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ROLE OF PHOTOSYNTHETIC PIGMENTS AS INDICATORS OF AIR POLLUTION

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Plants are very sensitive to gaseous and particulate pollution and these can be used as indicators of air pollution. Air pollution can alter the physiological processes of plants, thereby affecting growth patterns. Photosynthesis is known to be one of the most stress-sensitive processes and it can be completely inhibited by stress. Changes in chlorophyll (Chl.) and carotenoid content were investigated in the selected plant species exposed to automobile pollution growing along road side of high traffic prone zones of Mehdipatnam. In the present investigation changes in chl. 'a', 'b', total chl. and carotenoids in the leaves of *Amaranthus viridis, Euphorbia hirta* and *Oxalis corniculata* collected from polluted zones was observed. The present study also suggests that plants have the potential to serve as excellent quantitative and qualitative indices of pollution levels.

Keywords: Air pollution; Carotenoids; Chlorophylls; Photosynthesis.

Introduction

Natural materials such as dust, pollen, fibers and salt are important components of air pollution. But industrialization and urbanization have contributed to the problem by adding carbon particles, metallic dust and oil droplets. In urban environment, a large percent of the pollution comes from automobiles. All combustion release gases and particulates into the air[1] and these include sulphur and nitrous oxides, carbon monoxide and soot particles, toxic metals, organic molecules and radioactive isotopes[2]. Plants growing in polluted zones are affected greatly due to exposure to a variety of pollutants[3]. Ambient level of air pollution has been shown to affect stomatal conductance, photosynthesis and root morphology of beech plants[4]. One of the most recent studies of these stresses was dust accumulation, which provokes severe damage in the photosynthetic apparatus[5].

The crops are very sensitive to gaseous and particulate pollution and these can be used as indicators of air pollution[3,6]. Plants provide enormous leaf area for adsorption, absorption and accumulation of air pollutants to reduce pollution levels[7].

Air pollution can alter the physiological processes of plants, thereby affecting growth patterns[8] cause damage to leaf cuticles and affect stomatal conductance[8-11]. They also have direct affect on photosynthetic system[8, 11-13]. Photosynthesis is known to be one of the most stress-sensitive processes and it can be completely inhibited by stress before other symptoms of the stress are detected[14]. Chlorophyll content of plant signifies its photosynthetic activity as well as the growth and development of biomass[15]. The photosynthetic pigments like chlorophyll 'a', 'b', total chlorophyll and carotenoids decreased in the plants growing in polluted areas[16-28].

The main aim of the present study is to provide an assessment of the use of chlorophylls and carotenoids as indicators that can be used for air quality monitoring in urban areas in Hyderabad.

Material and Methods

Hyderabad, a Deccan plateau region of Telangana exhibits a semi arid type of climate. During the study period the mean daily maximum temperature was 36 ± 2°C and mean daily minimum temperature was 22 ± 2°C. The annual mean humidity was 47%. The air environment of this region is contaminated with different concentrations of SO_2, CO_2 and NO_2. The major source of pollution in this region is automobile exhaust.

Plants like *Amaranthus viridis, Euphorbia hirta* and *Oxalis corniculata* were selected from the highly polluted zones of Mehdipatam and the chlorophyll and carotenoid content was estimated. The fully matured leaves were collected from the selected plants in the morning hours from four different zones from the road side and were taken to the laboratory in an ice box and were stored in a refrigerator for further study. Utmost care was taken to see that the plants had isoecological conditions.

Estimation of chlorophylls and carotenoids:

Table 1. Variation in chlorophyll pigments in three different plant species.

Plant species	Chlorophyll 'a' (mg/g.fr.wt.)			Chlorophyll 'b' (mg/g.fr.wt.)			Total chlorophyll (mg/g.fr.wt.)		
	P	C	± %	P	C	± %	P	C	± %
Amaranthus viridis	1.389	1.558	- 10.84	0.683	0.521	+31.09	2.503	1.802	+38.90
Euphorbia hirta	2.22	0.759	+192.4	0.739	0.261	+183.14	2.961	1.021	+190
Oxalis corniculata	0.083	0.649	-87.2	0.085	0.398	-78.64	0.168	1.160	-85.51

P = polluted site, C = Control site, ± % indicates percent increase or decrease in percent increase or decrease over control.

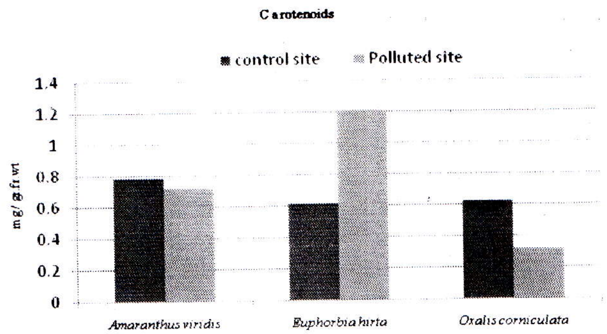

Fig.1. Variation in Carotenoid content in three different plant species.

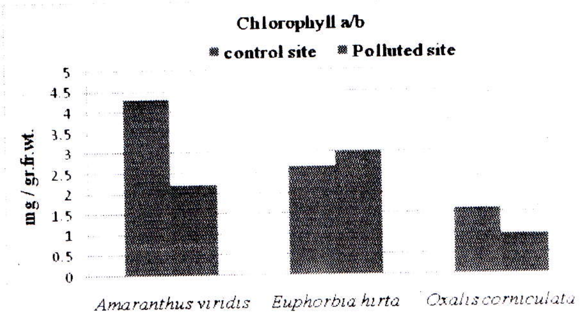

Fig.2. Variation in Chl.a/b ratio in three different plant species.

Chlorophylls were estimated by Arnon method[29]. 200 mg of fresh leaf material was taken in a mortar and ground finely with the help of a pestle using 10ml of 80% acetone. The supernatant was collected and utilized for chlorophyll estimation. Absorbance was read at 663, 645 and 470 nm in UV- spectrophotometer. The following equations were used for quantification of the total chlorophyll, chlorophyll a, chlorophyll b and carotenoids content in an 80% acetone extract:

Chl a (mg g^{-1}) = [(12.7 × A663) - (2.6 × A645)]

Chl b (mg g^{-1}) = [(22.9 × A645) - (4.68 × A663)]

Total Chl. = Chl a+ Chl b.

Carotenoids = 1000 A470 - 1.90Chl a - 63.14 Chl b/214.

Results and Discussion

Pigments are functionally important molecules in photosynthetic organisms. They not only harvest the light energy necessary for carbon reduction but some serve to protect the plants from excess stress.

Amaranthus viridis: The concentration of chlorophyll 'a'content in the leaves of *Amaranthus* at polluted site was recorded as1.389 mg/g.fr.wt. which was 1.55 mg/g.fr.wt. at control site. The concentration of chlorophyll 'b' of the leaves of *Amaranthus* collected at polluted site was 0.683 mg/g.fr.wt. and 0.521mg/ g.fr.wt. at control site. The polluted sample had 31.09% more chlorophyll b content as compared to control. Total chlorophyll content in the leaves of plants in polluted site was recorded as 2.053 mg/g.fr.wt.and 1.802 mg/g.fr.wt. in the control plant. There was an increase of 38.90%as compared to control (Table 1). The concentration of carotenoid pigments in the leaf sample from polluted site had 0.81 mg/g.fr.wt. and control site recorded 0.777 mg/g.fr.wt. 5.148% increase was recorded in the leaf sample from polluted sites (Fig. 1). The chlorophyll a/b ratio in the leaf samples collected at polluted site was 2.219 and the content in leaves collected from control site was 4.309 (Fig. 2).

Euphorbia hirta: This plant showed 2.22 mg/g.fr.wt. in chlorophyll 'a' in the leaves from polluted site and 0.759 in the leaves of control site. The leaves collected from polluted site recorded 192.4% more chlorophyll a content as compared to the control plants. In the leaf samples from the polluted site chlorophyll b was 0.739 mg/g.fr.wt. and from the leaves of control site show 0.261 mg/g.fr.wt. 183.14% more chlorophyll 'b' was recorded in the leaves collected from polluted site. The leaf samples from the polluted site showed 2.961 mg/g/fr.wt. of total chlorophyll as compared to the control which is 1.021 mg/g.fr./wt. 190% more total chlorophyll was recorded from the polluted site (Table 1).

The leaf samples from the polluted site showed 1.208 mg/g.fr.wt. carotenoid content and those from the control site showed 0.616 mg/g.fr.wt. of carotenoids. 96.42% more carotenoids were observed in the leaf samples from the polluted site (Fig. 1).

The chlorophyll a/b ratio in the samples from the polluted site was 3.014 and that of control site was 2.652 (Fig.2.).

Oxalis corniculata: The chl 'a' content in the leaves from the polluted site was 0.83mg/g.fr.wt. and from the control site the leaves had 0.649 mg/g.fr.wt. The percent reduction in chl 'a'content of the polluted site is 87.2%. The leaves of the polluted site showed 0.085mg/g.fr.wt. chl 'b' and those from the polluted site showed 0.398 mg/g.fr.wt. The percent reduction in chl 'b' in the polluted samples 78.64% (Table 1).

The total chl. from the leaves of polluted site was 0.168 mg/g.fr.wt. and those from the control site was 1.160 mg/g.fr.wt. The percent reduction in total chl. in the leaves collected from polluted site is 85.51%. The carotenoid content in the leaves of the plant collected from the polluted site was recorded to be 0.315 mg/g.fr.wt. and in the leaves from the control site was noted to be 0.618 mg/g.fr.wt. The percent reduction in the carotenoids in the polluted site is 49.02% (Fig.1.). The chl. a/b ratio in the leaves of polluted site was 0.977 and in the leaves of control site it was 1.623 (Fig.2.).

Air pollutants, fly ash and dust emissions have a profound impact on the concentration of different photosynthetic pigments. Polluted and dusted leaf surface is responsible for reduced photosynthesis and thereby causing reduction in chlorophyll content[30].

Pigment degradation has been widely considered as an indicator of air pollution[22]. Pollutants can cause leaf injury, stomatal damage, premature senescence, decreased photosynthetic activity, disturb membrane permeability and reduce growth and yield in certain sensitive plants[31]. The total chlorophylls, chl. 'a', chl. 'b' and carotenoids are essential pigments for the conversion of light energy to chemical energy. The chlorophyll pigment content that directly determines photosynthetic potent and production depends on the amount of solar radiation absorbed by a leaf.

Chlorophylls- Chloroplast pigments were shown to be very sensitive to various environmental pollution. Chlorophyll content of plants signifies its photosynthetic activity as well as the growth and development and varies from species to species depending on the age of the plant, pollution levels and other biotic and abiotic conditions[15].

Changes in chlorophyll and carotenoid content were investigated in the selected plant species exposed to automobile pollution / exhaust (vehicular pollution) growing along road side of high traffic prone zones of Mehdipatnam area of Hyderabad in comparison with control site.

In the present investigation marked reduction was observed in chl. 'a', 'b' and total chl. in the leaves of *Amaranthus viridis* and *Oxalis corniculata* collected from polluted zones. The percent reduction in chl 'a' recorded was 84% in *Amaranthus viridis* and 87.2% in *Oxalis corniculata.* Chl. 'b' was reduced by 7.29% in *Amaranthus viridis* and 78.64% in *Oxalis corniculata.* Total chl. reduced by 9.95% in *Amaranthus viridis* and in *Oxalis corniculata* 85.5% reduction was observed.

Reduction in chl.'a', 'b' and total chl. can be directly related to the reduction in plant growth. In the present study chl 'a' was more sensitive than chl 'b'. The same was suggested by a number of workers[32-39] in the leaves of plants growing in polluted atmosphere. William *et al.*[40] reported abnormally higher chl. 'a' than chl. 'b' in SO_2 polluted woodland in *Quercus petracea.*

Reduction or changes in chlorophyll content in the plants growing in polluted zones could be due to carbon and dust accumulation on the leaf lamina and other parts of the plant leading to photosystem damage. Air pollution induced degradation in photosynthetic pigments was reported by a number of workers[23,26,41,42].

However in the present experiment increase in chl. 'a', chl. 'b' and total chlorophyll was observed in the leaves of *Euphorbia hirta* plants collected from the polluted sites. Increase in chlorophyll pigments in *Euphorbia hirta* could be attributed to an increase in the carotenoid content in the leaves which protect the chl. pigment against pollution stress or photo-oxidative damage[43].

Carotenoids: Carotenoids are the structural components of the photosynthetic antenna and reaction centre[26]. They play a critical role in photosynthetic process and protect chlorophyll from photo-oxidative damage[43].

In the present study reduction in the carotenoid content was observed in the leaves of *Amaranthus viridis* and *Oxalis corniculata* growing in polluted zones. Low values of carotenoids in the plant could be because of stress suggesting sensitivity nature to pollution.

Reduction in carotenoid content under air pollution was reported by many researchers[23,26,43,44]. Whereas, increase in the carotenoid content in the leaves of *Euphorbia hirta* was observed in the present study. The increase content could be a protective role of carotenoids to prevent the damage caused to chlorophylls and photosynthetic system against reactive oxygen species (ROS) caused by pollution[45-47].

In the present study variation in the carotenoids were found in the plant species exposed to vehicular pollution. This variation can be used as an indicator of air pollution for diagnosis of stress caused by pollution.

Lichtenthaler *et al.*[48] stated that the increase in the ratio Chl a/b is associated with a change in pigment composition of the photosynthetic apparatus towards a more sun-type like chloroplast which possesses less light harvesting chlorophyll proteins (LHCPs).

The ratio of chl a/b indicates the functional characters of photosynthetic pigments. The chl a/b ratio in the present investigation showed a decrease in leaves of *Amaranthus viridis* and *Oxalis corniculata* collected from polluted regions. Decrease in chl. a/b ratio has been shown by a number of workers due to dust pollution[49]. However chl a/b ratio increased markedly in *Euphorbia hirta* as compared to control. Increase in chl a/b ratio is associated with a change in pigment composition of the photosynthetic apparatus towards sun type chloroplast which possesses less light harvesting chlorophyll protein[48]. Researchers note different ranges of variation in the chlorophyll a/b ratio under air pollution[50-52].

Present study revealed that total chlorophyll content in *Amaranthus viridis* and *Oxalis corniculata* species growing in the polluted zones decreased. The higher pollution levels in the traffic zones lowered the chlorophyll content whereas in *Euphorbia hirta* chlorophyll content increased indicating its tolerance to air pollution stress.

The results presented in the study shows that vehicular pollution markedly reduced the photosynthetic pigments in *Amaranthus viridis* and *Oxalis corniculata*. It is clear that *Oxalis corniculata* is very sensitive and *Euphordia hirta* is tolerant among the three plants studied. The present study also suggests that plants have the potential to serve as excellent quantitative and qualitative indices of pollution levels.

References

1. Seyyednejad S M, Koochak H and Vaezi J 2013, Some biochemical responses due to industrial air pollution in *Prosopis juliflora* plant. *J. Biology and today's world* **2** 471-481.
2. Agbaire P O and Esiefarienrhe E 2009, Air pollution tolerance indices (apti) of some plants around Otorogun gas plant in Delta State, Nigeria. *J Appl. Sci. Environ. Manage.* **13** 11-14.
3. Jahan S and Iqbal M Z 1992, Morphological and anatomical studies of leaves of different plants affected by motor vehicles exhaust. *J. Islamic Academy of Sciences* **5** 21-23.
4. Taylor G and Davies W J 1990, Root growth of *Fagus sylvatica* Impact of air quality and drought at a site in Southern Britain. *New Phytologist* **166** 457-464.
5. Santosh K P and Tripathi B D 2008, Seasonal Variation of Leaf Dust Accumulation and Pigment Content in Plant Species Exposed to Urban Particulates Pollution. *J. Environ. Qual.* **37** 865-870.
6. Joshi N, Chauhan A and Joshi PC 2009, Impact of industrial air pollutants on some biochemical parameters and yield in wheat and mustard plants. *Environmentalist* **29** 398-404.
7. Liu YJ and Ding H 2008, Variation in air pollution tolerance index of plants near a steel factory: implication for landscape-plant species selection for industrial areas. *Wseas Transactions on Environment and Development* **4** 24-32.
8. Kuddus M, Kumari R and Ramteke P W 2011, Studies on air pollution tolerance of selected plants in Allahabad city, India. *J. Environmental Research and Management* **2** 42-46.
9. Morrison J I L 1987, Intercellular CO_2 concentration and stomatal responses to CO_2 . *In: Stomatal Function.* (eds.) Zieger, E., G.D. Farquhar and I.R. Cowen. Stanford University Press, Stanford, CA, pp. 229-251.
10. Field C B, Jackson R B and Mooney H A 1995, Stomatal responses to increased CO_2: Implications from the plant to the global scale. *Plant Cell Environ.* **18** 1214-1225.
11. Saquib M, Ahmad A and Ansari K 2010, Morphological and Physiological responses of *Croton bonplandianum* Baill. to air pollution. *Ecoprint* **17** 35-41.
12. Carison R W 1983, The effect of SO_2 on photosynthesis and leaf resistance at varying concentration of CO_2. *Environ. Pollution* **3** 309-321.
13. Bazzaz F A 1990, The response of natural ecosystems to the rising global CO_2 levels. *Annu. Rev. Ecol. Syst.* **21** 167-196.
14. Berry J A and Bjorkman O 1980, Photosynthetic response and adaptation to temperature in higher plants. *Annu. Rev. Plant Physiol.* **31** 491-543.
15. Katiyar V and Dubey P S 2001, Sulphur dioxide sensitivity on two stage of leaf development in a few tropical tree species. *Ind. J. Environ. Toxicol.* **11**

78-81.

16. Singh S N, Yunus M, Srivastava K, Kulshreshtha K and Ahmad K J 1985, Response of *Calendula officinalis* L. to long-term fumigation with SO_2. *Env. Pollution* 39 17-25.
17. Singh S N, Yunus M .and Singh N 1990, Effect of sodium metabisulphite on chlorophyll, protein and nitrate reductase activity of tomato. *Sci. Total Environ.* **81** 269-274.
18. Malabari A A, Ahmad Z and Saquib M 1991, Effect of air pollution on *Gnephalium pensylvanicum* willd- a cropland weed. *Geobios* **18** 7-10.
19. Dhir B, Sharma M P, Mahmooduzzafar and Iqbal M 1999, Form and function of Achyranthes aspera Linn. under air pollution stress. *J. Environ. Biol.* **20** 19-23.
20. Nighat F, Mahmooduzzafar and Iqbal M 1999, Foliar responses of *Peristrophe bicalyculata* to coal smoke pollution. *J. Plant Biol.* **42** 205-212.
21. Nighat F, Mahmooduzzafar and Iqbal M 2000, Stomatal conductance, photosynthetic rate and pigment content in *Ruellia tuberose* leaves as affected by coal-smoke pollution. *Biol. Plant* **43** 263-267.
22. Ninave S Y, Chaudhri P R, Gajghate D G and Tarar J L 2001, Foliar biochemical features of plants as indicators of air pollution. *Bull. Environ. Contam. Toxicol.* **67** 133-140.
23. Tripathi A K and Gautam M 2007, Biochemical parameters of plants as indicators of air pollution. *J. Environ. Biol.* **28** 127-132.
24. Mir Q A, Yazdani T, Kumar A, Narain K and Yunus M 2008, Vehicular population and pigment content of certain avenue trees. *Poll. Res.* **27** 59-63.
25. Saquib M 2008, Effect of coal smoke pollution on the biomass and chlorophyll pigments of *Brassica juncea. Ecoprint* **15** 1-6.
26. Joshi P C and Swami A 2009, Air pollution induced changes in the photosynthetic pigments of selected plant species. *J. Environ. Biol.* **30** 295-298
27. Iqbal M, Mahmooduzzafar, Nighat F and Khan P R 2010, Photosynthetic, metabolic and growth responses of *Triumfetta rhomboidea* to coal-smoke pollution at different stages of plant ontogeny. *J. Plant Interactions* **5** 11-19.
28. Angela and Shri 2012, Studies on air pollution tolerance index in *Amaranthus* and *Euphorbia* species. *J. Phytol. Res.* **25** 141-144.
29. Arnon D I 1949, Copper enzymes in isolated chloroplasts. *Plant Physiol.* **24** 1-15.
30. Kalyani V and Singaracharya M A 1995, Biomonitoring of air pollution in Warangal city (A.P.). *Acta Bot. Indica.* **23** 21-23.
31. Tiwari S, Agrawal M and Marshall F M 2006, Evaluation of ambient air pollution impact on carrot plants at a sub urban site using open top chambers. *Environmental Monitoring and Assessment* **119** 15-30.
32. Dubey P S and Pawar K 1985, Air pollution and plant response- Review. *In* : *Perspective in environment botany* (Eds.:D. N. Rao,K. J. Ahamed. M. Yunus and S. N. Singh). Print House, Lucknow. **1** 101-118.
33. Singh S N, Yunus M , Srivastava K, Kulshreshtha K and Ahmad K J 1985, Response of *Calendula officinalis* L to long-term fumigation with SO_2. *Env. Pollution* **39** 17-25.
34. Singh N and Rao D N 1986, Influence of sulphur dioxide on the growth and productivity of *Phaseolus aureus* plants. *Acta Bot. Indica* 230-235.
35. Shah F H, Ilahi I and Rashid A 1989, Effect of cement dust on the chlorophyll contents, stomatal clogging and biomass of some selected plants. *Pakistan J. Sci. Indust. Res.* **32** 542-545.
36. Saxena R M 1991, Effect of motorway pollution on seed health of some vegetable crops. *Ind. J. Environ. Hlth.* **33** 385-387.
37. Swami A D, Bhatt and Joshi P C 2004, Effect of automobile pollution on Sal *(Shorea robusta)* and Rohini *(Mallotus phillipinesis)* at Asarori, Dehradun. *Him. J. Environ. Zool.* **18** 57-61.
38. Wali B, Mahmooduzzafar and Iqbal M 2004, Plant growth, stomatal response, pigments and photosynthesis of *Althea officinalis* as affected by SO_2 stress. *Ind. J. Plant Physiol.* **9** 224-233.
39. Giri S, Shrivastava D, Deshmukh K and Dubey P 2013, Effect of Air Pollution on Chlorophyll Content of Leaves. *Curr. Agri. Res. J.* **1**(2) 93-98.
40. Williams RJH, Lloyd MM and Ricks GR 1971, Effect of atmospheric pollution on deciduous woodland. Part 1: Some effectson leaves of *Quercus petraea* (Mattuschka) Leibl. *Environ. Pollution* **2** 57.
41. Bansal S 1988, *Studies on the effect of certain atmospheric pollutants on fruit diseases of Lycopersicon esculentum Mill. caused by Alternaria alternate,* Ph.D thesis, Bhopal, Bhopal University,
42. Sandelius A S, Naslund K, Carlson A S, Pleijel H and Sellden G 1995, Exposure of spring wheat *(Triticum aestivum)* to ozone top chambers. Effects on acyl lipid composition and chlorophyll content of flag leaves. *New Phytolgist* **131** 231-239.
43. Joshi N, Chauhan A and Joshi PC 2009, Impact of industrial air pollutants on some biochemical

parameters and yield in wheat and mustard plants. *Environmentalist* **29** 398-404.

44. Joshi P C and Swami A 2007, Physiological responses of some tree species under roadside automobile pollution stress around city of Haridwar, India. *Environmentalist* **27** 365-374.
45. Young AJ 1991, The photoprotective role of carotenoids in higher plants. *Physiol. Plant.* **83** 702-708.
46. Asada K, Endo T, Mano J and Miyake C 1998, Molecular mechanism for relaxation of and protection from light stress. *In :* K. Sato, N. Murata, (eds), *Stress Responses of Photosynthetic Organisms.* Elsevier Science Publishing, Amsterdam. pp. 37-52.
47. Loggini B, Andrea, Scartazza, Enrico A, Brugnoli E and Navari-Izzo F 1999, Antioxidative defense system, pigment composition, and photosynthetic efficiency in two wheat cultivars subjected to drought. *Plant Physiol.* **119** 1091-1100.
48. Lichtenthaler HK, Babani F, Langsdorf G, Buschmann C 2000, Measurement of differences in red chlorophyll fluorescence and photosynthetic activity between sun and shade leaves by fluorescence imaging. *Photosynthetica* **38** 521-529.
49. Kumar saravana and Thambavani sarala 2012, Effect of cement dust deposition on physiological behaviors of some selected plant species. *Inter. J. Sci. & Technol. Res.* **1**(9) 98-105.
50. Muller J 1957, Ein spezifscher Nachweis von SO_2 Rauch schäden an Pflanzen mit Hilfe von Blatt pigment analyse. *Naturwissenschaften.* **44** 453.
51. Williams RJH, Lloyd MM and Ricks GR 1971, Effect ofatmos pheric pollution on deciduous woodland. Part 1: Some effectson leaves of *Quercus petraea* (Mattuschka) Leibl. *Environ. Pollution.* **2** 57.
52. Dassler HG 1972, Zur Wirkungsweise der Schadstoffe der Ein fluss von SO_2 auf Blattfarbstoffe. Mitteild. *Forstlichen Bun des-Versuchsanstalt.* **97** 353