Chapter 3

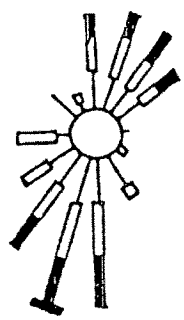
RESULTS

All the results obtained are presented in tabular form and are given in appendix (Tables 3 - 39). Standard deviations were calculated. Analysis of variance was carried out for some of the studies. Results of each study were given under seperate headings.

3.1 DATA ON AMBIENT AIR QUALITY

Periodic data on ambient air quality and peak concentrations of major pollutants such as sulphur dioxide, oxides of nitrogen and suspended particulate matter were recorded and are given in Tables 3 and 4. This is based on weekly (3 x 8 h) monitoring of pollutants at different localities. Localities were arranged based on increasing sulphur dioxide concentration. Two localities were designated as reference for comparison; reference 1 was for the general vegetation survey and reference 2 for the potted - plant - exposure study. Air quality data were represented in two forms, annual and seasonal. Seasonal concentrations were taken for studying the effect of air pollutants on the phenology of tree species in different seasons. The gaseous pollutants exhibited concentrations of 1.2 to 125.4 $\mu g.m^{-3}$ for sulphur dioxide and 4.7 - 243.0 $\mu g.m^{-3}$ for oxides of nitrogen. Peak concentrations were recorded at all the localities. The frequency was more in localities 3 - 5. Though the concentrations of oxides of nitrogen were high, the magnitude of damage to plants was more by sulphur dioxide; oxides of nitrogen seem to augment the SO_2 damage by acting synergistically. The high level of suspended particulate matter in localities 1, 2 & 4 covered the vegetation thickly thereby reducing the incidence of sunlight. At reference variations in concentrations were very less. The concentrations of SO_2 and NO_X were increasing from localities 1 - 5 with the exception of locality 3. SPM did not show any specific pattern.

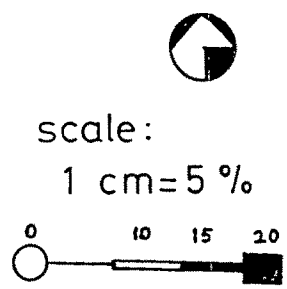
WINDROSE DIAGRAMS (Fig. 1)



ANNUAL

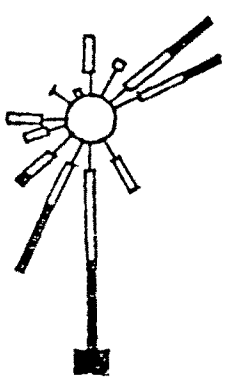
N

scale:
1 cm = 5 %

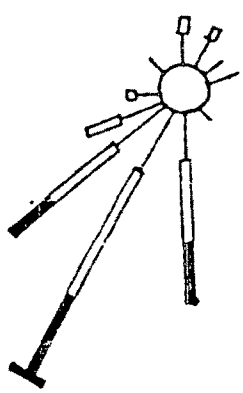


SEASONAL

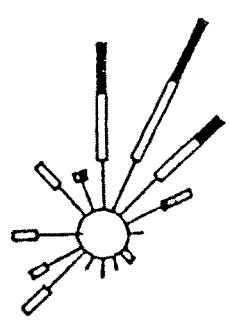
summer



monsoon



winter



3.1.1 Seasonal Concentrations

Fluctuations in seasonal concentrations, influenced by meteorological conditions were seen to be more at localities 3 - 5. The concentrations at reference varied in a narrow range. In all the localities excepting locality 5, the concentrations of pollutants were maximum in winter (Table 4); at locality 5 maximum was in summer. The concentrations fluctuated considerably in monsoon. Seasonal concentrations varied by 50 to 100% at all the localities, except the third. Both SO_2 and NO_x showed similar changes. During monsoon, SPM recorded was minimum and the other two seasons showed greater amounts.

3.2 METEOROLOGICAL OBSERVATIONS

Meteorological data were obtained from the University observatory. It was computed on 4 - yearly mean and was presented in Table 5. General climatic conditions are, a dry area having 20.9 and 34.6°C as minimum and maximum monthly mean temperatures. Mean monthly relative humidity is 60.5%. Three prominent seasons are seen; summer (March to June), monsoon (July to October) and winter (November to February). Summer is the hottest (40°C) and winter is the coolest (10°C) part of the year. Humidity is maximum during monsoon (85%) and minimum in summer (41%). Average wind speed is maximum in summer (> 20 Kmph). Wind direction during major part of the year is south-west. Details are given in windrose diagrams (Fig.1).

3.3 GENERAL VEGETATION SURVEY

3.3.1 Visual Symptoms on the Vegetation

Common visual symptoms observed were chlorosis, necrosis, tip burning, premature leaf fall, stunted growth etc. Pattern of injury varied from species to species and often was more

Explanations for Plate 1

Visual symptoms recorded on vegetation

A : *Zizyphus jujuba* Lamk.

B : *Bauhinia racemosa* Lamk.

Symptoms : Chlorosis, necrosis and tip burning are seen.

Plate 1

in mesophytes and annuals as compared to xerophytes and perennials. Among the tree species, leaf fall due to pollution stress was more in deciduous species as compared to evergreen ones. Appearance of visual damage on leaves was a gradual process, starting from cooked green and water - soaked appearance to chlorosis and finally necrosis leading to the death of leaf (Plate 1). Sometimes chlorosis appears directly. Damage was faster when pollutant concentrations were high. Sometimes the petiole became chlorotic and leaf fall was hastened. In leaves of evergreen species such as Ficus religiosa, Tamarindus indica etc., only tip burning and marginal chlorosis/necrosis were seen. Overall, visual symptoms were more in deciduous species. At high pollution zones Mangifera indica had shown 40 - 50% leaf area damage. Leaf fall was also very high. High reduction in leaf size was seen in some species such as Calotropis procera etc. Retardation of growth was a common phenomenon in all the species. Spread and shape of the canopy cover in trees was very much distorted.

3.3.2 Gradient analysis

The distribution of various herbaceous and shrub vegetation varied from one point of study to another point. Both on windward and leeward directions species distribution and diversity was less nearer the source and along the gradient with the increase of distance, number and distribution of species increased (Table 6). Nearer to the source of pollution number of species present were more on leeward as compared to windward, but at > 2.5 Km species distribution was more on windward direction. Number of species present from 1.25 to 3.00 Km on windward and leeward directions were 8, 11, 14 & 17, and 12, 14 & 16 respectively.

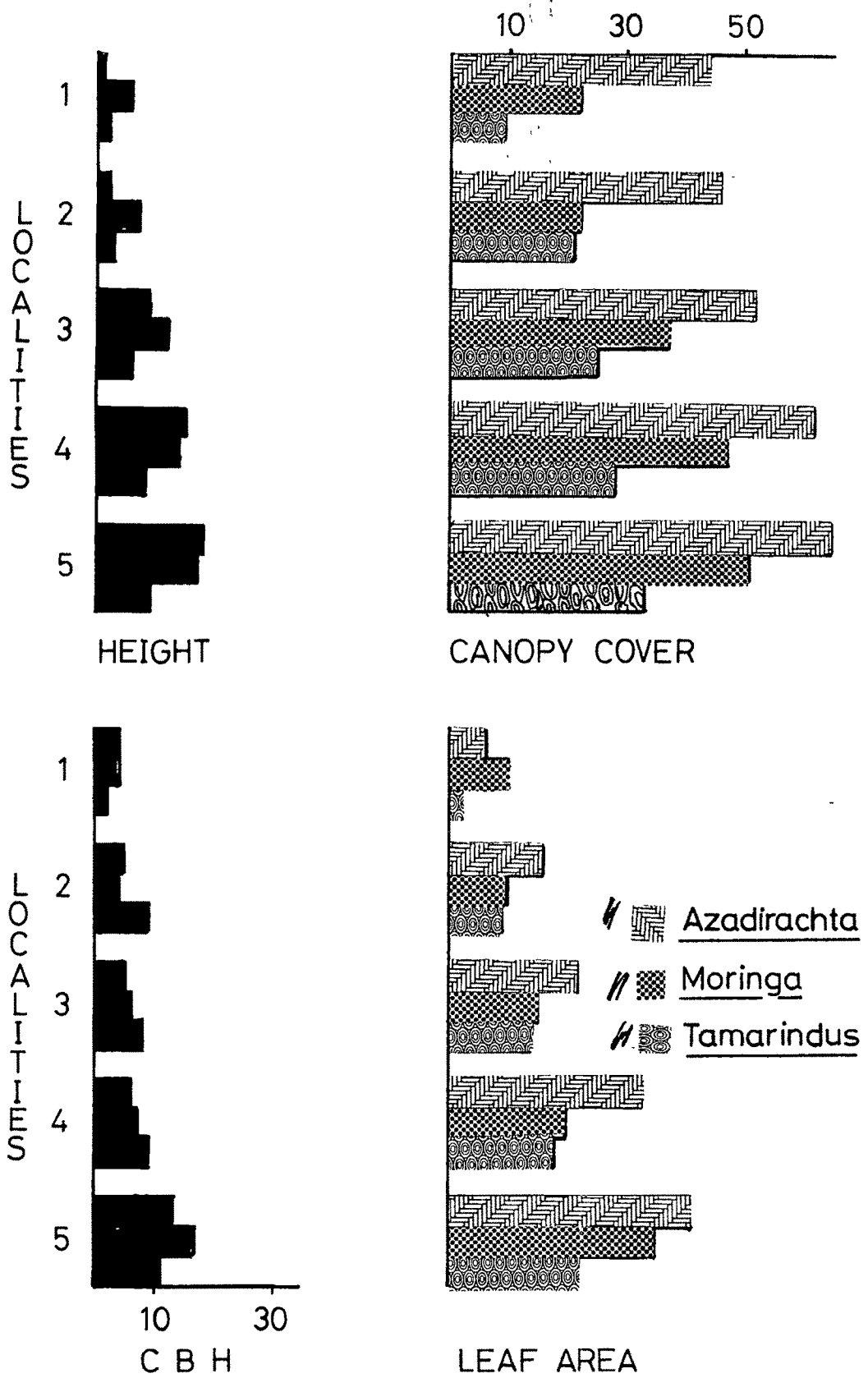
Widely distributed species on windward direction were Prosopis juliflora, Portulaca oleracea, Cocculus hirsutus and Achyranthus aspera. Species with medium distribution were

Tridax procumbens, Boerhavia diffusa, Cenchrus ciliaris, Calotropis procera and Zyziphus jujuba. Less common were Ipomoea alba, Vernonia cinerea, Tephrosia villosa, Eclypta prostrata etc. In all the quadrats studies both occurence and abundance of Prosopis juliflora, Zyziphus jujuba, Achyranthus aspera and Portulaca oleracea were maximum. Species with less abundance were Eclypta prostrata, Chloris montana and Hydrocotyl asiatica.

The distribution pattern was almost similar on leeward direction. Some of the salient features were, nearer the source number of species recorded were more by 30% as compared to windward. Increase in species distribution was gradual from one point to another point with increasing distance from the source. At 2.0 Km species distribution was almost equal to reference in number and abundance. Prominent species were Calotropis procera, Phyllanthus niruri, Tephrosia villosa, Alternanthera sessilis, Launea residifolia etc. Species with medium distribution are Cynodon dactylon, Tridax procumbens, Ipomoea alba, Cassia tora. Less common were Chloris montana and Prosopis juliflora. While in windward Prosopis juliflora was very common. Abundant species were Tridax procumbens, Ipomoea pes-caprae, Withania somnifera, Alternanthera sessilis. Tephrosia villosa, Phyllanthus niruri etc., were less abundant.

Visual symptoms are more on windward as compared to leeward direction. Saplings of Azadirachta indica were more on leeward side at all the 3 points. Saplings of various other tree species were also seen. On both the sides xerophytic species such as Prosopis juliflora, Achyranthus aspera, Zyziphus jujuba etc., were more prominent nearer the source and their distribution was seen all along the gradient. More mesophytes such as Tridax procumbens, Ipomoea alba etc., started appearing prominently after 1.5 Km and were dominant at 3 Km.

Fig. 2 Changes in growth at field level (% decrease)



3.4 TREE SPECIES SURVEY

3.4.1 Visual Symptoms on the three tree species

General visual symptoms observed on the three tree species studied were chlorosis, necrosis, tip burning, reduction in leaf size etc. Canopy cover was much distorted in deciduous species as compared to evergreen ones. Overall impact of air pollution was more in the deciduous species as compared to evergreen ones (Tamarindus). All the variations mentioned for different parameters is as compared to reference and only recorded observations were given in Tables. Histograms were made based on % increase or decrease over reference for the parameters studied in all the experiments (Figs. 2 - 10).

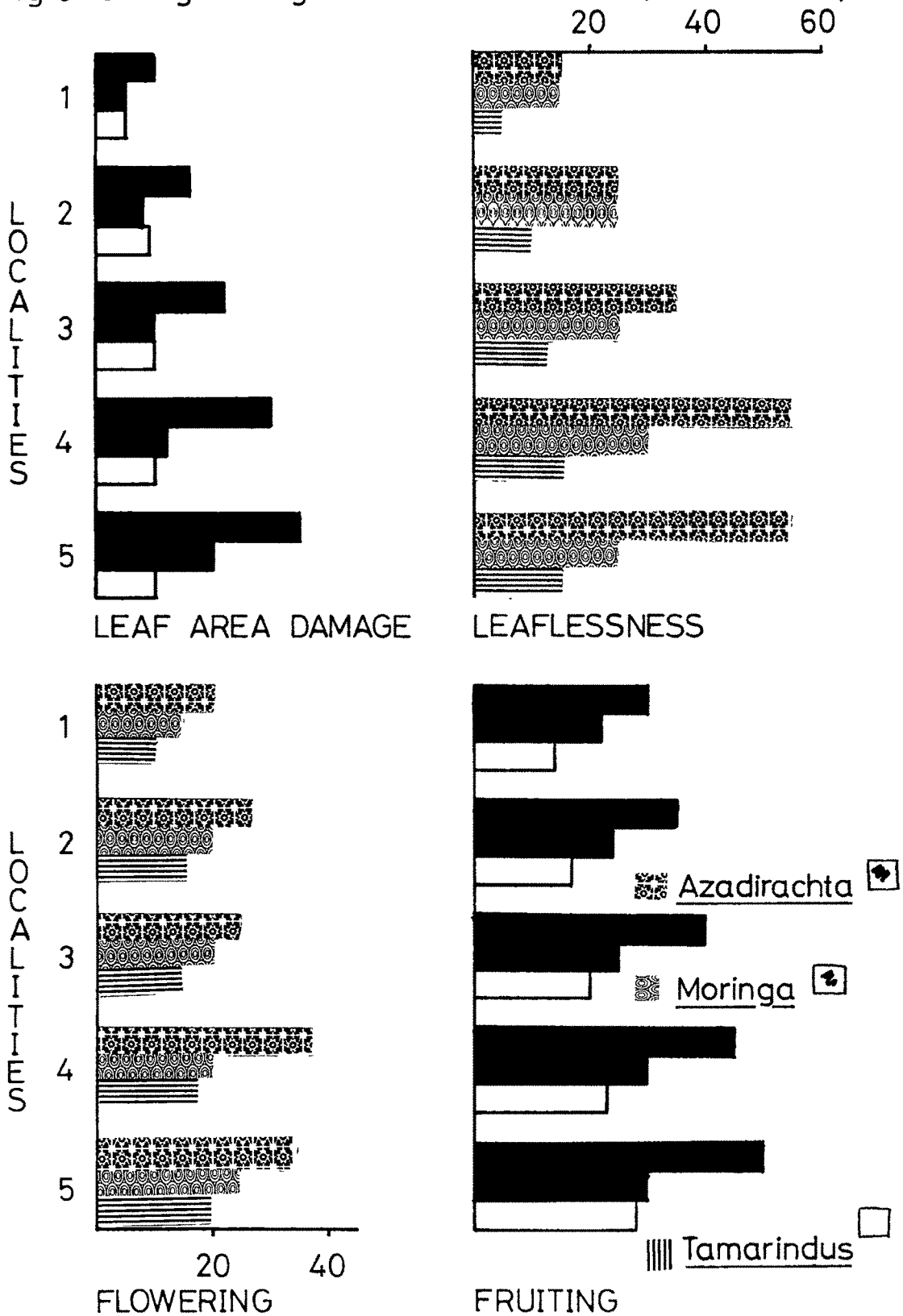
3.4.2 Azadirachta indica Juss.

Reduction in height ranged between 1 - 18%. In localities 1 and 2 the reduction was very less (1 - 2%). A spurt in reduction was seen from locality 3 onwards. C B H showed a decrease of 4 - 13%. At localities 2 & 3 the decrease was same. Canopy cover was maximum affected with a reduction of 44 - 65%. Though decrease in leaf area was low at localities 1 & 2, it was very high at localities 4 & 5. It ranged between 6 - 41%. Damaged leaf area expressed as a percentage of damaged leaf area over leaf area recorded, varied from 10 - 55%. Leaflessness ranged between 15 - 55%. Reduction in flowering and fruiting was 20 - 35 and 30 - 50% respectively. Observations are tabulated in Table 7.

3.4.3 Moringa pterygosperma Goert.

Decrease in height varied from 6 - 17%. C B H showed 4 - 17% reduction. Canopy cover was adversely effected with a range of 22 - 51%. Reduction in leaf area was 10 - 35%. Damaged leaf area and leaflessness recorded were 5 - 20% and 15 - 25%

Fig. 3 Changes in growth at field level (% decrease)



respectively. Flowering and fruiting showed a damage of 15 - 25 and 22 - 30% respectively. Readings were given in Table 8.

3.4.4 Tamarindus indica Linn.

Compared to the other two species the reduction was less. Decrease in height was 2 - 9%. CBH showed a reduction of 2 - 11%. Comparatively decrease in canopy cover was high (9 - 33%). This was attributed to its greater exposure to gaseous pollutants. Leaf area showed a reduction of 2 - 22%. Damaged leaf area and leaflessness recorded were 5 - 10 and 5 - 15% respectively. Flowering and fruiting showed a reduction of 10 - 20 and 14 - 28% respectively. Observations recorded are given in Table 9.

Reproductive phase was maximum affected in Azadirachta followed by Moringa and Tamarindus. In all the three species both flowering and fruiting were adversely affected by air pollutants.

3.5 BIOCHEMICAL CHANGES IN THE THREE TREE SPECIES GROWING AT DIFFERENT LOCALITIES

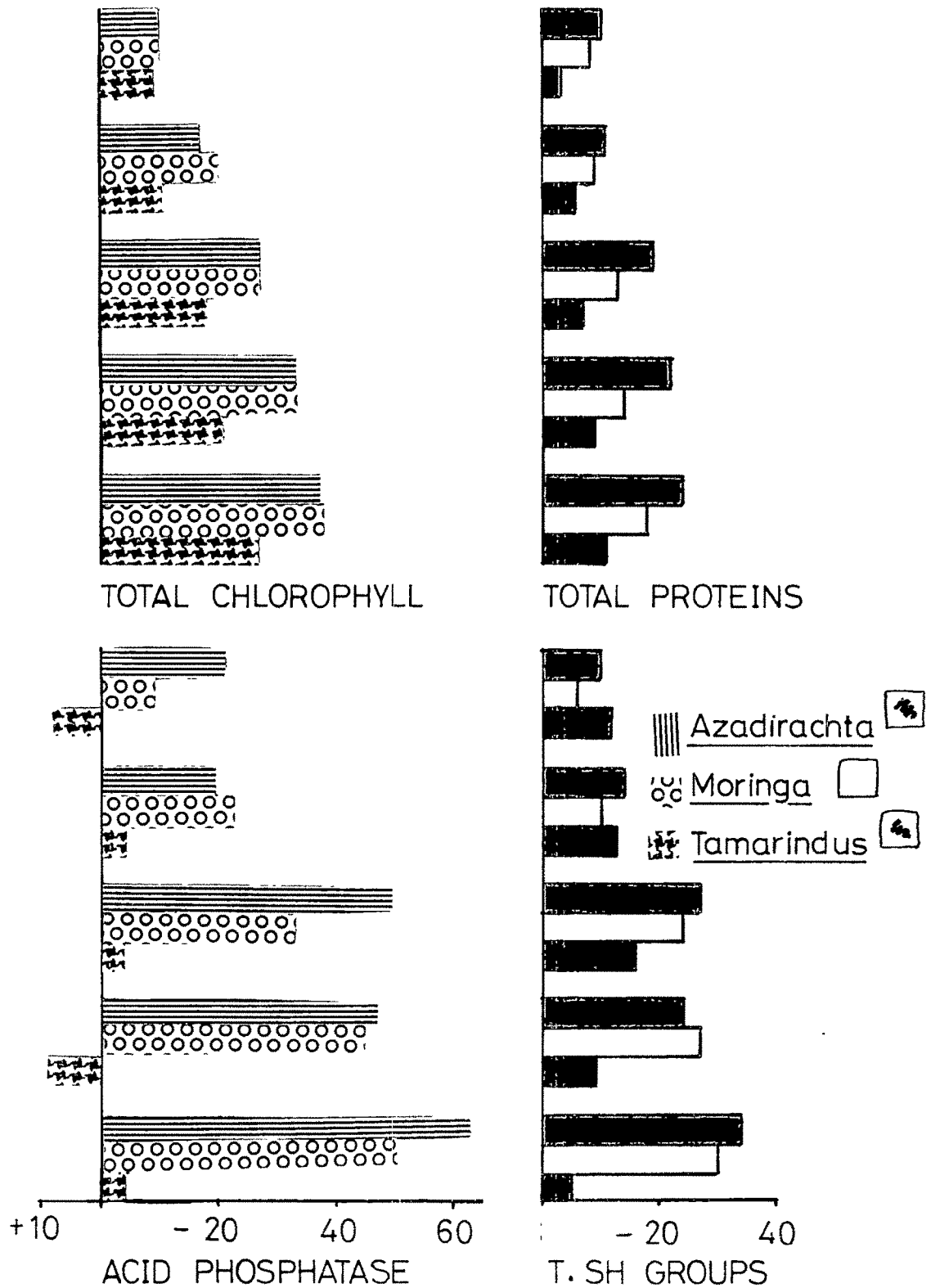
3.5.1 Chlorophylls

Total chlorophyll content was more on Tamarindus as compared to the deciduous species at all the localities (Table 10). All the three species showed an increase from summer to monsoon and a fall from monsoon to winter. In Azadirachta and Moringa the reduction was 3 - 45 and 9 - 43% respectively. In Tamarindus it was comparatively less (6 - 32%).

3.5.2 Chlorophyll a & b

Chlorophyll a & b showed similar pattern as of total chlorophyll (Tables 11 & 12). Reduction was more in chlorophyll a

Fig. 4 Biochemical changes at field level (% increase + - decrease)



as compared to chlorophyll b. Deciduous species showed higher amount of reduction as compared to evergreen ones. Azadirachta showed 5 - 44 and 4 - 41% reductions in chlorophyll a & b while Moringa showed 11 - 48 and 7 - 44% respectively. Decrease in Tamarindus was 6 - 35 and 6 - 27%.

3.5.3 Total Proteins

Total protein content at reference was maximum in Azadirachta followed by Tamarindus and Moringa. All the three species showed a discernable decrease in protein content, both from localities 1 - 5 as well as from summer to winter (Table 13). In deciduous species the reduction was maximum (2 - 39%). In Tamarindus it was 1 - 17%. Decrease was maximum in winter in both the deciduous species.

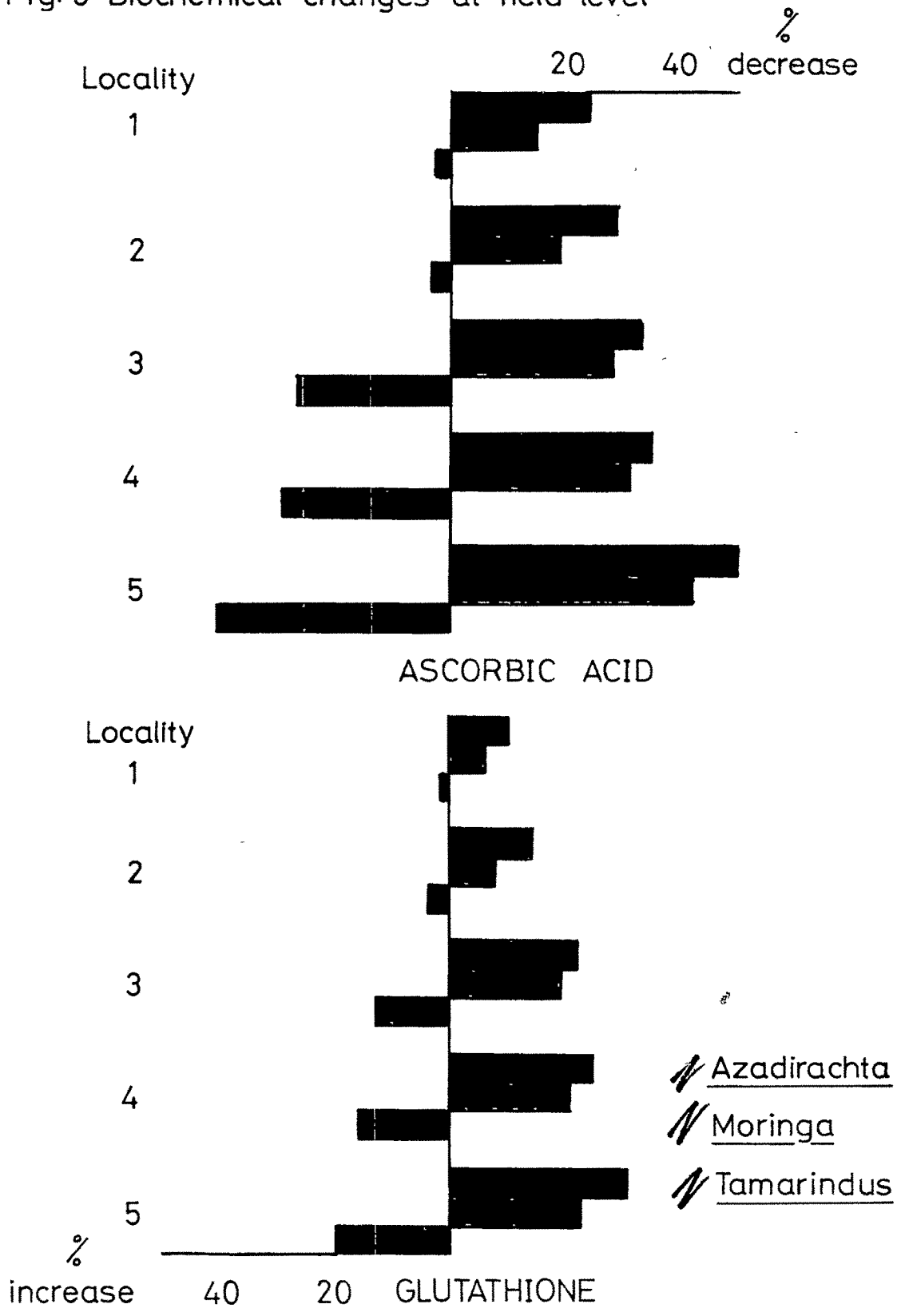
3.5.4 Ascorbic acid

Ascorbic acid content was maximum in Azadirachta followed by Moringa and Tamarindus. All the three species showed a linear decrease from summer to winter but even at reference the decrease was less from summer to monsoon (Table 14). It was reduced almost to half from monsoon to winter in Azadirachta and Moringa whereas in Tamarindus it was only by 11%. The decrease was 20 - 51% in Azadirachta, 10 - 56% in Moringa. Tamarindus showed an increase from localities 1 - 5 (1 - 42%). During summer the increase was linear. In monsoon Tamarindus showed a mixed trend and in winter maximum was at locality 4.

3.5.5 Glutathione

Glutathione content was maximum at reference in Moringa followed by Azadirachta and Tamarindus. In deciduous species maximum content was in summer followed by a drop in monsoon and again an upward trend in winter. In Tamarindus there was a continuous increase from summer to winter. The decrease

Fig. 5 Biochemical changes at field level



in Azadirachta and Moringa ranged between 4 - 41 and 5 - 28% respectively. In Tamarindus the general pattern was a continuous increase except at localities 1 and 2 in summer. The increase ranged between 2 - 26%. Results were tabulated in Table 15.

3.5.6 Total Sulphydryl groups

Total sulphydryl groups showed a discernible decrease both from localities 1 - 5 as well as from summer to winter in Azadirachta and Moringa. In the case of Tamarindus this reduction from localities 1 - 5 was seen only in monsoon. These reductions varied from 5 - 42%, 4 - 40% and 1 - 29% respectively in the three species. In summer and winter Tamarindus showed a decrease followed by an increase from localities 1 - 5. Increase was upto 20%. Readings were given in Table 16.

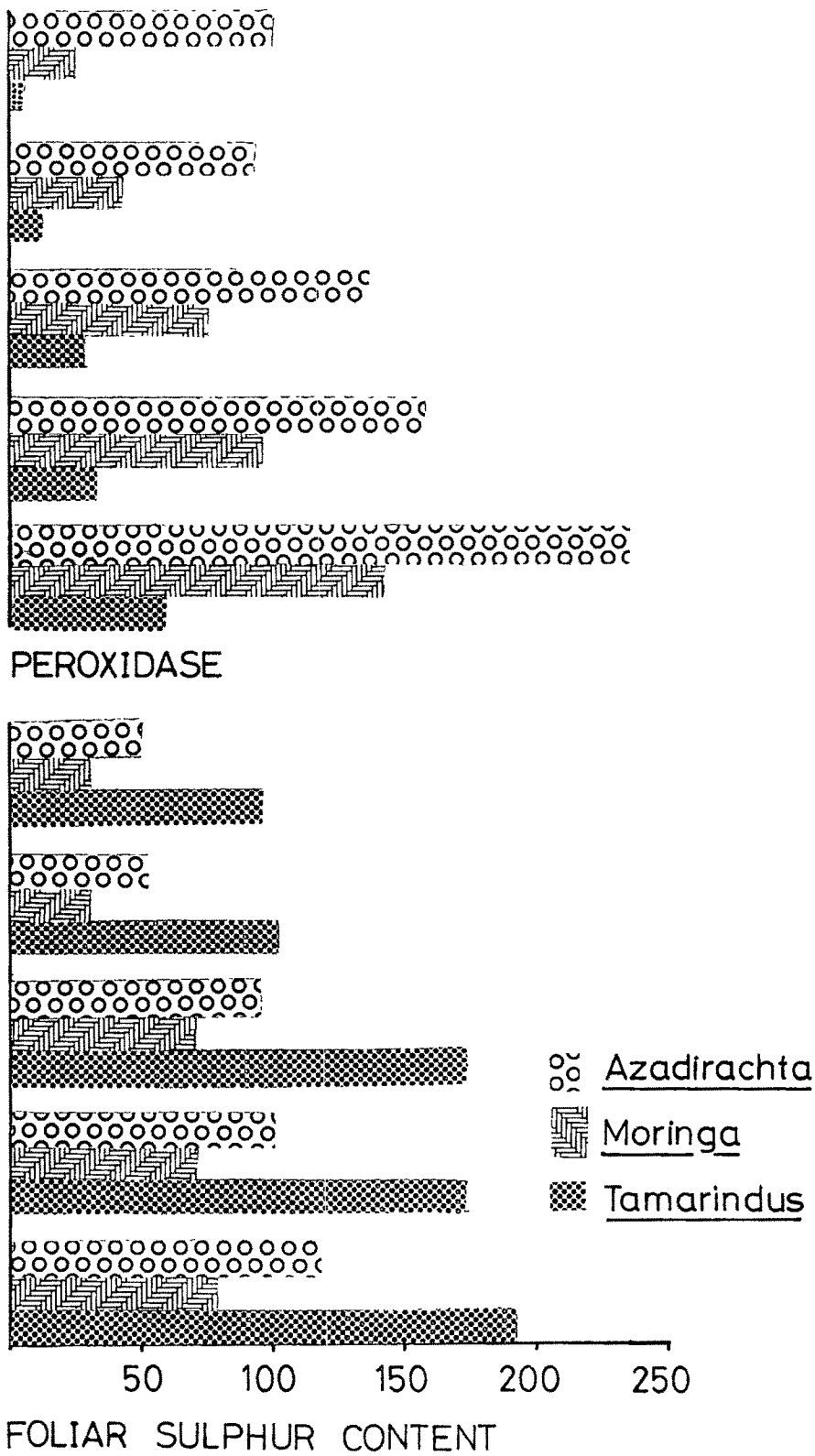
3.5.7 Acid phosphatase

Acid phosphatase activity in deciduous species showed a gradual decrease from localities 1 - 5 in summer and monsoon. In winter excepting locality 4, at all other localities Azadirachta showed a positive response, maximum was at locality 5 (61%). At locality 4, the reduction was 7%. Moringa showed negative response in winter also. Decrease in Azadirachta and Moringa was 12 - 85 and 9 - 62% respectively. In Tamarindus excepting localities 1 and 4, all other localities showed reductions during summer and monsoon (4 - 46%). In summer locality 1 showed positive response and in monsoon locality 4 had same amount as of reference. During winter the response was positive (18 - 106%). Observations were given in Table 17.

3.5.8 Peroxidase

Peroxidase content in all the three species showed an increase from localities 1 - 5 in all the seasons. Deciduous species showed a continuous increase from summer to winter,

Fig. 6 Biochemical changes at field level (% increase)



whereas in Tamarindus there was a drop in monsoon and again an increase during winter but maximum was in summer (Table 18). At reference the content was twice in Tamarindus to that of deciduous species. Increase in Azadirachta and Moringa over reference was 1.2 to 3.6 times. In evergreen species it was 1.0 to 1.9 times. Peroxidase content was always high in Tamarindus at different localities.

3.5.9 Foliar Sulphur content

Foliar sulphur content at reference was maximum in Moringa followed by Azadirachta and Tamarindus. Continuous increase was seen from locality 1 - 5 as well as from summer to winter in all the three species (Table 19). Pattern of increase was similar in all the three species but increase over reference was maximum in Tamarindus (1.97 to 2.99 times) as compared to the deciduous species (1.29 to 2.20 times).

3.5.10 Statistical data and Seasonal effects

Analysis of variance (ANOVA) was performed for all the investigated biochemical parameters, using 3 factors (species, season and locality) with more than one observation (equal number, 8) showed the following results. It showed that there are significant differences between localities, between species and between seasons. Significance of the interactions species x seasons, localities x species and localities x seasons showed differential response of the species to pollution in different seasons, at different localities as pollutant levels at different seasons are different. In some parameters 1 or 2 interactions are not significant (Tables 21 & 22). Percentage decrease or increase over reference for all the parameters were presented in graphic form (Figs. 4 - 6).

3.6 POTTED PLANT - EXPOSURE STUDY

3.6.1 Visual symptoms on the potted tree saplings kept at different localities

Chlorosis and necrosis were the most common symptoms observed in the saplings and were severe in Azadirachta. Chlorosis and premature leaf fall were prevalent in Moringa. Leaflet fall and necrosis were common in Tamarindus. Branching was less in Azadirachta and absent in Moringa. In Tamarindus the branching was more and the general pattern exhibited was more branches in polluted localities. Negative growth observed in the height of Moringa and Tamarindus at localities 3 & 1 was due to drying and falling of upper portion of the shoot.

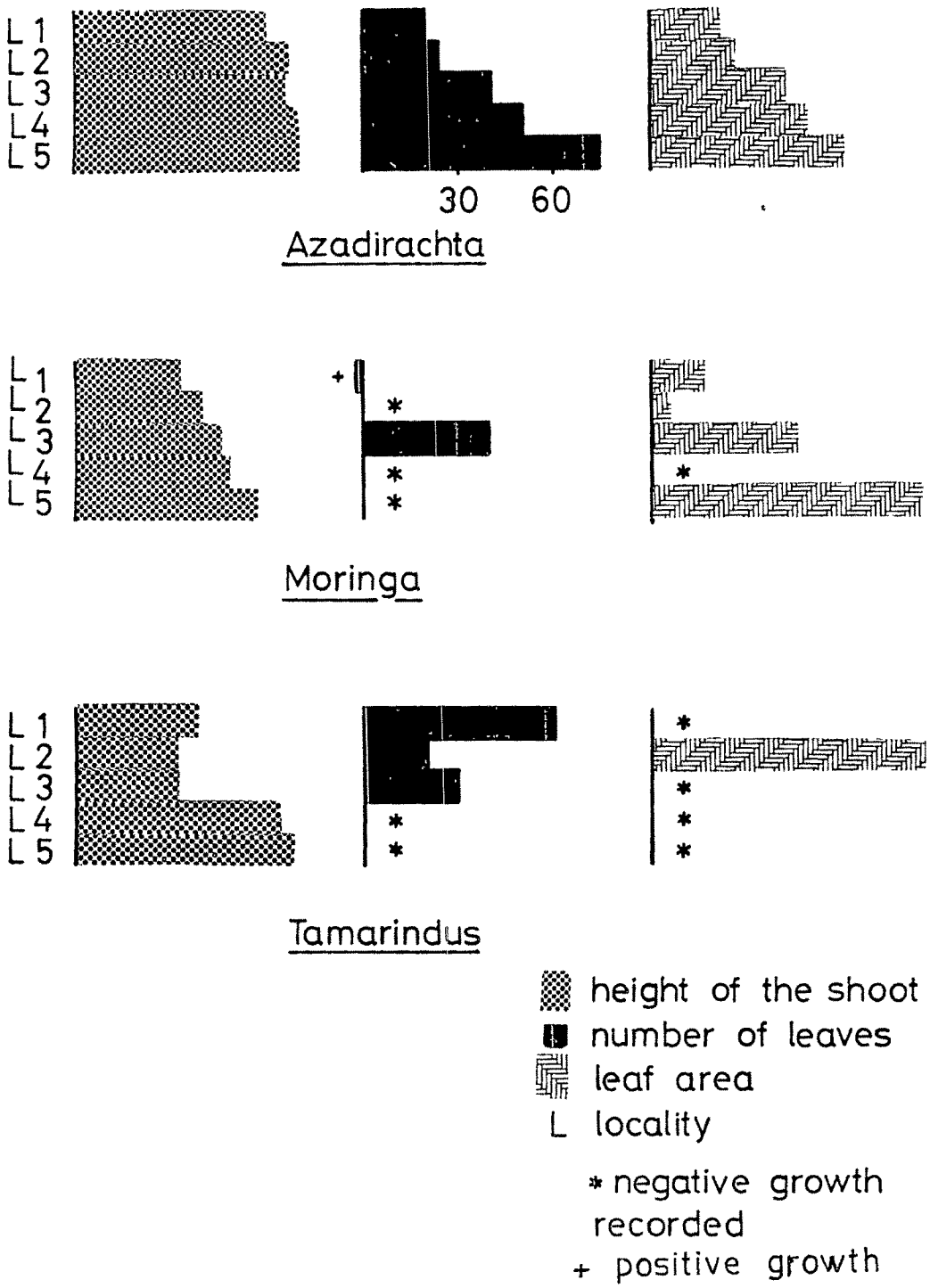
3.7 GROWTH PARAMETER STUDIES

Compound growth rates had been obtained for all the parameters, in all the species through linear regressions of logarithms on time (growth rate/month). Minimum and maximum increase in each parameter at different localities had been calculated. Observations recorded for 10 months were divided into three seasons according to meteorological factors. July to October - monsoon, November to February - winter and March to June - summer. Growth rates for different seasons were also calculated.

3.7.1 Growth of the shoot

The positive correlation for individual growth rates showed a definite growth rate at decreasing rate with increasing pollutant concentration. The correlations between annual means of SO_2, NO_X and growth rates of different species were found significant. Growth rate was maximum in Moringa followed by Azadirachta and Tamarindus. Reduction in growth relative to reference was minimum in Moringa (34 - 58%) followed by

Fig. 7 Decrease in growth rate (%) in the three tree saplings kept at different localities



Tamarindus (39 - 69%) and Azadirachta (61 - 72%). Actual monthly mean observations and growth rates calculated were given in Tables 21 & 22.

3.7.2 Number of leaves

In Azadirachta the number of leaves/plant showed a definite growth at decreasing rate with increasing concentration of pollutants. Correlations with annual pollutant concentrations (SO_2 and NO_x) was significant. In the other two species the correlation was not significant. In Moringa negative growth was seen in localities 2 and 5. In Tamarindus localities 4 and 5 showed negative growth while other localities showed positive correlation. Observations were tabulated in Tables 23 and 24.

3.7.3 Leaf area

Leaf area/leaf in Azadirachta showed positive correlation indicating growth rate at decreasing order with increasing pollutant concentrations (Table 26). Correlations with annual mean concentrations were significant. In Moringa upto locality 3 they were significant. Negative growth was seen at locality 4. In Tamarindus upto locality 2 the response was not significant. Localities 3 - 5 showed negative growth rate which was found significant against SO_2 concentration. Actual monthly mean observations were given in Table 25.

Actual readings of minimum and maximum changes in various parameters were also given (Tables 22, 24, 26). Negative growth was seen in the saplings growing at different polluted localities. During early months after the transfer or when there is a respite in ambient pollutant concentration, the actual growth in the saplings was higher at different polluted localities as compared to reference. As the n (number of values/season) for the seasonal growth rate was smaller

Explanations for Plate 2

Visual symptoms recorded on the three tree saplings exposed to SO_2

C : Azadirachta indica Juss.

D : Moringa pterygosperma Goert.

E : Tamarindus indica Linn.

Chlorosis and necrosis are seen.

Plate 2

correlation values were not taken for consideration. In localities 3 - 5 growth rates responded to the differences in seasonal concentrations. The general pattern observed was higher the concentration lesser the growth rate. In Moringa and Tamarindus number of leaves/plant and leaf area/leaf showed negative growth rate in some seasons. Averages of all the monthly mean observations alongwith growth rates and r^2 values were given in Table 27. Fluctuations in the parameters studied as compared to reference were drawn in Fig. 7.

3.7.2 Foliar sulphur content

Foliar sulphur content/unit leaf area was maximum in Tamarindus (2.8 times), followed by Azadirachta (2.4 times) and Moringa (2.2 times) at locality 5. The correlations of foliar accumulation of sulphur with growth rate and with concentrations of ambient SO_2 have been found to be significant in all the three species.

3.8 ARTIFICIAL FUMIGATION STUDY

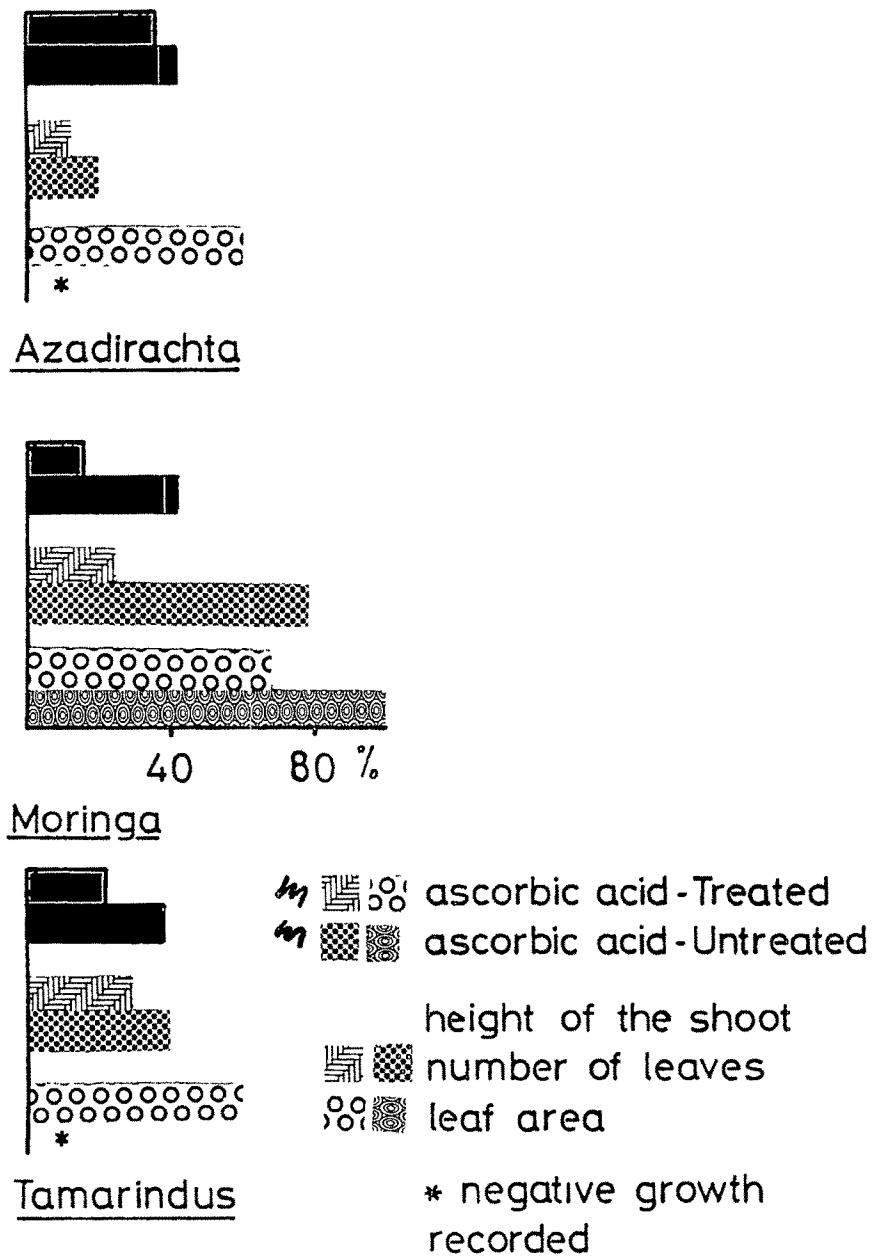
3.8.1 Visible symptoms

Visible symptoms started appearing after 30 - 45 days of exposure. Development of the injury was faster in the untreated exposed saplings. Chlorosis, necrosis and tip burning were the most common symptoms on all the leaves. Premature leaflet fall was seen in all the three species (Plate 2).

3.8.2 Growth parameter studies

In this study also, for growth parameter observations, compound growth rates were calculated at 60, 120 and 180 days after SO_2 exposure. Comparisons were made with reference. After 180 days of exposure, maximum reduction was seen in exposed, untreated plants. Saplings treated with ascorbic

Fig. 8 Changes in growth rate after 180 days of SO_2 exposure



acid showed less damage, deciduous species showed 43% reduction while Tamarindus (evergreen) showed 38% reduction in growth rate of shoot. Maximum reduction in number of leaves was in Moringa (78%) followed by Tamarindus and Azadirachta (40 and 16% respectively). Azadirachta and Tamarindus showed negative growth rate in leaf area/leaf while Moringa showed positive growth rate and reduction as compared to reference was very high (84%).

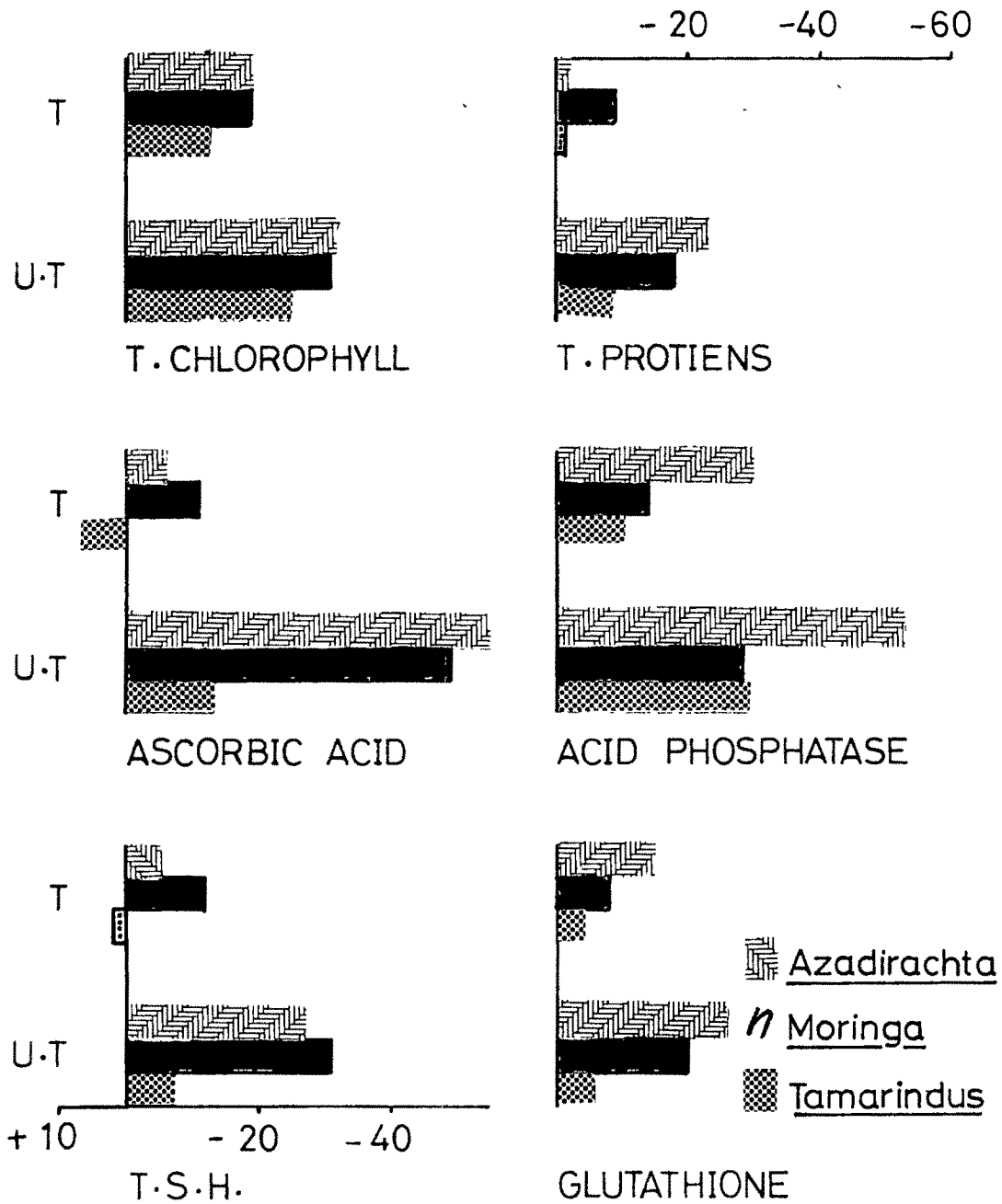
To see the response of plants to dose x time, growth rates at 60 and 120 days were calculated. At 60 days maximum reduction in shoot growth was in Moringa (65%) followed by Azadirachta and Tamarindus (31 and 26%). Number of leaves/plant was maximum effected in Moringa (65%) followed by Tamarindus (48%) while Azadirachta showed greater production of leaves and the increase was by 10%. Azadirachta and Tamarindus showed negative growth in leaf area and Moringa showed 97% reduction.

After 120 days of exposure, both the deciduous species showed less reductions as compared to previous month's observations. Tamarindus showed higher amount of damage. Even then reductions among the 3 species were maximum in Moringa (53%) followed by Tamarindus and Azadirachta (42 and 25% respectively). Reduction in leaf production was maximum in Moringa (44%) medium in Tamarindus (41%) and minimum in Azadirachta (14%). As it was at 60 days after exposure, leaf area showed negative growth in Azadirachta and Tamarindus. Though Moringa showed positive growth, decrease as compared to reference was very high (97%). Results are given in Tables 29 - 31 and Fig. 8.

3.9 BIOCHEMICAL ESTIMATIONS

Monthly observations of all the parameters were divided into 3 groups of 2 months each 60, 120 and 180 days respectively. Original values of all the parameters were given in Tables (32 - 39). Analysis of variance was carried out using 2-way

Fig. 9 Biochemical changes in SO_2 - exposed saplings



T : Ascorbic acid - Treated
U·T : Ascorbic acid - Untreated

- decrease
+ increase

classification to study the difference between treatments and between different durations. Analysis of variance showed that F values for the difference between treatments was significant at a probability of < 0.05. This clearly revealed that ascorbic acid treatment significantly mitigates the SO_2 impact on the three tree saplings studied. Difference between durations was not significant. Response of individual species was the same as in field study. Greater damages were recorded in deciduous species as compared to evergreen ones. Fluctuations in various parameters as compared to reference were less in ascorbic acid treated plants as compared to untreated ones (Figs. 9, 10). Response of each species was different to ascorbic acid treatment.

3.9.1 Total Chlorophyll content

Chlorophyll content was higher in Tamarindus followed by Moringa and Azadirachta. Reductions were maximum in the two deciduous species (16 - 33%). Tamarindus comparatively showed less reduction (11 - 27%).

3.9.2 Total Proteins

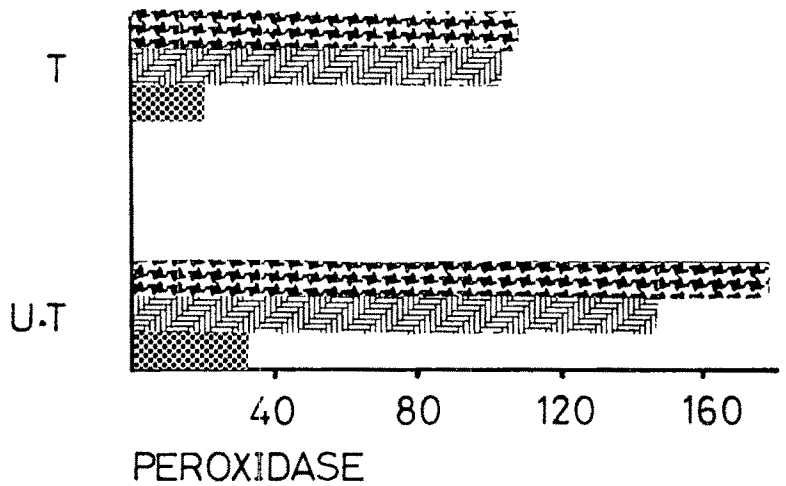
Total protein content in Moringa and Tamarindus showed a continuous increase while Azadirachta showed a rise and a fall in all the saplings. Increase was maximum in the evergreen species. Reduction in protein content was 2 - 26% in the deciduous species whereas in Tamarindus it was 1 - 22%. Among the ascorbic acid treated saplings recovery rate was higher in Azadirachta as compared to the other two species, but untreated saplings of the same species showed greater damage.

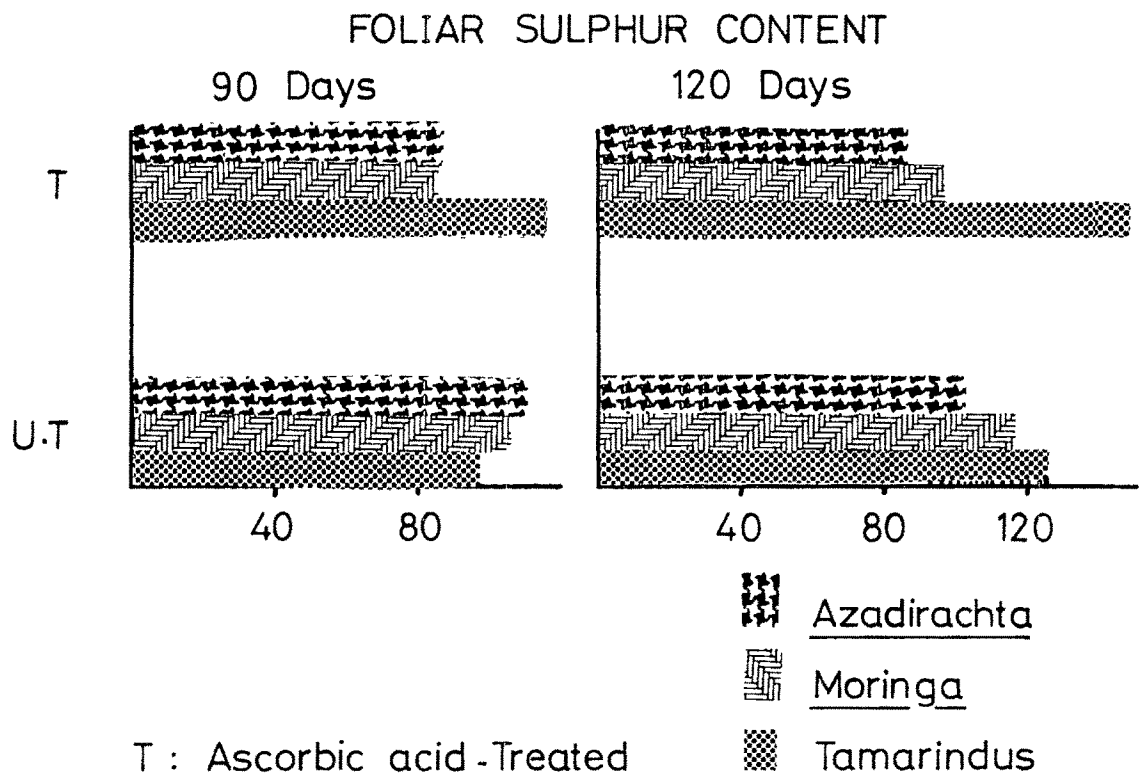
3.9.3 Ascorbic acid

This showed a continuous increase in all the three

Fig. 10 Biochemical changes in SO_2 - exposed saplings

(% increase)





T : Ascorbic acid - Treated

U.T : Ascorbic acid - Untreated

species. Higher amounts were seen in Moringa. Moringa and Tamarindus showed an increase in the treated saplings at 60 days (8 - 20%). At 120 days increase was seen only in Tamarindus. Reductions recorded in all the 3 species ranged between 4 - 64%. Ascorbic acid treated saplings of Azadirachta showed less reduction at 120 and 180 days as compared to Moringa. Overall, decrease was minimum in Tamarindus.

3.9.4 Glutathione

Glutathione content showed a continuous increase in Tamarindus while deciduous species showed a decrease followed by an increase. Azadirachta showed higher reductions (14 - 29%). In Moringa it was 6 - 22%. Tamarindus showed comparatively less reduction (3 - 9%).

3.9.5 Total sulphydryl groups

Deciduous species showed a fall followed by an increase in T S H content while Tamarindus showed a continuous increase. Fluctuations were more in deciduous species as compared to evergreen ones. Reductions in deciduous species were 1 - 35%, maximum being in Moringa (8 - 35%) Tamarindus showed an increase at 60 days (6%), while reductions were seen at 120 and 180 days (1 - 11%).

3.9.6 Peroxidase

Peroxidase content was maximum in Tamarindus as compared to the two deciduous species. Its content showed a rise upto 120 days and then a fall. Higher amounts were seen in saplings exposed to sulphur dioxide. It was manifold in the two deciduous species (31 - 246%). In Tamarindus it was just 11 - 36%.

3.9.7 Acid Phosphatase

Deciduous species showed an increase upto 120 days and then a decrease while evergreen species showed continuous increase. Reductions in the deciduous species were 10 - 58%. In Tamarindus increase was by 2 - 36%.

3.9.8 Foliar Sulphur content

Deciduous species responded similarly to foliar sulphur content while evergreen species showed some difference. Both the deciduous species showed higher foliar sulphur content in untreated exposed plants (103 - 117%) and the increase was less in ascorbic acid treated saplings (86 - 96%). While in Tamarindus maximum increase seen in the treated saplings was 117 - 148% and untreated saplings showed less increase (97 and 125%). Overall sulphur uptake was maximum in the evergreen species as compared to the two deciduous species.

3.10 ANATOMICAL OBSERVATIONS

3.10.1 Surface study

Leaf samples collected from two polluted localities and from reference showed the following observations. At reference the stomata in all the three species were normal. Cuticular wax deposition was maximum in Tamarindus followed by Moringa. Azadirachta did not show any wax. Linearity was seen in pollutant concentration vs stomatal damage. Of the two localities taken (2 & 5), plants at locality 5 showed maximum damage. In Azadirachta stomatal pore was reduced. Deformed stomata were seen. In Moringa stomatal clogging was seen. Guard cells at inner periphery (around pore margin) showed malformation. In Tamarindus deformed stomata and clogging were seen. Cuticular wax was deteriorated in both Moringa and Tamarindus. This deterioration was less at locality 2.

Explanations for Plate 3

SEM photographs of leaf surface of the three tree species

F : Reference of Azadirachta OR - Outer Ring;
IR - Inner Ring

G : Reference of Moringa

H : Reference of Tamarindus

Arrow in G & H indicates abundant cuticular wax.

I : Azadirachta leaf from Locality 5

Stomatal pores are of various sizes; Arrow indicates reduction in stomatal pore.

Cuticular wax is absent in Azadirachta.

F - I : 5 µm

plate 3

Explanations for Plate 4

J :Azadirachta leaf from Locality 3
Arrow indicates the stomatal clogging

K & L : Moringa leaf from Locality 5 showing partial development of wax
Arrow indicates the clogging of stomata

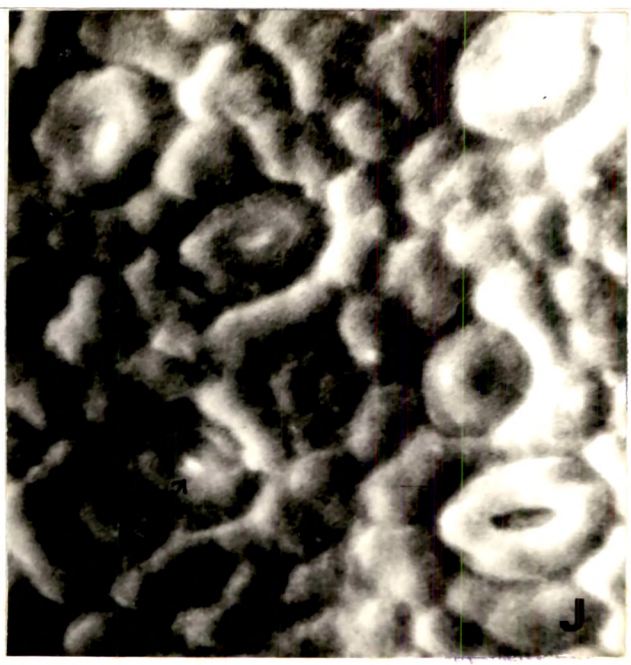
M & N : Tamarindus leaf from Locality 5

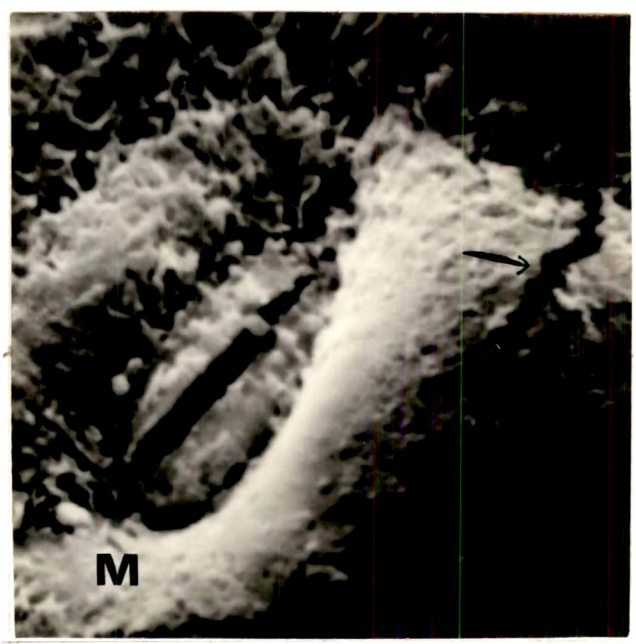
M : Arrow indicates the damage (breaking) of cuticular wax

N : Arrow indicates reduction in the size of stomatal pore

J & K : 20 µm

L - N : 5 µm





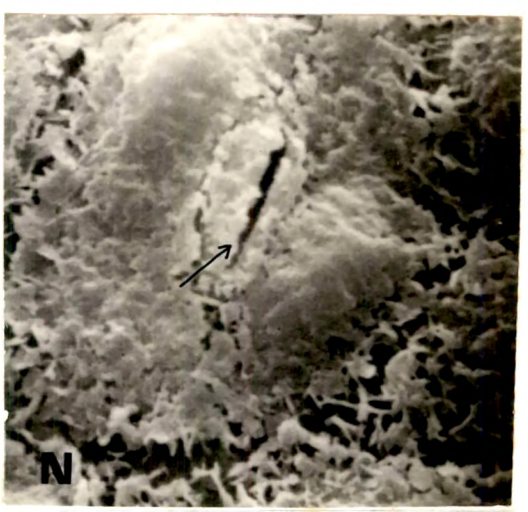


Plate 4

Clogging of stomata was less in Moringa. Azadirachta and Tamarindus also showed less degree of damage. Overall Azadirachta was maximum effected followed by Moringa and Tamarindus (Plates 3, 4).

3.10.2 Ultrastructure

Palisade cells of reference plant (Azadirachta) showed discoidal chloroplasts with well organised grana and stroma. Stroma contained 1 - 2 starch grains and a few plastoglobuli. In SO_2 exposed plants the cells were greatly disorganised and most of the chloroplasts were damaged. SO_2 caused the swelling of chloroplasts and disorganisation of grana and stroma. The thylakoids were greatly distended and the chloroplast envelopes were disrupted at several places. Plastoglobuli were more and they were often seen outside the chloroplast along with starch grains. High vacuolation was evident and the cells were probably on the verge of autolysis. In saplings treated with ascorbic acid the damage was minimal. The chloroplast structure was more similar to those in the reference plants. However, the chloroplasts occasionally showed dilated grana stackings and accumulation of plastoglobuli (Plates 5, 6).

Explanations for Plate 5

Chloroplasts from the leaves of Azadirachta

O & P : Chloroplasts from reference leaves

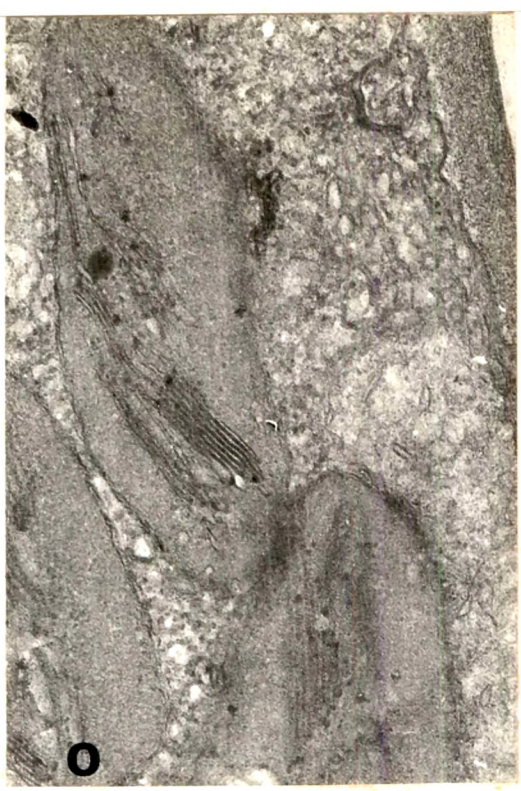
(X 90,000)

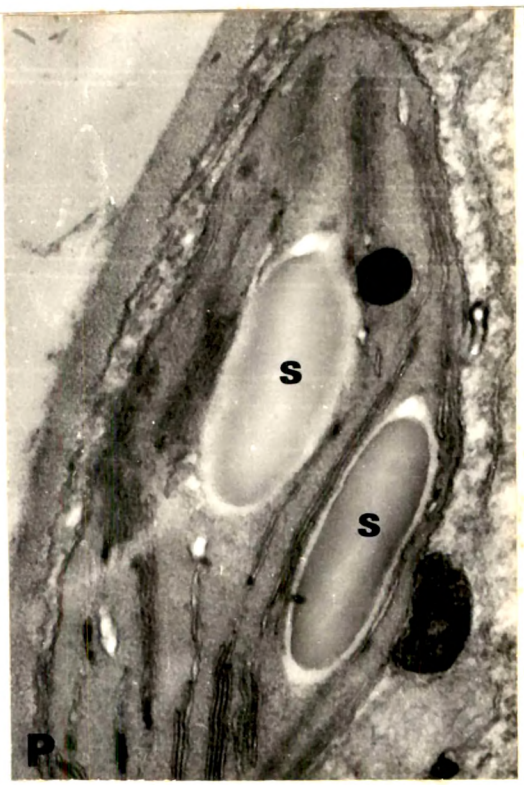
Q & R : Chlolroplasts from the leaves exposed to SO_2 followed by ascorbic acid treatment

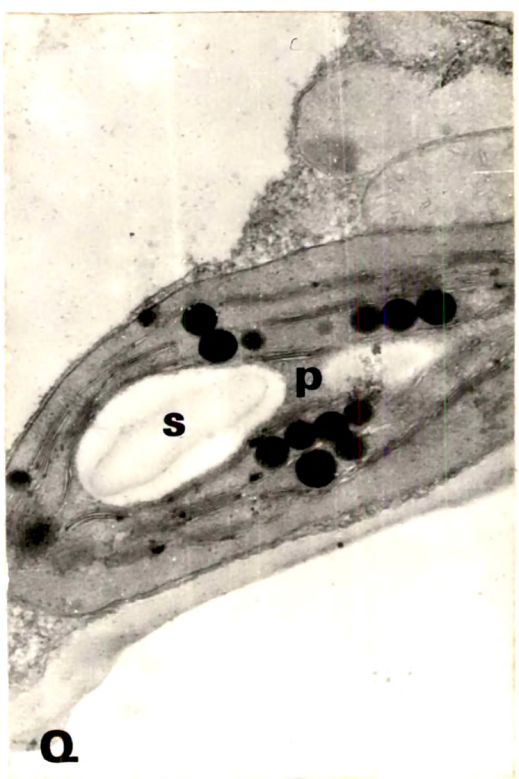
(X 70,000)

Arrow indicates dilated thylakoids

s - starch grain p - plastoglobuli







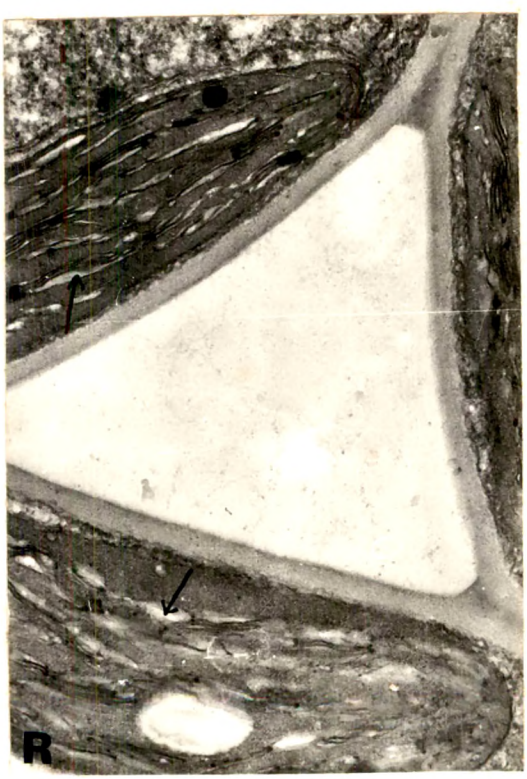


Plate 5

Explanations for Plate 6

Chloroplasts from the leaves of Azadirachta

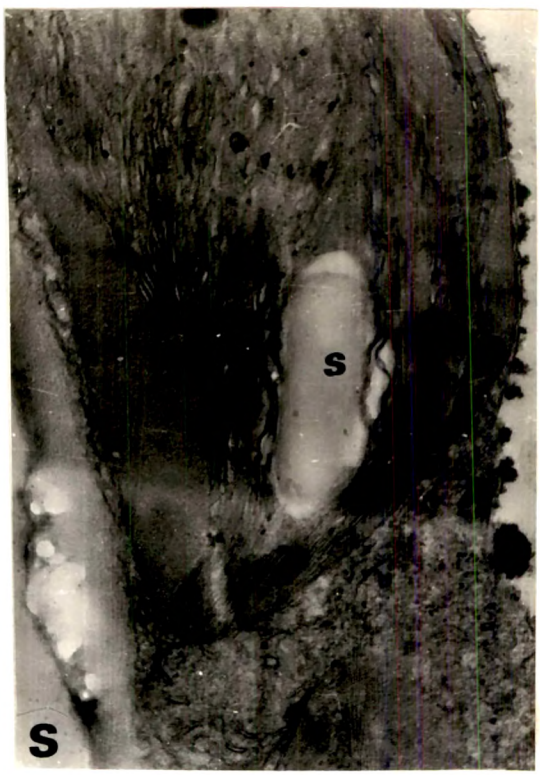
S - V : Degenerated chloroplasts from the leaves exposed to SO_2

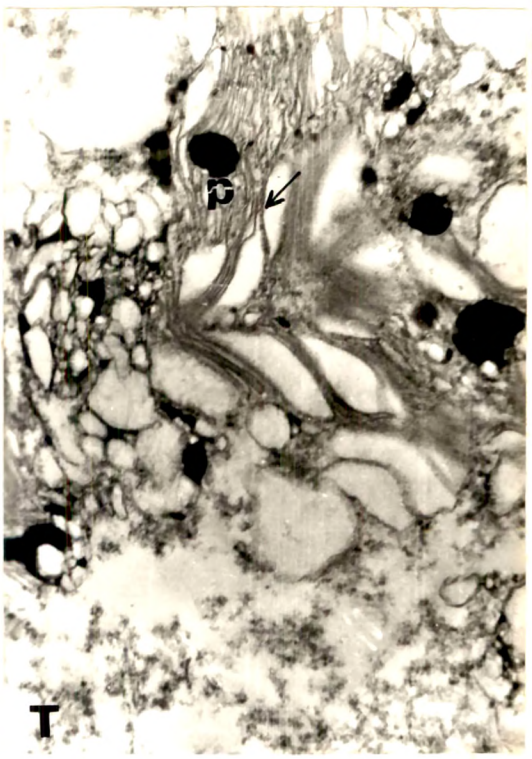
(X 70,000)

Extrusion of starch grains and plastoglobuli are seen.

Arrow indicates highly dilated thylakoids

s - starch grain p - plastoglobuli





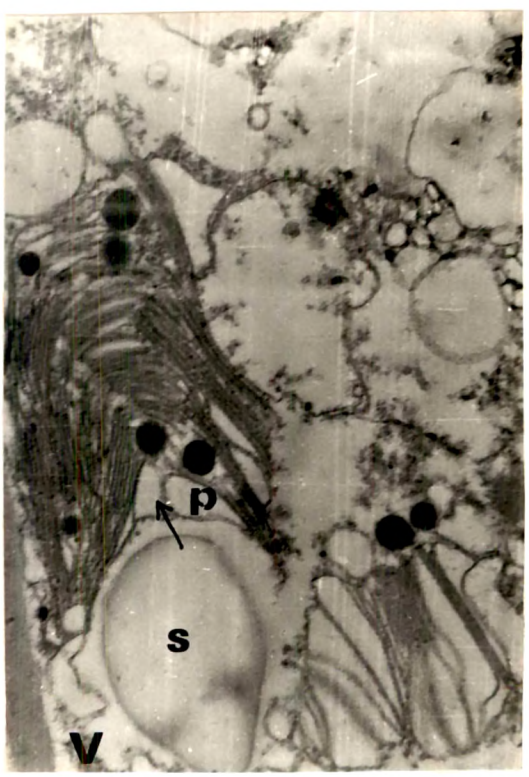


Plate 6