$ (IPCC, 2014) [2]. Although its concentration represents only 0.5% that of CO_2, concerns arise regarding a jump in CH_4 atmospheric release. Indeed, it is 30 times more powerful than CO_2 as GHG (IPCC, 2014) [2]. CH_4 generates O_3 (see below), and along with carbon monoxide (CO_2), contributes to control the amount of OH in the troposphere (Wuebbles and Hayhoe, 2002) [9].

Impact of greenhouse gases on horticultural crops

Impact of elevated CO_2

Carbon dioxide is responsible for 20% of the thermal absorption (Schmidt *et al.,* 2010) [6]. Natural sources of CO_2 include organic decomposition, ocean release and respiration. Anthropogenic CO_2 sources are derived from activities such as cement manufacturing, deforestation, fossil fuels combustion such as coal, oil and natural gas, etc. Surprisingly, 24% of direct CO_2 emission comes from agriculture, forestry and other land use, and 21% comes from industry (IPCC, 2014) [2]. Atmospheric CO_2 concentrations climbed up dramatically in the past two centuries, rising from around 270 μmol.mol-1 in 1750 to present concentrations higher than 385 μmol.mol-1 (Mittler and Blum Wald, 2010; IPCC, 2014) [2, 5]. Around 50% of cumulative anthropogenic CO_2 emissions between 1750 and 2010 have taken place since the 1970s (IPCC, 2014) [2]. It is calculated that the temperature rise produced by high CO_2 concentrations, plus the water positive feedback, would increase by 3-5° C the global mean surface temperature in 2100 (IPCC, 2014) [2].

Empirical records provide incontestable evidence for the global rise in carbon dioxide (CO_2) concentration in the earth's atmosphere. Plant growth can be stimulated by elevation of CO_2; photosynthesis increases and economic yield is often enhanced. The application of more CO_2 can increase plant water use efficiency and result in less water use. After reviewing the available CO_2 literature, we offer a series of priority targets for future research, including: 1) a need to breed or screen varieties and species of horticultural plants for increased drought tolerance; 2) determining the amount of carbon sequestered in soil from horticulture production practices for improved soil water-holding capacity and to aid in mitigating projected global climate change; 3) determining the contribution of the horticulture industry to these projected changes through flux of CO_2 and other trace gases (i.e., nitrous oxide from fertilizer application and methane under anaerobic conditions) to the atmosphere; and 4) determining how CO_2-induced changes in plant growth and water relations will impact the complex interactions with pests (weeds, insects, and diseases). Such data are required to develop best management strategies for the horticulture industry to adapt to future environmental conditions Empirical records provide incontestable evidence for the global rise in carbon dioxide (CO_2) concentration in the earth's atmosphere. Plant growth can be stimulated by elevation of CO_2; photosynthesis increases and economic yield is often enhanced. The application of more CO_2 can increase plant water use efficiency and result in less water use. After reviewing the available CO_2 literature, we offer a series of priority targets for future research, including: 1) a need to breed or screen varieties and species of horticultural plants for increased drought tolerance; 2) determining the amount of carbon sequestered in soil from horticulture production practices for improved soil water-holding capacity and to aid in mitigating projected global climate change; 3) determining the contribution of the horticulture industry to these projected changes through flux of CO_2 and other trace gases (i.e., nitrous oxide from fertilizer application and methane under anaerobic conditions) to the atmosphere; and 4) determining how CO_2-induced changes in plant growth and water relations will impact the complex interactions with pests (weeds, insects, and diseases). Such data are required to develop best management strategies for the horticulture industry to adapt to future environmental conditions Empirical records provide incontestable evidence for the global rise in carbon dioxide (CO_2) concentration in the earth's atmosphere. Plant growth can be stimulated by elevation of CO_2, photosynthesis increases and economic yield is often enhanced. The application of more CO_2 can increase plant water use efficiency and result in less water use. After reviewing the available CO_2 literature, we offer a series of priority targets for future research, including: 1) a need to breed or screen varieties and species of horticultural plants for increased drought tolerance; 2) determining the amount of carbon sequestered in soil from horticulture production practices for improved soil water-holding capacity and to aid in mitigating projected global climate change; 3) determining the contribution of the horticulture industry to these projected changes through flux of CO_2 and other trace gases (i.e., nitrous oxide from fertilizer application and methane under anaerobic conditions) to the atmosphere; and 4) determining how CO_2-induced changes in plant growth and water relations will impact the complex interactions with pests (weeds, insects, and diseases). Such data are required to develop best management strategies for the horticulture industry to adapt to future environmental conditions.

Because of the high level of emissions, the concentration of CO_2 is now as high as 398μmol mol-1 in the atmosphere. The carbon dioxide level is one of the most regulated growth factors for fruit trees. The increase of CO_2 concentration in the air near the leaf blade decreases stomatal aperture, stomatal conductance and transpiration; in consequence, photosynthesis and growth increase because of elevated water use efficiency. An increase in growth because of an elevated CO_2 requires higher water and fertilizer supply. This is because more nitrogen is required to ensure high crop productivity under climate change conditions. Kumar *et al.,* (2020) [1]. The horticultural crops having C_3 photosynthetic metabolism have shown beneficial effects indicated the increase in onion yield by 25-30% mainly due to increases in bulb size at 530 ppm CO_2 (Wurr *et al.* 1998; Wheeler 1996) [53, 54]. Tomato also showed 24% higher yield at 550 ppm CO_2 due to increase in number of fruits (Srinivas Rao 2010) [52]. In perennial crops like coconut studies indicate the increase in shoot height, leaf area and shoot dry matter due to elevated CO_2 to the tune of 36% over chamber control.

Impact of NO_2

The emission of atmospheric nitrogen dioxide (NO_2) has been a growing trend in many areas worldwide during the last few decades Munzi *et al.*, 2009 [10], especially in some Asian countries Hu *et al.*, 2015 [11]. Due to the development of industrialized production and the continuous increase in automobile exhaust emissions, the NO_2 concentration will likely continue to increase, and the NO_2 level will continue to exceed the standard level of NO_2 pollution Hultengren *et al.*, 2004 [12]. Nitrogen dioxide (NO_2) is a precursor of harmful secondary air pollutants such as ozone and particulate matter Rahmat *et al.*, 2013 [13], Brmejo-Orduna *et al.*, 2014 [14]. The use of ecological methods to reduce air concentrations, such as plant absorption and catabolism of atmospheric NO_2, is very important. At present, scholars hold different views towards the effects of NO_2 on plants. One hypothesis purport that, by being metabolized and incorporated in the nitrate assimilation pathway, NO_2 can form organic nitrogenous compounds in plants Stulen *et al*., 1998 [16]. This process does not injure leaves Midddelton *et al.*, 1958. Another hypothesis purports that most plants exhibit both low amounts of NO_2-N incorporation into total plant nitrogen (N) and resistance to NO_2 Morikawa *et al.*, 2001 [18]. Complex physiological responses can be triggered when plants are exposed to NO_2, including changes in antioxidant enzyme activity Liu *et al.*, 2015 [20], Norby *et al.*, 1989 [21]. N metabolic enzyme activity Vighi *et al.*, 2017 [22], Weber *et al.*, 1995 [23], and both the components and distribution of nitrogenous metabolic products in plant tissues.

The dissolution of low concentrations of NO_2 in water can result in the formation of nitrate and nitrite, both of which are used by plants during the normal process of nitrate metabolism; as such, NO_2 may act as an airborne fertilizer. However, high concentrations of NO_2 can lead to excessive accumulations of nitrite (NO_2-) Okano *et al.*, 1986 [25] and cell acidification Schmutz *et al.*, 1995 [26], which lead to negative responses such as the generation of reactive oxygen species (ROS) and inhibition of both N assimilation and plant growth, further causing acute damage to leaves, whole-plant chlorosis or even death. However, exposure of NO_2 to different plant species elicits different physiological responses. Therefore, the effects of NO_2 exposure on plants remain highly controversial, and a unified conclusion has not been reached. In addition, information concerning different plants that are highly tolerant to NO_2 and their natural recovery is scarce. To identify garden plants that exhibit good absorption and strong resistance, we studied the physiological responses of 41 garden plants exposed to specific NO_2 environments under controlled conditions in the laboratory; the plants were located in Jiangsu Province. Few studies have investigated whether these 41 plants species, which are commonly planted along roadsides in urban areas of many countries, have high NO_2 absorption capacity and/or are resistant to the effects of NO_2. Several studies have focused on the effects of NO_2 concentration on plant growth and reported both that low concentrations (0.1 μl/L) of NO_2 did not significantly influence the height, leaf area or dry weight of 1-year-old Buxus Sinica seedlings and that 0.5μl/L NO_2 significantly stimulated the leaf growth of Populus Deltoides and Populus Nigra Italic a; however, a higher NO_2 concentration (1 μl/L) significantly reduced the stem growth. When Arabidopsis thaliana plants were exposed to 0.85, 2, 4.25, and 9.4μl/L NO_2, the plants exhibited acute visible leaf injuries, and the plants eventually died. When those plants were treated with NO_2 concentrations between 2 and 4.25 μl/L, some injury occurred, but the plants remained alive; furthermore, no significant differences were recorded between leaf growth and chlorophyll (Chl) content. Therefore, we chose 6 μl/L as the NO_2 fumigation concentration Sheng *et al.*, 2019 [27].

There is little research on the impact of nitrogen dioxide on agricultural production in developing countries. Although the study by Magazine *et al.* (1995) indicated that NO_x had no environmental impact on wheat and rice production in the suburbs of Lahore, which may be significant in urban and adjoining areas. The above study also examined the effects of NOx, which studied the effects of SO_2 on four crops in Delhi and Varanasi. In winter, wheat yield was significantly negatively correlated ($p<0.05$) with NO_2 concentrations ranging from 31 to 105 μg m-3 Marshall *et al.*, 1997 [28]. In Delhi the yields of both mustard and wheat were negatively correlated with NO, which ranged from 79 and 197 μg m-3 Marshall *et al.*, 1997 [28]. The transect study in Varanasi also raised the possibility that urban air pollution was having an impact on the nutritional quality, in addition to the yield of crops. The results showed significant negative relationships with SO_2 and NO_2 for carbohydrate and energy content, as well as for beans and wheat.

Impact of SO_2

Stress conditions, in particular air pollutants, alter physiological, biochemical, and morphological processes in plants by inhibiting net photosynthesis, reducing growth rates, and causing acute visible damage (Darrall, 1989; Ashraf and Harris, 2013) [29, 30]. Photosynthesis is one of the first processes to be affected by high SO_2 concentration (Ziegler, 1972) [50], and affected plants display an initial decrease in photosynthetic rate and an increased rate of respiration (Gheorghe and Ion, 2011) [34]. The effects of SO_2 on physiological processes have been shown to be related to stomatal responses (Raschke, 1975; Rao *et al.*, 1983; Verma and Singh, 2006) [42, 43, 49], likely because stomata cannot close properly when the plant is under environmental stress (Robinson *et al.*, 1998) [44]. Furthermore, SO_2 can affect carbon allocation, and chlorophyll contents, which affect plant growth and productivity (Treshow, 1984; Aminifar and Ramroudi, 2014; Singh *et al.*, 2013) [31, 46, 48], and affects plant growth by altering the photosynthetic rate and distribution of photosynthates (Khan and Khan, 1993) [40]. It also affects the cell membrane structure and changes membrane permeability. The water use efficiency (WUE) of a plant is the ratio of carbon gain to water loss. Swanepoel *et al.* (2007) [45] reported that long-term SO_2 exposure, even at low concentrations, reduced chlorophyll content and decreased WUE. However, high concentrations and short-term SO_2 exposure increased WUE. Chlorophyll content is known to be affected by environmental stress (Mcainsh *et al.*, 2002) [41]. In agreement, a decrease in chlorophyll content has been proposed to indicate SO_2 injury (Gilbert, 1968; Haworth *et al.*, 2012) [32, 35]. When SO_2 is absorbed by a plant, the degree of injury is classified as either acute or chronic (Thomas and Hill, 1935) [47]. Acute injury occurs when high concen-trations of SO_2 are absorbed over a relatively short period, whereas chronic injury is caused by long-term absorption of SO_2 at threshold concentrations. According to Robinson *et al*. (1998) [45], when plants are exposed to low concentrations of SO_2, the absorbed SO_2 is oxidized and used to synthesize proteins. However, at high concentrations, it disrupts thylakoid function and interferes with the electron transport chain (Heber and Hueve,

1997) [37], which leads to the breakdown of physiological systems. It has been suggested that SO_2 injury depends on the rate of SO_2 absorption. SO_2 can enter the plant tissues either from soil via the roots or from the atmosphere via the leaves. Atmospheric SO_2 enters plant leaves through stomata, which can be opened or closed by guard cells. A raised SO_2 concentration usually causes stomatal changes, specifically stomata tend to close when there are long-term high SO_2 concentrations (Guderian, 2012) [33]. Following SO_2 exposure, guard cells accumulate sulfur and lose the ability to open or close the stomata (Knabe, 1976) [39]. Consequentially, SO_2 affects plant growth by altering the production and distribution of photosynthates (Khan and Khan, 1993) [41]. The inhibition of photosynthesis from excessive levels of sulphur can impair the reproductive process in plants, which may lead to a reduction in the number of flowers or fruits (Hetherington and Woodward, 2003) [38].

CH_4 emission

Methane is produced by microorganisms in a process called methanogenesis. Methane stored in rocks and soil stems from ancient biomass and the generation mechanisms are the not the same as for other fossil fuels. There are both natural and human sources of methane emissions. The main natural sources include wetlands, termites and the oceans. Natural sources create 36% of methane emissions. Human sources include landfills and livestock farming. But the most important source being the production, transportation and use of fossil fuels. Human-related sources create the majority of methane emissions, accounting for 64% of the total. Most of the methane releases come from paddy fields (91%) and less significantly from animal husbandry (7%) and the burning of agricultural wastes (2%). Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills.

Increased incidence of physiological disorders such as tip burn and blossom end rot. Due to temperature increase early maturity of Citrus, Grapes, Melons and Onion. Low fruit set in Citrus due to warm temp. Two recent warm spells triggered many springs flowering plants (e.g., Mango) to blossom up to 4 days earlier for every 1℃ rises in average spring temperature. The traditional region (Hilly Mountain area of Himachal Pradesh) of apple and other temperate crops were found suitable for the cultivation because of prevalence of optimum temperature required for flowering & fruiting but gradually becoming warmer due to global warming and may likely to become unsuitable for the cultivation. (JNKV source Abiotic stress management in fruit crop).

Conclusion

Studies conducted by various researchers indicate the likely impact of climate change on various horticultural crops. The quantication of impacts of variations in Studies conducted by various researchers indicate the likely impact of climate change on various horticultural crops. The quantification of impacts of variations in temperature, excess and limited moisture conditions is the first step to prepare the horticulture sector for developing adaptation strategies under climate change scenarios. Concerted efforts are needed to study and assess the impacts on individual crops under the major agro-ecological regions and growing seasons. Efforts should be intensified to develop new varieties suitable to different agro-ecological regions under changing climatic conditions. In comparison to annual crops, where the adaptation strategies can be realized relatively fast using a wide range of cultivars and species, changing planting dates or season, the planting and rearrangement of orchards requires a consideration of the more long-term aspects of climate change. Therefore, before resorting to any adaptation option, a detailed investigation on the impact of climate change on perennial crops is necessary.

References

1. Ashish Kumar, Pallavi Singhal, Shardulya Shukla, Vivek Kumar Tiwari. Impact of greenhouse gases on fruits production. Journal of Medicinal Plants Studies. 2020;8(2):133-134.
2. IPCC. Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, eds O.R. Edenhofer, Y Pichs-Madruga, E Sokona, S Farahani, K Kadner, A Seyboth, *et al*., Cambridge: Cambridge University Press, 2014.
3. Kiehl J, Trenberth K. Earth's annual global mean energy budget. Bull. Amer. Meteor. Soc. 1997;78:197-208.
4. Le Treut H, Somerville R, Cubasch U, Ding Y, Mauritzen C, Mokssit A, *et al.* Historical overview of climate change science, in Climate change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, eds S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt *et al*. (Cambridge: Cambridge University Press), 2007.
5. Mittler R, Blumwald E. Genetic engineering for modern agriculture: challenges and perspectives. Annu. Rev. Plant Biol. 2010; 61:443-462., DOI: 10.1146/annurev-arplant-042809-112116
6. Schmidt GA, Ruedy RA, Miller RL, Lacis AA. Attribution of the present-day total greenhouse effect. J. Geophys. Res. 2010;115:D20106, DOI: 10.1029/2010JD014287
7. Stephen Prior A, Brett R union G. A Review of Elevated Atmospheric CO_2 Effects on Plant Growth and Water Relations: Implications for Horticulture. Hort science, 2011 Feb;46:2.
8. Singh HP. Impact of climate change on horticultural crops. In: Challenges of Climate Change-Indian Horticulture, Westville Publishing House, New Delhi, 2010, 1-8.
9. Wuebbles DJ, Hayhoe K. Atmospheric methane and global change. Earth Sci. Rev. 2002; 57:177-210., DOI: 10.1016/S0012-8252(01)00062-9
10. Munzi S, Pisani T, Loppi S. The integrity of lichen cell membrane as a suitable parameter for monitoring biological effects of acute nitrogen pollution. Ecotoxicol. Environ. Saf, 2009, 72.
11. Hu YB, Bellaloui N, Tigabu M, Wang JH, Diao J, Wang K *et al*. Gaseous NO_2 effects on stomatal behavior, photosynthesis and respiration of hybrid poplar leaves. Acta Physiol. Plant, 2015, 37, 39.
12. Hultengren S, Gralen H, Pleijel H. Recovery of the epiphytic lichen flora following air quality improvement in south-west Sweden. Water Air Soil Pollution. 2004;154:203-211.

13. Rahmat M, Maulina W, Rustami E, Azis M, Budiarti DR, Seminar KB, *et al*. Performance in real condition of photonic crystal sensor based NO_2 gas monitoring system. Atmos. Environ. 2013;79:480-485.
14. Bermejo-Orduna R, McBride JR, Shiraishi K, Elustondo D, Lasheras E, Santamaría JM. Biomonitoring of traffic-related nitrogen pollution using *Letharia vulpina* (L.) Hue in the Sierra Nevada, California. Sci. Total Environ. 2014;490:205-212.
15. Marais EA, Jacob DJ, Choi S, Joiner J, Belmonte-Rivas M, Cohen RC *et al*. Nitrogen oxides in the global upper troposphere interpreted with cloud-sliced NO_2 from the Ozone Monitoring Instrument. EGU Gen. Assem. 2017;19:12156.
16. Stulen I, Perez-Soba M, De Kok LJ, Van der Eerden L. Impact of gaseous nitrogen deposition on plant functioning. New Phytol. 1998;139:61-70.
17. Middleton JT, Darley EF, Brewer RF. Damage to vegetation from polluted atmospheres. J Air Pollut. Control Assoc. 1958;8:9-15.
18. Morikawa H, Higaki A, Nohno M, Takahashi M, Kamada M, Nakata M *et al.* Effects of high nitrogen load on growth, photosynthesis and nutrient status of Cryptomeria japonica and Pinus Densiflora seedlings. Trees. 2001;15:453-461.
19. Teklemariam TA, Sparks JP. Leaf fluxes of NO and NO_2 in four herbaceous plant species: The role of ascorbic acid. Atmos. Environ. 2006;40:2235-2244.
20. Liu XF, Hou F, Li GK, Sang N. Effects of nitrogen dioxide and its acid mist on reactive oxygen species production and antioxidant enzyme activity in Arabidopsis plants. J Environ. Sci. 2015;34:93-99.
21. Norby RJ, Weerasuriya Y, Hanson PJ. Induction of nitrate reductase activity in red spruce needles by NO_2 and HNO_3 vapor. Can. J For. Res. 1989;19:889-896.
22. Vighi IL, Benitez LC, Amaral MN, Moraes GP, Auler PA, Rodrigues GS *et al*. Braga, EJB Functional characterization of the antioxidant enzymes in rice plants exposed to salinity stress. Biol. Plant. 2017;61:540-550.
23. Weber P, Nussbaum S, Fuhrer J, Gfeller H, Schlunegger UP, Brunold C *et al*. Uptake of atmospheric 15 NO_2 and its incorporation into free amino acids in wheat (*Triticum aestivum* L.). Physiol. Plant. 1995;94:71-77.
24. Zeevaart AJ. Some effects of fumigating plants for short periods with NO_2. Environ. Pollut. 1976;11:97-108.
25. Okano K, Totsuka T. Absorption of nitrogen dioxide by sunflower plants grown at various levels of nitrate. New Phytol. 1986;102:551-562.
26. Schmutz P, Tarjan D, Günthardt-Goerg MS, Matyssek R, Bucher JB. Nitrogen dioxide-A gaseous fertilizer of Poplar trees. Phyton. 1995;35:219-232.
27. Qianqian Sheng, Zunling Zhu. Effects of Nitrogen Dioxide on Biochemical Responses in 41 Garden Plants. Plants. 2019;8:45., DOI: 10.3390/plants8020045
28. Marshall FM, Ashmore MR, Hinchcliffe F. A Hidden Threat to Food Production: Air Pollution and Agriculture in the Developing World. Gatekeeper Series No. SA 73. International Institute for Environment and Development, London, 1997.
29. Darrall NM. The effect of air pollutants on physiological processes in plants. Plant Cell Environ. 1989;12:1-30.
30. Ashraf M, Harris PJC. Photosynthesis under stressful environments: An overview. Photosynthetic a. 2013;51:163-190.
31. Aminifar J, Ramroudi M. Ecophysiological aspects of environmental pollutions on growth of plants. Appl. Sci. Rep. 2014;8:99-10.
32. Gilbert OL. Bryophytes as indicators of air pollution in the Tyne Valley. New Phytol. 1968;67:15-30.
33. Guderian R. Air pollution: Phytotoxicity of acidic gases and its significance in air pollution control, Vol. 92. Springer Science & Business Media. Berlin, 2012, 11-40.
34. Gheorghe IF, Ion B. The Effects of air pollutants on vegetation and the role of vegetation in reducing atmospheric pollution. The Impact of Air Pollution on Health, Economy, Environment and Agricultural Sources. Intech Publisher, Shanghai, China, 2011, 256-259.
35. Haworth M, Elliott-Kingston C, Gallagher A, Fitzgerald A, Mcelwain JC. Sulphur dioxide fumigation effects on stomatal density and index of non-resistant plants: implications for the stomatal palaeo-[CO_2] proxy method. Rev Palaeobot Palynol. 2012;182:44-54.
36. Heather G. Effects of air pollution on agricultural crops. Ministry of Agricultural, Air Pollution on Agricultural Crops. Ontario, 2003, 85.
37. Heber U, Hueve K. Action of SO_2 on plants and metabolic detoxification of SO_2. Int Rev Cytol. 1997;177:255-286.
38. Hetherington AM, Woodward FI. The role of stomata in sensing and driving environmental change. Nature. 2003;424:901-908.
39. Knabe W. Effects of sulfur dioxide on terrestrial vegetation. J Hum Environ. 1976;5:213-218.
40. Khan MR, Khan MW. The interaction of SO_2 and root-knot nematode on tomato. Environ Pollution. 1993;81:91-102.
41. Mcainsh MR, Evans NH, Montgomery LT, North KA. Calcium signalling in stomatal responses to pollutants. New Phytol. 2002;153:441-447.
42. Rao IM, Amundson RG, Alscher-Herman R, Anderson LE. Effects of SO_2 on stomatal metabolism in *Pisum sativum* L. Plant Physiol. 1983;72:573-577.
43. Raschke K. Stomatal action. Annu Rev Plant Physiol. 1975;26:309-340.
44. Robinson MF, Heath J, Mansfield TA. Disturbances in stomatal behavior caused by air pollutants. J Exp Bot. 1998;49:461-469.
45. Swanepoel JW, Krüger GHJ, Van Heerden PDR. Effects of sulphur dioxide on photosynthesis in the succulent Augea capensis Thunb J Arid Environ. 2007;70:208-221.
46. Singh RP, Tripathi P, Kumar A, Gupta A, Singh K. Effect of SO_2 on chlorophyll content and leaf temperature on leaves of potato (*Solanum tuberosum* L.) genotypes. University of Agriculture and Technology, Kumarganj, Faizabad, India, 2013, 224-229.
47. Thomas MD, Hill Jr GR. Absorption of sulphur dioxide by alfalfa and its relation to leaf injury. Plant Physiol. 1935;10:291.
48. Treshow M. Air Pollution and Plant Life. John Wiley and Sons, New York. 1984, 239-280.
49. Verma A, Singh SN. Biochemical and ultra-structural changes in plant foliage exposed to auto-pollution. Environ Monit Assess. 2006;120:585-602.
50. Ziegler I. The effect of SO_3 on the activity of ribulose-1, 5-diphosphate carboxylase in isolated spinach

chloroplasts. Plantae. 1972;103:155-16.
51. Naresh Kumar S, Agarwal PK. Climate change and coconut plantations in India: Impacts and potential adaptation gains. Agricultural Systems. 2016;117:45-54.
52. Srinivasa Rao, NK Laxman RH, Bhatt RM. Impact of climate change on vegetable crops. (In) Challenges of Climate Change in Indian Horticulture. Singh HP, Singh JP and Lal SS (Eds.). Westville Pub. House, New Delhi, 2010, 113-23.
53. Wheeler TR, Ellis RH, Hadley P, Morison JIL, Batts GR, Daymond AJ. Assessing the effects of climate change on field crop production aspects. Applied Biology. 1996;45:49-54.
54. Wurr DCE, Hand DW, Edmondjon RN, Fellows JR, Hannah MA, Cribb DM. Climate change: a response surface study of the effects of the CO_2 and the temperature on the growth of the beetroot, carrots and onions. Journal of Agriculture Science, Camb. 1998;131:125-33.