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Impact of air pollution on plant growth and yield

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ABSTRACT

Effect of common pollutants like SO_2, NO_x, SPM etc. on the growth of plants and their yield is discussed. Vegetation as a mitigating agent as well as a biological indicator of pollution are presented. Effects of pollutants singly and synergistically are also discussed.

Key words: Air pollution, Vegetation,Pollutants

Climate, soil composition and man influence the plant growth. Plant requirements for optimal growth are light, air, temperature for the aerial parts and water, nutrients and soil for the subsoil parts. The climatic parameters that influence crop growth are temperature, soil moisture, air, light and wind. Human influences on crops are plant selection, land use, cultural practices, water and air pollution.

Air pollution and vegetation

Plants are relatively more sensitive to pollutants compared to man and animals as they remain stationary and continuously get exposed to environmental pollution stresses. The factors involved in air pollution effects on vegetation are i) environmental factors - temperature, humidity, radiation, oxidation and wind and ii) edaphic or biotic factors - structure, carbon, acidity, microbes and minerals. The effect of pollutants on plants depends upon the dose - combination of pollutant concentration, duration of exposure each time and number of exposures if any. Gaseous pollutants diffuse into leaves through stomata, though small amounts are also absorbed from the cuticle itself. Pollutants cause extensive losses to plants leading to often irreversible changes in the ecosystem. Vegetation injury due to air pollution commences with foliar lesion, phytomass and impairment in reproduction and regeneration. This is followed by canopy change viz., open shrunken asymmetrical canopy and defoliated branches. Further impacts are gradual elimination and disappearance of plant species, injury to ground cover of herbs and shrubs. In most of the plants, leaf areas collapse under intense exposure to pollutants. Pollutants discolour foliage, irreversibly change the chlorophyll molecule into a photosynthetically inactive pigment incapable of making any food for the plant. Thus, crops exposed to pollution suffer reduction in root and shoot lengths, number of leaves per plant, biomass, productivity, number of grains per spike and yield response to pollutants depends upon its age, geographical location in relation to pollution, source/sinks, cultural practices followed, pests and diseases, soil, microclimatic conditions and above all the concentration and duration of exposure to pollutants. Some plants are sensitive while other are resistant/tolerant. Tolerant species serve as sinks of pollution hence are used as greenbelts around industries. Sensitive species serve as bio-indicators of pollutants.

Light, adequate moisture supply to the root system, high relative humidity and moderate temperatures induce stomata to open for maximum food production which also predispose the plant to maximum absorption of pollutants and consequent injury. Most plants that close their stomata at night are much more resistant at night than the daytime to pollutants. With adequate moisture supply in the day time and particularly with high relative humidity, the stomata will open and susceptibility to pollutants will approach the maximum. The relative resistance of a plant is 10 times more when the relative humidity is 1 per cent than when it is 100 per cent. For the same relative humidity during the whole day injury will be slight in the early morning, increases rapidly to a maximum at about 11 a.m., then it will fall off appreciably until mid-afternoon and decreases rapidly to low values or even to zero in the late afternoon.

***So_2* - chlorophyll interaction**

The effect of SO_2 on chlorophyll is considered under two cellular pH conditions i.e. pH values < and > 3.5. At pH 2.2 to 3.5 the free H^+ ions generated in the cell from the splitting of H_2SO_3 into SO_3^{-2} and H^+, displace the Mg^{2+} from chlorophyll molecule to degrade them into "phacophytin" molecule - a chlorophyll degradation product which does not help the continuation of the normal photosynthetic process. At pH > 3.5, SO_2 reduces the level of chlorophyll pigment in the cell and affects the photosynthetic ability of the plant. When the chlorophyll pigment is injured the production potential of plants is reduced.

SO_2 gas diffuses into the leaves mainly through the stomata, however small amounts are also absorbed through culticle itself. Depending upon the concentration and duration of exposure (dose) plant response to SO_2 can be :

i) Acute: This is caused by rapid absorption of SO_2 concentration > 1 ppm for short periods. In acute injury most of the plant leaf areas collapse under intense exposure to SO_2. Initially affected areas appear dull or water-soaked later on changing to whitish yellow colour due to bleaching and drying. In some species infected leaf areas appear brown or brownish red in colour. Exposure to sub-lethal concentrations of SO_2 causes yellowing of green leaves.

ii) Chronic: This is due to prolonged exposure to SO_2 concentrations > 0.2 to 1 ppm for several days/weeks. Chronic cases resemble the chlorotic symptoms of higher plants. The affected areas may later on change to a brownish red colour. The chronic symptoms may start slowly with bleaching of chlorophyll until most of the pigments are destroyed and the interveinal leaf areas are nearly white. SO_2 irreversibly changes chlorophyll molecule into a photosynthetically inactive brown pigment called "phacophytin". Leaf tissues may not collapse at this stage, but by this time the leaf itself may be ascribed as lost.

iii) Physiological and /or biological injury:

Several studies have been made in India and abroad on the effects of various air pollutants on several plant characteristics at different stages of growth. Greengram sprayed with petro coke has reduced root and shoot length, number of leaves, nodules, flowers and pods and leaf area per plant, ascorbic acid, protein, carbohydrates and calorific values. The reduction increased with the age of the plant, total chlorophyll, biomass productivity and energy in the petro vapour treated spinach decreased with dose as well as with age of plant. Of all the parameters productivity was reduced maximum followed by loss in total chlorophyll.

Sensitivity and tolerance of plants depend upon geographical location, climate, plant stage of growth and maturation. Most sensitive are fodder plants (Clover type) and moderately sensitive are wheat, leafy vegetables, beans, strawberries, roses etc. Least sensitive are root crops and cabbage.

The environmental factors which aid SO_2 injury are sunlight, moderate temperature, high relative humidity, wind, adequate soil moisture, time and day of the season and plant factors like genotype, nutrition, stage of growth and tissue maturation.Plants in active growth months and with open stomata are the most susceptible to injury.

Oxides of nitrogen (NO_x)

These are NO_x and NO_2. Injury due to NO_2 is similar to that of SO_2. 120 day old wheat plants exposed to SO_2/NO_2 and simultaneously to SO_2 and NO_2 showed reduction in chlorophyll, root and shoot length, biomass and net primary productivity in all the cases; highest being in the case of NO_2 followed by SO_2. Synergistic effects are lower than either of the above pollutants individually.

Dust

Coal dust reduced drastically the rate of fruit production and yield (92 - 98%) in mango and lemon trees. Cement dust on 120 day old cotton plant reduced plant height, stem width, number of leaves and bolls per plant and chlorophyll content considerably. Also cement dusted wheat,soybean plants at various stages of growth showed reduction in plants at various stages of growth showed reduction in chlorophyll. Number of tillers/leaves/ears and photosynthetic area per plant, root and shoot length, transpiration, phytomass and net primary productivity decreased at all stages and doses but comparatively higher at later stages of crop growth. Urban dust also has similar effects.

Vegetation is a potential sink of Suspended Particulate Matter (SPM). SPM in the atmosphere varies in size from a few microns to several hundred microns. The origin could be either from industrial or vehicular sources or from natural sources like the bare soil surfaces. Where there is no industrial or vehicular source, it could be local particularly domestic or agricultural source. In urban areas dust pollution from fallow lands where the soil is directly exposed to strong winds and intense solar radiation can be mitigated by vegetation such as growing lawns and grassy surfaces. Wetting the soil or growing tall evergreen trees with large foliage also reduces the SPM levels. It lowers the temperature of ambient air below the canopy as well as above the canopy. Lowering the temperature below the canopy inhibits turbulence and prevents dust raising from the soil into the air. Evapotranspiration from the canopy lowers the ambient air temperature above in relation to the surroundings hence vegetation acts as a sink of pollution. SPM gets deposited on the leaf surfaces which are slightly greasy, cool and moist and these features prevent the dust from re-entrainment into the atmosphere. The larger the greener area, the greater will be the reduction of SPM from the ambient air. Paving the roads and planting evergreen perennial tall trees on both sides of the roads reduces the SPM level. Plumes which pass over these vegetated areas descend down and SPM could be deposited on leaves of tall trees. Vegetation can filter out dust, soot, smoke and any other fine particulate matter present in the air. The dust collecting effectiveness of plants depends upon the morphological trends of leaves such as epidermal and cuticular features, surface geometry, orientation, size and area of leaf etc. Evergreen plants with horizontally spread leaves are very good dust collectors. Also evergreen trees with simple leaves having rough and hairy surface are better dust collectors. Upper leaf surface collects most of the dust particles though lower leaf surface also plays an important role in dust collection. For dust abatement purposes, the fast growing, hardy and pollution tolerant perennial and evergreen species of trees/plants with limited water requirement and which remain generally ungrazed are best suited. Green belts reduce air pollution from area sources of pollution such as a metropolis or controlled marginal emissions from large point sources such as super thermal power plants.

Vegetation can reduce SPM of 120 $\mu g\ m^{-3}$ for a distance up to 200 m. Also plants accumulate dust at different sites from 10 g m^{-3} in relatively clean areas to 119 g m^{-3} in heavy traffic density areas. In London's Hyde Park, a green area of about 1.5 Km^2 in the centre of London reduced the smoke concentration by 27 per cent.Effects of Ozone, PAN, Flourides and synergistic effects of O_3 and SO_2area also similar to those reported above.

Aesthetic effects

Pollution discolours foliage reducing visual attraction hence value and marketability of fruits, vegetables, flowers and ornamental plants. At high SO_2 concentrations morphological damage occurs. Trees suffer more than the shrubs and herbs.

Beneficial effects of pollution on crop yields

Land with 20 to 50 Kg of S ha^{-1} gives good yields. Unfertilized forests need 15 Kg $ha^{-1}yr^{-1}$ for new growth. Natural sources supply 10 Kg $ha^{-1}yr^{-1}$ on a global scale. Absorption of 40 $\mu g\ m^{-3}$ on an average by barley/wheat leaves indicate 20 Kg $ha^{-1}yr^{-1}$. This assumes that all this S in the air if scavenged is considered sufficient for a large number of crops. Continuous fumigation of crops with SO_2 < 400 $\mu g\ m^{-3}$ increased yield. At higher concentrations duration of exposure should be controlled to avoid damage.

To avoid damage the following expression is used

$(C - 400)\ t = 1700\ \mu g\ m^{-3} yr^{-1}$

where

C = actual concentration $\mu g\ m^{-3}$, t = time in hours.

400 $\mu g\ m^{-3}$ is 10 times higher than that needed as fertilizer i.e. adequate margin exists between beneficial and damaging concentrations. Plants grown under deficiency of S or N are less susceptible to damage by high concentration SO_2 than was normal. They give higher yields than those growing under optimal nutritional conditions. Likewise, crops under certain deficiency conditions are less susceptible to O_3 damage. O_3 has beneficial effect by increasing root development. CO_2, NO_2, NH_3 and certain other trace metals increase crop yield besides SO_2.

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