Chapter 3

RESULTS

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3.1 AMBIENT AIR CONCENTRATION OF THE MONITORED POLLUTANTS

Monitoring data recorded at different points (for SO_2 & NO_x) are given in Table 5. Annual average concentration data show that points 1a, 1b, 2 and 3 had SO_2 concentration less than 10 μgm^{-3}, while at other points the SO_2 concentration exceeded 12 μgm^{-3}. Maximum concentration was recorded at point 7 (21.8 μgm^{-3}). The range of minimum to maximum concentration (recorded during monitoring) show maximum concentration at point 7 (125.4 μgm^{-3}). Average NO_x concentration at all the points was higher than SO_2 concentration. Point 1b showed least NO_x concentration (12.5 μgm^{-3}), at points 1a, 2, 3 and 4, 30 - 35 μgm^{-3} NO_x concentration was recorded. At points 5, 6 & 7 more than 40 μgm^{-3} concentrations were recorded. Peak concentration of NO_x during the year at various points varied from 18.5 to 243 μgm^{-3}.

Growth periods (seasons) of crops studied were monsoon and winter, so average concentrations of these seasons are considered in the respective crop growth study.

During monsoon lower concentrations of SO_2 were recorded at points 1b, 1a and 2 (2.1, 3.0 & 3.3 μgm^{-3} respectively). Higher SO_2 concentrations (more than 14.0 μgm^{-3}) were recorded at points, 5, 6 & 7 with maximum concentration at point 7 (22.8 μgm^{-3}). NO_x concentrations ranged from 10.1 to 50.9 μgm^{-3} at different points.

During winter, lower SO_2 concentrations as compared to monsoon were recorded at points 3, 4, 6 & 7 (4.0, 3.6, 14.5 and 10.0 μgm^{-3} respectively). At points 1a,1b, 2 & 5 concentrations recorded were more than during monsoon (5.0, 2.6, 5.7 and 22.1 μgm^{-3} respectively). Average NO_x concentration during winter was recorded maximum at point 6 (98.8 μgm^{-3}), at other points intermediate values were recorded (30.3 - 64.9 μgm^{-3}).

Pollutant concentration in general showed the following trend.

1a > 1b < 2 < 3 < 4 < 5 < 6 < 7

Monitoring of chlorine was done at zone II and VIII. The average concentrations recorded were 6.7 & 5.8, and 15.3 & 32.7 μgm^{-3}, respectively during winter and monsoon.

The average concentrations of pollutants are based on periodic (weekly) monitoring and many higher peaks might have been missed in absence of continuous monitoring system. The peaks recorded showed a wide variation and at most of the places values were much higher than the average concentration.

SEASONAL VARIATIONS IN POLLUTANT DISPERSION

Change in pollutants concentration during different seasons was observed at different zones, because of change in the wind direction.

Zones I, II, III, VI & VII were in windward direction during monsoon and in leeward direction during winter while zone IV, V & VIII were in leeward direction during monsoon and in windward direction during winter from major pollution sources. The winds were mostly SW or S during monsoon and NE or N during winter (Fig.1).

Zone I was 2 Km NW to major pollution source (Industrial estate) and during both the seasons wind direction towards this zone was comparatively very less (1.6 and 2.3% during monsoon and winter respectively). Greater distance from the source was also the reason for very low pollutant concentration at this zone. This zone had lesser concentration of pollutants during monsoon (3.3 SO_2 & 21.7 NO_x μgm^{-3}) than during winter (5.7 SO_2 & 46.6 NO_x μgm^{-3}).

During monsoon zone II, III, VI and VIII experienced wind direction for maximum days (58%). Out of these zones, zone II & III had comparatively less pollutant concentration (Table 5). Zone III was at a greater distance from the major pollution source (3 Km from industrial estate, Fig.2) and thus had lesser pollutant concentration than zone VII, inspite of receiving wind in this direction for higher percentage of days. Zone II though was nearer to the source (0.5 Km from Petrochemicals and Refinery) had comparatively lesser pollutant concentration (of SO_2 & NO_x) than zone III. This was because of lesser pollutant emission from the source (due to adaptation of better safety measures). Chlorine was present at zone II which was emitted from an alkalies and chemical industry.

Zone VI and VII were very close to their respective sources (0.5 Km NE of fertilizer complex and industrial estate respectively). During monsoon these zones faced winds for maximum number of days (58%). Wind direction and their closer location were responsible factors for higher concentration of pollutants at these zones.

Zone IV, V and VIII were SW to their respective sources, but at different distances. Wind direction towards these zones was for 12.8% of the days during monsoon. Zone IV was 2.5 Km from the source while zone V was 0.5 Km from the same source and thus had higher pollutant concentration than zone IV (Fig.2). Zone VIII was 1 Km from the major source, but local pollutant (chlorine) intensified the effects of other pollutants. During winter zone IV, V and VIII experienced wind direction for maximum number of days (42%). Zone V was maximum polluted during this season (22.1 SO_2 and 64.9 NO_x μgm^{-3}) which was because of its closer location to the source and predominant wind in this direction. Zone IV was also in the same direction but was at a greater distance from the source and therefore experienced lesser pollution load. Zone VIII which was in the windward direction from major source (industrial estate) during this season, had high pollutants concentration.

Zone II, III, VI & VII experienced wind direction for 15.6% of days during winter. Zone II, III & VII therefore had lesser pollutant concentration during winter than monsoon. Zone VI was very close to the source. High pollution emission (and probably less dispersion) from the source during winter with frequent changes in the wind direction during late winter (February) resulted in high pollution level at this zone. SO_2 concentration did not show much difference during the two seasons and NO_x concentration was maximum (98.8 μgm^{-3}) here.

3.2 FIELD SURVEY OF COMMON CROPS

Preliminary survey was done to get a general idea about the damage occuring to different crops at different places. The yield of different crops were compared to yield of respective crop at reference zone (R_1). Variable degree of damage was recorded at all the eight zones. Comparatively lesser damage was recorded at zone I, II and III and higher at zones V, VI, VII and VIII. In monsoon crops (millet, paddy and maize) more damage was recorded at zone III, VI and VII. Winter crops (wheat & potato) showed maximum damage at zone V. The crops grown from monsoon to winter (tobacco & pigeon pea) showed minimum damage at zone I and maximum at zone VIII (Table 6).

Tobacco was the only crop which was grown at all the zones. In this crop lesser damage was recorded at zone I and III (5 and 10% respectively) and higher at zone VII and VIII (42 and 44% respectively).

This survey gave a rough idea about the damage occuring to crops at different zones. Further survey was done for some selected crops with more detailed recording of data for different parameters. The common crops grown in the area were tobacco, pigeon pea and potato. Former two crops are long term crops (monsoon - winter) and the later one is a short term crop (winter).

3.2.1 *Nicotiana tabacum* Linn. (Tobacco)

3.2.1.1 Height

Reduction in height of crop was recorded at all the zones, except at zone II (Table 7.1). At zone I the reduction was not very significant (2.6% at 120 days). At zones III, VI & VII more damage was recorded during monsoon than in winter, while at zones IV, V & VIII damage was more during winter than in monsoon. The % reduction recorded at zones I, IIIc, IIIb, IV, Vc, VII, Vb, IIIa, Va, VII and VI during monsoon (at 60 days) was 1.6, 7.3, 8.2, 12.2 12.3, 15.0, 15.2, 19.8, 20.1, 35.4 and 38.2% respectively. During winter (at 120 days) the % reduction was 2.6, 7.0, 10.4, 13.1, 20.4, 22.6, 23.1, 28.0, 32.1, 34.6 and 35.1 respectively at zone I, IIIc, IIIb, IIIa, Vc, Vb, IV, Va, VI, VII and VIII (Fig.3). At zone

II, 6.6 & 9.4% increase in height as compared to reference was observed at 60 and 120 days respectively. Height was only recorded upto 120 days, as after that topping was done.

3.2.1.2 Total leaf area

Reduction in total leaf area at 90 days (during monsoon) at zone I, IIIc, IIIb, IIIa, Vc, IV, Vb, Va, VIII, VI & VII was 3.0, 11.6, 12.0, 14.0, 15.2, 16.4, 17.2, 18.3, 25.0, 50.2, and 52% respectively. During winter (at 150 days) 4.5, 8.0, 8.4, 10.0, 20.1, 21.8, 22.2, 27.3, 34.1, 42.2 and 44.0% reduction was recorded at zone I, IIIc, IIIb, IIIa, Vc, IV, Vb, Va, VIII, VI and VII respectively (Fig.3). At zone II, 3 to 6.5% increase in leaf area (during 30 - 150 days) was recorded (Table 7.2).

3.2.1.3 Injury index

Crop showed visible symptoms only at zone Va, VI, VII & VIII. Tip and marginal burning of leaves was observed at zone VI and VII with 2-3% injury index at 60 days . At zone VIII interveinal chlorosis and bleaching resulting in ivory patches were observed, injury index was 4.5% (at 120 days), (Table 7.3).

3.2.1.4 Biomass

Reduction in biomass at different zones also showed the same trend as the leaf area reduction. During monsoon (at 90 days) the percentage biomass reduction recorded was 4.9, 10.9, 17.9, 19.9, 24.8, 26.0, 27.1, 28.8, 35.2, 50.1 and 52.3 at zone I, IIIc, IIIb, IIIa, Vc, IV, Vb, Va, VIII, VI and VII respectively (Table 7.4). During winter (at 150 days) at zone I, IIIc, IIIb, IIIa, Vc, Vb, IV, Va, VI, VII and VIII the respective reduction was 6.8, 8.3, 9.2, 11.1, 26.0, 28.0, 28.9, 32.4, 44.7, 46.7 and 46.8% (Fig.3).

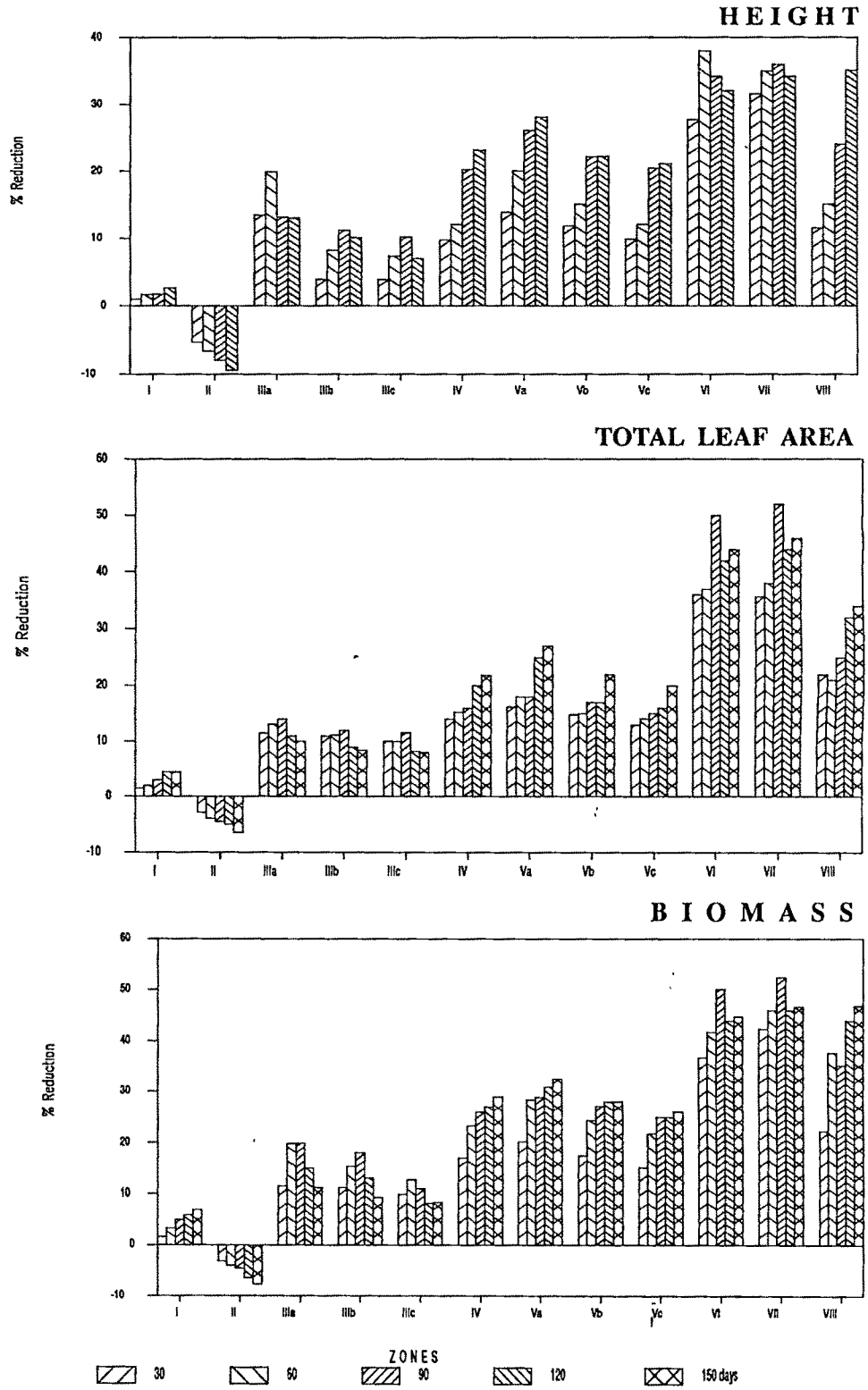
3.2.1.5 Relative growth rate (RGR) and Net assimilation rate (NAR)

Both the rates were reduced as compared to reference zone upto 60 days, at all the zones, except at zone II. In RGR 1 - 12.2% reduction and in NAR 1.7 - 24.7% reduction was recorded, during 30 - 60 days, at different zones. At zone II at all the ages RGR and NAR was more as compared to reference with maximum increase during 120 - 150 days, in RGR 57.5% and in NAR 85.5% increase was recorded (Table 7.5 & 7.6).

3.2.1.6 Yield

Among zones VI, VII and VIII slight difference in yield reduction was recorded (47.0, 46.8 and 46.9% respectively). At zones I, IIIc, IIIb, IIIa, Vc, Vb, IV and Va reduction recorded was 5.2, 7.4, 8.3, 10.2, 21.2, 22.0, 25.8 and 37.0% respectively (Table 10). At zone II, 6.1% increase in yield as compared to reference was recorded (Fig. 6).

Fig. 3 : IMPACT OF INDUSTRIAL AIR POLLUTION
FIELD SURVEY : Nicotiana tabacum Linn.



3.2.2 *Solanum tuberosum* Linn. (Potato)

Cultivation of this crop was restricted to few zones (III, IV, V and VI). At all the sub zones of zone III (IIIa, b & c) increase in growth parameters and yield as compared to reference zone was observed. At all the other zones crop showed reduction in various parameters as compared to reference zone. Maximum reduction was recorded at zone Va being in windward direction and very close to the source.

3.2.2.1 Height

Maximum reduction was recorded at 90 days at all the zones. The % reduction recorded at zone VI, IV, Vb and Va was 34.8, 35.1, 39.2 and 48.2% respectively (Fig.4). At zone IIIa, IIIc and IIIb the respective % increase than reference was 4.0, 5.0 and 15.0 at the same age (Table 8.1).

3.2.2.2 Total leaf area

During whole life cycle maximum reduction in leaf area was recorded at 90 days. The reduction recorded at zone VI, IV, Vb, and Va was 42.8, 43.0, 46.1 and 60.1% respectively (Fig.4). At zone IIIb, IIIc and IIIa, 5.2, 8.6 and 28.0% respective increase was recorded (Table 8.2)

3.2.2.3 Injury index

Tip and marginal burning of leaves was observed at zone Va, Vb and VI. Injury index at the above zones ranged from 10-22% (Table 8.3).

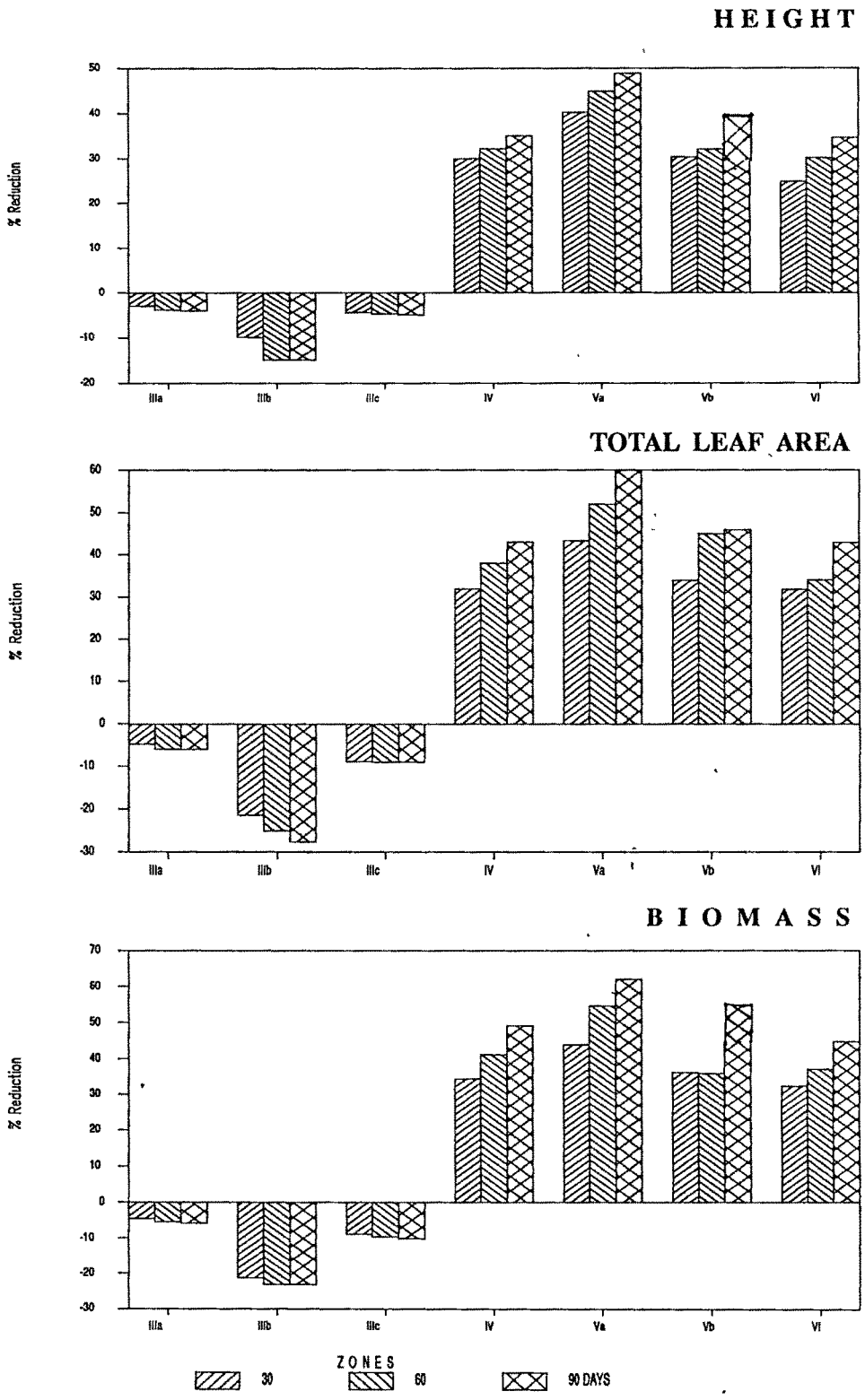
3.2.2.4 Biomass

The above ground biomass showed maximum reduction at 90 days at zones VI, IV, Vb and Va, where respective reduction recorded was 44.7, 49.2, 54.7 and 62.0% (Fig.4). At zone IIIa, IIIc, and IIIb the % increase than reference was 5.8, 10.1 and 23.1 respectively (Table 8.4).

3.2.2.5 Relative growth rate (RGR) and Net assimilation rate (NAR)

The RGR was maximum during 30-60 days age of crop at all the zones. The NAR was maximum during 0-30 days. Reduced RGR and NAR was recorded at zones IV, Va, Vb and VI than at reference zone at all the ages. In RGR 22.3 - 30.9% reduction during 60 - 90 days was recorded at zones IV, Vb, VI and Va. At zone IIIa, IIIb and IIIc the rates were slightly more than reference at all the ages, 10.0 - 32.4% increase in RGR and 20.0 - 46.0% increase in NAR was recorded during 30 - 60 days (Tables (8.5 & 8.6).

Fig. 4 : IMPACT OF INDUSTRIAL AIR POLLUTION
FIELD SURVEY : Solanum tuberosum Linn.



3.2.2.6 Yield

The percentage reduction in yield recorded at zone IV, VI, Vb, and Va was 20.0, 20.5, 21.0 and 31.8% respectively. At zone IIIc and IIIb the % increase than reference was 2.3 and 22.7 respectively (Fig.6). At zone IIIa the yield was almost same as at reference (Table 10).

3.2.3 *Cajanus cajan* Spreng. (Pigeon pea)

Of all the zones where crop was cultivated (I, IIIa, IIIb, IIIc, IV & VII). maximum reduction in all the parameters was recorded at zone VII. At zone IIIa, IIIb, IIIc and VII more reduction was recorded during monsoon than in winter, while at zone I & IV more reduction was recorded during winter in all the parameters.

3.2.3.1 Height

Height reduction at zone IIIc, IIIb, IIIa and VII was 17.6, 20.5, 32.3 and 68.8, respectively at 90 days (monsoon), while at 150 days (winter) the respective reduction was 8.4, 10.6, 22.2 and 60.2% (Fig.5). At zone I & IV, 5.8 and 27.6% reduction during monsoon (at 90 days) and 13.6 and 32.9% reduction during winter (at 150 days) was recorded respectively (Table 9.1).

3.2.3.2 Total leaf area

Leaf area reduction during monsoon (at 90 days) at zone I, IIIc, IIIb, IIIa, IV and VIII was 5.5, 8.7, 9.6, 13.3, 30.6 and 63.7% respectively (Fig.5). During winter (at 150 days) 3.6, 3.9, 8.7, 9.4, 30.9 and 61.0% reduction was recorded at zone IIIc, IIIb, I, IIIa, IV and VII respectively (Table 9.2).

3.2.3.3 Injury index

Crop showed visible symptom at zone IV and VII. At zone IV fall of young fruits was recorded (during 120 - 150 days). Maximum foliar damage (injury index 60%) was recorded at zone VII at 120 days with defoliation and severe leaf burning (Table 9.3).

3.2.3.4 Biomass

Reduction in biomass (above ground vegetative parts) accumulation, recorded at zone IIIc, I, IIIb, IIIa, IV and VII was 3.6, 4.4, 9.5, 13.2, 29.8 and 62.8% (Fig.5) respectively at 90 days (Monsoon). During winter (at 150 days) 6.4, 7.3, 8.6, 10.0, 35.8 and 63.2% reduction was recorded at zone I, IIIc, IIIb, IIIa, IV and VII respectively (Table 9.4).

Fig. 5 : IMPACT OF INDUSTRIAL AIR POLLUTION
FIELD SURVEY : Cajanus cajan Spreng.

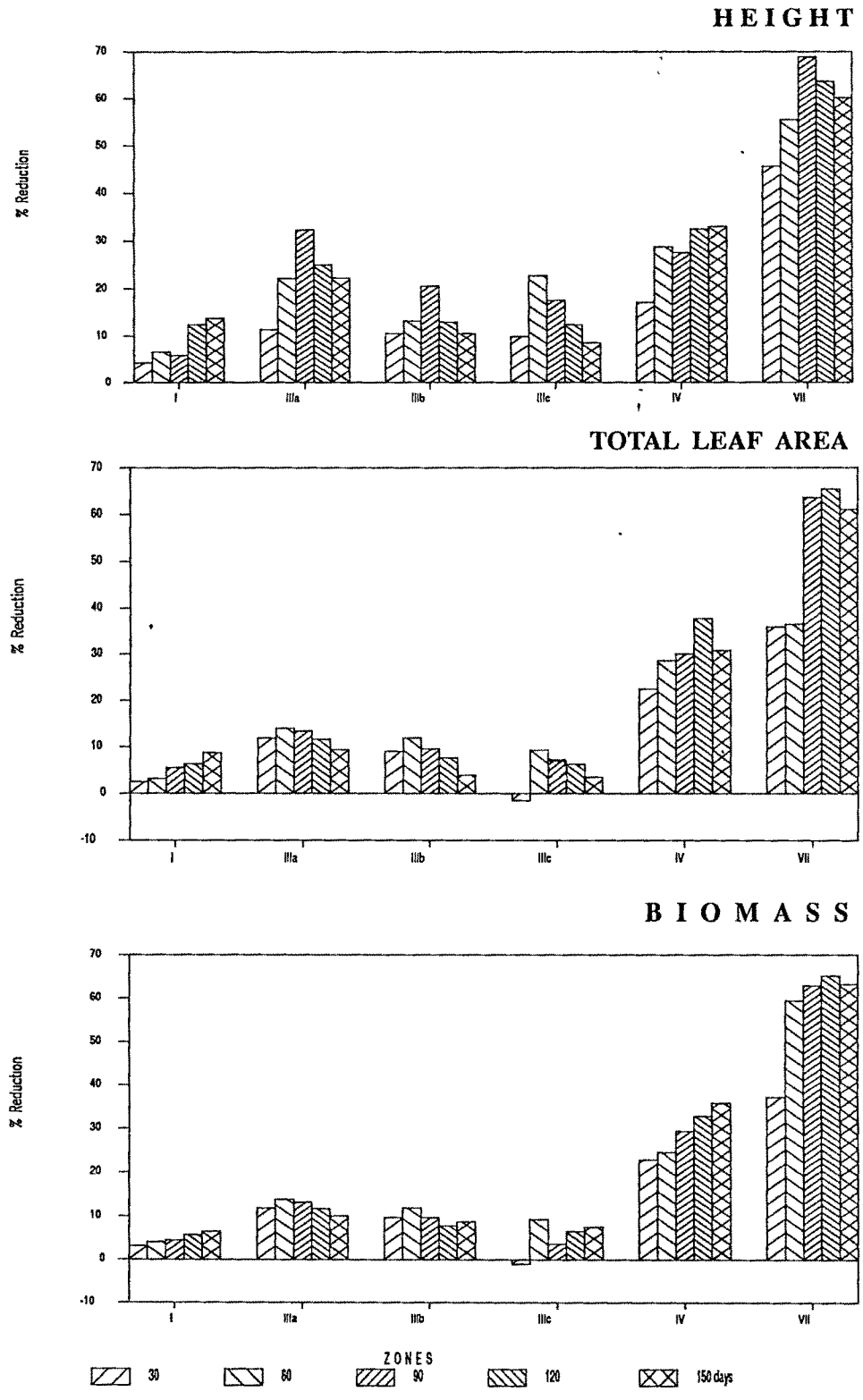
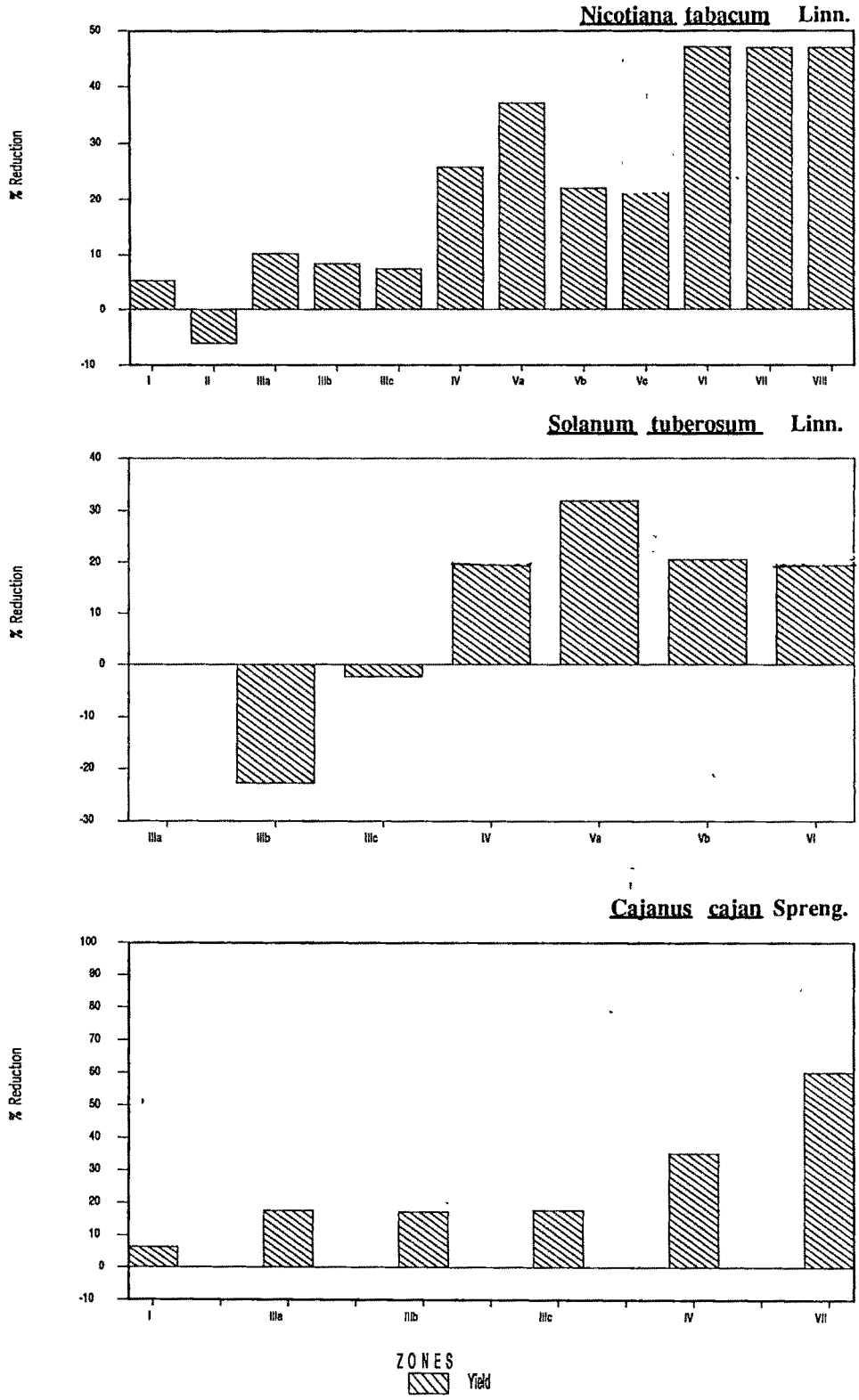


Fig. 6 : IMPACT OF INDUSTRIAL AIR POLLUTION
F I E L D SURVEY : Y I E L D



3.2.3.5 Relative growth rate (RGR) and Net assimilation rate (NAR)

The RGR of plants was maximum during 60-90 days (Table 9.5), NAR was also maximum during 30-60 days (Table 9.6) at all the zones. Both the values did not show much variation than reference at all the zones except at zone VIII. Reduction at zone VIII was 2.3% in RGR (during 60-90 days) and 52.1% in NAR (during 30 - 60 days).

3.2.3.6 Yield

The yield reduction was 6.4, 17.5, 17.0, 17.5, 35.0, and 60.0% at zone I, IIIa, IIIb, IIIc, IV and VIII respectively (Table 10, Fig.6).

3.3 POTTED PLANT EXPOSURE

In field survey various factors (viz. soil, water and other agricultural practices), other than air pollution were also influencing the growth of crops. To reduce these variables to minimum, potted plant exposure study was carried out by keeping all the conditions identical except the air quality.

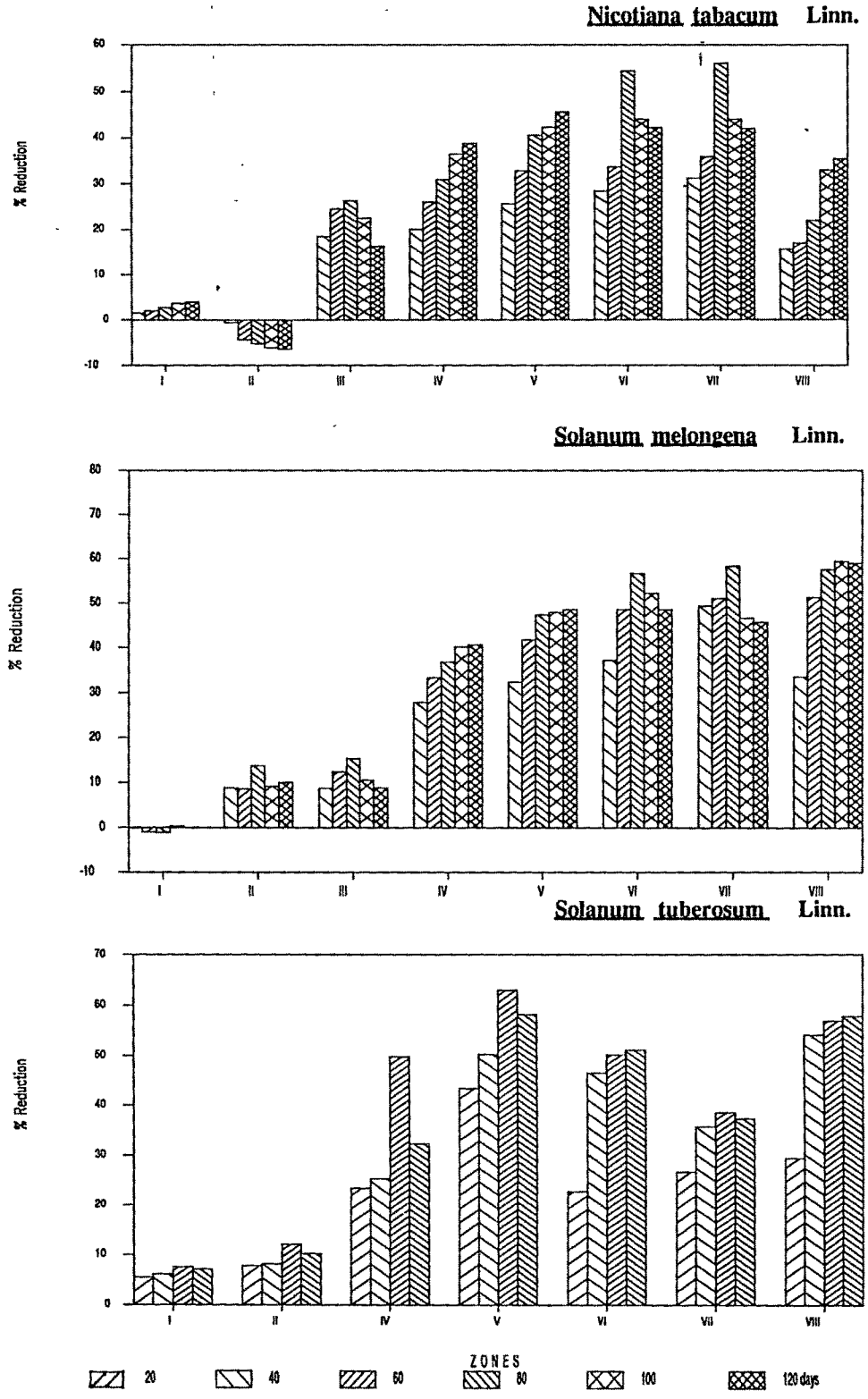
Twenty days old saplings of tobacco and egg plant were transplanted in the pots kept at different zones. First observation was recorded after 20 days of transplantation (i.e. at 40 days age of plants). Potato eyes (reproductive buds) were sown directly in pots and first observation was recorded after 20 days. Value for each parameter was recorded at all the zones, at regular interval of 20 days. Percentage increase or decrease in various parameters was calculated with respect to reference and is expressed in the text at respective places.

3.3.1 *Nicotiana tabacum* Linn. (Tobacco)

Tobacco is a long term crop, it was grown from mid monsoon to mid winter. Upto the 80 days age of plants it was monsoon season thereafter till last observation (120 days) it was winter season. Reduction in various growth and biochemical parameters (except sulphur, nitrogen and chloride content) was observed at most of the zones. At zone II crop showed better growth performance than reference (R_2).

It was observed that the response of crop at different zones varied with season and age. The damage was more in monsoon, at zone III, VI & VII (WW) and less at zone IV, V and VIII (LW) as compared to winter. Maximum damage during this season in various parameters was recorded at 80 days at all the zones and minimum at 40 days. During winter with the change in wind direction the extent of damage increased at zone IV, V and VIII (WW) and decreased at Zone III, VI and VII (LW). At zone II gradual increase over reference was recorded with increase in age.

Fig. 7 : IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE : H E I G H T



3.3.1.1 Height

Maximum reduction in height of plants, during monsoon (at 80 days) was recorded at VII (56.0%). Reduction recorded at zone I, VIII, III, IV, V and VI was 2.7, 21.9, 26.2, 30.9, 40.7 and 54.3% respectively. At zone II, 5.2% increase than reference was recorded (Table 11).

During winter (at 120 days) maximum reduction was recorded at zone V (45.6%), the other in the decreasing order of reduction were 42.2, 42.0, 38.8, 35.4, 16.3 and 3.9% at zone VI, VII, IV, VIII, III and I respectively. At zone II, 6.4% increase was recorded over reference (Fig.7).

3.3.1.2 Number of leaves

Maximum reduction in number of leaves per plant during monsoon was recorded at zone VII (40.9%). Percentage reduction in reducing order was 38.9, 32.2, 29.5, 25.3, 22.7, and 1.0 at zone VI, V, IV, VII, III and I respectively. At zone II, 8.7% increase over reference was recorded (Fig.8).

During winter the percent reduction was maximum at 120 days at zone V (35.2%). At zone VIII, IV, VI, VII, III and I, 32.9, 31.6, 30.1, 29.0, 13.4, and 1.3 % reduction was recorded (Table 12).

3.3.1.3 Total leaf area

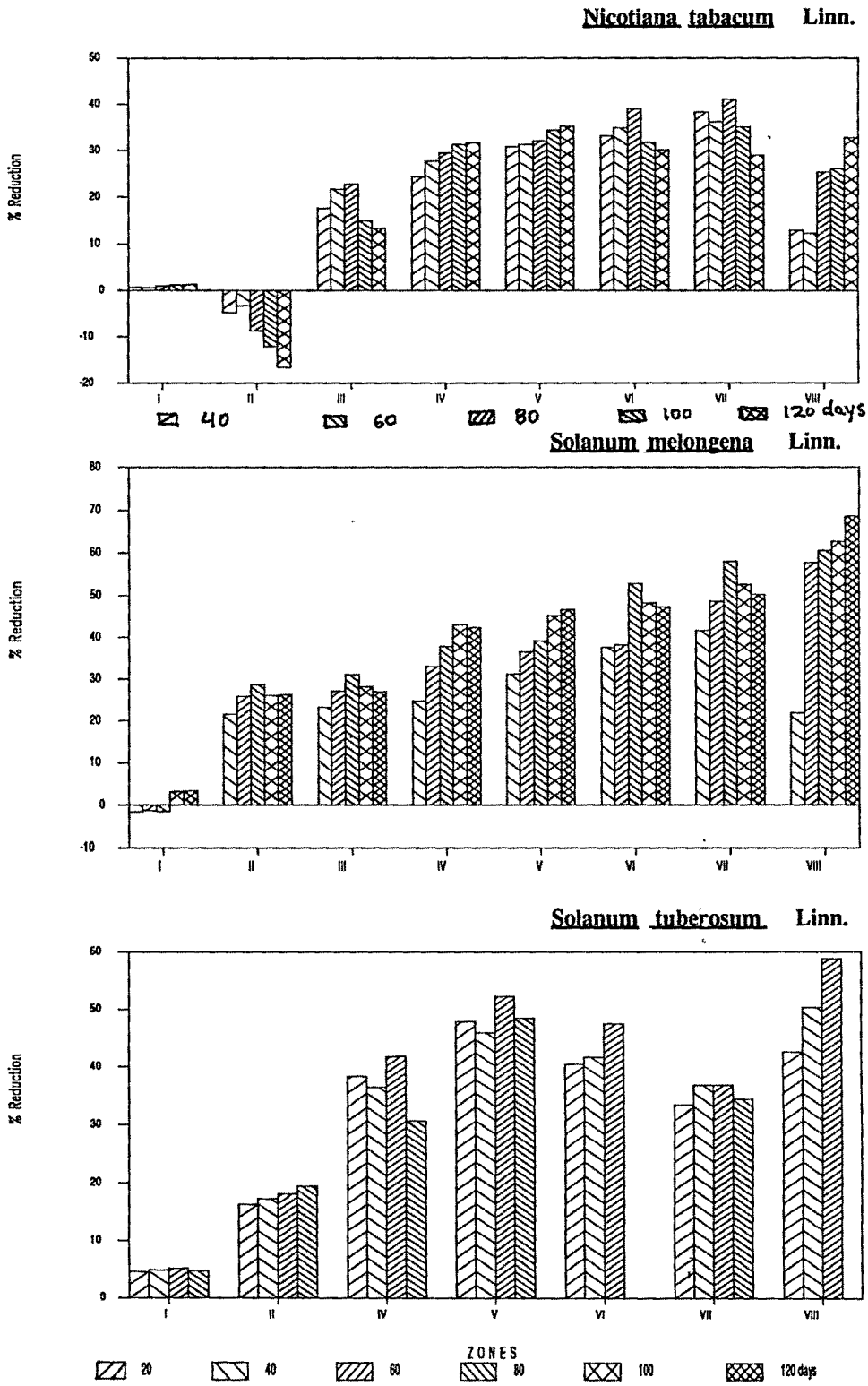
The highest percentage reduction was recorded at zone VII (63.7%) at 90 days (during monsoon) followed by 52.6, 33.7, 32.5, 22.5, 20.4 and 3.8% at VI, VIII, V, IV, III and I respectively. At zone II the total leaf area was 7.4% more than reference (Table 13).

During winter maximum reduction was recorded at zone VIII (40.5%) at 120 days. At zone V, VII, VI, IV, III and I, the % reduction recorded was 38.1, 36.8, 35.4, 25.1, 10.0 and 4.3 respectively. At zone II, 9.1% increase over reference was recorded (Fig.9).

3.3.1.4 Injury index

Plants exhibited visible injury at zone V, VI, VII and VIII only. At zone VI and VII plants showed visible damage at all the ages with increasing extent of injury index (3.9 - 7.2 and 5.2 - 9.5% respectively). At zone V and VIII visible injury appeared during winter (after 80 days age). At pollution zones higher chlorosis with bleaching, necrosis and burning of leaf tip and margin was observed which may be due to combination of senescence and pollution effect. After 100 days differentiation between normal maturity symptoms and pollution effect was difficult. At zond V and VIII, 3.5% and 7.8% injury index was recorded at 100 days (Table 14).

Fig. 8 : IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE : NUMBER OF LEAVES



3.3.1.5 Foliar epidermal structure

Epidermal study was carried out at the age of 80 days old plants of the zone V and reference (R_2). Variations in epidermal features were observed at the pollution zone. Decrease in stomatal density and stomatal index and increase in trichome and epidermal cell density was observed on both the surfaces. In lower epidermis decrease in stomatal index and stomatal density was 32.2 and 43.9% respectively. Trichome density increased to 28.3% (Table 15). In upper epidermis, 37.3 and 38.4% decrease in stomatal index and stomatal density respectively was recorded. Increase in trichome density was 26.4%.

3.3.1.6 Biomass

Maximum reduction in biomass during monsoon (at 80 days) was recorded at zone VII (58.6%). At zone VI, VII, V, IV, III and I the % reduction recorded was 52.0, 32.5, 29.2, 26.0, 17.8 and 3.1% respectively. At zone II, 8.3% increase than reference was recorded (Table 16).

During winter (at 120 days) maximum reduction was recorded at zone VIII (46.5%). Reduction in the reducing order of damage was 43.0, 40.1, 36.9, 30.1, 10.9 and 4.4% at zone VI, VII, V, IV, III and I respectively. At zone II, 9.7% increase than reference was recorded (Fig.10).

3.3.1.7 Relative growth rate (RGR) and Net assimilation rate (NAR)

At all the zones plants exhibited best growth and assimilation rates during 60-80 days of all the ages studied.

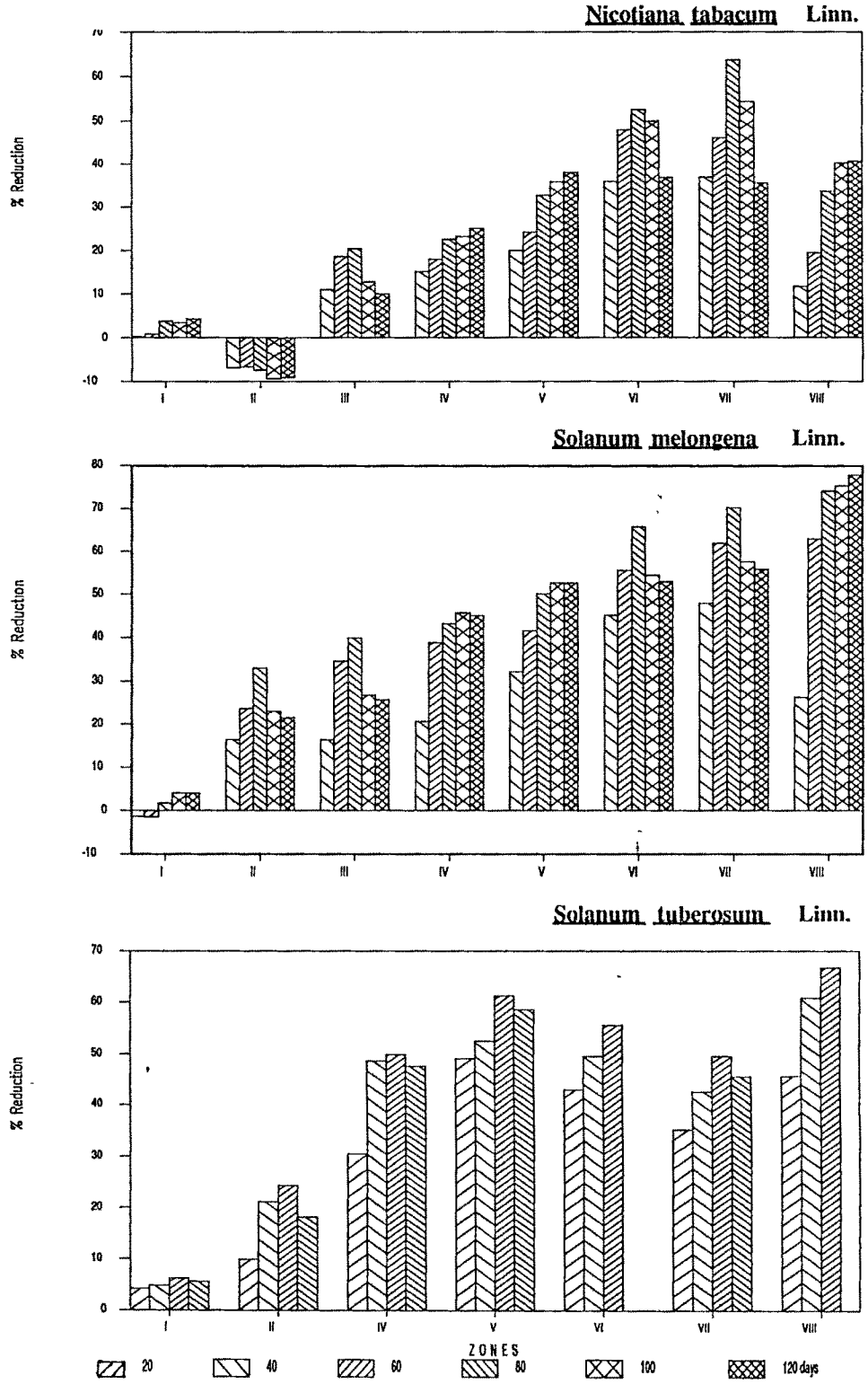
During monsoon (upto 80 days) reduction in both the values as compared to reference was recorded at all the polluted zones. The reduction in RGR was 0.24 - 53.5% and in NAR it was 0.15 - 58.4% with minimum reduction at zone I and maximum at zone VII (Table 17 & 18). At zone II, RGR was more than reference at all the ages, with maximum increase during 80 - 100 days (23.5 and 22.8%) and minimum during 100-120 days (0.32 and 0.09%).

During winter the RGR and NAR of plants was more than reference at (LW) zones III, VI and VII with higher increase during 80 - 100 days. The increase was 6.0, 2.6 and 1.2 times in RGR and 7.4, 2.9 and 1.3 times in NAR at zone VII, VI and III respectively. At all the other zones reduction as compared to reference was recorded. Maximum reduction was recorded at zone VIII (2 times less than reference in both the values during 80 - 100 days). At zone V, IV and I, 1.5, 0.89 and 0.09 times reduction was recorded respectively in both the values.

3.3.1.8 Chlorophyll

Chlorophyll *a* : Maximum reduction was recorded during monsoon at 80 days, at zone VIII (49.6%). The percentage reduction was 48.7, 36.6, 23.5, 19.9, 12.8 and 7.2 at

Fig. 9 : IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE : TOTAL LEAF AREA



zone VI, V, IV, III, VIII and I respectively. At zone II Chlorophyll a content was 5.9% more than reference (Table 19).

During winter highest reduction was recorded at zone VIII (48.7%) at 120 days. The percentage reduction recorded in reducing order of damage was 46.7, 38.9, 38.2, 35.0, 7.6 and 5.1 at zone V, IV, VI, VII, I & III respectively. At zone II, 4.6% increase over reference was recorded (Fig.11).

Chlorophyll *b*: : Maximum reduction during monsoon was recorded at zone VII (38.0%) at 80 days (Table 20). At zone VI, V, VIII, IV, III and I, the reduction recorded was 36.1, 28.6, 27.8, 18.5, 11.9 and 5.2% respectively. At zone II increase than reference was 6.0%.

Highest reduction (35.2%) during winter was recorded at zone VIII at 120 days. The reduction at zone V, VI, VII, IV, I and III was 34.4, 31.6, 29.8, 23.4, 5.7 and 4.2% respectively. At zone II, 6.2% increase was recorded (Fig.12).

3.3.1.9 Total soluble sugars

Maximum reduction in soluble sugars during monsoon was recorded at 80 days at zone VII (36.7%). At zone VI, V, IV, VIII, III and I; 30.8, 28.8, 28.0, 13.2, 14.05, and 4.9% reduction respectively was recorded (Table 21). At zone II, 5.7% increase over reference was recorded.

During winter maximum reduction (31.6%) in soluble sugar content was recorded at 120 days, at zone VIII. At zone V, VI, VII, IV, I & III the percent reduction recorded was 26.3, 26.2, 25.4, 22.9, 6.0, and 4.4 respectively. At zone II, 2.2% more sugar content than reference was recorded (Fig.13).

3.3.1.10 Nicotine

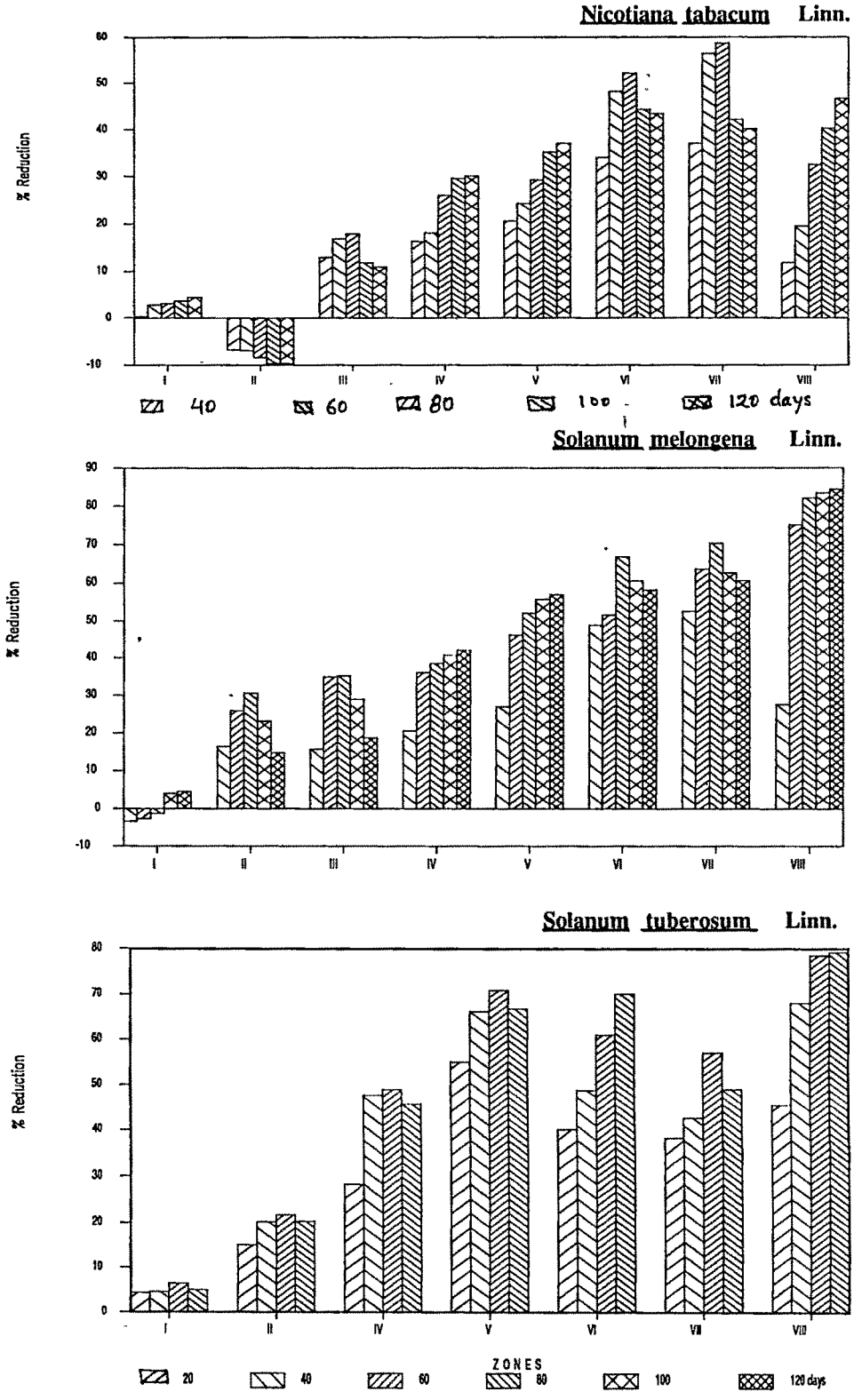
Nicotine content was determined in mature leaves. Increase in nicotine content was recorded at zones II and VIII (3.66 and 1.74 times respectively). At other zones 8 - 40% reduction in nicotine content was observed (Table 25).

3.3.1.11 Sulphur

Gradual increase in foliar sulphur content was recorded as compared to reference at all the ages at all the zones. Maximum accumulation of sulphur during monsoon was recorded at 80 days, at zone VII (1.12 times more than reference) Increase in sulphur content with respect to reference was 1.09,0.71,. 0.55, 0.54, 0.44, 0.39, and 0.23 times at zone VI, V, IV, III, VIII, II and I respectively (Table 22).

The sulphur accumulation during winter (at 120 days) was recorded maximum at zone VI (3.1 times more than reference). At zone V, VII, VIII, IV, III, II and I the respective increase was 2.7, 2.6, 1.9, 0.98, 0.43, 0.35, and 0.27 times, than the reference (Fig.14).

Fig. 10 : IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE : B I O M A S S



3.3.1.12 Total Nitrogen

Increase as compared to reference in nitrogen content of foliar tissues was observed at all the zones, at all the ages, but the increase was not as much as was found in sulphur content.

Maximum increase in nitrogen content during monsoon (at 80 days) was recorded at zone VII (0.75 times more than reference). At zone VI, VIII, V, IV, III, II and I the increase was 0.70, 0.62, 0.45, 0.40, 0.35, 0.30 and 0.25 times more than reference respectively (Fig.15).

During winter (at 120 days) maximum increase was recorded at zone VI (1.2 times more than reference). The increase was 0.95, 0.75, 0.71, 0.69, 0.32, 0.28 and 0.25 times more than reference at zone V, IV, VIII, VII, II, I and III respectively (Table 23).

3.3.1.13 Chloride

Higher degree of chloride accumulation as compared to reference was recorded at zone II and VIII, at other zones no significant difference in chloride content was observed with respect to reference (Table 24).

During monsoon maximum accumulation of chloride at both the zones was recorded at 80 days. The accumulation was more at zone VIII (1.5 times) and less at zone II (0.5 times) as compared to the reference.During winter also (at 120 days) the accumulation was more at zone VIII (2.6 times) and les at zone II (1.8 times) than reference.

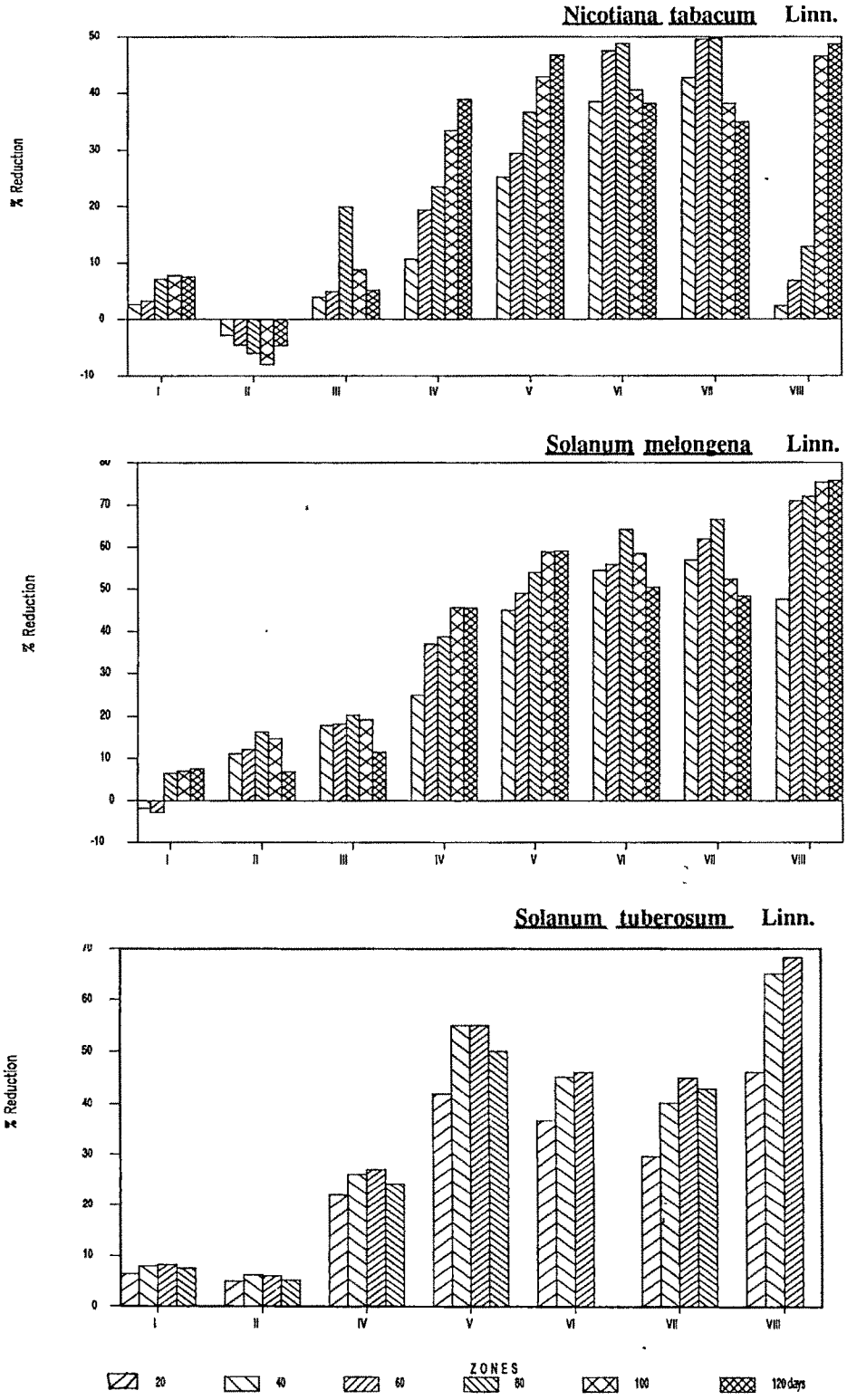
3.3.1.14 Yield

Yield was recorded in terms of total dry weight of leaves per unit area, at harvest.Maximum reduction in yield was recorded at zone VIII (47.7%). At zone VI, VII, V, IV, III and I reduction was 40.4, 38.1, 35.9, 31.1, 20.9 and 4.3% respectively (Fig.16). At zone II, 7.8% increase in yield than reference was recorded (Table 25).

3.3.2 *Solanum melongena* Linn. (Egg Plant)

It is also a long term crop and was grown from mid monsoon to mid winter. For first 60 days of experiment (i.e. upto 80 days of plant age) the season was monsoon and then upto last observation (120 days) it was winter. It was observed that various growth and biochemical parameters (except sulphur, nitrogen and chloride content) were reduced as compared to reference at most of the zones, in initial stages only at zone I (upto 80 days) increase over reference was recorded in most of the parameters, while later on reduction in all the parameters was observed (except higher accumulation of the pollutants).

Fig. 11 : IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE : C H L O R O P H Y L L a



Variation in crop's response was recorded with age and season. During monsoon more damage than winter was recorded at zone II, III, VI, and VII (WW) and less at zone IV, V and VII (LW). Maximum damage during monsoon was recorded at 80 days and minimum at 40 days (except at zone I) in all the parameters. During winter with the change in wind direction damage was more than monsoon at zone IV, V and VIII (WW) and less than monsoon at zone II, III, VI and VII (LW).

3.3.2.1 Height

Maximum reduction during monsoon was recorded at zone VIII (58.4%) at 80 days. At zone II, III, IV, V, VI and VIII, the respective % reduction recorded was 13.7, 15.4, 36.8, 47.4, 56.7 and 57.6. At zone I, 1.1% increase than reference was recorded (Fig.7).

During winter, maximum reduction recorded was at 120 days i.e. 59.0%, at zone VIII. The respective % reduction was 48.6, 48.0, 45.8, 40.7, 10.0, 8.8 and 0.02. at zone V, VI, VII, IV, II, III and I (Table 11).

3.3.2.2 Number of leaves

At 80 days maximum reduction in number of leaves was recorded at zone VIII (60.6%). Reduction in reducing order was 58.0, 52.8, 39.1, 37.9, 31.1 and 28.7% recorded at zone VII, VI, V, IV, III and II respectively. At zone I, 1.7% increase than reference was recorded (Table 12).

During winter also the reduction at 120 days was maximum at zone VIII (68.7%). At zone VII, VI, V, IV, III, II and I the reduction was 50.3, 47.3, 46.6, 42.4, 27.1, 26.3 and 3.5% respectively (Fig.8).

3.3.2.3 Total leaf area

The maximum reduction in total leaf area during monsoon was at 80 days, at zone VIII (74.1%). The reduction was 70.2, 65.8, 50.1, 43.3, 39.8,and 33.0% recorded at zone VII, VI, V, IV, III and II respectively. At zone I, 2.5% increase over reference was recorded (Table 13).

Reduction in total leaf area per plant was maximum at zone VIII (77.7%) at 120 days. At zone VII, VI, V, IV, III, II and I the respective reduction was 55.8, 53.0, 52.6, 45.1, 25.8, 21.4 and 4.0% (Fig.9).

3.3.2.4 Injury index

Visual foliar damage was observed at zone V, VI, VII and VIII (Table 14). At zone VIII defoliation (45.7%) was recorded at 60 days (occured during 40-60 days because of accidental leakage of local pollutant chlorine). Chlorosis and tip & marginal burning of

Visible symptoms recorded on species

A *Solanum tuberosum* Linn.

B *Solanum malongena* Linn.

C *Nicotiana tabacum* Linn.

Symptoms : Chlorosis, necrosis, tip and marginal burning are seen.

Plate 1

leaves were the symptoms exhibited by the crop. At zone VI and VII, 11 and 15% respective injury index was recorded during monsoon at 80 days. At zone V, visible injury appeared after 80 days. Injury index at 100 days was 4.8% and 5.8% at zone V and VIII respectively.

3.3.2.5 Foliar epidermal structure

The epidermal structure of leaves was studied at the age of 80 days. Significant difference in epidermal structure was observed between plants of high pollution zone (V) and reference zone (R_2). In lower epidermis reduction in stomatal frequency and stomatal index was 38.1 and 40.8% respectively (Table 15). Trichome density increased to 93.7%. In upper epidermis the stomatal frequency and stomatal index was 37.6 and 39.2% less than reference samples. Trichome density increase was 89.8%.

3.3.2.6 Biomass

Maximum reduction during monsoon was recorded at zone VIII (82.1%) at 80 days. Reduction recorded at zone VII, VI, V, IV, III and II was 70.3, 66.7, 52.1, 38.3, 35.0 and 30.5% respectively. At zone I, 1.2% increase than reference was recorded (Fig.10).

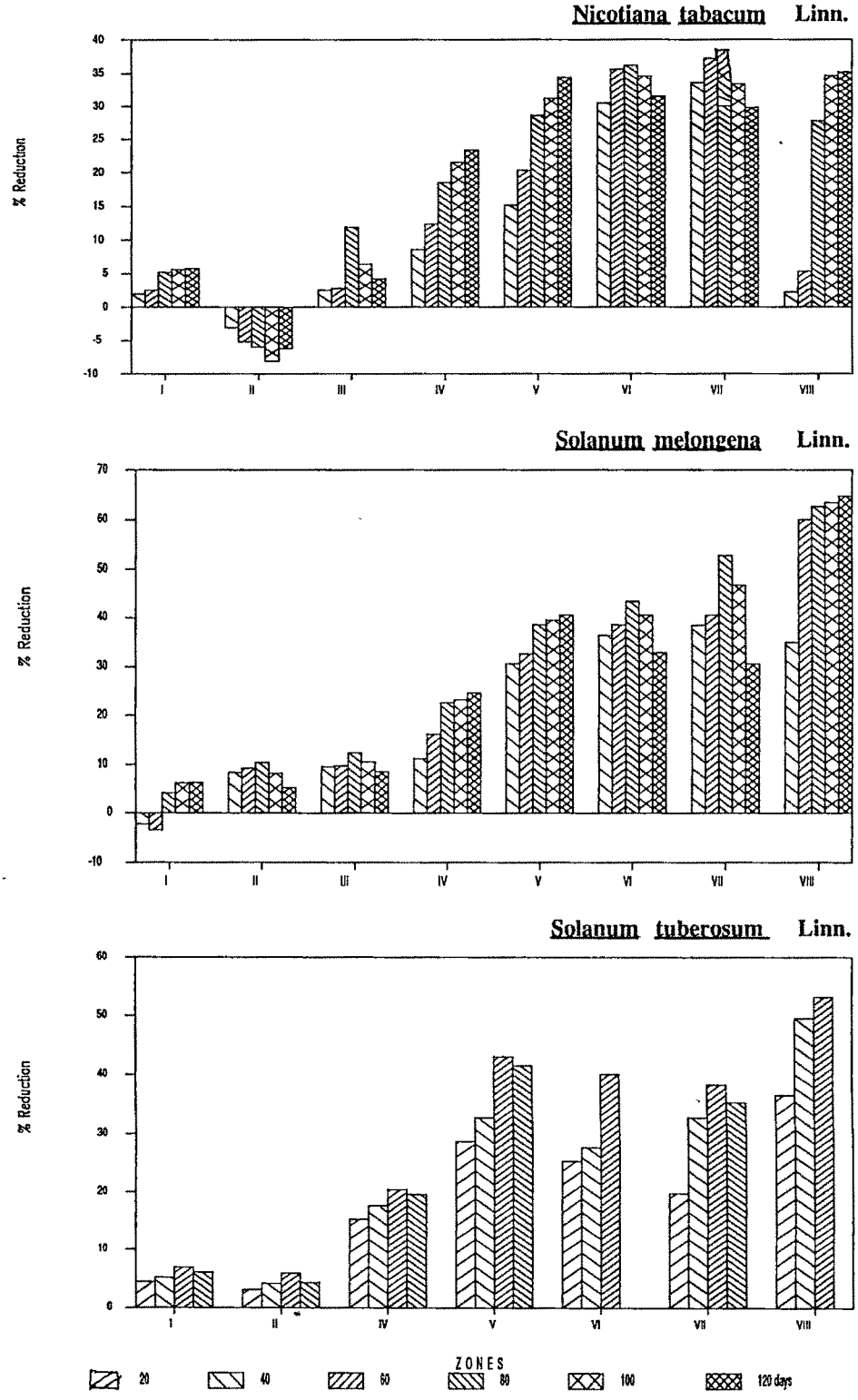
During winter (at 120 days) also the reduction was maximum at zone VIII (84.2%). Reduction in reducing order of damage was 60.6, 58.1, 57.0, 42.1, 18.8, 14.7 and 4.4% recorded at zone VII, VI, V, IV, III, II and I respectively (Table 16).

3.3.2.7 Relative growth rate (RGR) and Net assimilation rate (NAR).

Maximum RGR and NAR of plants (in the whole life cycle) was recorded during the age of 40 - 60 days at all the zones, except at zone VIII where RGR was maximum during 60-80 days. During monsoon at all the zones both the rates were less as compared to reference upto 80 days age. Reduction in both the values was maximum at zone VIII, during 40 - 60 days (88.5 and 90.7% reduction in RGR and NAR respectively). At other zones 0.55 - 69.4% reduction in RGR and 0.49 - 68.6% reduction in NAR was recorded during different ages (40 - 60 and 60 - 80 days).

During winter (after 80 days) the RGR and NAR of plants at zone II, III, VI and VII (LW) was more than reference. The increase in RGR was 1.8, 1.4, 0.82 and 0.73 times and in NAR it was 1.6, 1.1, 0.85, and 0.77 times at zone VII, VI, II and III respectively (during 80 - 100 days). During 100 - 120 days the increase over reference was reduced. At zone I, IV, V and VIII (WW) both the rates were reduced as compared to reference with more reduction during 80 - 100 days (Table 17 & 18). In RGR 32.5, 43.1, 60.0 & 63.9% reduction and in NAR 26.5, 42.3, 65.8 & 72.8% reduction was recorded at zone I, IV, V and VIII respectively.

Fig. 12 : IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE : C H L O R O P H Y L L b



3.3.2.8 Chlorophyll

Chlorophyll *a* : Maximum reduction during monsoon was recorded at zone VIII (72.0%) at 80 days (Table 19). At zone VII, VI, V, IV, III, II and I; 66.6, 64.3, 54.0, 38.7, 20.2, 16.3 and 6.5% reduction was recorded respectively.

During winter (at 120 days) maximum reduction was recorded at zone VIII (75.8%). At zone V, VI, VII, IV, III, I and II the reduction recorded in respective zones was 59.1, 50.4, 48.3, 45.6, 11.6, 7.6 and 6.9% (Fig.11).

Chlorophyll *b*: : Reduction in chlorophyll b content during monsoon (at 80 days) was maximum at zone VIII (62.8%). At zone VII, VI, V, IV, III, II and I reduction was 52.8, 43.4, 38.6, 22.6, 12.4, 10.4 and 4.2% respectively (Fig.12).

During winter maximum reduction recorded was at zone VIII (64.8%). Reduction in reducing order was 40.6, 32.8, 30.6, 24.7, 8.6, 6.4 and 5.2% at zone V, VI, VII, IV, III, II and I respectively (Table 20).

3.3.2.9 Total soluble sugars

Maximum reduction in soluble sugars during monsoon was recorded at zone VIII (51.8%) at 80 days. At zone VII, VI, V, IV, III, II and I, reduction recorded was 49.2, 44.6, 38.2, 23.9, 15.6, 12.7 and 2.7% respectively (Table 21).

During winter maximum reduction in soluble sugars was recorded at zone VIII (54.8%) at 120 days. At zone VI, V, VII, IV, III, II and I the reduction recorded was 42.6, 41.3, 38.3, 30.0, 10.0, 6.6 and 6.1% respectively (Fig.13).

3.3.2.10 Sulphur

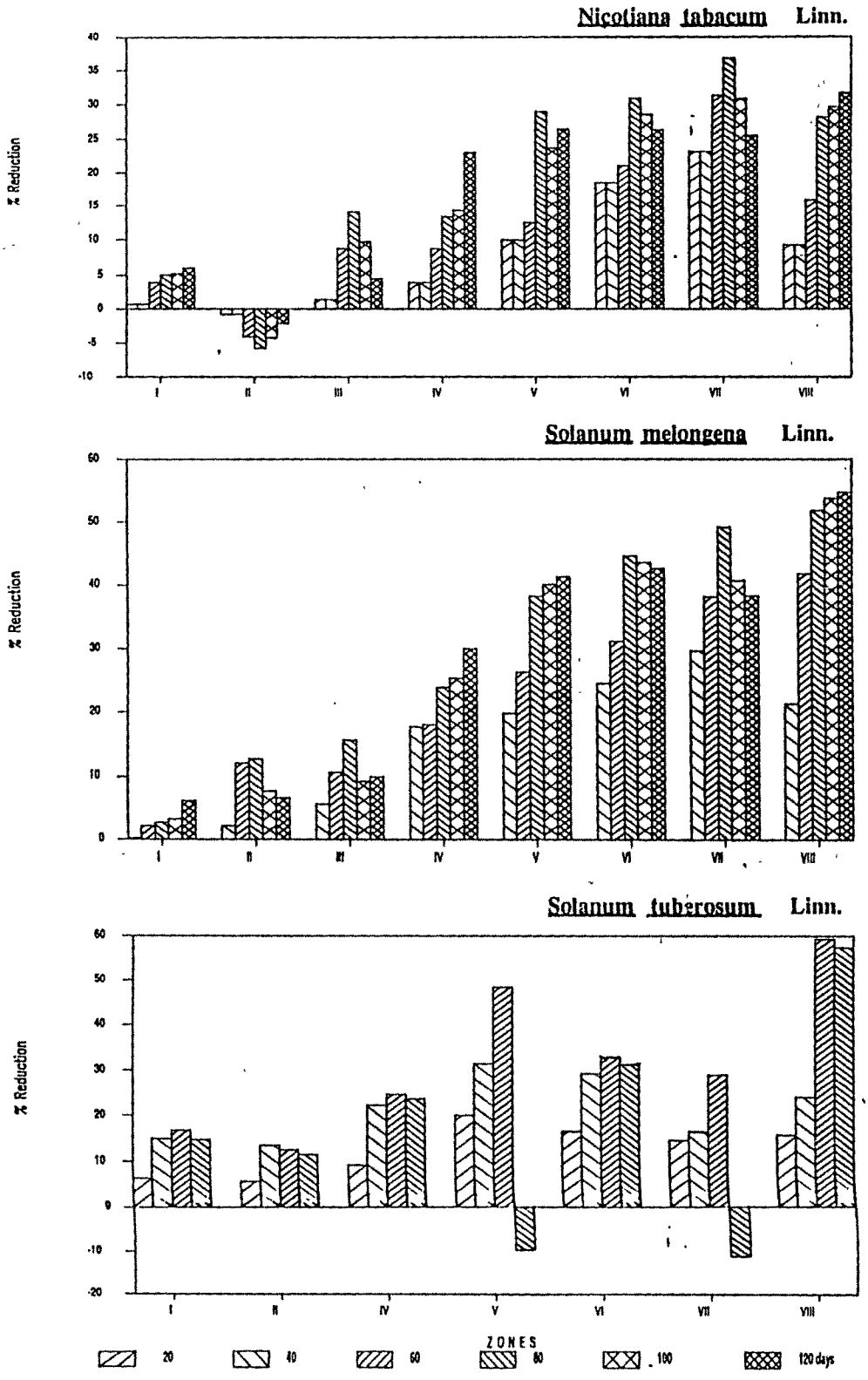
Gradual increase in sulphur content of foliar tissues, as compared to reference was recorded with increasing age at all the zones. Maximum foliar sulphur accumulation during monsoon was recorded at zone VII (1.4 times more than reference) at 80 days (Table 22). At zone VI, V, VIII, IV, III, II and I the increase recorded over reference was 1.3, 1.0, 0.94, 0.60, 0.48, 0.48 and 0.24 times respectively.

During winter sulphur accumulation at zone V and VI was almost the same (2.39 and 2.40 times respectively). At zone VII, VIII, IV, III, II and I the increase was 2.2, 1.1, 0.92, 0.68, 0.35 and 0.16 times respectively (Fig.14).

3.3.2.11 Total nitrogen

Increase in nitrogen content of leaves was observed at all the ages, with respect to reference (Table 23.). During monsoon maximum increase was recorded at 80 days at zone VII (0.85 times). At zone VI, V, VIII, IV, III, II and I the increase over reference

Fig. 13 : IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE : TOTAL SOLUBLE SUGARS



was 0.80, 0.50, 0.49, 0.43, 0.32, 0.27 and 0.20 times respectively (Fig.15).

During winter (at 120 days) maximum increase was recorded at zone VI (0.99 times). The increase was 0.79, 0.76, 0.66, 0.52, 0.28, 0.24 and 0.20 times over reference at zone VI, V, VIII, IV, II, I and III respectively.

3.3.2.12 Chloride

Significant increase in foliar chloride content over reference, was recorded at zone II and VIII (Table 24).

During monsoon maximum accumulation was recorded at 80 days at both the zones. The accumulation was more at zone VIII (0.60 times more than reference) and less at zone II (0.42 times more than reference).

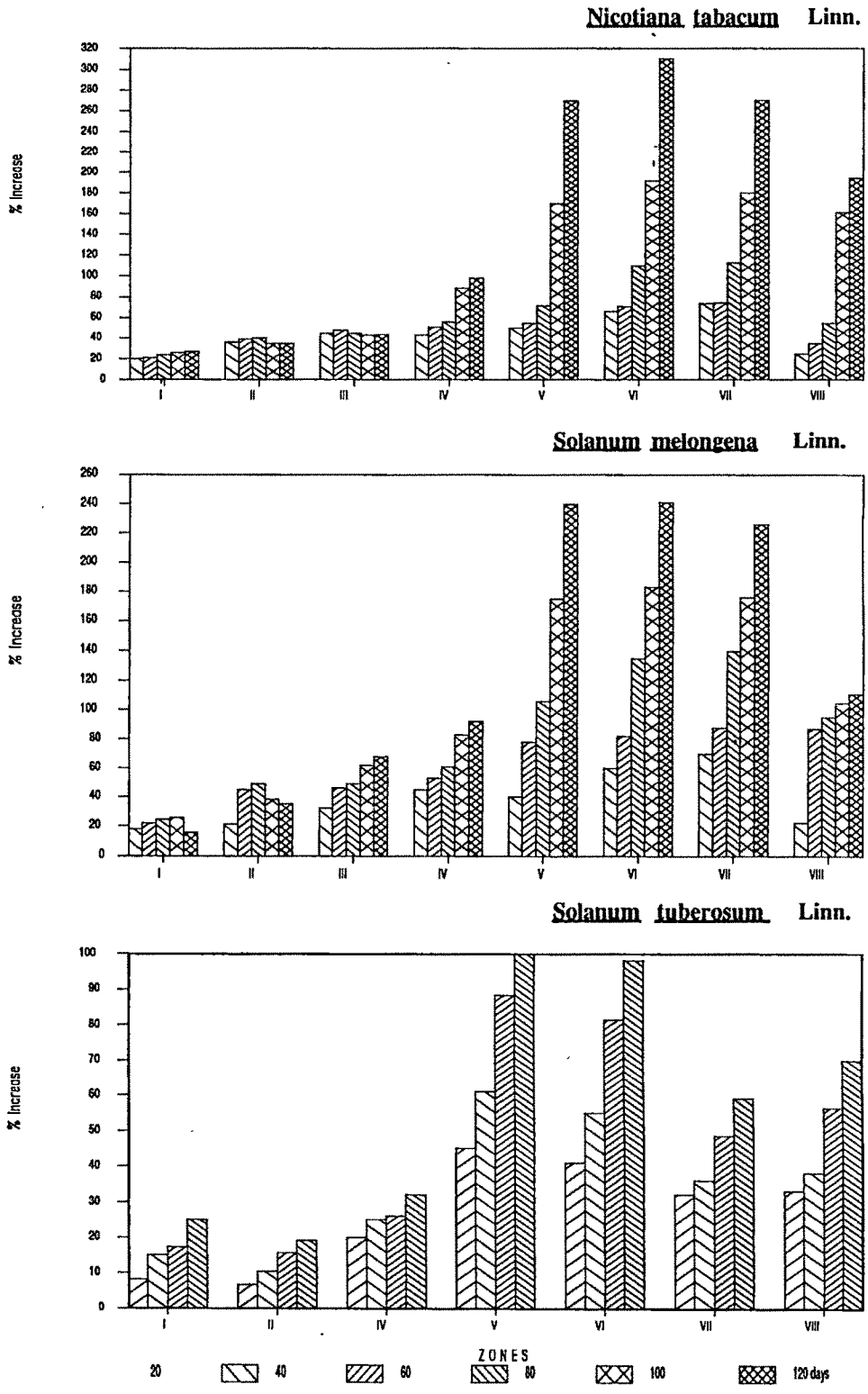
During winter (at 120 days) also the accumulation was more at zone VIII (1.4 times) and less at zone II (0.80 times more than reference).

3.3.2.13 Yield

Different parameters like % flowering, % fruiting and average weight of fresh fruits were recorded (Table 25).Maximum reduction in % flowering was recorded at zone VIII (80%). At zone VII, VI, V, IV, III and II reduction recorded was 60.6, 45.0, 34.0, 25.0, 25.0 and 15.0% respectively. No reduction was recorded at zone I.

Maximum reduction in % fruiting was recorded at zone VIII (86.6%). At zone VII, VI, IV, V, II and III, the reduction was 66.7, 60.1, 60.0,46.7, 40.5 and 26.7% respectively. At zone I, fruiting was not reduced. Maximum reduction in ultimate yield was recorded at zone VIII (85.2%). At zone VII, VI, IV, V, II, III and I the % yield reduction was 66.6, 64.7, 64.0, 63.0, 58.3, 41.6 and 6.0 respectively (Fig.16).

Fig. 14 : IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE : S U L P H U R



3.3.3 *Solanum tuberosum* Linn. (Potato)

It is a short term crop and completes its life cycle during winter season. Crop showed reduced growth and yield at all the polluted zones[1] as compared to reference. Varying degree of damage in various parameters (except pollutant accumulation) was recorded with maximum damage at the age of 60 days at all the zones[2]. Minimum damage was recorded at 20 days.

3.3.3.1 Height

Maximum reduction in height the of plants was recorded at zone V (62.9%) at 60 days (Fig.7). At zone VIII, VI, IV, VII, II and I respective reduction recorded was 57.0, 50.2, 49.8, 38.2, 12.2 and 7.6% (Table 11).

3.3.3.2 Number of leaves

Number of leaves were maximum reduced at the age of 60 days (Fig.8) at zone VIII (58.7%). The percentage reduction was 52.3, 47.4, 41.8, 36.6, 18.2 and 5.2 at zone V, VI, VII, IV, II and I respectively (Table 12).

3.3.3.3 Total leaf area

Percentage reduction in total leaf area was recorded maximum at zone VIII (66.7%) at 60 days (Table 13). At zone V, VI, VII, IV, II and I the % reduction recorded was 61.2, 55.6, 49.5, 49.8, 24.2 and 6.2 respectively (Fig.9).

3.3.3.4 Injury index

Maximum visible damage to leaves was recorded at the age of 60 days. The injury index recorded at zone V, VI, VII and VIII was 12.0, 5.0, 9.6 and 15.2% respectively (Table 14). At zone VIII 12% defoliation was recorded at the same age. No defoliation was recorded at any other zone. At 80 days complete drying of plants was recorded at zone VI and VIII.

3.3.3.5 Foliar epidermal structure

The study was conducted at 60 days age of the plants of zone V (WW) and

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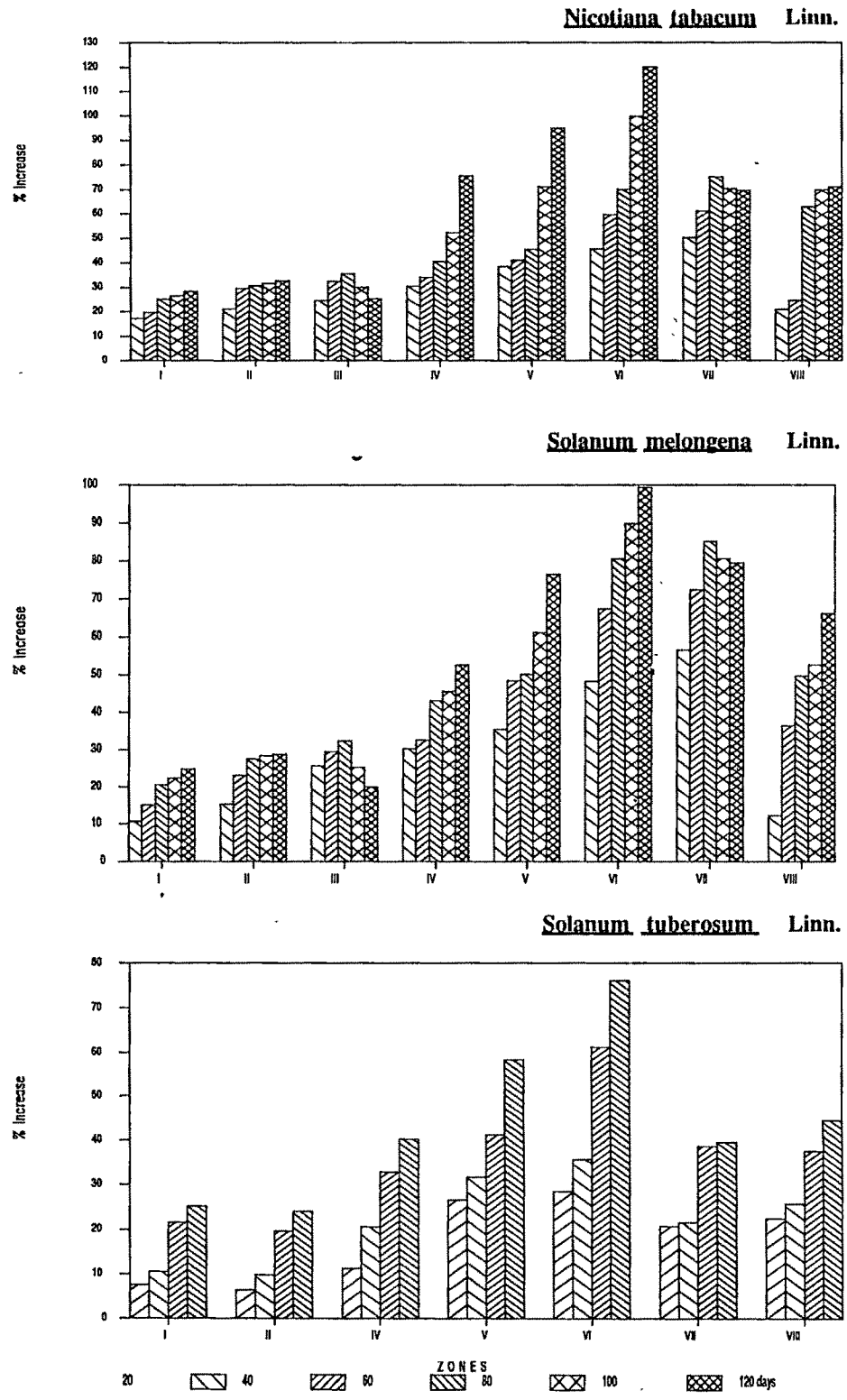
1. At zone III crop was partially destroyed(by pathogens) so data was not available.

2. At zone VI & VIII all plants dried because of accidental leakage of high concentration of pollutants, therefore data for some parameters (number of leaves, total leaf area and chlorophyll content) was not recorded. After 60 days damage in other parameters was not related with the age sensitivity.

Fig. 15 : IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE : N I T R O G E N



reference (R_2).Change in epidermal structures was observed in both the epidermis. In lower epidermis stomatal index and stomatal frequency was reduced to 41.9 and 44.9% respectively in high pollution zone (V) and trichome density was 1.2 times more than at reference zone. In upper epidermis 40.8 and 43.4% reduction in stomatal index and stomatal frequency respectively was recorded. Trichome density was double than reference (Table 15).

3.3.3.6 Biomass

Maximum reduction (in above ground biomass) was recorded at zone VIII (78.4% at 60 days). Reducing order of damage at zone V, VI, VII, IV, II and I was 70.8, 60.8, 56.9, 48.9, 21.5 and 6.4% respectively (Table 16, Fig.10).

3.3.3.7 Relative growth rate (RGR) and Net assimilation rate (NAR)

The RGR of plants was maximum during 40 - 60 days, while NAR was maximum upto the age of 20 days at all the zones. Both the rates were reduced at polluted zones as compared to reference, upto 60 days. Maximum reduction in both the values (during 40 - 60) days was recorded at zone VIII (31.1 and 51.1% reduction in RGR and NAR respectively). Reduction in RGR was 22.5, 21.1, 11.7, 2.0, 1.5 and 1.4% and in NAR it was 29.6, 26.5, 35.3, 1.5, 0.11 and 0.9% at zone VII, VI, V, IV, II and I respectively (Table 17 & 18). During 60 - 80 days the RGR and NAR of plants was more than reference at zones I, II, IV, V and VII.

3.3.3.8 Chlorophyll

Chlorophyll *a* : The chlorophyll content was reduced maximum at zone VIII (68.2%) at 60 days (Table 19). At zone V, VI, VII, IV, II and I the % reduction was 55.0, 46.0, 45.1, 27.0, 8.1 and 6.2 respectively (Fig.11).

Chlorophyll *b* : Maximum reduction in chlorophyll b was recorded at zone VIII (53.2%). The respective reduction recorded at zone V, VI, VII, IV, II and I was 43.1, 40.1, 38.2, 20.4, 6.9 and 5.9% (Table 20, Fig.12).

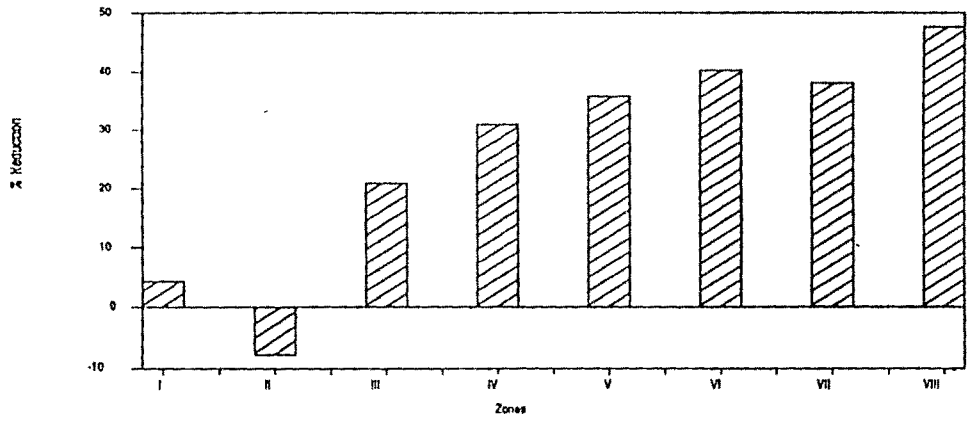
3.3.3.9 Total soluble sugars

Maximum reduction (59.3%) was recorded at zone VIII at 60 days (Table 21). Reduction was 48.4, 33.6, 28.9, 24.6, 16.7 and 12.5% at zone V, VI, VII, IV, I and II respectively (Fig.13).

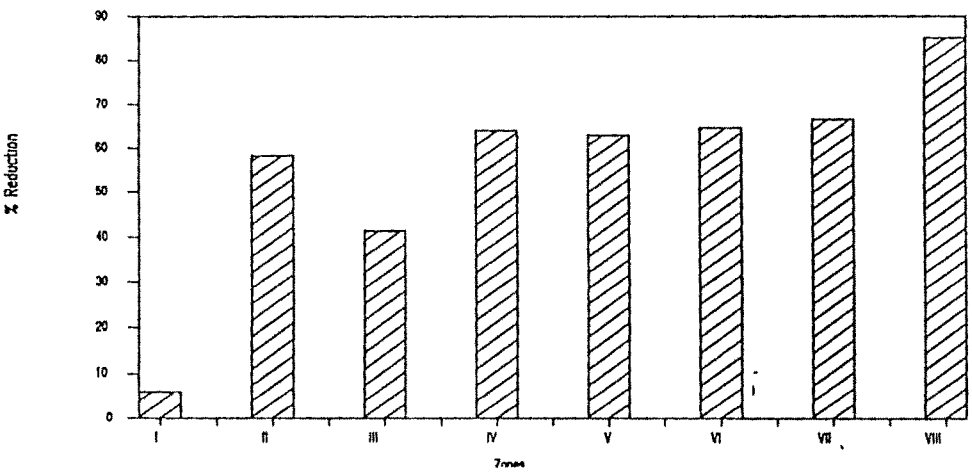
Starch content of tubers was also decreased significantly. The percentage reduction recorded at zone I, II, IV, V, VII, VI and VIII was 5.2, 6.7, 17.6, 34.6, 37.8, 67.9 and 72.9 respectively (Table 25).

Fig. 16 : IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE : YIELD

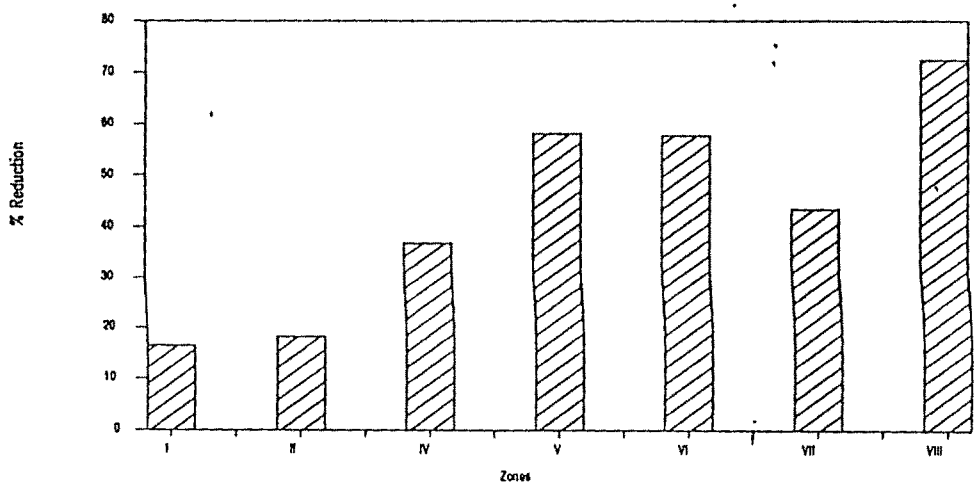
Nicotiana tabacum Linn.



Solanum melongena Linn.



Solanum tuberosum Linn.



3.3.3.10 Sulphur

Gradual increase in foliar sulphur content, as compared to reference was recorded with increasing age at all the polluted zones. Maximum increase at 100 days was recorded at zone V (0.99 times over reference). At zone VI, VIII, VII, IV, I and II the increase recorded was 0.97, 0.69, 0.58, 0.31, 0.24 and 0.19 times more as compared to reference (Table 22, Fig.14).

3.3.3.11 Total nitrogen

Nitrogen content also exhibited gradual increase over reference, with increasing age, at all the zones. Maximum increase was recorded at 100 days at zone VI (0.76 times over reference). At zone V, VIII, VII, IV, I and II the increase in nitrogen content was 0.58, 0.44, 0.40, 0.39, 0.25 and 0.24 times more than reference respectively (Table 23, Fig.15).

3.3.3.12 Chloride

Significant increase in chloride content, over reference was recorded only at zone II and VIII (Table 24). At both the zones gradual increase with age was observed. At 100 days the chloride content was 0.12 and 1.30 times more than reference recorded at zone II and VIII respectively. At other zones no significant difference in chloride content, was observed as compared to reference.

3.3.3.13 Yield

Maximum reduction in tuber yield, (fresh weight/unit area) was recorded at zone VIII (72.6%). Yield reduction in reducing order at zone V, VI, VII, IV, II and I was 58.2, 57.8, 43.6, 36.8, 18.2 and 16.4% respectively (Table 25, Fig.16).

3.3.4 Statistical Analysis Of The Data

Analysis of variance was performed for three parameters viz. total leaf area, biomass and chlorophyll *a* content, using 3 factors (species, season and zones) with more than one observation (equal number,8) for tobacco and egg plant. Significant results were observed in all the three interactions species x seasons; zones x species & zones x seasons. This showed that (1) behaviour of same species was different at different zones (2) same species behaved differently during different seasons at same zone (3) pollution level at different zones varied with seasons. To find out dependency of yield on sulphur accumulation correlation was done which showed negative correlation between sulphur accumulation (in leaves) and yield at all the zones.

For potato multiple regression analysis was done using some parameters viz. total leaf area, biomass, chlorophyll *a*,, sulphur content and yield. Number of replicates for each parameter were 8. Positive relationship between all the parameters was observed except for sulphur. Sulphur content showed negative correlation with all the parameters. This showed that increase in total sulphur content with chlorophyll, biomass and leaf area reduction can be used as early indicators of final yield loss in pollution exposed plants. Values calculated for all the analyses were significant at<0.05% probability and are presented in Table 26.

3.4 ARTIFICIAL FUMIGATION

3.4.1 *Nicotiana tabacum* Linn. (Tobacco)

The experiment was done to study the effect of intermittant short exposures (2 hours) with 48 hour recovery period, of single air pollutant (SO_2) under simulated conditions. Potted plants were exposed to 0.2 ppm SO_2 for 2 hours on alternate days (from 20 to 120 days age). In all the parameters (except sulphur) reduction as compared to unexposed plants (UE) was observed. Plants showed maximum sensitivity at the age of 80 days. At later stages (i.e. at 100 and 120 days age) gradual decrease in damage, than at 80 days was observed in all the parameters except in sulphur which showed continued increase. The data are represented in table 27 & 28. Percentage increase or decrease in various parameter has been shown in Fig.17.

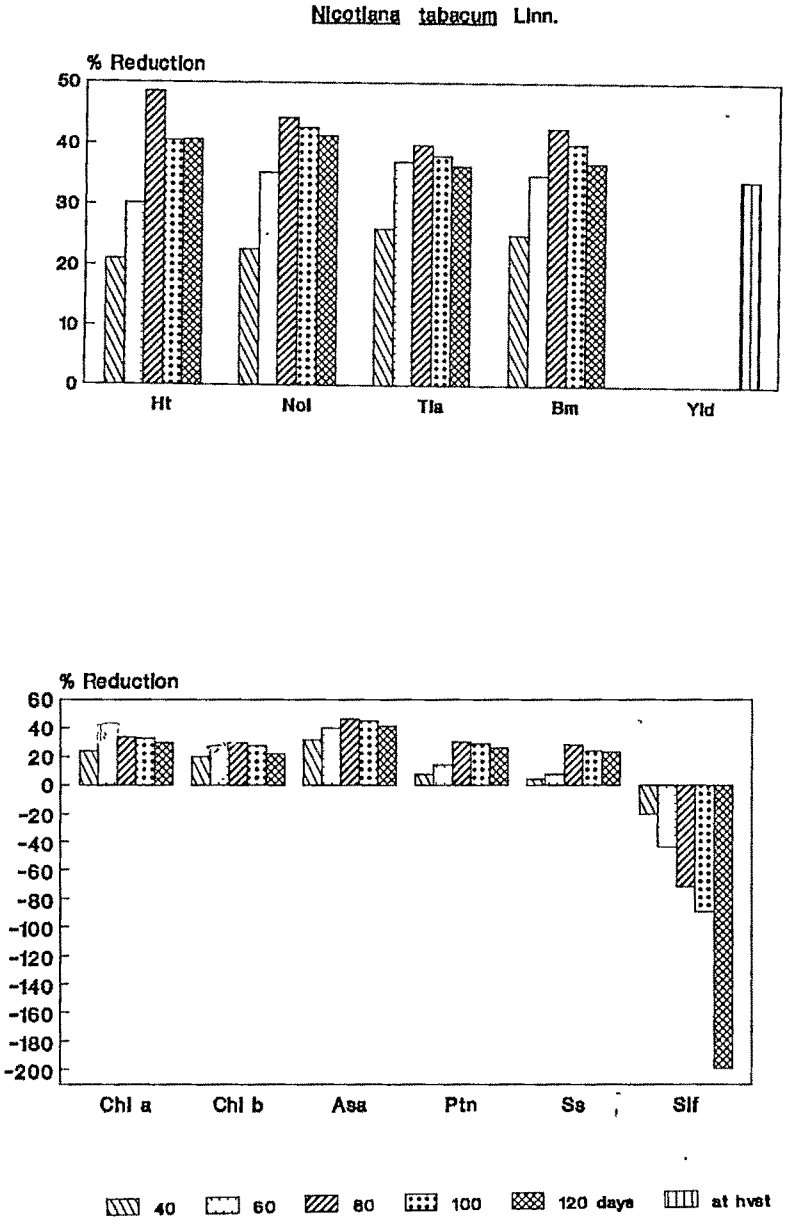
3.4.1.1 Height

Maximum reduction in height of exposed plants was 48.4% at 80 days. At 120 days 40.5% reduction was recorded. At 40 days minimum damage was recorded (21.05%).

3.4.1.2 Number of leaves

Reduction in number of leaves was maximum at 80 days (44.2%), at 120 days 41.2% reduction was recorded. The damage at 40 days was 22.5%.

Fig. 17 : **IMPACT OF SO_2 FUMIGATION**



Ht : Height , Bm : Biomass
Tla : Total Leaf Area
Nol : Number of Leaves, Yld : Yield

Chl a : Chlorophyll a.; Slf : Sulphur
Chl b : Chlorophyll b.; Ptn : Protein
Asa : Ascorbic acid ; Ss : Soluble sugar

3.4.1.3 Total leaf area

At 80 days exposed plants showed maximum reduction in leaf area (39.8%), at 120 days reduction recorded in leaf area was 36.4%. At 40 days minimum damage (26.1%) was recorded.

3.4.1.4 Injury index

The visible injury appeared from 60 days, thereafter there was a gradual increase in injury index with age (60 - 100 days). Injury index at 60 and 100 days was 8.5 and 10.2% respectively. Interveinal chlorosis and marginal burning of leaves were the visible symptoms observed.

3.4.1.5 Biomass

Maximum reduction in biomass accumulation recorded was at 80 days (42.6%). At 120 days 36.8% reduction was recorded. The reduction at 40 days was 25.1%.

3.4.1.6 Relative growth rate (RGR) and Net assimilation rate (NAR)

The RGR and NAR of plants of both the sets (exposed and unexposed) was maximum during 60 - 80 days. Both the rates in exposed plants were decreased as compared to unexposed plants upto 80 days with maximum decrease during 40 - 60 days (27.6% in RGR and 26.2% in NAR). After 80 days (during 80 - 100 and 100 - 120 days age) exposed plants showed more RGR and NAR than unexposed plants, 48.9% increase in RGR and 42.1% increase in NAR was recorded during 80 - 100 days.

3.4.1.7 Chlorophyll

Maximum reduction in chlorophyll *a*, & *b*, was 33.8 and 29.6% respectively at 80 days. At 120 days the reduction recorded was 29.7 and 22.1% in chlorophyll *a*, and *b*, respectively. At 40 days the reduction in chlorophyll *a*, and *b*, was 24.1 and 20.0% respectively.

3.4.1.8 Ascorbic acid

Reduction in ascorbic acid content was maximum at 80 days (46.3%), at 120 days 41.3% reduction was recorded. Minimum reduction (31.6%) was recorded at 40 days.

3.4.1.9 Protein

Maximum reduction (30.1%) in protein content of leaves was recorded at 80 days. At 120 days the reduction recorded was 26.2%. At 40 days 7.6% reduction was recorded.

3.4.1.10 Total soluble sugars

Total soluble sugar content was maximum reduced at 80 days (28.4%). At 120 days the reduction recorded was 23.2%. Sugar content was minimum reduced at 40 days (4.6% less than unexposed plants).

3.4.1.11 Sulphur

Gradual increase in foliar sulphur content of the exposed plants over unexposed plants was recorded with increasing age. The sulphur content of 40, 80 and 120 days old plants was 0.20, 0.71 and 1.99 times more than unexposed plants respectively.

3.4.1.12 Yield

The yield of exposed plants was 34.0% less than unexposed plants.

3.5 MITIGATION OF POLLUTION DAMAGE

Experiments were conducted to minimize the pollution injury caused by pollutants under simulated as well as under field conditions.

3.5.1 Under Simulated Conditions

3.5.1.1 *Nicotiana tabacum* Linn. (Tobacco)

Ascorbic acid (aa) was used as mitigating agent. Three concentrations (0.005, 0.0075 and 0.01 M) were used. One set of each treatment was kept unexposed to know the effect of ascorbic acid under normal conditions. Percentage increase or decrease in various parameters was calculated with reference to untreated and unexposed plants (UTUE). Other set was exposed to SO_2 (0.2 ppm), percentage increase (recovery) or decrease in various parameters was calculated ith reference to untreated and exposed plants (UTE). Results of both the sets are given separately.

A. Unexposed plants

It was observed that treated plants (T_1, T_2, T_3) showed better growth than untreated plants (UTUE). The increase over UTUE plants was minimum in T_1 (0.005 Maa) and maximum in T_3 (0.01 Maa) plants. Plants showed differential response with age. Maximum increase in all the parameters (except sulphur) was recorded at 100 days. At 120 days the increase over UTUE plants was less than at 100 days. Minimum increase was recorded at 40 days.

i. Height

The increase in height was maximum at 100 days (10.8, 14.8 & 15.9%) and minimum at 40 days (6.0, 7.0 & 8.7%) in T_1, T_2 and T_3 plants respectively (Table 29).

ii. Number of leaves

In T_1, T_2 and T_3 plants, the respective percentage increase recorded at 100 days was 11.2, 15.0 and 22.9, minimum increase was recorded at 40 days viz. 8.5, 9.0 and 10.2% (Table 29).

iii. Total leaf area

At 100 days, 11.6, 14.5 and 17.5% increase over UTUE plants was recorded respectively in T_1, T_2 and T_3 plants, at 40 days the increase was 8.7, 9.5 and 11.5% respectively (Table 29).

iv. Biomass

The percentage increase recorded at 100 days was 12.5, 15.4 and 19.0, at 40 days the increase was 8.5, 10.1 and 12.2% in T_1, T_2 and T_3 plants respectively (Table 30).

v. Relative growth rate (RGR) and net assimilation rate (NAR)

The RGR and NAR of all the plants was maximum during 60 - 80 days. Upto 80 days the RGR and NAR of T_1, T_2 and T_3 plants was more than UTUE plants, in RGR 1.7, 2.2 and 3.4% increase and in NAR 2.4, 2.6 and 4.0% increase was recorded respectively in T_1, T_2 and T_3 plants during 60 - 80 days. At later stages RGR and NAR of all the plants (UTUE, T_1, T_2 and T_3) was almost the same (Table 30).

vi. Chlorophyll

Maximum increase in chlorophyll content was recorded at 100 days. The increase in chlorophyll *a* and *b* was 8.4, 11.6 & 13.8 and 7.8, 10.9 & 12.6% in T_1, T_2 and T_3 plants. Chlorophyll *a*, and *b*, content at 40 days was 5.6, 6.5 and 7.8% and 5.2, 6.3 and 7.4% more than UTUE plants in T_1, T_2 and T_3 plants respectively. (Table 31).

vii. Ascorbic acid

The ascrobic acid content showed maximum increase over reference at 100 days(9.4, 13.4 and 15.2%), the increase was minimum at 40 days (6.4, 7.9 and 10.4%) in T_1, T_2 and T_3 plants respectively (Table 31).

viii. Protein

At 100 days maximum increase over UTUE was recorded. The increase was 5.5, 6.1 and 6.8% while at 40 days the increase was 3.2, 4.2 and 4.9% respectively in T_1, T_2 and T_3 plants (Table 32).

ix. Total soluble sugars

The increase in soluble sugar content of T_1, T_2 and T_3 plants was 11.2, 14.5 and 15.4% at 100 days and 6.5, 7.2 and 9.9% at 40 days in T_1, T_2 and T_3 plants respectively (Table 32).

x. Sulphur

The sulphur content of treated plants was slightly less than untreated plants. Maximum reduction in sulphur content was recorded at 120 days (2.5, 3.6 and 4.1%) and minimum at 40 days (0.66, 0.67 and 0.72%) in T_1, T_2 and T_3 plants respectively (Table 32).

xi. Yield

The increase in yield (at harvest) in T_1, T_2 and T_3 plants was 13.1, 15.4 and 26.6% respectively (Table 32).

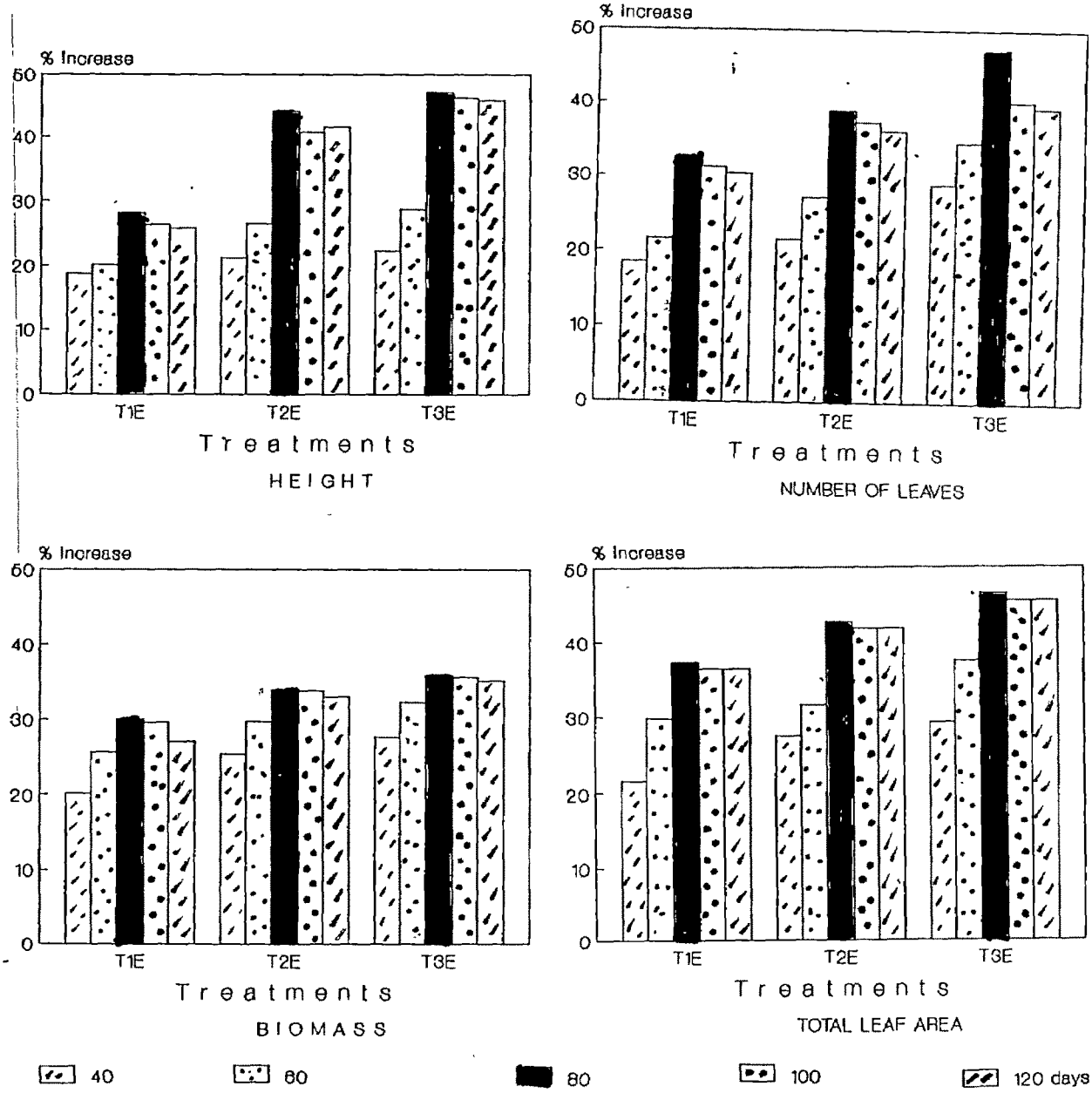
B. Exposed plants

It was observed that the plants treated with ascorbic acid were more tolerant and showed lesser damage than untreated plants (UTE). The recovery in all the parameters and decrease in sulphur was minimum in T_1E (0.005 Maa) plants and maximum in T_3E (0.01 Maa) plants. Variation in plants response with age was observed. Maximum response of plants was recorded at 80 days. At later stages (100 - 120 days) the recovery was decreased. Minimum recovery in different parameters was recorded at 40 days in all the treatments. The percentage recovery or decrease in different parameters are shown in Fig.18-20.

i. Height

The height of T_1E T_2E and T_3E plants was 28.1, 44.1 and 47.1% more than UTE plants at 80 days, and 18.7, 21.2 and 22.3% more at 40 days respectively (Table 29).

Fig. 18 : MITIGATION OF POLLUTION EFFECT
Under Simulated Condition
Nicotiana tabacum Linn.



ii. Number of leaves

The percentage recovery in number of leaves was 32.2, 38.9 and 47.1 at 80 days and at 40 days the recovery was 18.5, 21.6 and 28.9% in T_1E, T_2E and T_3E plants respectively (Table 29).

iii. Total leaf area

Recovery in total leaf area in T_1E, T_2E and T_3E plants at 80 days was 37.2, 42.6 and 46.4% and 21.6, 27.4 and 29.2% at 40 days respectively (Table 29).

iv. Injury index

In UTE plants visible injury was observed from 60 days, 8-10% injury index with chlorosis, necrosis and burning of leaf tip and margin was observed upto 100 days. In treated plants visible injury appeared after 80 days, injury index recorded at 100 days was 2.6, 3.4 and 4.1% in T_2E, T_3E and T_1E plants respectively (Table 29).

v. Biomass

The percentage recovery in T_1E, T_2E and T_3E plants was maximum at 80 days (30.0, 34 .0 and 36.2) and minimum at 40 days (20.2, 25.4 and 27.6%) respectively (Table 30).

vi. Relative growth rate (RGR) and Net assimilation rate (NAR)

The RGR and NAR of all the plants was maximum during 60 - 80 days. The RGR of treated plants was more than untreated (UTE) plants upto 80 days with 3.01, 2.83 and 2.3% increase in T_1E, T_2E and T_3E plants respectively. The NAR of treated plants was more than untreated plants upto 60 days age with 10.6, 8.7 and 7.7% increase in T_1E, T_2E and T_3E plants respectively, during 40 - 60 days. At later stages slight reduction in RGR (0.09 - 3.0% and NAR (0.2 - 5.0%) was observed (Table 30).

vii. Chlorophyll

Maximum percentage recovery in chlorophyll content was recorded at 80 days. Chlorophyll *a* showed more recovery than chlorophyll *b*. The percentage recovery in chlorophyll *a* and *b* was 20.1, 28.6 & 30.2 and 17.6, 21.2 & 25.6% in T_1E, T_2E and T_3E plants respectively. Minimum recovery was recorded at 40 days with 9.8, 11.5 and 12.6% in chlorophyll *a* and 10.4, 15.4 and 17.8% in chlorophyll *b*, in T_1E and T_2E and T_3E plants respectively (Table 31).

Fig. 19 : MITIGATION OF POLLUTION EFFECT

Under Simulated Condition

Nicotiana tabacum Linn.

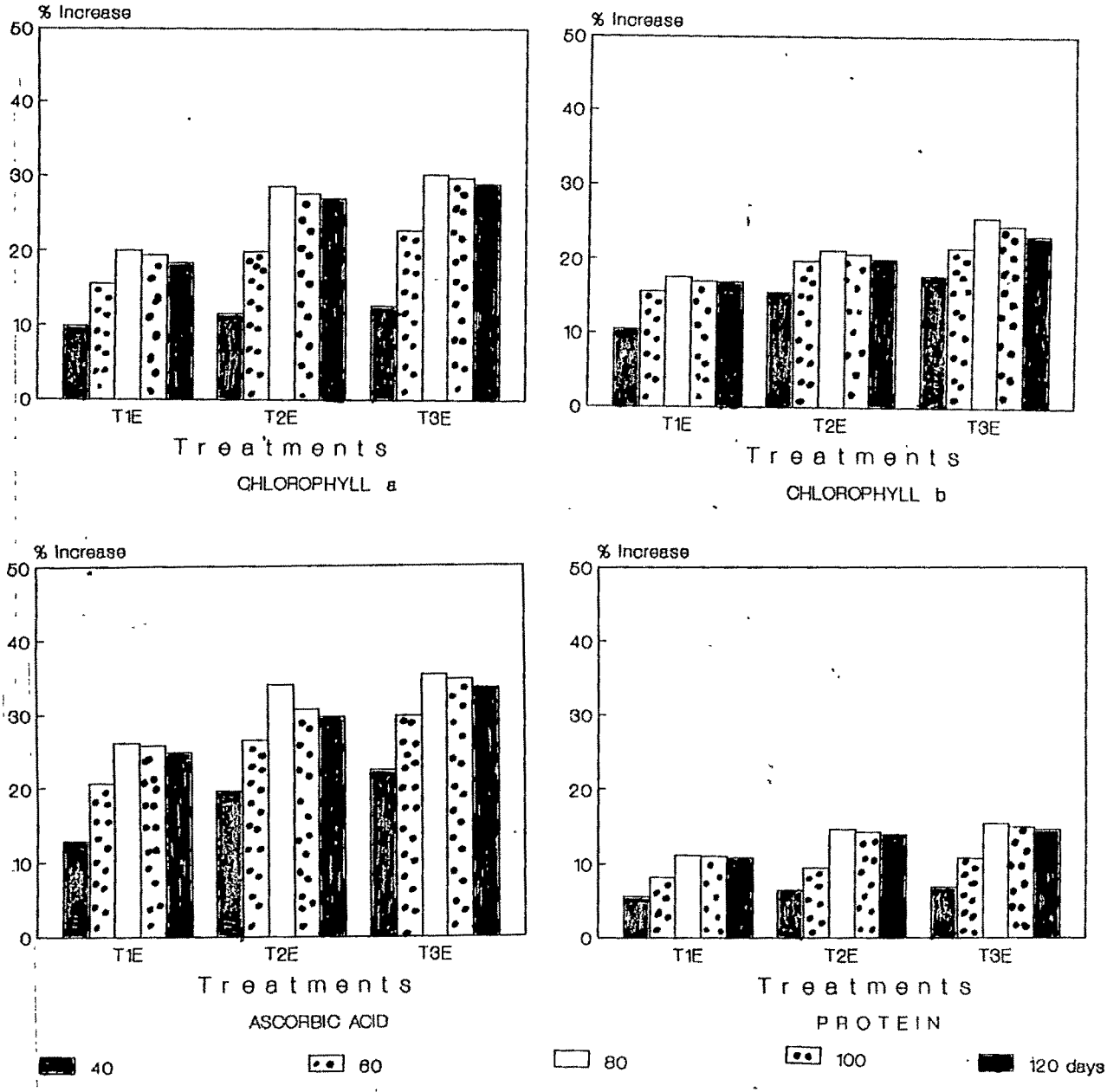
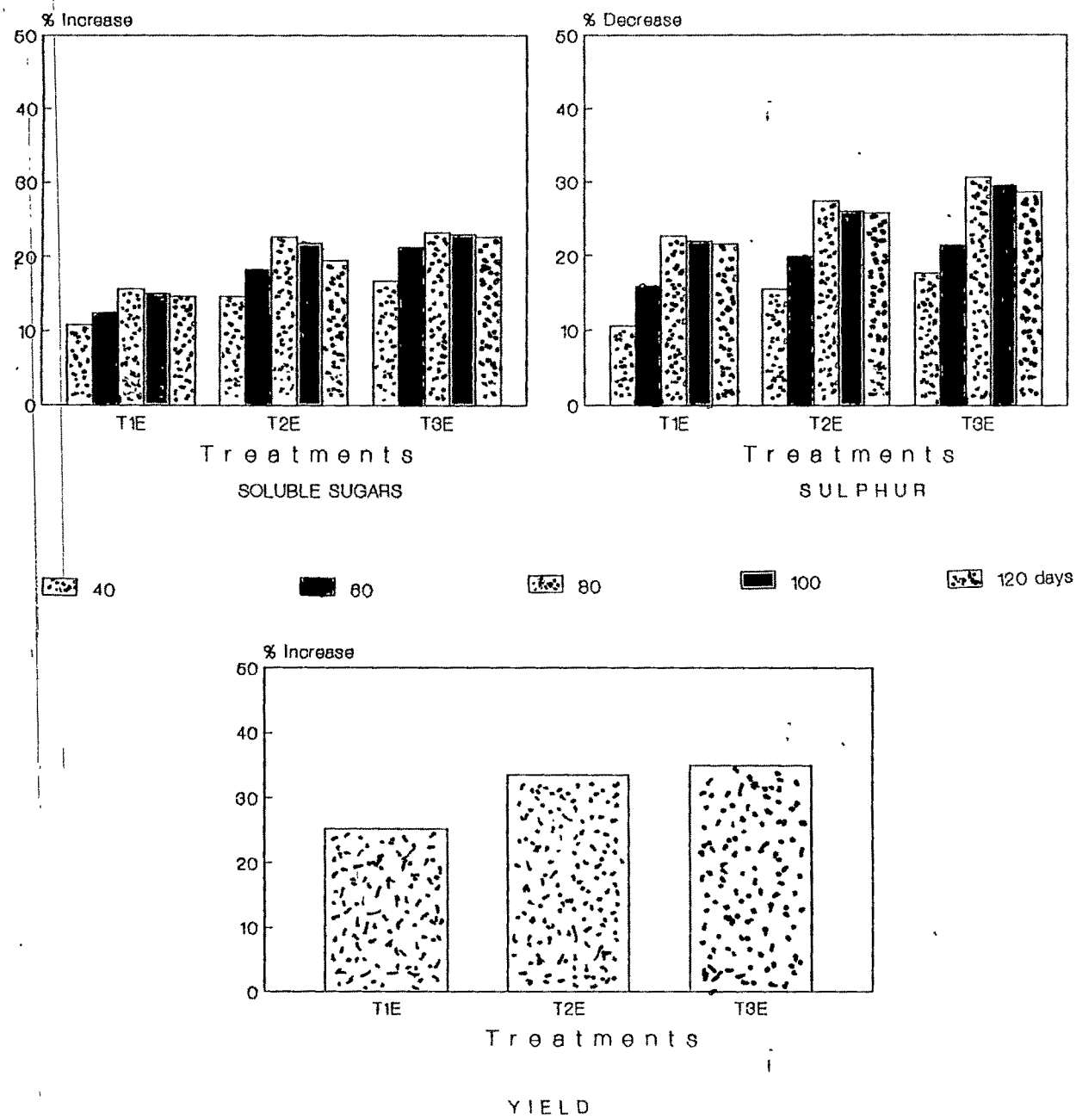


Fig. 20 : MITIGATION OF POLLUTION EFFECT
Under Simulated Condition
Nicotiana tabacum Linn.



viii. Ascorbic acid

Maximum recovery in ascorbic acid content, over untreated plants was recorded at 80 days. The % recovery in T_1E, T_2E and T_3E plants was 26.1, 34.1 and 35.4 respectively, at 40 days the respective ascorbic acid content was 12.8, 19.6 and 22.4% more than UTE plants (Table 31).

ix. Protein

In treated plants the protein content showed maximum recovery at 80 days (11.2, 14.6 and 15.4%) and minimum at 40 days (5.6, 6.4 and 6.9%) in T_1E, T_2E and T_3E plants respectively (Table 32).

x. Total soluble sugars

The sugar content of leaves was more in treated plants. Maximum recovery with each treatment was observed at 80 days viz. 15.6, 22.6 and 23.2%, while at 40 days 10.8, 14.6 and 16.6% recovery was observed respectively in T_1E, T_2E and T_3E plants (Table 32).

xi. Sulphur

It was observed that sulphur content of treated plants was less than untreated plants at all the ages. Minimum decrease in sulphur content than UTE plants was recorded at 40 days in all treatments. Maximum decrease was recorded at 80 days and then (at 100 and 120 days) gradual reduction in the rate of decrease than reference was recorded. The T_1E plants had highest and T_3E plants had lowest sulphur content out of the three treatments at all the ages. The sulphur content of T_1E, T_2E and T_3E plants was 22.6, 27.4 and 30.6% less than UTE plants at 80 days, at 120 days, 21.6, 25.8 and 28.6% decrease respectively was recorded (Table 32).

xii. Yield

The yield of T_1E, T_2E and T_3E plants was 25.2, 33.5 and 35.0% more than UTE plants, respectively (Table 32.)

xiii. Cost benefit ratio

Maximum profit was observed in T_1E (0.005 M) treatment. In T_2E (0.0075 M) and T_3E (0.01 M) the profit was comparatively less. The cost/benefit ratio was 1:4.2, 1:3.4 and 1:3.3 in T_1E, T_2E and T_3E treatments respectively

3.5.2 Under Field Conditions

Experiments were conducted on field grown crops (tobacco, egg plant and

potato). Plants were treated with different doses of different chemicals viz. ascorbic acid (0.005, 0.01 and 0.02 M) and urea (0.15, 0.30 and 0.45 M). In all the species, with all the six treatments increase in different parameter values was observed as compared to untreated plants. Only sulphur and leaf area damage showed decrease in treated plants. The percentage increase or decrease in each parameter with each treatment was calculated with reference to untreated plants (C) at respective ages and are shown in Fig.21-31.

3.5.2.1 *Nicotiana tabacum* Linn.

First treatment was given to 20 days old, newly transplanted saplings. Observations were recorded from 40 - 120 days, at a regular interval of 20 days. All the treated plants showed better growth than untreated plants, which was exhibited by recovery in various parameters. Maximum recovery in different parameters was recorded at 80 days. At later stages i.e. after 80 days the recovery in various parameters declined.

i. Height

All the treated plants showed recovery over untreated plants. The percentage recovery recorded at 80 days was 7.0, 11.0 and 8.5 in A_1, A_2 and A_3 plants and 12.0, 16.5 and 19.2% in U_1, U_2 and U_3 plants respectively (Table 33).

ii. Number of leaves

Maximum recovery was recorded at 80 days in all the treatments. The respective recovery in A_1, A_2 and A_3 plants was 10.0, 20.1 and 18.0% while it was 22.5, 30.0 and 35.0% respectively in U_1, U_2 and U_3 plants (Table 34).

iii. Total leaf area

Recovery in total leaf area recorded at 80 days was 18.0, 24.0, 21.0; 27.5, 38.0 and 47.5% with A_1, A_2, A_3; U_1, U_2 and U3 treatments respectively (Table 35).

iv. Injury index

Plants did not show any visible injury upto 80 days. At 100 days 40% injury index in untreated plants and 0.5-2.0% injury index in ascorbic acid treated plants was recorded. No visible symptom was recorded in urea treated plants (Table 36).

v. Biomass

Above ground biomass showed maximum recovery at 80 days. The percentage recovery recorded with A_1, A_2 and A_3 treatments was 20.0, 28.0 and 25.0 and with U_1, U_2 and U_3 treatments it was 30.8, 42.0 and 51.0 % respectively (Table 37).

Fig. 21 : MITIGATION OF POLLUTION EFFECT
FIELD EXPERIMENT : H E I G H T

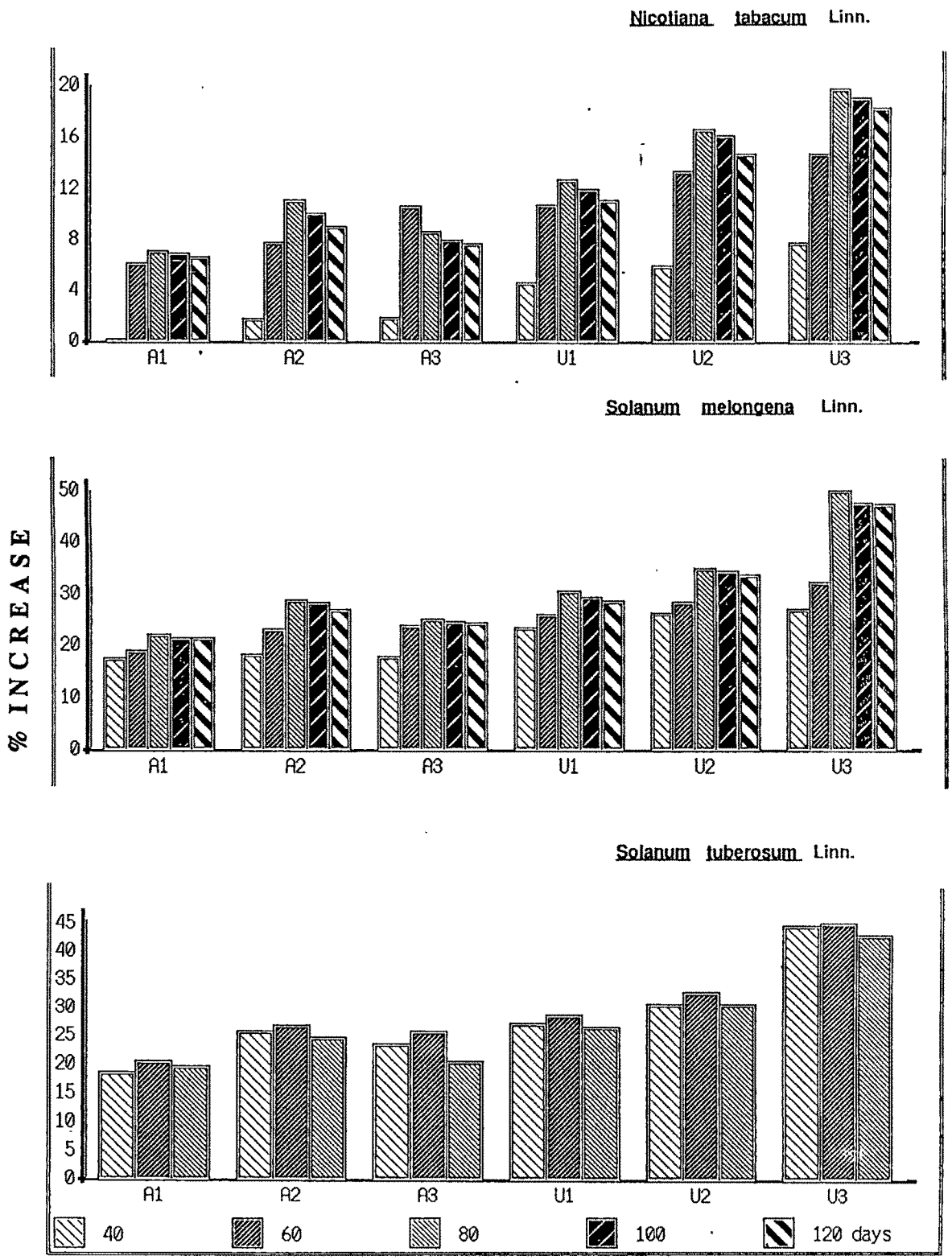
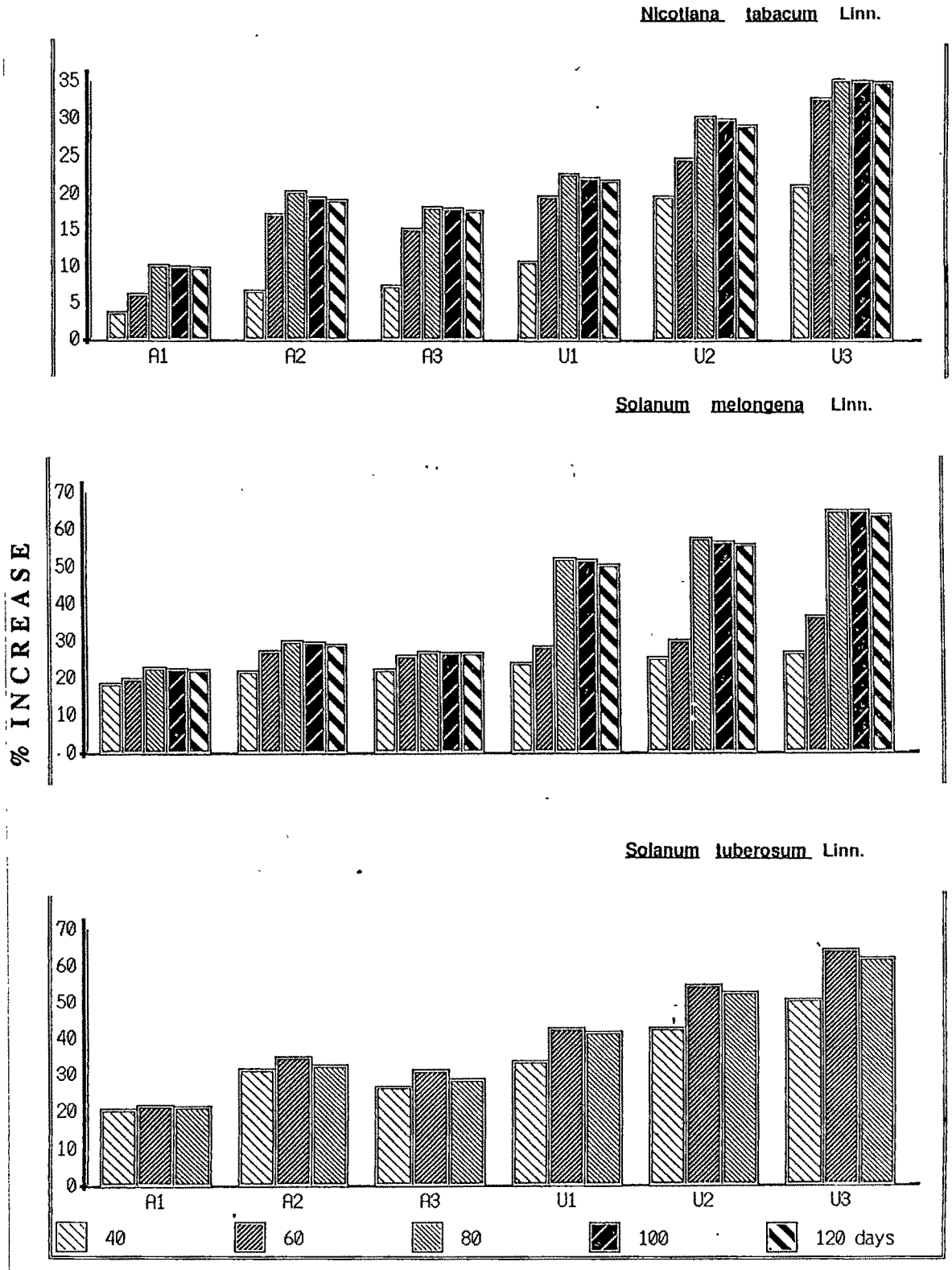


Fig. 22 : MITIGATION OF POLLUTION EFFECT
FIELD EXPERIMENT : NUMBER OF LEAVES



vi. Relative growth rate (RGR) and net assimilation rate (NAR).

The RGR and NAR of plants was maximum during the age of 40 - 60 days both the rates of treated plants were more than untreated plants upto 80 days. Maximum increase was recorded during 60 - 80 days. The increase in RGR was 5.9, 10.4, 9.4; 14.6, 18.2 and 21.7% (Table 38) and in NAR it was 10.0, 14.7, 13.6; 18.0, 20.9 and 23.5% in A_1, A_2, A_3; U_1, U_2 and U_3 plants respectively (Table 39).

vii. Chlorophyll

Recovery in chlorophyll content was recorded in all the treatments and at all the ages but was maximum at 80 days. Chlorophyll *a* showed 14.1, 26.1 and 23.0% recovery in A_1, A_2 and A_3 and 26.8, 32.6 and 38.0% recovery in U_1, U_2 and U_3 plants respectively (Table 40). The percentage recovery in chlorophyll *b* was 13.8, 25.2 and 24.6 in A_1, A_2 and A_3 plants while in U_1, U_2 and U_3 plants the recovery was 26.2, 30.2 and 36.7 respectively (Table 41).

iii. Ascorbic acid

Maximum recovery with all the treatments was recorded at 80 days. The recovery with A_1, A_2 and A_3 treatments was 18.4, 29.6 and 28.0% while it was 28.2, 30.1 and 32.3% with U_1, U_2 and U_3 treatments respectively (Table 42).

ix. Protein

Recovery in protein content at 80 days was 7.9, 10.2 and 8.6% in A_1, A_2 and A_3 plants and 25.2, 32.6 and 44.2% in U_1, U_2 and U_3 plants respectively (Table 43). Of all the ages recovery recorded at 80 days was maximum

x. Total soluble sugars

The content was more in treated plants than in reference plants, maximum recovery was recorded at 80 days. In A_1, A_2, A_3; U_1, U_2 and U_3 treatments the respective recovery recorded was 17.2, 20.6, 18.2; 34.3, 36.7 and 40.2% (Table 44).

xi. Sulphur

Decrease in foliar sulphur content as compared to untreated plants was recorded in treated plants. The percentage decrease recorded at 120 days was 15.4, 18.6 and 16.4 with A_1, A_2 and A_3 treatments respectively. In U_1, U_2 and U_3 plants the decrease was 27.2, 31.6 and 39.6% respectively (Table 45). At 80 days maximum decrease was recorded viz. 18.2, 21.8, 19.0; 30.1, 34.2 and 43.7% respectively in A_1, A_2, A_3; U_1, U_2 and U_3 plants.

Fig. 23 : MITIGATION OF POLLUTION EFFECT
FIELD EXPERIMENT : TOTAL LEAF AREA

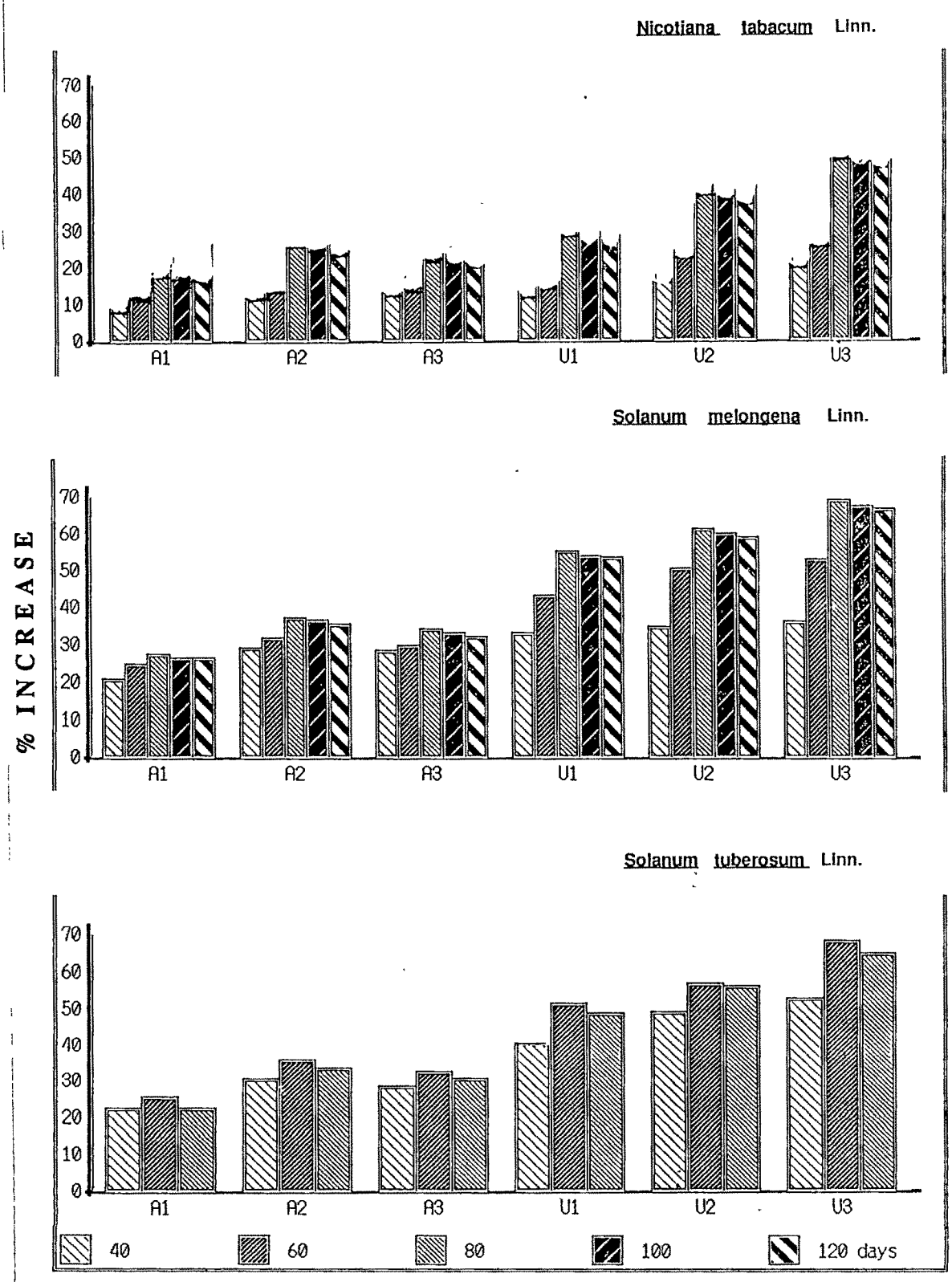
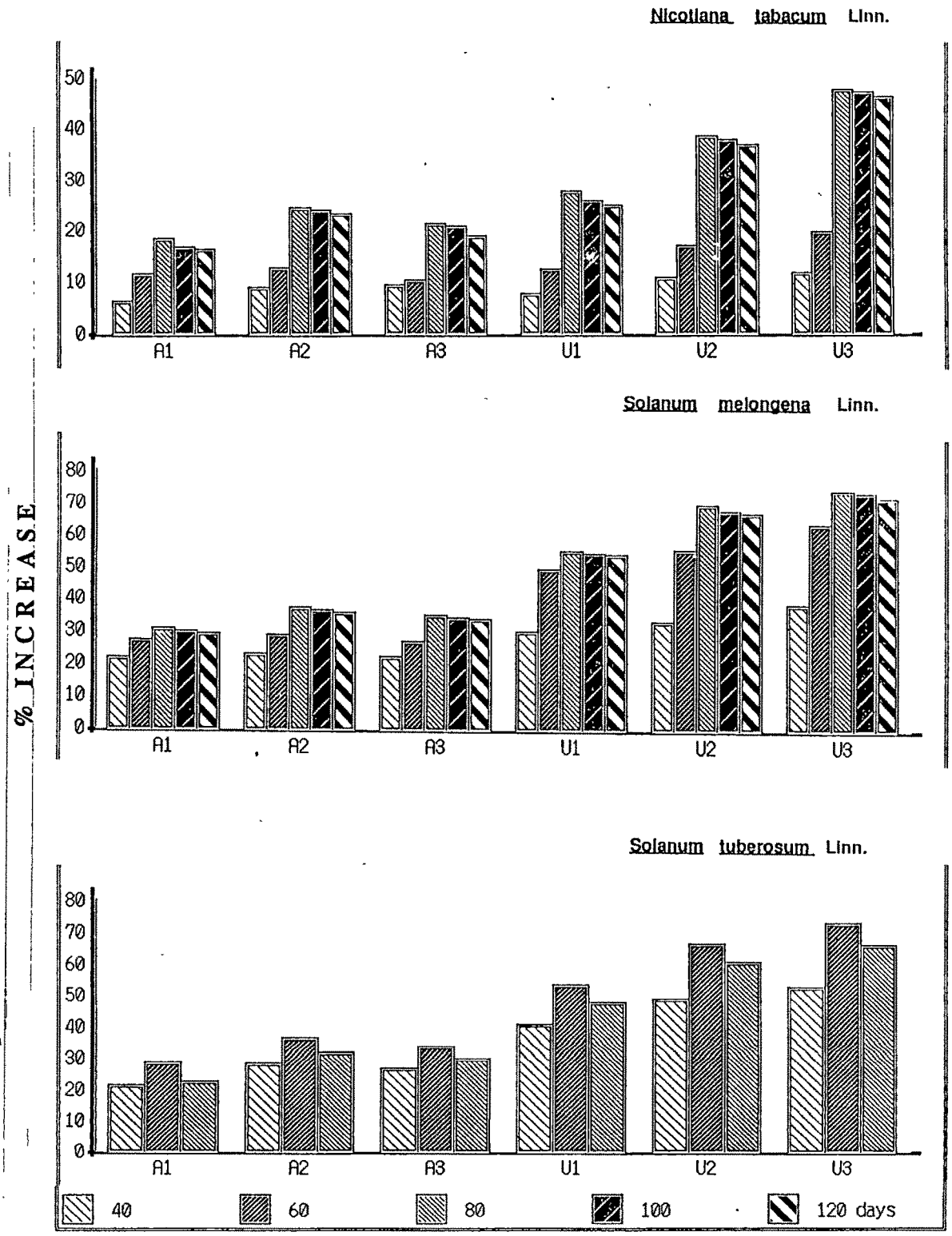


Fig. 24 : MITIGATION OF POLLUTION EFFECT
FIELD EXPERIMENT : B I O M A S S



xii. Yield

The yield was increased with all the treatments as compared to untreated plants. The recovery was 20.4, 29.8, 25.4; 30.8, 45.0 and 52.4% with A_1, A_2, A_3; U_1 U_2 and U_3 treatments respectively (Table 46).

xiii. Cost benefit ratio

The cost/benefit ratio was 1:6.5, 1:4.7, 1:2.03, 1:11.4, 1:10.5 and 1:6.4 in A_1, A_2, A_3; U_1, U_2 and U_3 treatments respectively. Of all the treatments U_1 (0.15 M urea) treatment gave maximum profit.

Among treatments of both the chemicals it was found that there was a linear progressive recovery with urea treatments ($U_1 < U_2 < U_3$) while in ascorbic acid treatment the recovery was reduced in third treatment (A1 < A2 > A3).

3.5.2.2 *Solanum melongena* Linn. (Egg plant)

First treatment was given to 20 days old plants, further treatments were given at regular interval of 20 days upto 100 days age of plants. Observations were recorded from 40 - 120 days age at 20 days interval. Maximum recovery in all the parameters, with all the treatments was recorded at 80 days and minimum at 40 days. After 80 days the recovery was decreased.

i. Height

The percentage recovery recorded at 80 days in A_1, A_2, A_3; U_1, U_2 and U_3 plants was 21.6, 28.4, 24.5; 30.1, 34.4 and 49.6% respectively (Table 33).

ii. Number of leaves

In A_1, A_2, A_3; U_1, U_2 and U_3 plants the respective number of leaves were 22.4, 29.4, 26.5; 51.4, 56.7 and 64.1% more than untreated plants (Table 34) at 80 days.

iii. Total leaf area

Maximum recovery was (at 80 days) 27.1, 36.8, 33.6; 54.8, 60.7 and 68.5% respectively in A_1, A_2, A_3; U_1, U_2 and U_3 treated plants (Table 35).

iv. Injury index

Untreated plants started showing visible injury symptom from 60 days onwards, 5 - 8% injury index at various ages was recorded (Table 36). In ascorbic acid treated plants

Fig. 25 : MITIGATION OF POLLUTION EFFECT
FIELD EXPERIMENT : CHLOROPHYLL a.

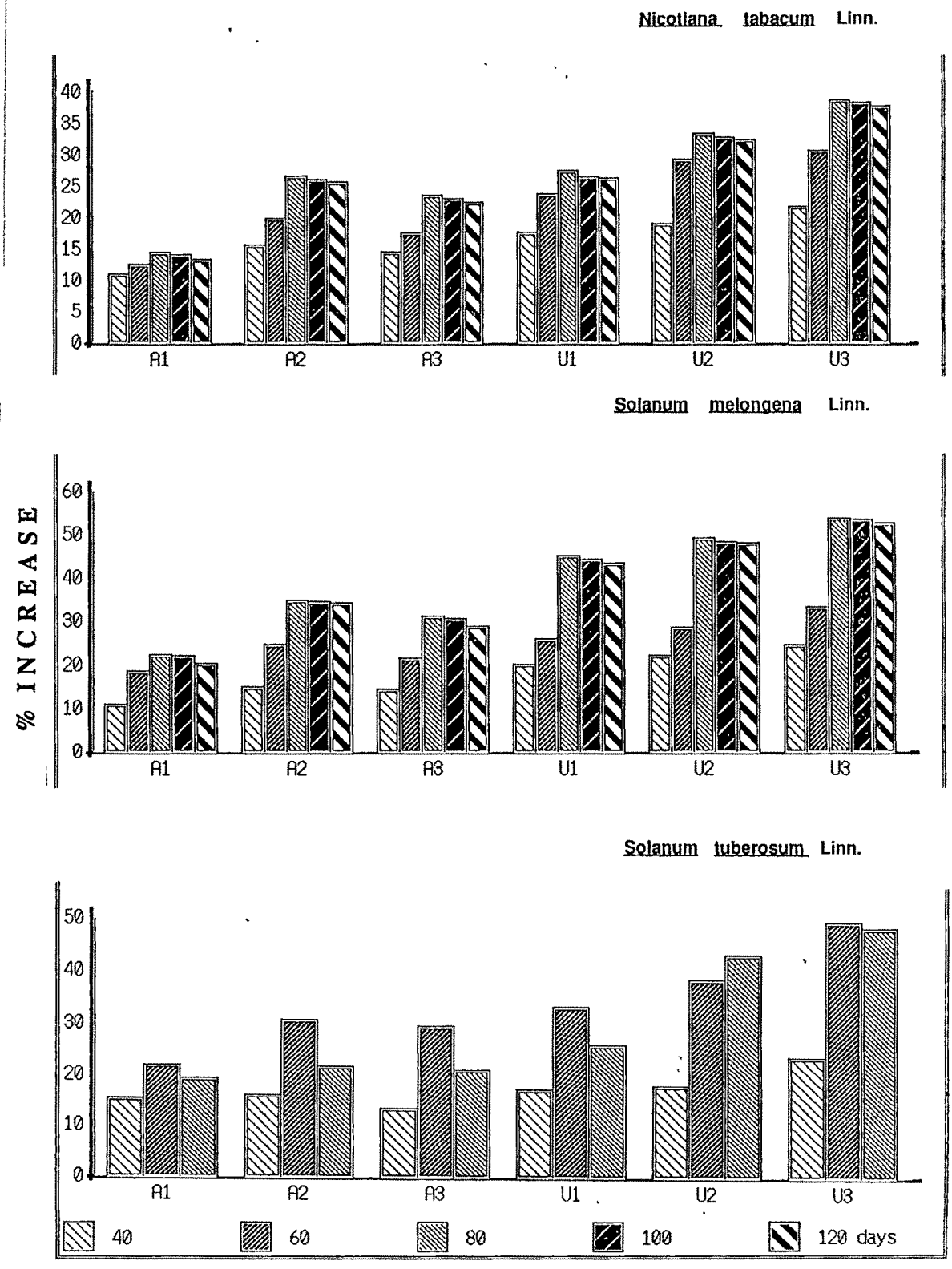
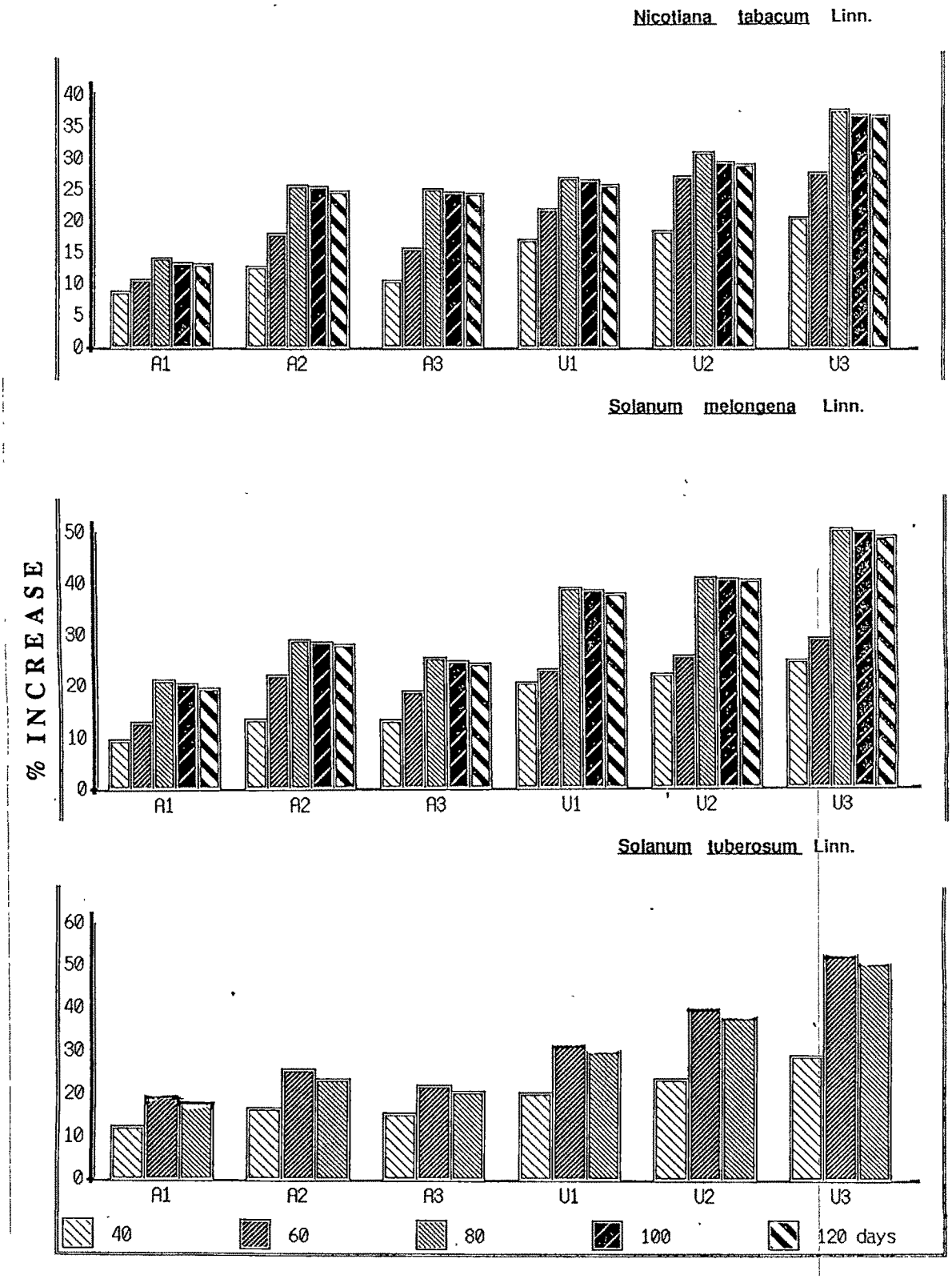


Fig. 26 : MITIGATION OF POLLUTION EFFECT
FIELD EXPERIMENT : CHLOROPHYLL .b.



1 - 4% injury index was recorded after 80 days. No visible injury was recorded in urea treated plants.

v. Biomass

Biomass accumulation (of above ground vegetative parts) was 30.1, 36.5, 34.1; 54.6, 68.9 and 73.5% more in A_1, A_2, A_3; U_1, U_2 and U_3 plants respectively, at 80 days (Table 37).

vi. Relative growth rate (RGR) and net assimilation rate (NAR)

The RGR and NAR of all the plants was maximum during 40 - 60 days, of all the ages. Both the rates were more in treated plants than in untreated plants upto 80 days. The increase was maximum during 60 - 80 days. In RGR 7.2, 17.8, 16.7; 11.1, 24.5 and 25.1% (Table 38) and in NAR 8.9, 20.6, 18.4; 14.6, 29.8, and 31.2% (Table 39) increase was recorded respectively in A_1, A_2, A_3; U_1, U_2 and U_3 plants.

vii. Chlorophyll

Chlorophyll *a* content showed 22.1, 34.4, 30.6; 44.6, 48.7 and 53.2% recovery in A_1, A_2, A_3; U_1, U_2 and U_3 plants at 80 days (Table 40). Percentage recovery in chlorophyll *b* at 80 days was 20.8, 28.6, 24.9; 38.4, 40.2 and 49.6 with A_1, A_2, A_3; U_1, U_2 and U_3 treatments respectively (Table 41).

viii. Ascorbic acid

The percentage recovery recorded at 80 days was 34.5, 53.8, 50.2; 51.6, 59.4 and 62.6 respectively in A_1, A_2, A_3; U_1, U_2 and U_3 plants (Table 42).

ix. Protein

The respective protein content of A_1, A_2, A_3; U_1, U_2 and U_3 plants was 12.6, 28.4, 20.6; 52.8, 56.7 and 61.2% more than the reference plants (Table 43).

x. Total soluble sugars

The percentage recovery recorded at 80 days was 21.6, 28.4, 24.1; 42.5, 59.4 and 63.7 with A_1, A_2, A_3; U_1, U_2 and U_3 treatments respectively (Table 44).

xi. Sulphur

Sulphur content of all the treated plants was less than untreated plants at all the ages. Minimum decrease was recorded at 40 days and maximum at 80 days. At 80 days the foliar sulphur content of A_1, A_2, A_3; U_1, U_2 and U_3 plants was 27.3, 29.6, 28.4; 29.8, 37.6 and

Fig. 27 : MITIGATION OF POLLUTION EFFECT
FIELD EXPERIMENT : ASCORBIC ACID

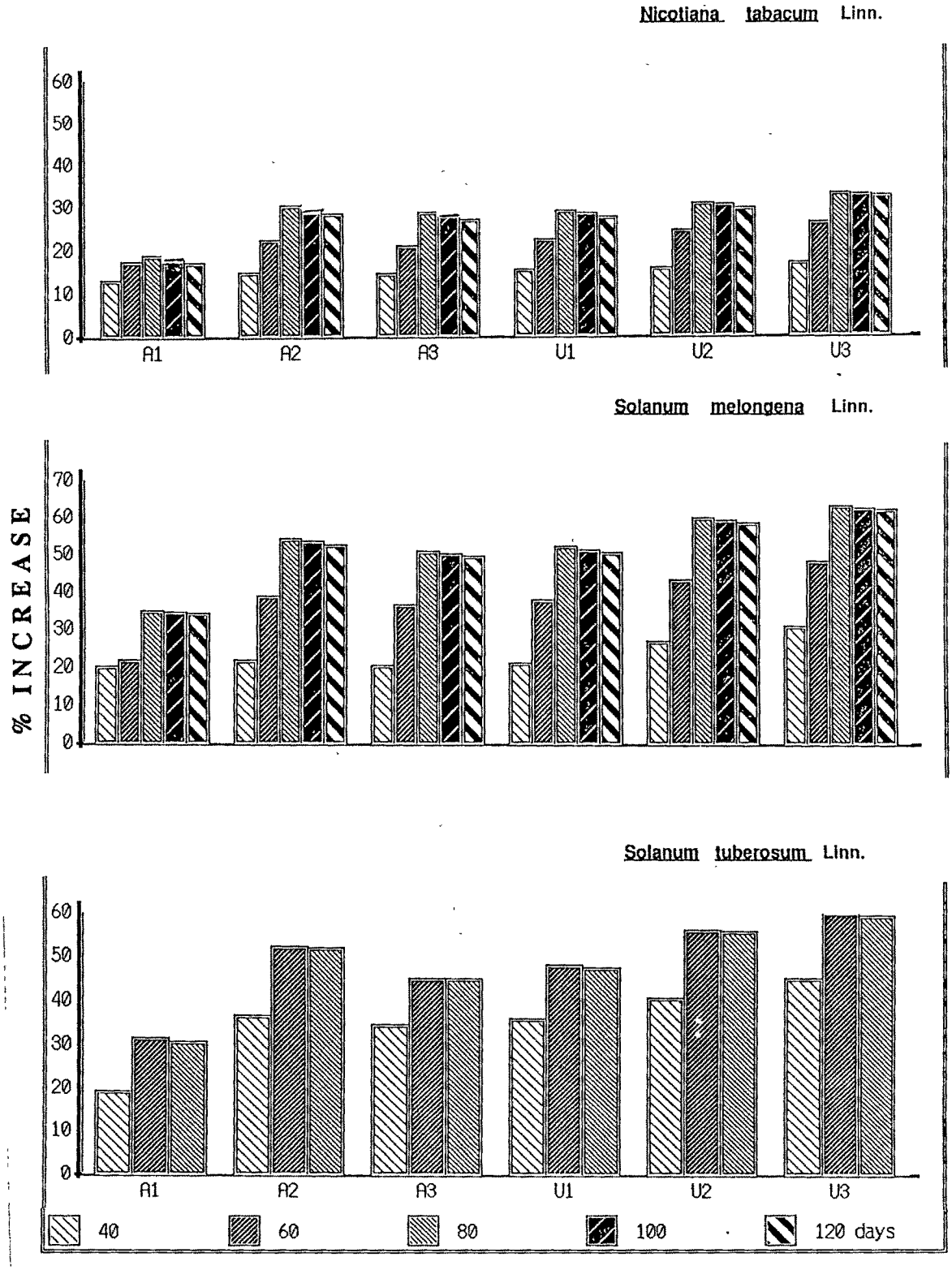
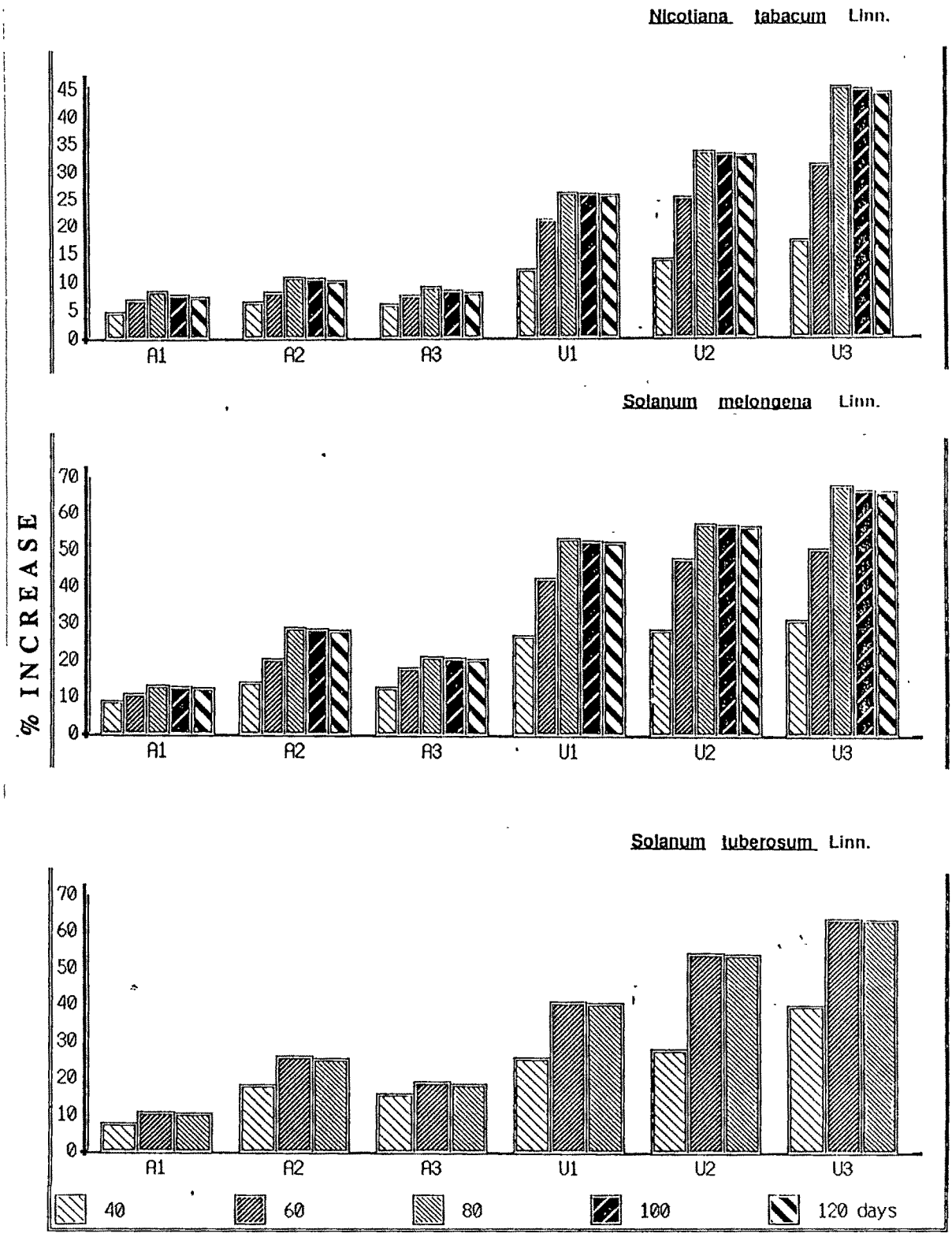


Fig. 28 : MITIGATION OF POLLUTION EFFECT
FIELD EXPERIMENT : P R O T E I N



42.4% less than untreated plants respectively (Table 45).

xii. Yield

Slight difference in percentage flowering and fruiting was recorded among treated and untreated plants. Significant increase in average weight of fresh fruits was observed in treated plants. The total percentage recovery recorded in yield was 21.6, 30.4, 27.2; 43.6, 58.4 and 65.9% respectively in A_1, A_2, A_3; U_1, U_2 and U3 plants (Table 46).

xiii Cost-benefit ratio

The ratio was 1:6.9, 1:4.8, 1:2.0; 1:16.1, 1:13.7 and 1:7.3 in A_1, A_2, A_3; U_1, U_2 and U_3 treatments respectively. Maximum profit was gained by U_1 treatment.

3.5.2.3 *Solanum tuberosum* Linn. (Potato)

First treatment to crop was given at the age of 20 days and observations were recorded 20 days after first treatment (i.e. at the age of 40 days). All the treated plants showed recovery in all the parameters (except sulphur), over untreated plants. Minimum recovery was recorded at 40 days and maximum at 60 days. At 80 days the recovery was less than at 60 days.

i. Height

The recovery recorded in A_1, A_2, A_3; U_1, U_2 and U_3 plants at 60 days was 20.1, 26.2, 25.0; 28.1, 32.1 and 44.3% respectively (Table 33).

ii. Number of leaves

The percentage recovery recorded at 60 days was 21.1, 34.2, 30.6; 41.1, 54.8 and 63.6 in A_1, A_2, A_3; U_1, U_2 and U_3 plants respectively (Table 34).

iii. Total leaf area

At 60 days the recovery recorded in A_1, A_2, A_3; U_1, U_2 and U_3 plants was 25.1, 35.4, 32.1; 51.1, 56.4 and 67.8% respectively (Table 35).

iv. Injury index

Untreated plants showed visible injury from 30 days onwards; 8% injury index was recorded at 60 days. In ascorbic acid treated plants visible injury was observed after 50 days, 3.8 - 5.2% injury index was recorded at 60 days. Very less injury index (1 - 2%) was recorded in urea treated plants (Table 36).

Fig. 29 : MITIGATION OF POLLUTION EFFECT
FIELD EXPERIMENT : SOLUBLE SUGARS

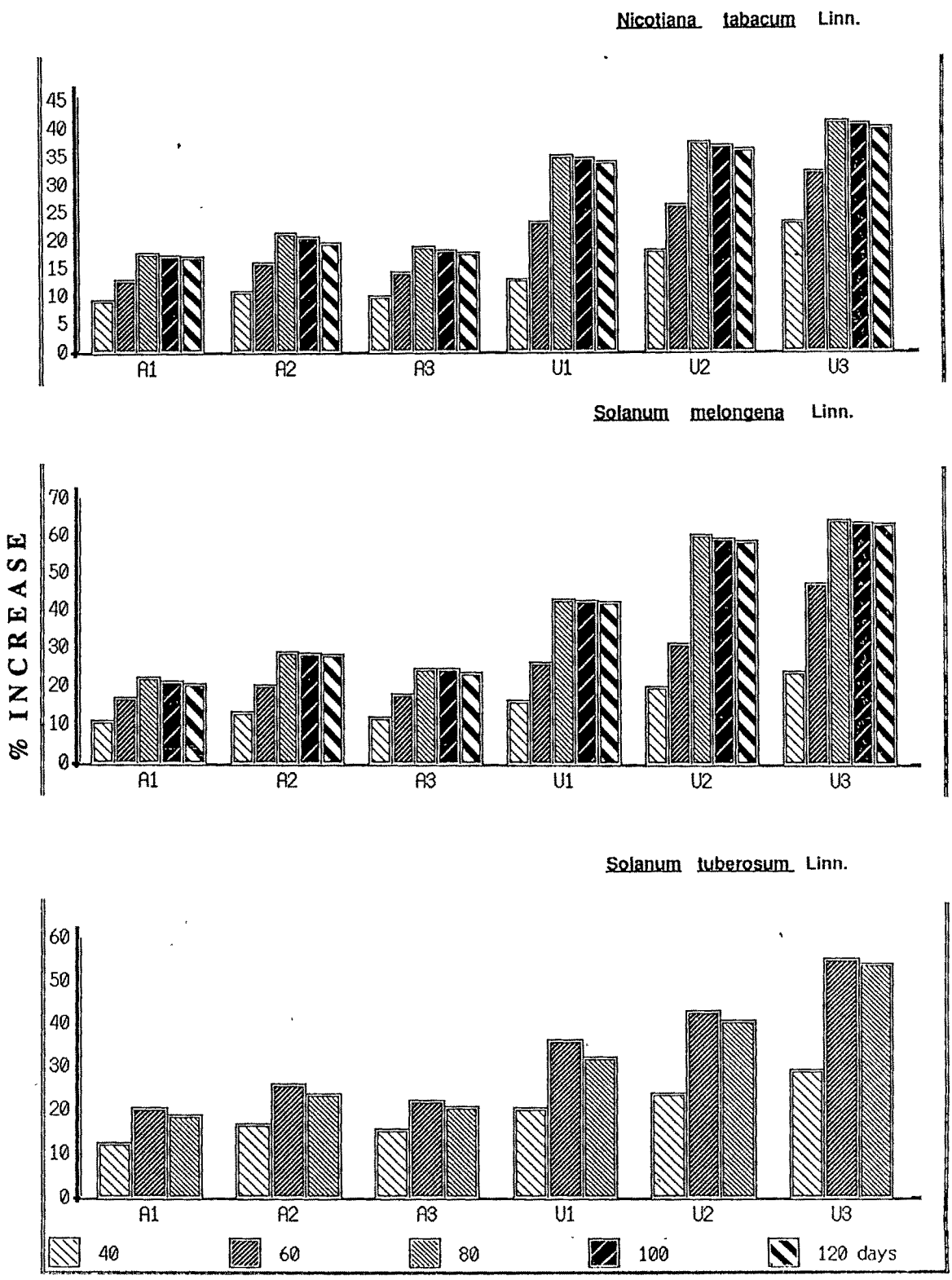


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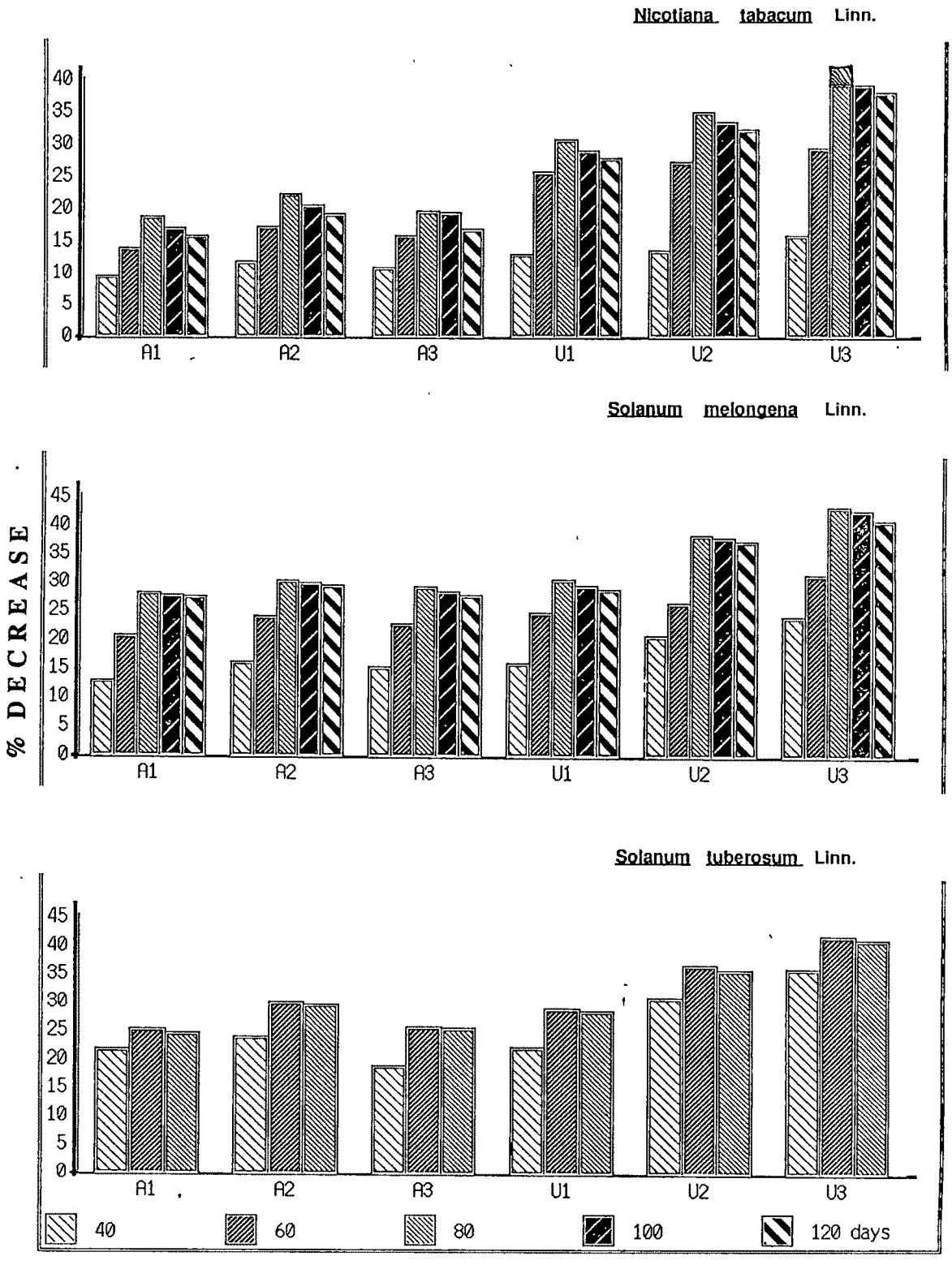
Fig. 30 : MITIGATION OF POLLUTION EFFECT
FIELD EXPERIMENT : S U L P H U R



v. Biomass

Treated plants showed more accumulation of biomass as compared to untreated plants at all the ages. The recovery recorded at 60 days was maximum viz. 28.1, 36.0, 33.0; 52.6, 65.7 & 72.0 with A_1, A_2, A_3; U_1, U_2 and U_3 treatments respectively (Table 37).

vi. Relative growth rate (RGR) and net assimilation rate (NAR)

The RGR and NAR of all the plants was maximum during 40 - 60 days. In treated plants both the rates were more than untreated plants at this age. In RGR 13.2, 14.1, 12.2; 19.8, 26.4 and 28.7% increase and in NAR 14.4, 14.8, 13.8; 21.0, 30.7 and 31.9% increase respectively was recorded in A_1, A_2, A_3; U_1, U_2 and U_3 plants (Tables 38 & 39)

vi. Chlorophyll

Chlorophyll content was more in treated plants. Chlorophyll *a* showed more recovery than chlorophyll *b*. At 60 days chlorophyll a showed 21.6, 30.5, 29.2; 33.0, 38.4 and 49.6% recovery in A_1, A_2, A_3; U_1, U_2 and U_3 treated plants respectively (Table 40). Percentage recovery recorded in chlorophyll *b* at the same age was 19.0, 27.1, 22.3; 29.9, 38.0 and 48.1, respectively in A_1, A_2, A_3; U_1, U_2 and U_3 plants (Table 41).

viii. Ascorbic acid

The recovery was 31.2, 52.0, 45.0; 48.0, 56.0 and 60.4% in A_1, A_2, A_3; U_1, U_2, U_3 plants respectively at 60 days (Table 42).

ix. Protein

The recovery in protein content was very high in urea trated plants 40.5, 54.0,and 63.5% recovery was recorded in U_1, U_2 and U_3 plants respectively at 60 days. With A_1, A_2 and A_3 treatments 10.5, 25.8 and 18.8% respective recovery was recorded at the same age (Table 43).

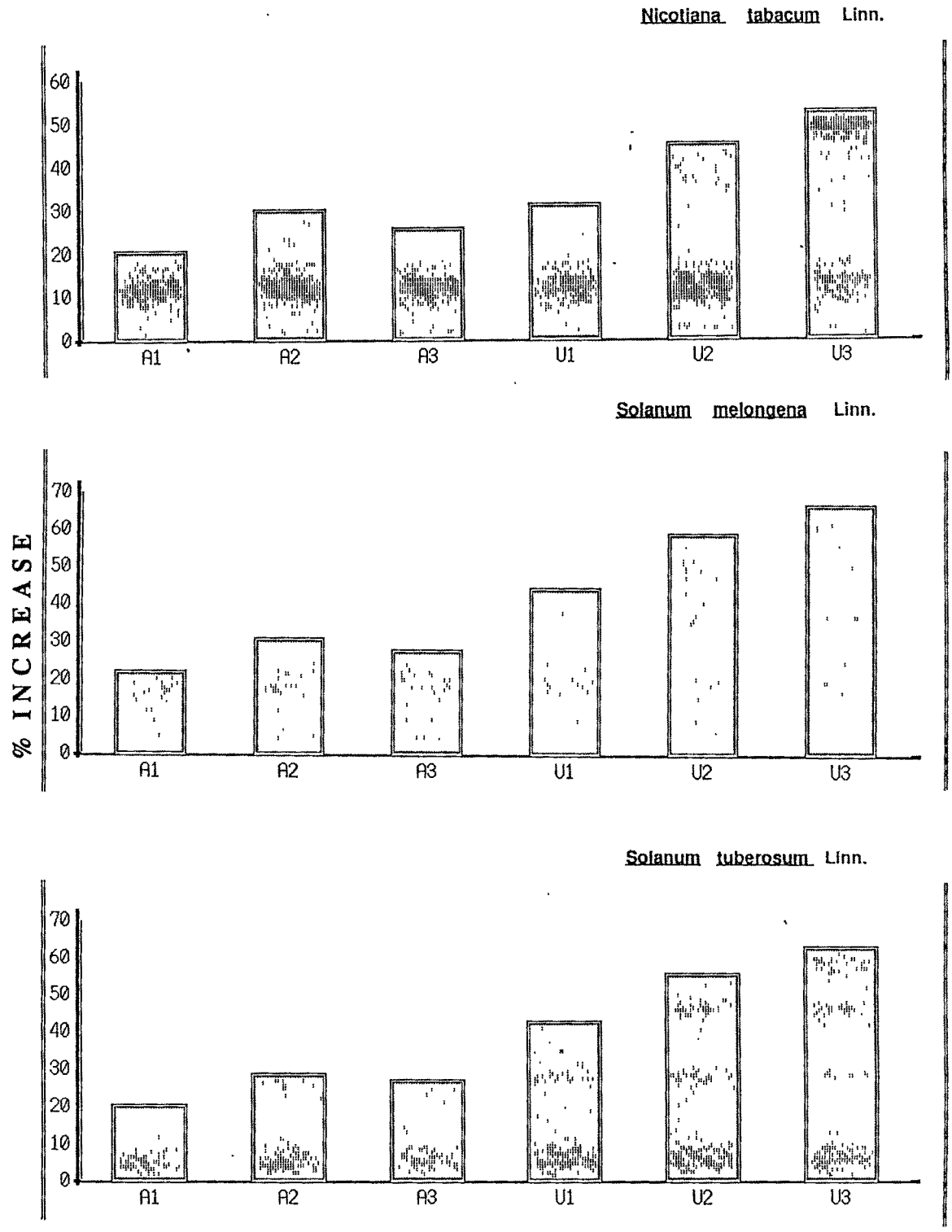
x. Total soluble sugars

Significant increase in foliar soluble sugar content was recorded. The percentage recovery at 60 days was 20.1, 25.4, 21.6; 35.8, 42.6 and 54.9 respectively in A_1, A_2, A_3; U_1, U_2 and U_3 plants (Table 45).

xi. Sulphur

Foliar sulphur accumulation was less in treated plants as compared to untreated plants. At 80 days 26.1, 28.9, 24.8; 27.9, 35.2 and 45.6% less accumulation than untreated plants was recorded in A_1, A_2, A_3; U_1, U_2 and U_3 plants respectively (Table 45).

Fig. 31 : MITIGATION OF POLLUTION EFFECT
FIELD EXPERIMENT : Y I E L D



xii. Yield

The yield was recorded at harvest on the basis of weight of fresh tubers, 20.1, 28.4, 21.6; 42.5, 55.4 and 62.8% recovery in yield was recorded in A_1, A_2, A_3; U_1, U_2 and U_3 treated plants respectively (Table 46).

xiii. Cost-benefit ratio

The ratio was 1:6.4, 1:4.5, 1:1.7; 1:15.7, 1:13.0 and 1:7.50 in A_1, A_2, A_3; U_1, U_2 and U_3 treatments respectively. U_1 (0.15 M urea) treatment gave maximum profit.

3.5.2.4 Statistical Analysis of the Data

Analysis of variance was done for some parameters (biomass, chlorophyll & protein) to know the effect of treatments. Two way interactions were applied, i) between treatments ii) between ages. Significant values were observed in both the cases at a probability of < 0.05. This clearly revealed that the chemicals used can significantly reduce the pollution injury. It also showed that behaviour of species was different at different ages.