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Plants As Indicators Of Environmental Pollution

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ABSTRACT: Every organism is the product of its genetic makeup and the environmental conditions (G x E), thus representing a measure of its environment. Plant indicators are the plants that represent a measure or index of the environment. Thus, plants which indicate some very specific conditions of the environment are called plant indicators. When a plant species or plant community acts as a measure of environmental conditions, it is referred to as biological indicator or bioindicator or phytoindicator.

KEYWORDS: plant indicators, phytoindicator, bioindicator, genetic makeup, index, environment, measure

I.INTRODUCTION

In this regard: 1. Dominant plant-species can prove better environmental indicators (bioindicators) as they experience full impact of the habitat environment over a long period. 2. Similarly, large species (spread over the large spectrum of the environment) may sever as better bioindicators than small species. 3. For the same reason, species populations and whole communities are more reliable than single species. The knowledge of plant indicators can be helpful to determine local soil, thus it can be decided which crops should be cultivated in a particular soil and which soil should be left for pasture or other purposes. Plant indicators are also used to determine optimum use of land resources for forest, pasture, and agricultural crops. Many plants also indicate the presence of particular mineral or metal in the environment. So, the presence of precious metal can be detected by the prevailing growth of the specific plant in an area. Plants that serve as bioindicators of some characteristic type of environmental conditions can be grouped.[1]

Plant indicators for agricultural possibility and soil characteristics Many plant indicators can help us to decide whether the soil is suitable for agriculture or not. Prevailing growth of particular crop plants is examined under different environmental conditions and if growth is satisfactory in a particular soil that soil is considered to be suitable for agriculture. [2]For example, growth of the short grasses indicates the water scarcity in the soil. Similarly, natural growth of tall and short grasses indicates that the soil is fertile and is also suitable for agriculture[3]

Plant indicators for land productivity Forests are good indicators of land productivity. For example, vegetative growth of forest tree species likes Quercus (Q. marilandica, Q. stellata) is low on infertile lowlands or sterile sandy soil. Plant indicators for climate Specific characteristics of plant communities of a particular region may provide information regarding the climate of the area concerned. For example: 1. Evergreen forests indicate high rainfall in winter as well as in summer[4]. 2. Sclerophyllous vegetation (plants with hard leaves and heavily cutinized epidermis) indicates heavy rainfall in winter and low during summer. 3. Xerophytic vegetation (plants that grow under scarcity of water) indicates very low or no rainfall throughout the year. 4. Grasslands indicate heavy rainfall during summer and low rainfall during winter. Plant indicators for petroleum deposits Some protozoans like Fusilinds indicate petroleum deposits in the soil. Plant indicators for water pollution 1. Populations of aquatic plants like Utricularia, Chara and Wolfia indicate the polluted water (water pollution) 2. High population of bacteria Escherichia coli in water also indicates water pollution. 3. High population of diatoms in water indicates water pollution by sewage 4. Movement of fishes like Catla catla, [5]Labeo gonius and Notopterus notopterus away from water indicates Industrial pollution of water. Plant indicators for ground-water depth Certain plant communities indicate the depth of ground water. Central Arid Zone Research Institute (Jodhpur) has made the use of certain plant communities to indicate the depth of ground water and level of salinity in the groundwater. Chatterjee and Bhaskar (1977) have listed the plant communities as ecological indicators for ground water in Indian deserts[6]

Plant indicators for overgrazed situation

Many plants are overgrazed, which result in modification of grassland. By overgrazing, the grasses are removed, while others are disturbed and forage production[7] is considerably reduced. However, some plants, which are vigorous and undisturbed; they remain viable and become distinct from rest of the plants. Thus, some plants show characteristic indications of overgrazing, which can be recognized. For example,[8]

The predominance of annual weeds and short-lived impalatable perennials indicate severe grazing. Examples of such plants are Polygonum, Chenopodium, Lepidium and Verbena. 2. Some plants are less pronounced and show poor or no

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overgrazing. Examples of these plants are Opuntia, Grindelia, Vernonia, etc.[9] Plant indicators of forest types Some plants indicate the characteristic types of forest; they grow in an area, which is not disturbed. If we know that particular forest plants grow better in certain area of specific soil, the productivity can be increased. Forest plants, given below exemplify it well: 1. Narenga porphyrocoma is a grass, which binds the soil. In such a soil, sal (Shorea robusta) can be cultivated. 2. Viola species in western Himalayas is a suitable indicator for plantation of Cedrus deodara and Pinus wallichiana. 3. Similarly, Quercus stellata [10]and Quercus mariandica grow on upland, lowland or on sterile sandy-soils. After the forest destruction due to fire, overgrazing or by other environmental factors, if the area is left to reach up to climax, subdominant species get favourable chances for growth and survival. This can indicates the future plants to grow and establish the particular forest species. Plant indicators for soil humus status Some plants act as humus indicators. Monotropa, Neottia and mushrooms indicate the presence of humus in soil. Strobilanthes and Impatiens species indicate the presence of high humus or litter in the soil, which prevents regeneration of tree species, indicating that in such area the forest growth must be incompatible with soil-humus status[11].

Plant indicators for soil moisture status Plants, which prefer to grow in arid (dry) area, indicate the poor or very low moisture content in the soil. Sacchamm munja, Acacia nilotica, Calotropis, Agave, Opuntia, and Argemone are such plants. Some other Examples of the plants, [12]which indicate soil-moisture status, are: 1. Some plants (such as Citrullus colocynthis) grow in low levels of soil moisture. 2. Eucalyptus lowers the water table, indicating low level of water table. Similarly, Echinops echinatus and Cassia auriculata are found in the area of deep water table. 3. Typha, Phragmites, and Vetiveria grow in water-logged soil. 4. Growth of Typha, Phragmites, Juncus and Carex indicates the swampy condition. 5. Mangrove vegetation and Polygonum are found in water-logged saline soils. Plant indicators for soil texture-type Many plants indicate the characteristic soils. For example, 1. Casuarina equisetifolia, Ipomoea pes-caprae, Citrullus colocynthis, Calligonum polygonoides, Lycium barbarum and Panicum grow in sandy soil. 2. Sacchamm munja prefers to grow in sandy-loam soil. 3. Imperata cylindrica and Vetiveria zizanioides grow on clayey soils. 4. Cotton prefers to grow in black soil. Plants indicators for soil reaction Many plants indicate whether the soil [13]is acidic or basic (soil pH condition). For example, 1. Rumex acetosa, Rhododendron, Polytrichum and Sphagnum indicate acidic soils. 2. Many forest trees, such as Shorea robusta and Pinus roxburghii, grow in calcium rich soils. 3. Tectona grandis (teak), Cupressus torulosa, Ixora parviflora and Taxus baccata are calcicoles (plants growing in lime-rich soil). 4. Some mosses e.g. Tartulla and Neckera grow on lime stones. 5. Halophytes, such as Suaeda fruticosa, Tamarix auriculata, Salicornea, Chenopodium, and Salsola foetida, grow in salty soil. Plant indicators for minerals Many plants indicate the presence of characteristic minerals in the soils. These plants are called metallocoles or metallophytes.[14]

II.DISCUSSION

Besides, certain plants can be used for biochemical mining of metals (e.g. it was discovered in Turkey that Helichrysum Arenarium plants contain silver and gold in the leaves (ICCESEN, 2016). The mineral content in a plant-tissue can be employed as pollution indicator, using specific plants. For example: 1. Olearia rani can be used as indicator of molybdenum [15]in the soil (Lyon and Brooks, 1969). 2. Sulphate content of Myoporum pictum leaves can be directly related to SO2 concentration in air (Al-Jahdali & Bin Bisher, 2008). 3. High sulphur content in pine needles indicates high SO2 concentration of in the atmosphere (Farrar, 1977). 4. Fluoride content in Sorghum vulgare leaves indicates the distance up to which air pollution by a fluoride source can fall out and this distance may be up to 4 km. 5. In some cases, higher copper content in plants may be due to high tension copper wires. 6. Mercury concentration in Festuca rubra grass may be due to the set-up of chloroalkali (used in electrodes) plant (Henry, 2000). 7. Lead in leaves may increase due to automobile exhaust (Smith, 2008). Plant indicators of fires Some plants are well adapted to grow in burnt and highly disturbed areas, for example, Agrostis hiemalis, Epilobium spicatum, and Populus tremuloides [16]are such plants. Also, the fern Pteris aquilina and fungus Pyronema confluens grow in areas affected by fire. Indicators of petroleum deposits Some protozoans, as Fusilinds indicate petroleum deposits in the area. Plant indicators for environmental pollution The use of vegetation as biological indicator of environmental pollution has a long history. Plants grown in industrial or thickly populated areas indicate specific resistance to the pollutants prevailing in those areas. Species differ in sensitivity to pollutants. In general, plants are more sensitive to pollutants than humans.[17] Therefore, plants can be used for the bio-indication of environmental pollution. Sensitive species can serve as indicators and resistant species as accumulators, which collect large amount of pollutants without any damage. Mosses, lichens and some fungi are much sensitive to SO2 and also to the halides [such as fluoride (F^-), chloride (Cl^-), bromide (Br^-), iodide (I^-) and astatide (At^-)]. Even 1% SO2 concentration is harmful to higher plants. Factually, lichens do not survive in areas exposed to SO2 for long time. Many chemicals, fertilizers, pesticides and fossil fuels release toxic substances into the environment that are taken up by the plants from air, water, and soil. Atmospheric pollutants, particularly SO2 halides (HF, HCl), Ozone and Peroxiacetyl-nitrate (PAN), produced from automobiles, industrial units and strong radiations, are dangerous to plants. Harmful substances that reach the plant through the air

are SO2, nitrogen oxides, hydrocarbons, dust, and smoke. Plants growing in water are severely affected by toxic chemicals like cyanide, chlorine, hypochlorate, phenols, benzyl derivatives and heavy-metal compounds of sewage. The effects of different kinds of pollution can be determined by the nature of pollutants, their concentrations and the period of exposure. Under exposure to high concentration,[18] plants suffer acute injury with externally visible symptoms, such as chlorosis, discolouration, necrosis and death of entire plant. Besides morphological changes, biochemical, physiological and fine structural-changes also occur in plants. To exemplify, the Pollution damage can be recognized by: 1. The accumulation of toxic material in the plant 2. Changes in soil or water pH 3. Reduced or increased activity of certain enzymes 4. Increase in compounds with SH groups and phenols 5. Low level of ascorbic acid in the leaves 6. Depression of photosynthesis 7. Stimulation of respiration 8. Low production of dry matter 9. Changes in membrane permeability 10. Disturbances in water balance 11. Reduced fertility under prolonged exposure 12. Disturbances in plant metabolism (due to chronic injury) 13. Reduced productivity, yield and quality 14. Altered structure of wood 15. Drying out of branches and gradual death of plants [19]The symptoms of pollution-affected plants are varied and unspecific. A particular pollutant affects different plants in very different ways and a particular symptom can be produced by a variety of substances. The influence of external factors (pollutants) on plants depends on the species, stage of development and the organ or tissue involved. Morphological alteration of a plant and floristic composition of a plant community are commonly used to indicate changes in the environment. According to Van Haut and Stratmann (1970), visible plant symptoms are most commonly used to indicate the responses of plants to pollutants. In this regard, Jacobson and Hill (1970) have studied the effects of common pollutants on plants. It is possible that any plant-part, if it responds specifically or characteristically to a pollutant, can be used plant indicator for the particular pollutant.[20] Number and kind of biological indicators can be subdivided in order of decreasing biological complexity, such as organism, organ, tissue, cell, cell-free preparation and enzymatic studies (Goldstein, 1974). M.U. Beg (1980) from Industrial Toxicology Research Centre (Lucknow) has reported the plant-responses to pollutants as a biological indicator, taking several parameters into consideration. Also, attempts have been made to use certain structures and functions of plants as indicators of pollution stresses. Such plant responses (parameters) to pollution stress are listed below: 1. Seed germination 2. Growth of plant 3. Development of lateral branches 4. Expansion and colour changes in leaf 5. Flower and fruit formation 6. Discoloration of flower 7. Loss of physiological control 8. Mineral composition 9. Chemical constituents of cells 10. Enzymatic activity and 11. Pollen germination[21]

Seed germination has been used by many workers to monitor pollution by plant responses. Several growth parameters such as percentage of germination, seedling survival, seedling height, cotyledonary expansion and fresh and dry weight have been taken as criteria to assess plant response to a specific pollutant. Phaseolus vulgaris has been grown in smoke-free and smoke-affected regions to monitor the effect of smoke and it proved that Phaseolus vulgaris can be used as indicator for bad effects of smoke (Sorauer, 1899). The toxic effect of thiosulphate has been indicated as germination inhibiter in many plants. Houstan and Dochinger (1977) have evaluated germination inhibition in relation to pollution by sulphur dioxide and ozone. Similarly, the bad effects of lead, cadmium, NO and CO2 have been studied on many plants. Besides seed germination, pollen germination in Nicotiana sylvestris has been used to indicate pollution (Wolters, 1987). Some plant species are good indicators of pollution. In this regard, Polygonum, Rheum, Vicia, Phaseolus, and Capsella [22]have been observed as pollution indicators. According to Brandt (1974), a large number of plant species are capable of indicating specific contaminants. Some pollution-mediated changes in plant growth have been observed as given below: 1. Stunting (reduced vertical growth) of com, sweet potato and rye has been reported due to high toxicity of pollutants. 2. Reduction in root and shoot length, numbers of tillers, leaves, and ears and grains/ear in wheat have been reported under condition of cement dust pollution. 3. Reduction in plant height, and number of leaves and bolls per plant in cotton exposed [23]to particulate pollution. 4. Inhibition of lateral growth of forest trees is caused by lime stone dust. 5. Inhibition in growth of Pine trees has been noticed in SO2 polluted areas. It has been noticed that leaf is the most sensitive organ to pollution. The pollution indicator value of leaf has been exploited by many workers in response to a variety of changed environmental-conditions. Leaf injury is a characteristic symptom to various pollutants. Symptoms produced by ozone, oxides of nitrogen and chlorine are almost similar. The characteristic symptoms on leaves include: 1. alteration in pigmentation such as chlorosis, yellowing, necrosis, etc. 2. The leaves of dicotyledons generally exhibit spotted markings between the veins, while monocotyledons usually show necrotic streaks between parallel veins. 3. Injury may also occur along the leaf margin and tip.[24]

III.RESULTS

4. Reduced expansion of cotyledonary leaves in response to pollution has been observed in several cases. Recently, epidermal morphology has been studied as indicator of different pollutants especially SO2. Examples are given below: 1. Cuticular and epidermal damage can be used to indicate air pollution. 2. Dry weight of leaf, decrease in leaf thickness, cell size,[25] loss of leaves and early senescence may be due to smoke and SO2 pollution. 3. Yunus and Ahmad (1980) have observed that leaves in the polluted area of cement factory showed higher stomatal and trichome densities,

smaller epidermal cells and trichomes as compared to leaves obtained from unpolluted atmosphere. Biochemical and physiological changes Chemical composition of leaf has widely been used to indicate environmental conditions. Among the biochemical estimations, the most important parameter is pigment analysis. Chlorophylls a and b have been measured as index for response to different types of pollution. In Cassia and Cynodon, 5% reduction of chlorophyll has been observed, while in Saccharum the pigment is least affected. Chemical estimation like proteins, [26]amino acids, soluble sugars, sucrose, and starch, reducing sugars, vitamin C, riboflavin, thiamine and carbohydrate are also used to indicate foliar sensitivity to air pollution. 1. Physiological activities, such as opening of stomata and rate of photosynthesis can also be used as indicators of pollution. 2. Photosynthesis as a pollution-response parameter has been used for mixed exposure of SO2, NO2 and dust. 3. Enzymatic parameters are also used to indicate the presence of particular pollutant. For example, enzyme Peroxidase was found to be most sensitive indicator of pollutants in the absence of visible injury. 4. Kellar (1974) and Jager (1975) have reported a differential response of enzymes in areas affected by fluoride, automobile pollution and SO2. Thus, on the basis of enzyme activity, the susceptible species of plants can be identified. Many workers have reported that enzymatic activity has been related to air pollution. Other common enzymatic parameters used are ribulose diphosphate carboxylase, glutamate-pyruvate transaminase, glutamateoxaloacetate transaminase and peroxidase for SO2 pollution. Plants can be effectively used as cheap and naturally-occurring monitoring systems or bioindicators of air, [27]soil and water pollution in an area. Bioindicators are the organisms, which in their presence or absence and in all features of their phenotype or physiology, serve as an index of the environmental status. Both positive and negative aspects of the environment can be monitored through bioindicators. A bioindicator provides quantitative information on the quality of the environment without examining the exact physical or chemical process responsible for the environmental toxicity. A good plant indicator not only indicates the presence of the pollutant in the environment but also it provides information about the amount and intensity of the pollutant-exposure to plants. Plants, as bioindicators (plant indicators), are used to determine: 1. How various conditions in an environment have changed over time 2. The health of an environment or ecosystem 3. The cumulative effects of different pollutants in the ecosystem 4. How long the pollutant(s) may have been present in the environment Realizing the need of biological monitoring of the environment, the International Union of Biological Sciences (IUBS) decided in its 21st general assembly meeting held in Ottawa (1982) to initiate worldwide programme for identifying and applying the biological indicators in environmental monitoring, particularly to evaluate the effect of hazardous substances[44] on ecosystems. The type and concentration of a pollutant can be reliably set up by various characteristic damage symptoms produced in the plants; [28]such damage symptoms are pollutant-specific as well as concentration-specific. For example, changes in young needles of Pinus indicate the atmospheric pollution as given below: 1. Chlorosis indicates SO2 pollution 2. Necrosis indicates HF pollution 3. Bleaching indicates NO2 pollution 4. Chlorotic mottling indicates[43] Cl2 pollution in the atmosphere. Certain precautions need to be taken while using plants as pollution indicators. Such as: 1. Damage symptoms in plants should preferably be studied in the local or native species. Cultivated and introduced species should be avoided. 2. The species, sensitive to pollutants, should be first identified in the local flora and then used for pollution monitoring. Tolerant species should be avoided in such work. 3. Damage symptoms due to a particular pollutant should be studied in different species sensitive to that pollutant so that presence of the pollutant in the area may be cross-checked. For example, grey necrosis in Geranium, ivory necrosis in Zinnia,[29] brown necrosis in Chrysanthemum and reddish necrosis in Azalea indicates the undoubted presence of SO2 pollution in the area. 4. Many types of damage symptoms, (viz. morphological, anatomical, ultrastructural, [42]physiological, biochemical, etc.) should be studied in one or more sensitive plant species to ascertain the presence of a particular pollutant in the area. 5. Samples should be taken from as many different sites in the area as possible.[30]

IV.CONCLUSIONS

6. The possibility of damage symptoms in plants, occurring due to some cause other than pollution, (e.g. due to pathogen, environmental condition or nutritional deficiency / excess) should be thoroughly checked and ruled out. [41]Important characteristics of plant species[31] used in pollution monitoring The plant species used to monitor pollution in an area should have certain important features, such features: 1. The species should be easy to identify in the field and easy to handle for damage analysis. 2. The species should have a wide range of distribution so that it can be used in different areas. 3. The species should be sensitive to many types of pollutants[32] so that it can be used to monitor different types of pollutants in the area. 4. The species should produce highly specific damage symptoms in response to particular types and concentrations of pollutants. [40]Pollution parameters regarding plant indicators/monitors For monitoring the environment, changes in the species composition of vegetation and distribution pattern of populations in the area are studied. Such studies indicate the type and concentration of pollutant(s)[33] concerned as well as the spread of pollution problem in the area. Following may be the pollution parameters for plant indicators: 1. Decrease in the densities of sensitive species and increase in the density of tolerant species. 2. Absence of highly sensitive species Changes in microbial systems Microbes are rapid detectors[34] of environmental pollution both in water and soil. Microbes, sensitive to some pollutant get eliminated, while those tolerant to that particular pollutant flourish well.

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Thus, elimination or abundance of certain microbe species can indicate the environmental change. Thus, alteration in microbial communities and reduction in species diversity of microbes may be the result of the presence of specific toxic agents[35]. 1. Microbial muds from continental and intercontinental water bodies serve as ideal pool for detecting several compounds, including sulphur. 2. Likewise, petroleum belts and sediments are used to detect polar lipids of Archaebacteria. 3. Salmonella typhimurium, other Bacteria and Fungi[39] (e.g. Neurospora and Aspergillus) provide excellent device for monitoring the genetic effects of physical and chemical agents. 4. Bacteria, like Escherichia coli and the bacterial species of Vibrio, Aeromonas, Pseudomonas, Clostridium, and Streptococcus are used in assessment and prediction of changes in marine environment[36] induced by human activities. 5. Cyanobacteria (blue-green Algae) are used as bioindicators of soil pesticides. For example: Nostoc microscopicum and Hapalosiphon welwitschii indicate pollution by pesticides (e.g. the following pesticides: Dithane, Deltan, Aldrex, BHC, Rogor, Phorate, etc.). 6. Various Algae are excellent monitors of water pollution. For example: (a) Ulva and Enteromorpha are used to monitor the water quality of estuaries. (b) Cladophora (heavy-metal sensitive alga) and Stigeoclonium (heavy-metal tolerant alga) get totally perished and flourish, respectively, in polluted environments, thus indicating the heavy-metal toxicity in the environment. [37](c) Chlorella alga is used to monitor toxic substances in water bodies.[38]

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