Chapter 3

# RESULTS

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## 3.1 AMBIENT AIR CONCENTRATION OF THE MONITORED POLLUTANTS

Concentrations of major pollutants like $SO_2$ and $NO_x$ were recorded at different monitoring zones (Table 5). The average annual concentration of $SO_2$ and $NO_x$ was maximum at zone VII (21.8 $\mu g/m^3$ and 61.2 $\mu g/m^3$). The annual average of $SO_2$ and $NO_x$ concentration in the monitoring zones exhibited the following order respectively

$$1a > 1b < 2 < 3 < 4 \ \&^* \ 5 > 6 < 7 \ \&^* \ 8$$
$$1a > 1b < 2 > 3 > 4 \ \&^* \ 5 < 6 < 7 \ \&^* \ 8$$

The range of maximum and minimum concentration of $SO_2$ and $NO_x$ recorded during monitoring period were 125.40 - 1.2 and 243.0 - 3.6 $\mu g/m^3$ respectively.

The seasonal (monsoon) average pollutants concentration recorded were $SO_2$, 22.8 $\mu g/m^3$ and $NO_x$ 50.9 $\mu g/m^3$ at zone VII, during the growth period of the crops. During winter season, the average $SO_2$ concentration was maximum at zone V (22.1 $\mu g/m^3$) while the $NO_x$ concentration was maximum at zone VI (98.8 $\mu g/m^3$). Chlorine was monitored at zone II & VIII only. The average concentrations recorded were 6.7 and 5.8 $\mu g/m^3$ (winter) and 15.3 & 32.7 $\mu g/m^3$ (monsoon) respectively.

The average pollutants concentrations were based on weekly monitoring and many higher peaks might have been missed in absence of continuous monitoring system. These peaks might have been much higher than the average concentration.

*Commom monitoring point

## SEASONAL VARIATION IN POLLUTANT DISPERSION

Change in pollutants concentration due to change in wind speed, wind direction etc. was recorded at all the eight experimental zones, during winter and monsoon (Ref. to windrose diagrams Fig.2).

The zones I, II, III, VI & VII were in windward direction during monsoon season ffrom the pollution source and the same zones were in leeward direction during winter seaon. The zones IV, V & VIII were in leeward direction during monsoon and were in windward during winter season. The wind direction during monsoon was generally SW or S and during winter was NE or N.

Zone I was 2 km. NW to pollution source (Industrial estate). This zone showed less pollutants concentration of $SO_2$ (3.3 & 5.7 ug/$m^3$) and $NO_x$ (21.7 & 46.6 ug/$m^3$) during winter and monsoon seasons. This might be due to greater distance of the zone from the pollution source and least number of days exposed to the poluted winds (9.6 % of days during monsoon and 2.3% of days during winter).

During monsoon season zones II, III, VI, VII & VIII were exposed to polluted wind, for 58% of days (maximum number of days) and zone IV & V faced the wind, for 12.8% of the days respectively. During winter, zones II, III, VI & VII were exposed to the winds for 16.5% of the days and zones IV, V & VIII for 42 % of the days.

Zone II was at 0.5 km NE from the Petrochemicals & Refinery. Though this zone was at a little distance from the pollution source but showed less pollutants concentration due to less pollutants emission from the source (Due to better

safety measures adapted) Zone III was at 3 km NE from the Industrial estate. Inspite of receiving wind in this direction for higher percentage of days at this zone,less pollutants concentration were recorded due to greater distance from the source. Zone IV was 2.5 km SW and Zone V was at 0.5 km SW from the same source. Due to greater distance of zone IV than zone V from the same pollution source, less pollutants concentration were found at zone IV than V.(Fig.3) Zone VI was at 1.5 km NE of a Fertilizer complex and VII & VIII were at 0.5 km from the pollution source (Industrial Estate) respectively. All these zones showed higher pollutants concentration due to closer location from the pollution sources. Though zones VI & VII were in leeward direction during winter, but recorded high pollution level due to higher pollution emission with lesser dispersion and frequent changes in the wind direction.

## 3.2 FIELD - SURVEY OF COMMON CROPS

A general field survey of common cash and cereal crops was conducted to observe the extent of damage and reduction in the yield of crops in the polluted zones with reference to control zones. Monsoon crops (maize, paddy, and millet) and winter crops (wheat, potato and tuwer) showed less foliar injury at zones I, II & IV and more at zones, V, VI, VII & VIII. The maximum damage recorded in monsoon crops was at zone III, VI & VII and during winter at zone IV, V & VIII. Tobacco was the only crop grown in both the seasons showed minimum damage at zone I and maximum at zone VIII. Among all the above mentioned crops, maize crop showed minimum damage (10 to 20%).

Among these crops wheat, paddy and maize were selected for more detailed study viz.,morphological and yield parameters. Growth analysis was done on the basis of biomass accumulation and total leafarea of the plants.

### 3.2.1 Triticum aestivum Linn.(Wheat)

Wheat being winter crop exhibited damage at zones VIII,V & IV (windward) at all the ages over reference sample. Though zone VII was in leeward direction exhibited reduction in all parameters next to zone vIII. Thus zones VIII, VII, V & IV in sequence recorded reduction. Rest all zones VI, III, II & I were in leeward direction, hence less damage was recorded. The maximum reduction in all the growth and yield parameters was recorded at 80 days at all the zones. The actual figures are recorded in tables and percentage reduction values are expressed with the graphs.

#### 3.2.1.1 Height

The plants exposed to air pollutants recorded reduction in height at all zones. The maximum reduction (31.33%) was recorded at 80 days at zone VIII. The zones VII, V, IV, VI,III, II & I recorded 26.69, 26.48, 19.31, 17.12, 11.59, 11.20 & 10.56 percent reduction respectively at the same age (Fig.4; Table 7.1).

#### 3.2.1.2 Total leafarea

The maximum reduction in total leafarea (36.11%)was recorded at 80 days at zone VIII. The zones VII,V, IV, VI, III, II & I recorded 31.22, 23.46, 22.22, 21.37, 20.73, 15.06 & 10.02 percent reduction at the same age respectively.The dried and fallen leaves were not counted at 80 days (Fig.5; Table 7.2).

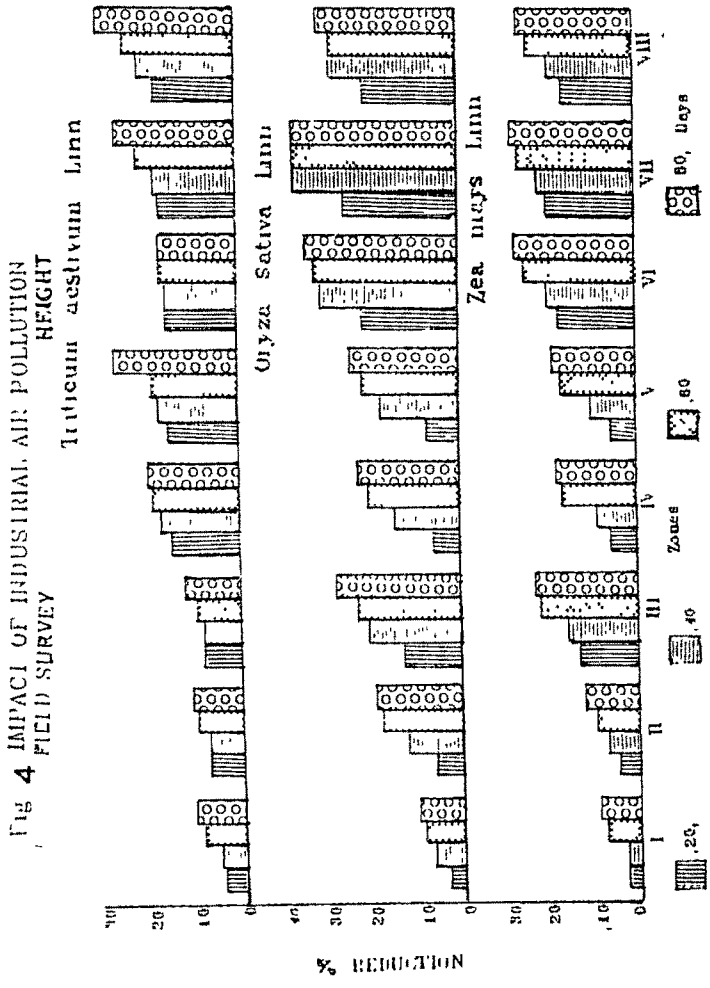
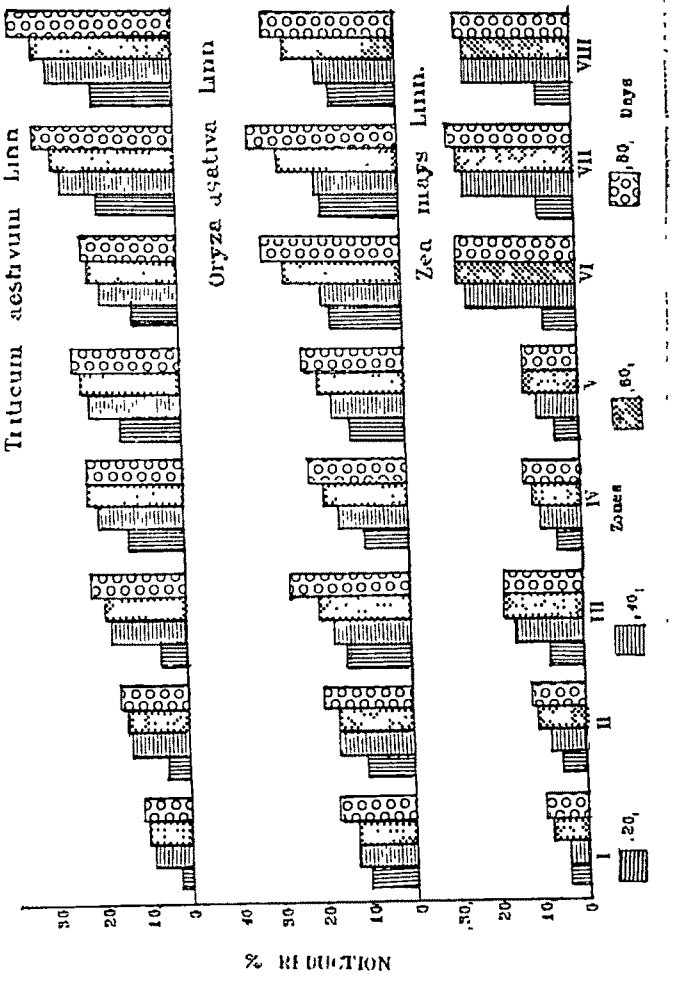



Fig 4 IMPACT OF INDUSTRIAL AIR POLLUTION
FIELD SURVEY
HEIGHT

Fig 5 IMPACT OF INDUSTRIAL AIR POLLUTION
FIELD SURVEY
TOTAL LEAF AREA



### 3.2.1.3 Injury Index

Crop recorded foliar damage at zone IV,V,VII & VIII. Maximum foliar damage (injury index 26.9%) was recorded at zone VIII at 80 days with smaller leaves and higher leafarea damage. The zones IV, V & VII exhibited 15.7, 20.0 & 20.5% injury index respectively at 80 days (Table 7.3).

### 3.2.1.4 Biomass

The maximum percentage reduction (42.77) in biomass accumulation was recorded at zone VIII at 80 days. The zones VII, V, IV, VI, III, II & I exhibited 33.68, 29.54, 29.39, 23.62, 13.93, 12.74 & 10.29 percent reduction respectively over reference samples at the same age (Fig.6; Table 7.4).

### 3.2.1.5 Relative growth rate (RGR)

The reduced RGR was recorded at all the zones at 20,40,60, & 80 days. The maximum percentage reduction (56.29) was recorded during 60-80 days at zone VIII. The zones V, IV, VII, III, II & I recorded 47.80, 38.00, 37.30, 36.78, 21.06, 16.67 & 14.96 percent reduction respectively during 60-80 days (Fig.7; Table 7.5).

### 3.2.1.6 Net assimilation rate (NAR)

Maximum percentage reduction in NAR (67.26) was recorded at zone VIII during 40-60 days. The reduction recorded during 60-80 days was maximum (59.60%) at zone IV. The zones V, VIII, VI, VII, II, III & I recorded 54.55,45.45, 43.43, 42.42, 23.23, 20.93 & 19.19 percent reduction respectively during 60-80 days (Fig.8; Table 7.6).

### 3.2.1.7 Yield

Quantitative reduction in grain yield was recorded at all the zones in kilograms per 100 $M^2$ basis. The maximum reduction (82.89%) was recorded at zone VIII. The zones VII, V, IV, VI, III, II & I recorded 73.44, 58.13, 50.75, 43.48, 23.85, 18.93 & 8.36 percent reduction respectively at the time of crop harvest (Fig.9; Table 10).

### 3.2.2 *Oryza sativa* Linn (Paddy)

The crop was observed at all the zones. The wind direction was south-west during the growth periods. The maximum damage in all the parameters was recorded at zone VIII which was followed by zones VI, VII & III. Rest all other zones showed lesser reduction in all the growth parameters and yield.

### 3.2.2.1 Height

The maximum percentage reduction in height (36.74) was recorded at zone VII at 80 days. The zones VI, VIII, III, V, IV, II & I recorded 34.03, 29.84, 27.69, 23.80, 23.39, 18.50 & 10.30 percent reduction respectively at the same age (Fig.4 Table 8.1).

### 3.2.2.2 Total leafarea

The highest percentage reduction in leafarea (31.49), was recorded at zone VII at 80 days. The zones VI, VIII,III,V, IV, II & I recorded 30.06, 28.49, 26.24, 21.43,21.0,19.11 & 15.87 percent reduction respectively at the same age. ?dired and fallen leaves were not counted at 80 days (Fig.5; Table 8.2).

### 3.2.2.3 Injury Index

Visible foliar damage was recorded at zones III,VI,VII & VIII respectively. Maximum foliar injury (injury index 28.9%) was recorded at zone VII at 80 days with high leafarea damage. The zones III, VIII & VI recorded 8.0, 21.7 & 26.4 percent injury index respectively over reference sample at the same age (Table 8.3).

### 3.2.2.4 Biomass

Gradual increase in biomass accumulation was recorded till 80 days. The maximum percentage reduction (38.13) was recorded at zone VII at 80 days. The zones VI, VIII, III,V,IV, II & I recorded 36.38, 34.21, 26.53, 22.95, 20.08, 10.52 & 9.77 percent reduction respectively at the same age(Fig.6; Table 8.4).

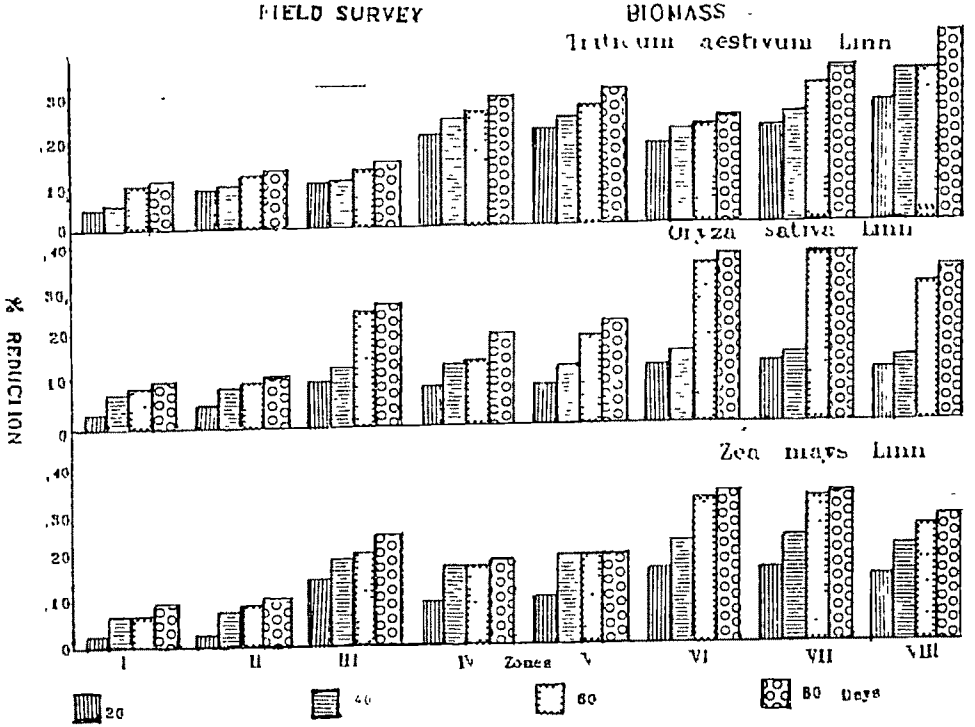
### 3.2.2.5 Relative growth rate (RGR)

RGR showed gradual increase unpto 60 days than recorded decrease. The maximum percentage reduction (47.28) was recorded at zone VII during 40-60 days. The zone VII recorded 42.66% during 60-80 days. The zones VI, VIII, III,V,II,IV & I recorded 41.56,40.76,28.91, 27.43, 26.25, 25.83 & 12.87 percent reduction respectively during 60-80 days as compared to reference plants (Fig.7; Table 8.5).

### 3.2.2.6 Net assimilation rate (NAR)

The maximum reduction in NAR (96.95%) was recorded at zone VII during 40-60 days. The zones VI, VIII, III, V, IV, II & I recorded 93.72, 91.29, 66.60, 56.69, 53.04, 26.40, & 21.30 percent reduction respectively at 40-60 days.

Fig 6 IMPACT OF INDUSTRIAL AIR POLLUTION



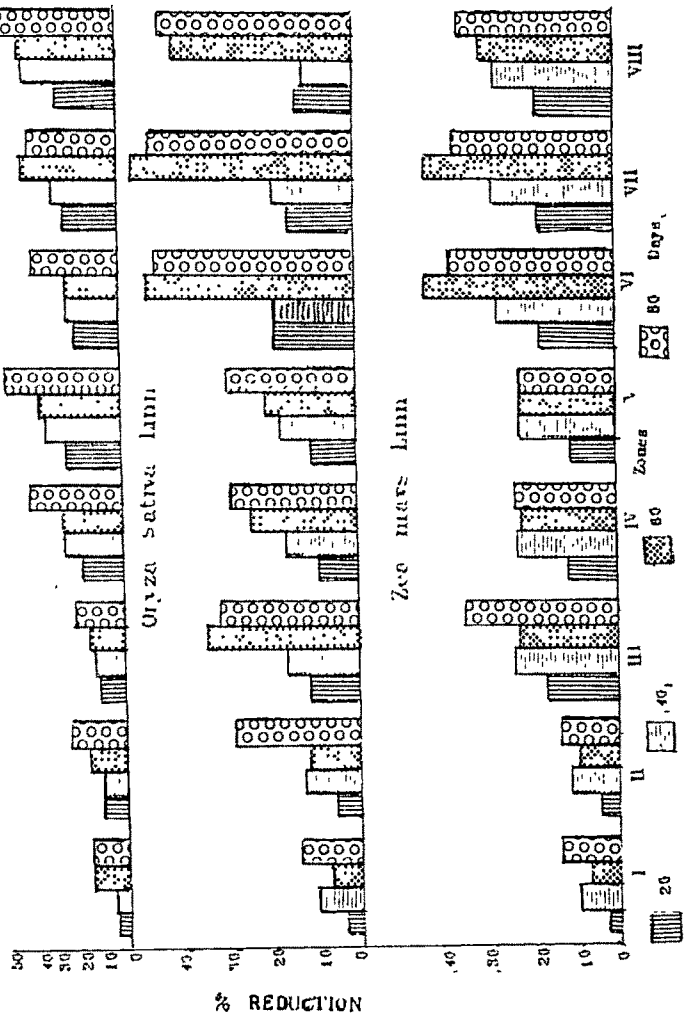



Fig 7 IMPACT OF INDUSTRIAL AIR POLLUTION
FIELD SURVEY R G R—
Triticum aestivum Linn

The zone III & I showed 12.03 & 16.54 percent increase respectively over reference plants at 60-80 days(Fig.8; Table 8.6).

### 3.2.2.7 Yield

Reduction in all growth parameters resulted in reduced grain uield. At harvest the maximum percentage reduction (71.52) was recorded at zone VII. The zones VI, VIII, III, V, IV,II & I recorded 68.17, 65.11, 26.67, 18.46, 17.72, 10.87 & 8.77 percent reduction respectively (Fig. 9; Table 10).

### 3.2.3 Zea mays Linn (Maize)

This crop exhibited less reduction in all parameters than wheat & paddy due to its more tolerance to air pollution. The highest affected zone was VII which was followed by zones VI, VIII, III, V, IV, II & I respectively as compared to reference plants.

### 3.2.3.1 Height

The maximum percentage reduction (27.68) was recorded at zone VII at 80 days over reference plants. The zones VI, VIII,III, V, IV, II & I recorded 26.55, 25.73, 23.10, 18.74, 18.38, 11.69 & 8.85 percent reduction respectively at the same age (Fig.4 ; Table 9.1).

### 3.2.3.2 Total leaf area

Gradual increase in total leaf area was recorded upto 80 days at all the zones. The maximum percentage reduction (28.11)was recorded at 80 days at zone VII. The zones VI, VIII,III,V,IV, II & I recorded 27.14, 26.06, 18.36, 13.75, 12.78, 11.90 & 8.62 percent reduction respectively at the same age (Fig.5; Table 9.2).

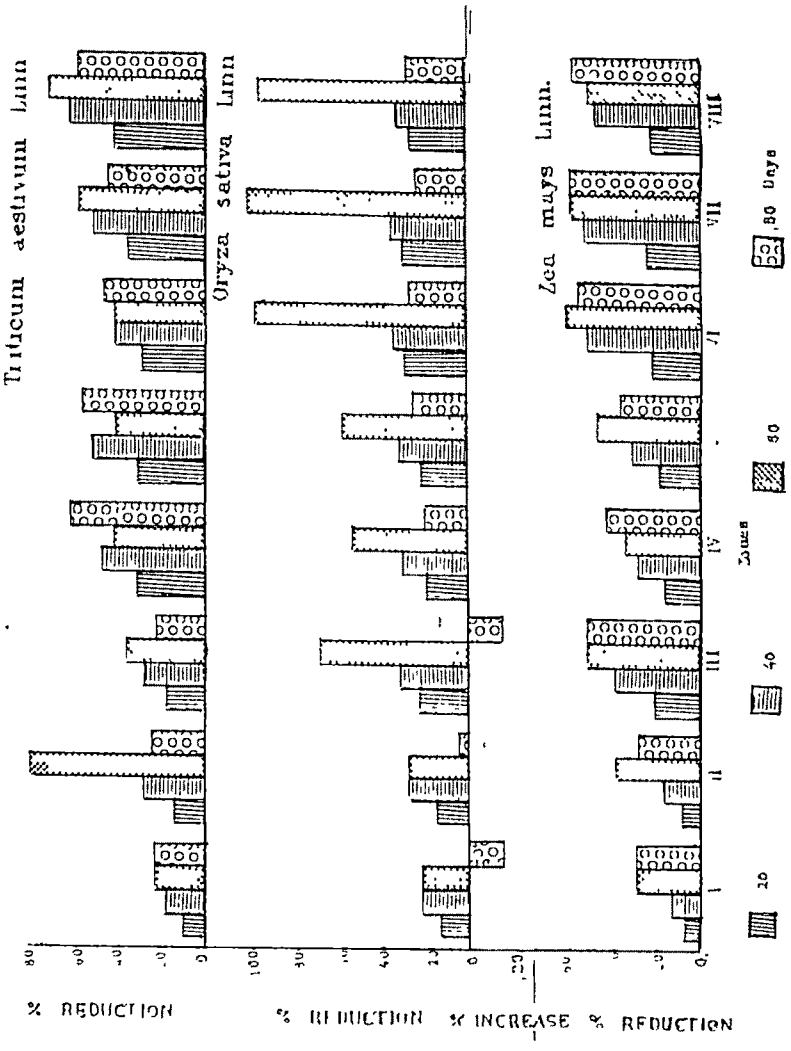



Fig 8 IMPACT OF INDUSTRIAL AIR POLLUTION
FIELD SURVEY
N A R

### 3.2.3.3 Injury Index

Crops showed visible symptoms at zones III, VI, VII & VIII.The maximum injury index (20.50%) was recorded at zone VII. The zones VI, VIII & III exhibited 17.5, 6.0 & 4.53 percent injury index respectively at the same age (Table 9.3).

### 3.2.3.4 Biomass

The maximum percentage reduction (33.59) in biomass was recorded at zone VII during 80 days. The zones VI, VIII, III, V IV,II & I recorded 33.52, 28.08, 24.67, 19.80, 19.29, 9.57 & 8.45 percent reduction respectively at the same age (Fig.6; Table 9.4).

### 3.2.3.5 Relative growth rate (RGR)

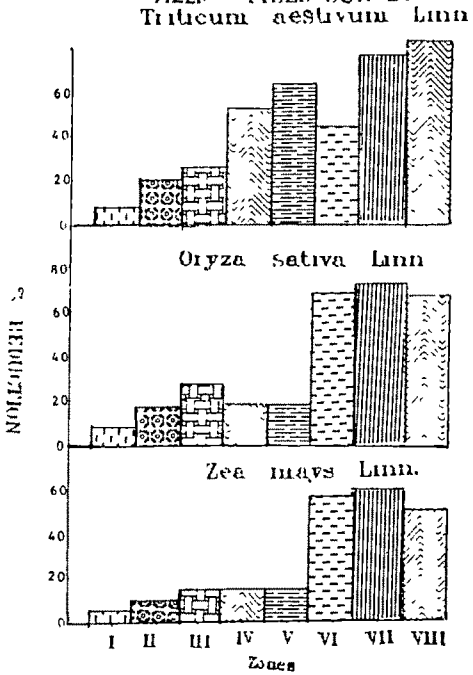
Maximum percentage reduction (39.81) was recorded during 40-60 days at zone VI. The zone VI recorded maximum reduction was 34.33% during 60-80 days. The zones VII, VIII,III, IV, V,II & I recorded 34.25, 32.43,31.77, 21.20, 20.08, 12.43 & 12.33 percent reduction respectively during 60-80 days (Fig.7; Table 9.5).

### 3.2.3.6 Net assimilation rate (NAR)

The highest reduction in NAR(59.69%) was recorded during 40-60 days. The maximum percentage reduction (58.50) during 60-80 days was recorded at zone VII. The zones VIII, VI, III, IV, V, II & I recorded 55.92, 54.58, 49.18,42.94, 35.22, 28.29 & 27.33 percent reduction respectively over reference during 60-80 days (Fig.8; Table 9.6).

Fig 9 IMPACT OF INDUSTRIAL AIR POLLUTION

YIELD FIELD SURVEY



### 3.2.3.7 Yield

Maximum reduction in grain yield at harvest (57.99%) was recorded at zone VII. The zones VIII, VI, III,V, IV, II & I recorded 50.08, 36.30, 14.63, 13.84, 13.09, 10.20 & 4.72 percent reduction respectively (Fig.9; Table 10).

## 3.3 POTTED PLANT EXPOSURES

Pot exposure study was conducted by keeping all the edaphic and cultural conditions identical for all the bags to reduce the variables like soil, water, agricultural practices etc. to minimum, only the quality of air was different in different experimental zones.

Observations were recorded at 20 days intervals. Percentage increase or decrease was calculated in all the parameters with respect to reference and are expressed with the graphs. The actual values are expressed in tables.

### 3.3.1 Triticum aestivum Linn.(Wheat)

Wheat seeds were sown during winter season. Reduction in various growth and biochemical parameters (except reducing sugars, sulphur and chloride content) was recorded at all zones at all ages of 20, 40, 60, 80 over reference samples. The crop was harvested at maturity.

Maximum damage was recorded at zones VIII, V & IV (windward) at 80 days and minimum at 20 days. Though the zone VII was in the leeward direction during winter but it recorded high damage due to closeness to the source.

### 3.3.1.1 Root length

Maximum reduction in root length (35.71%) was recorded at 80 days at zone VIII. The zones V, IV, VII, VI, III, II & I recorded 28.57, 26.98, 25.79, 18.65, 15.87, 12.69 & 10.32 percentage reduction respectively at the same age (Fig.10; Table 11).

### 3.3.1.2 Shoot length

The maximum percentage reduction (35.71) in shoot length was recorded at zone VIII at 80 days. The zones VII, V, IV, VI, III, II & I recorded 28.46, 25.30, 23.27, 20.12, 11.9, 10.6 & 7.93 percent reduction respectively at the same age (Fig. 11; Table 12).

### 3.3.1.3 Number of leaves

The number of leaves reduced at zone VIII & VII was 33.33 percent. At the zones VI, V & IV percentage of reduction in number of leaves was 30.30 and at zones III, II & I was 18.18 percent reduction respectively at 80 days as compared to reference (Fig.12; Table 13).

### 3.3.1.4 Total leafarea

The increase in total leafarea per plant was recorded upto 80 days. Maximum percentage reduction as compared to reference (34.15) was recorded at zone VIII at 80 days. The zones VII, V, IV, VI, III, II & I depicted 28.77, 27.69, 26.85, 21.97, 9.96, 9.36 & 7.16 percent reduction respectively at the same age (Fig.13; Table 14).

Fig 10 IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE ROOT LENGTH

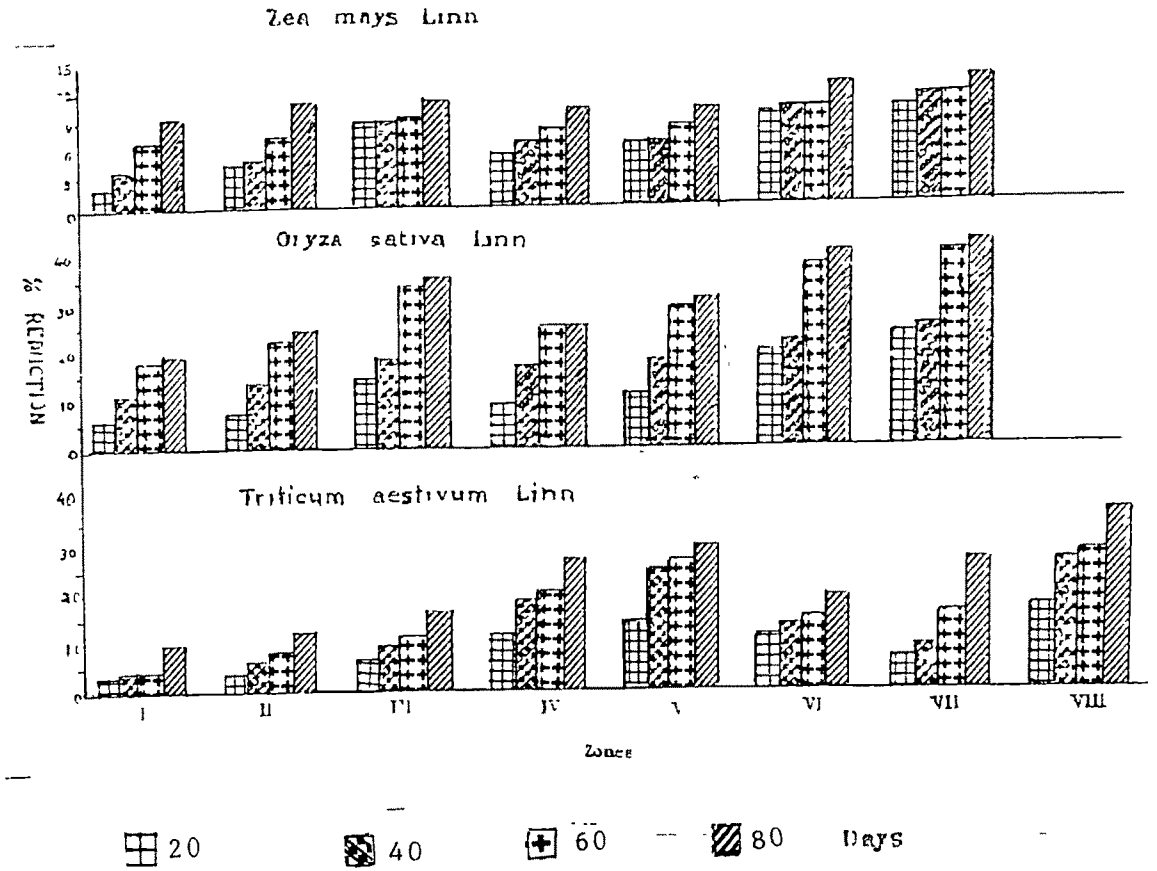
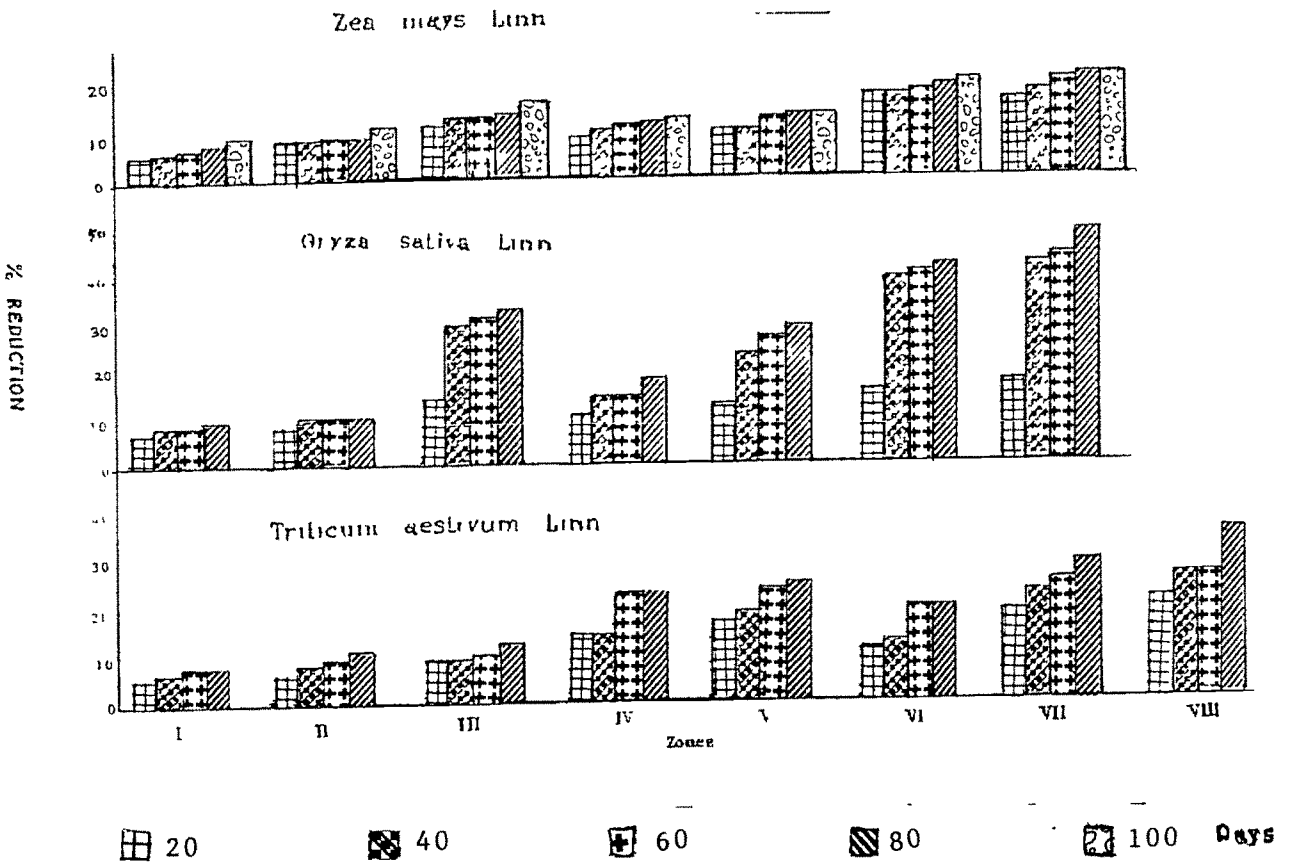


FIG. 11 IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE SHOOT LENGTH



12 IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE NUMBER OF LEAVES

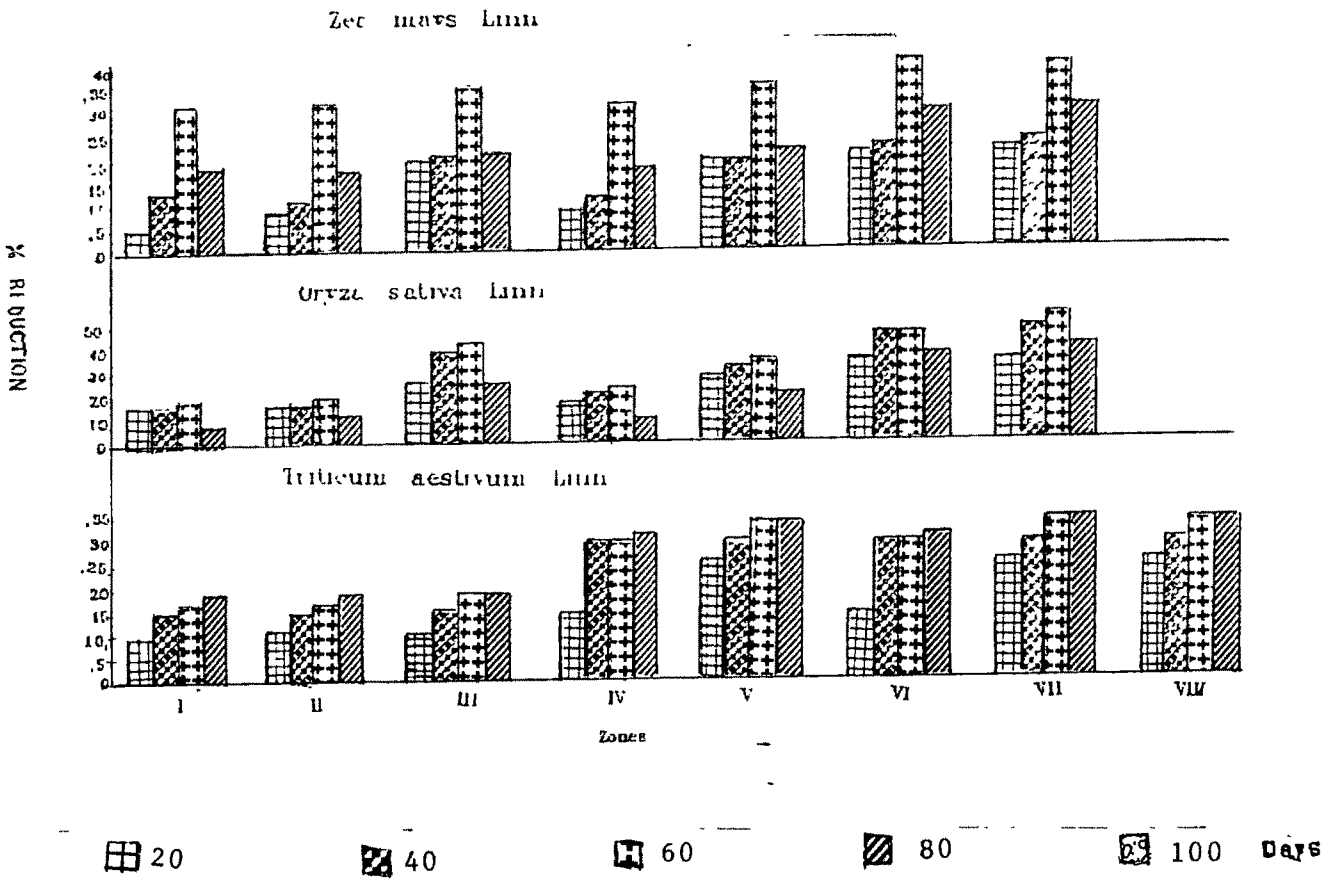
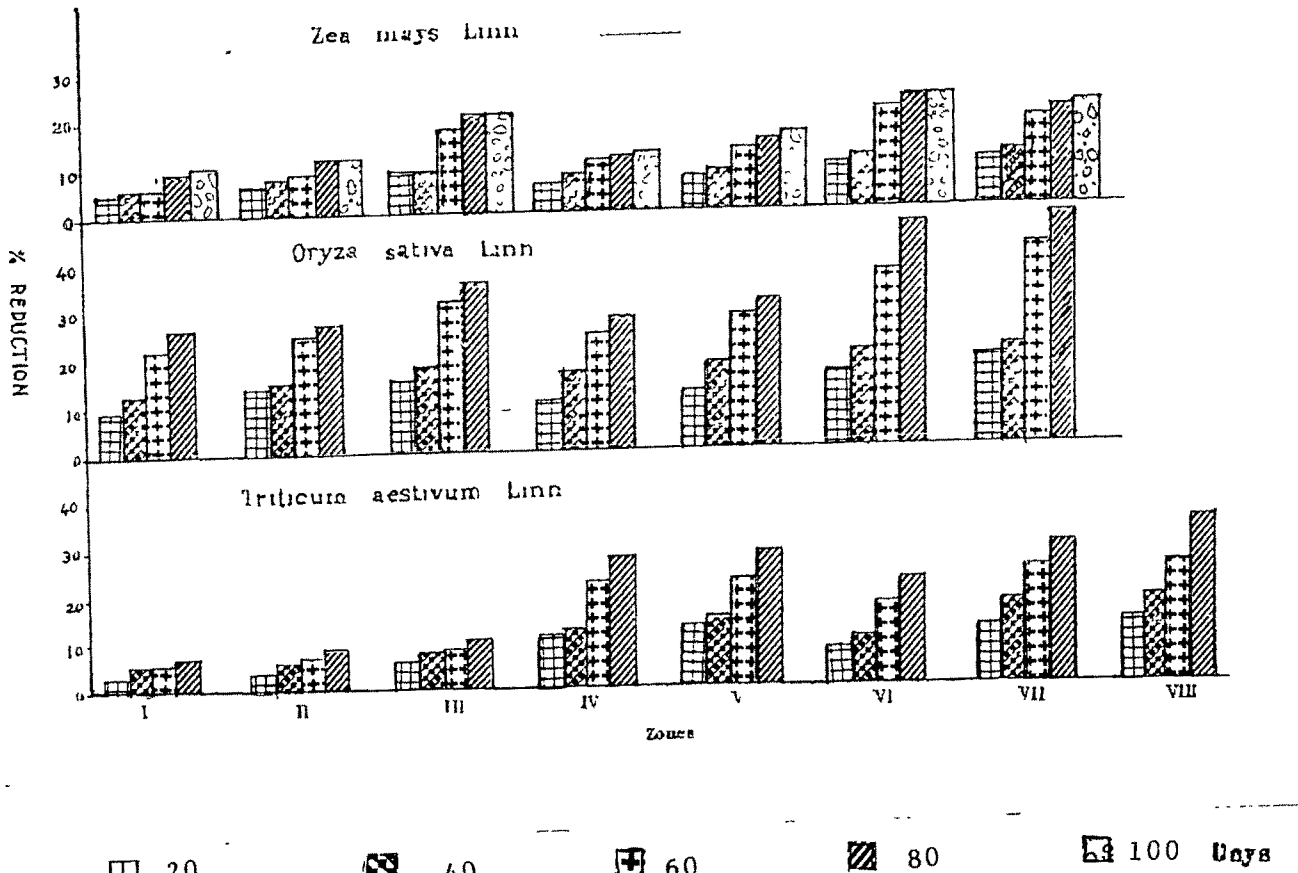


Fig. 13 IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE TOTAL LEAF AREA



### 3.3.1.5 Injury index

Tip and marginal burning of leaves was observed at zones IV, V, VII & VIII. Maximum injury index (28.4) was recorded at zone VIII. Injury index recorded at the zones IV, V & VII ranged from 4 to 25.8 % (Table 15).

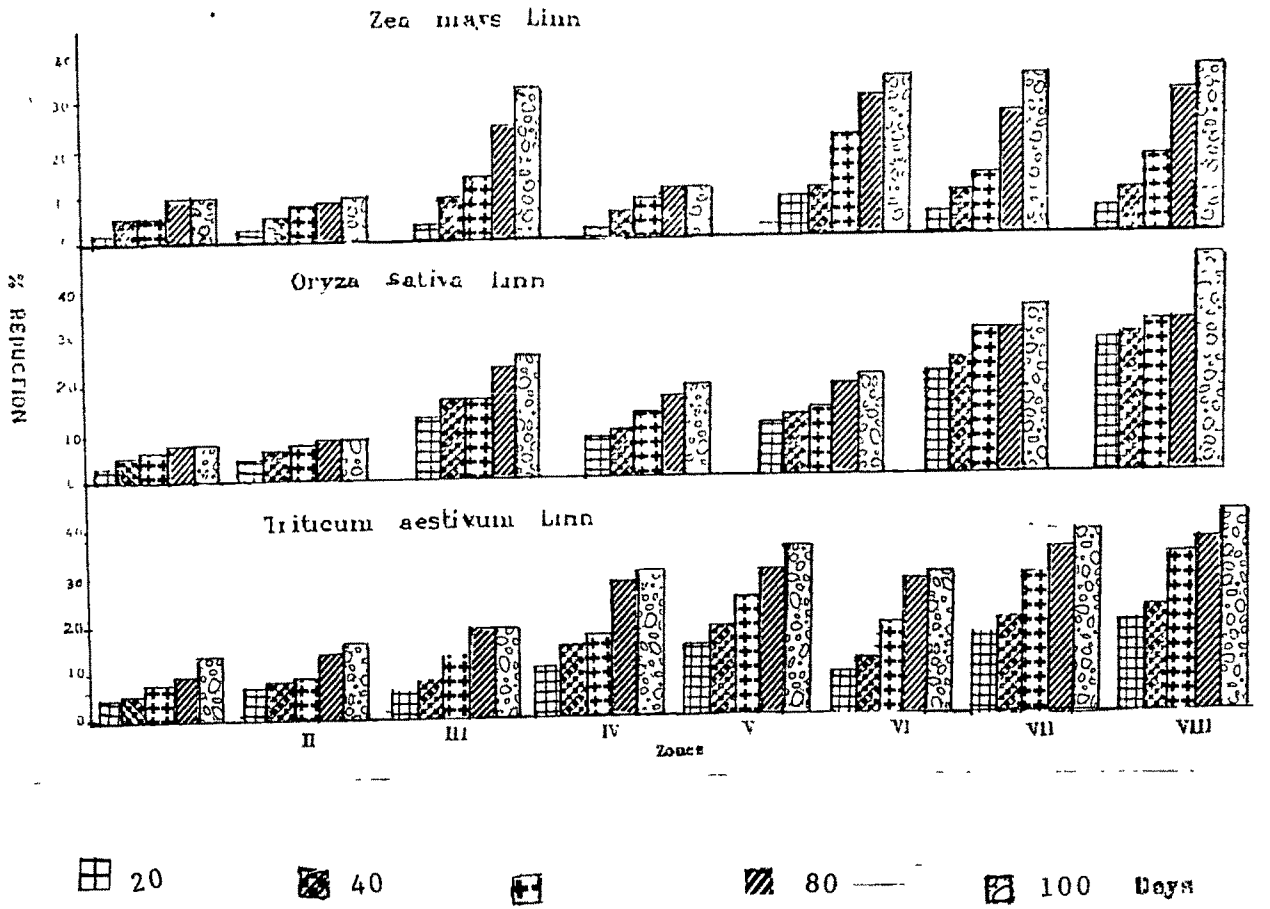
### 3.3.1.6 Foliar epidermal structure

Epidermal study was conducted in foliar tissues of reference samples and polluted samples at 80 days. The zone V was selected for present epidermal study and was highly polluted with maximum concentration of sulphur dioxide during winter. Maximum damage recorded in all parameters was at 80 days, hence foliar tissues of 80 days old plants were studied. Variation in epidermal features were observed in the plants of pollution zone. The mesophyll tissues were also damaged below the substomatal chamber in upper leaf surface of the wheat crop plants. Stomatal frequency was reduced by 22.22 % and epidermal cell frequency was increased by 14.83% as compared to reference sample. Stomatal index was reduced by 24.68% as compared to reference sample (Table 16).

### 3.3.1.7 Biomass

Gradual increase in biomass accumulation was recorded at all the zones at all the ages. Maximum percentage reduction (41.90%) was recorded at zone VIII at 100 days. The zones VII, V, IV, VI, III, II & I depicted 38.10, 34.67, 30.78,29.52, 19.05, 15.81 & 13.14 percent respectively at the same age (Fig.14; Table 17).

Fig.14 IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE BIOMASS



### 3.3.1.8 Relative growth rate (RGR)

Maximum percentage reduction (61.54) in RGR was recorded at zone VIII during 80-100 days compared to the reference plants. The zones VII, V, IV, VI, III,II & I recorded 49.57, 49.51, 37.61, 29.06, 21.37, 20.51 & 19.66 percent reduction respectively during 80-100 days (Fig.15; Table 18).

### 3.3.1.9 Net assimilation rate NAR

Maximum percentage reduction (74.76) was recorded during 60-80 days at zone VIII. The zones VII, V, IV, VI, III, II & I recorded 60.81, 60.94, 59.86, 46.51, 34.74, 27.28 & 14.66 percent reduction respectively at the same age (Fig.16; Table 19).

**Biochemical studies**

### 3.3.1.10 Chlorophyll

Chlorophyll -a:

The chlorophyll content was increased upto 60 days and then decreased at 80 days. The maximum percentage reduction (40.18) was recorded at zone VIII at 80 days as compared to the reference samples. The zones VII, V, IV, VI, III, II & I recorded 38.37, 35.29, 35.26, 28.86, 18.75, 12.17 & 9.08 percent reduction respectively at the same age (Fig.17; Table 20).

Chlorophyll-b:

Maximum reduction (37.34%) was recorded at 80 days at zone VIII over reference sample. The zones VII, V, IV, VI,

Fig 15 IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE R G R

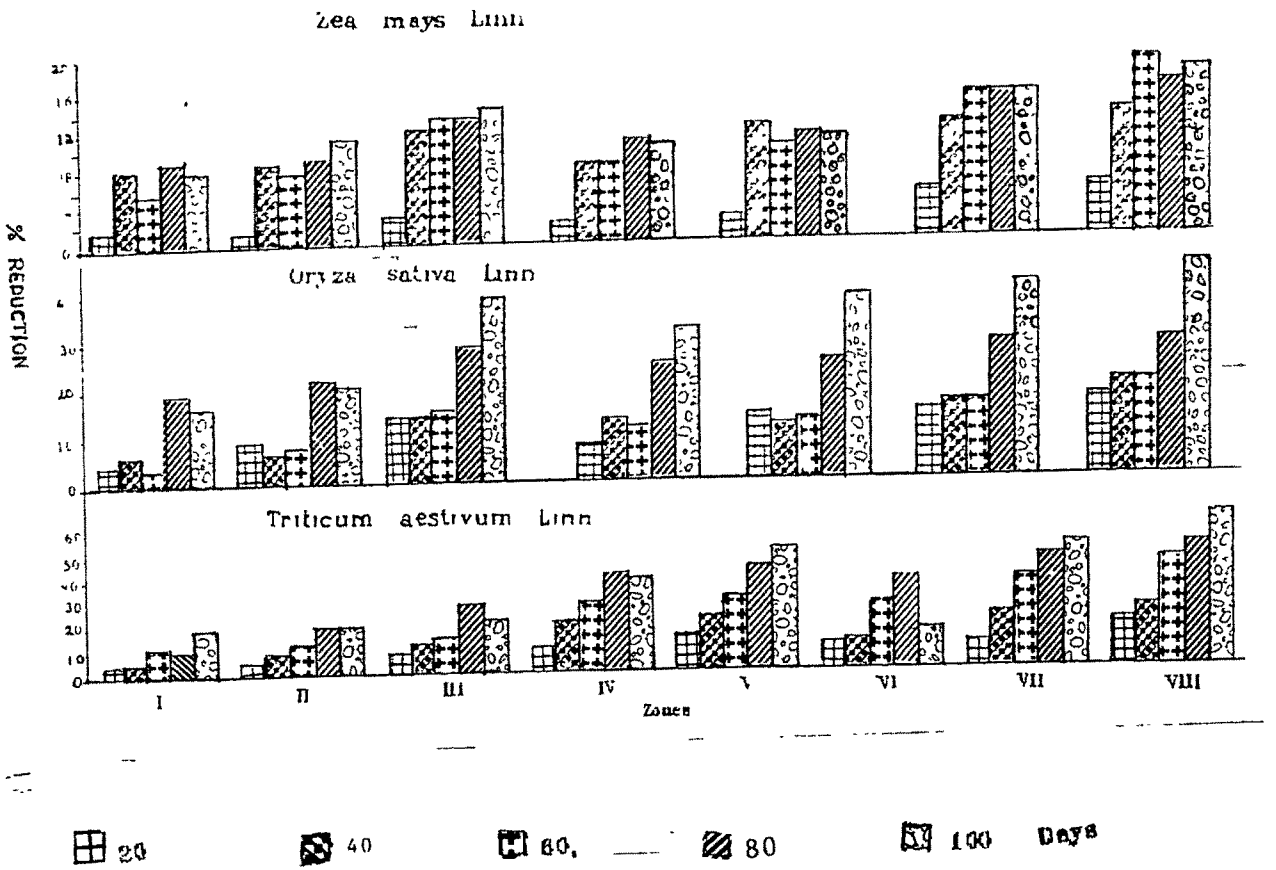


Fig 16 IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE N A R

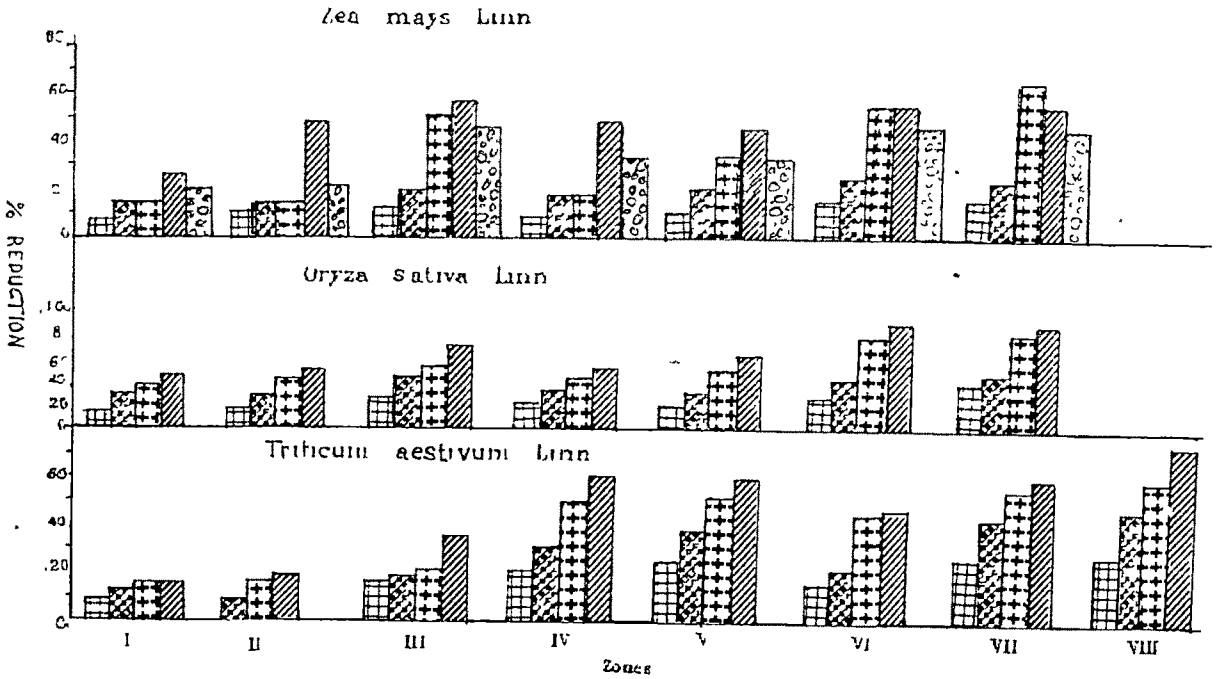
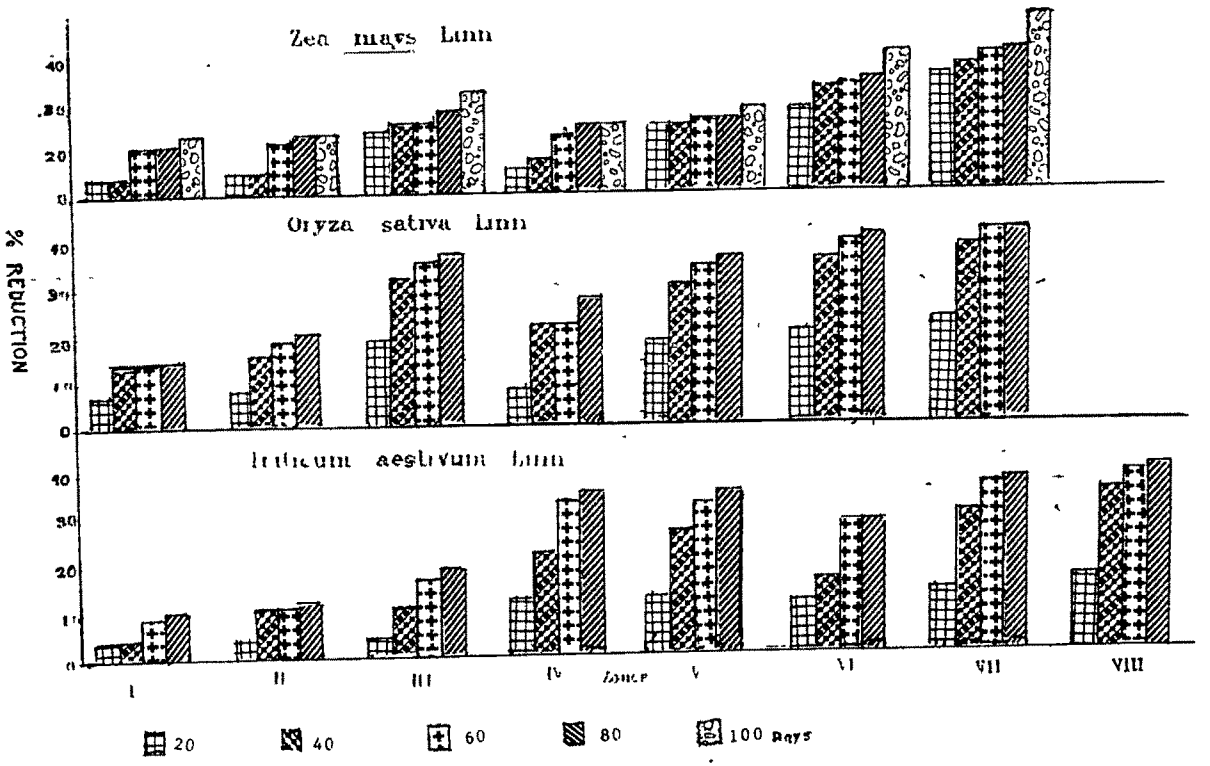


Fig 17 IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE CHLOROPHYLL – a



III, II & I recorded 32.04, 31.19, 28.85, 26.97, 14.21, 12.15 & 6.22 percent reduction respectively at the same age (Fig.18; Table 21).

### 3.3.1.11 Total soluble sugars

The maximum percentage reduction (51.06) was recorded at zone VIII at 100 days. The zones VII, V, IV, VI, III, II & I exhibited 48.45, 48.34, 46.73, 39.29, 28.24, 26.00 & 23.94 percent reduction respectively over reference plants at the same age (Fig. 21; Table 22).

### 3.3.1.12 Reducing sugars

Gradual increase in reducing sugars was recorded at all zones upto 100 days. The maximum percentage increase (46.62) was recorded at zone VIII at 100 days. The zones VII, V, IV, VI,III, II & I recorded 43.58, 41.55, 40.68, 39.53, 21.49, 20.95 & 20.68 percent increase respectively at the same age over reference plants (Fig. 22; Table 23).

### 3.3.1.13 Ascorbic acid

Maximum reduction (36.89%) in ascorbic acid was recorded at zone VIII at 80 days over reference sample. The zones VII,V, IV, VI, III, II & I depicted 34.75, 33.34, 31.70, 27.13, 19.51, 14.63 & 10.06 percent reduction respectively at the same age (Fig.20; Table 25).

### 3.3.1.14 Protein

Maximum percentage reduction (38.87) in protein was recorded at zone VIII at 80 days. The zones VII, V, IV,VI,III,II & I recorded 28.50, 25.71, 24.56, 22.03, 16.27,

Fig 18 IMPACT OF INDUSTRIAL AIR POLLUTION

POTTED PLANT EXPOSURE CHLOROPHYLL – b

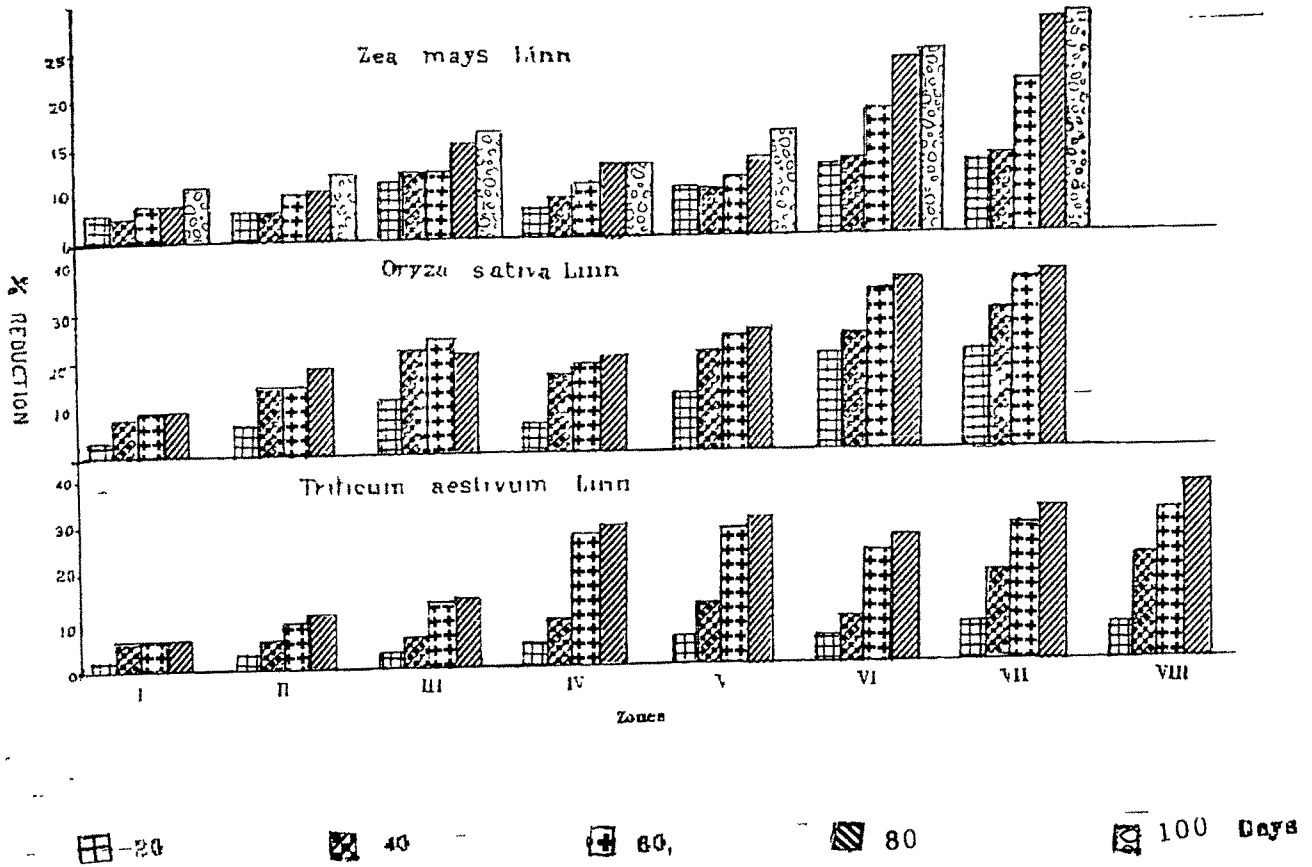


FIG 21 IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE TOTAL SOLUBLE SUGARS

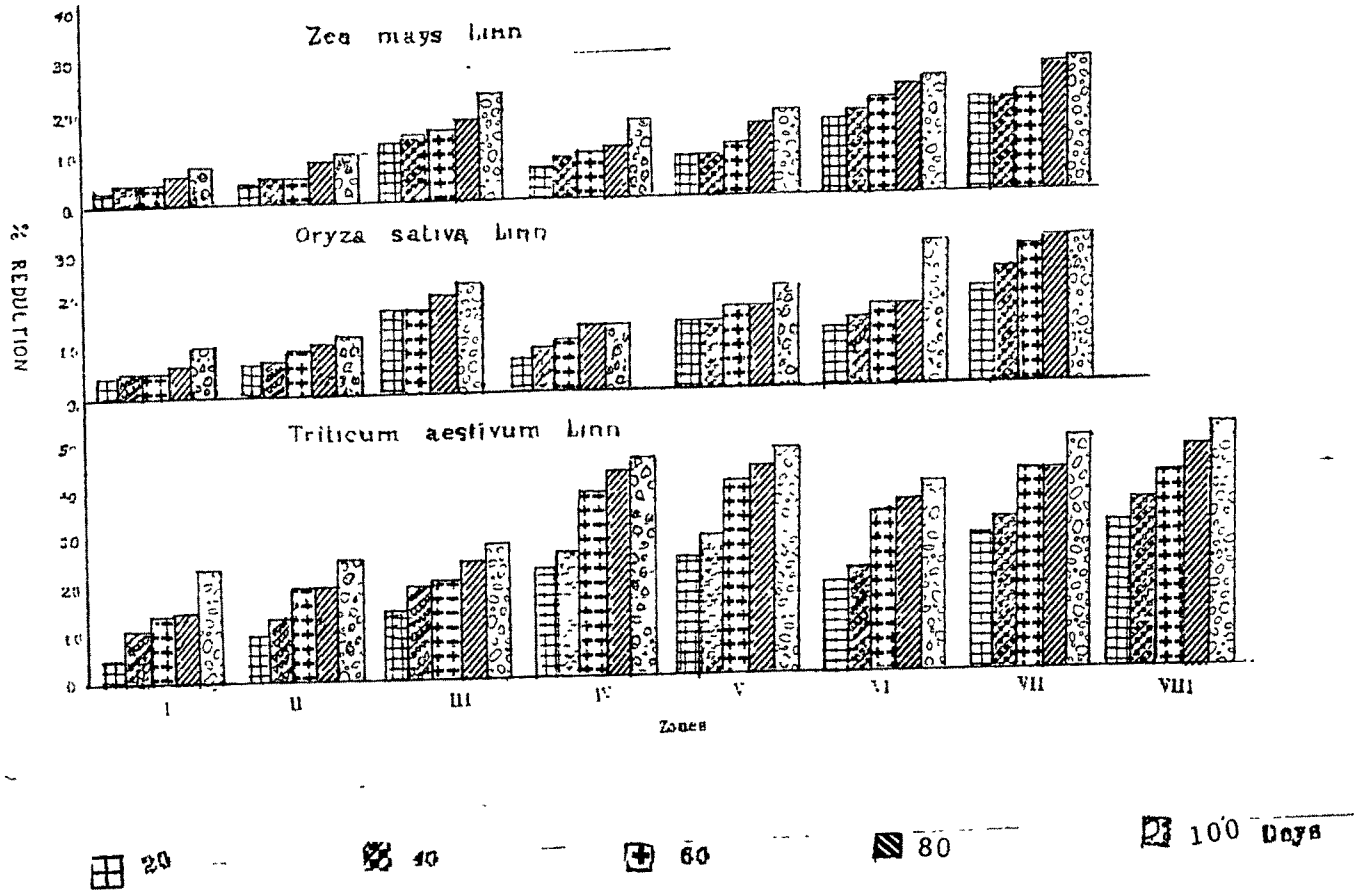


Fig 22 IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE REDUCING SUGARS

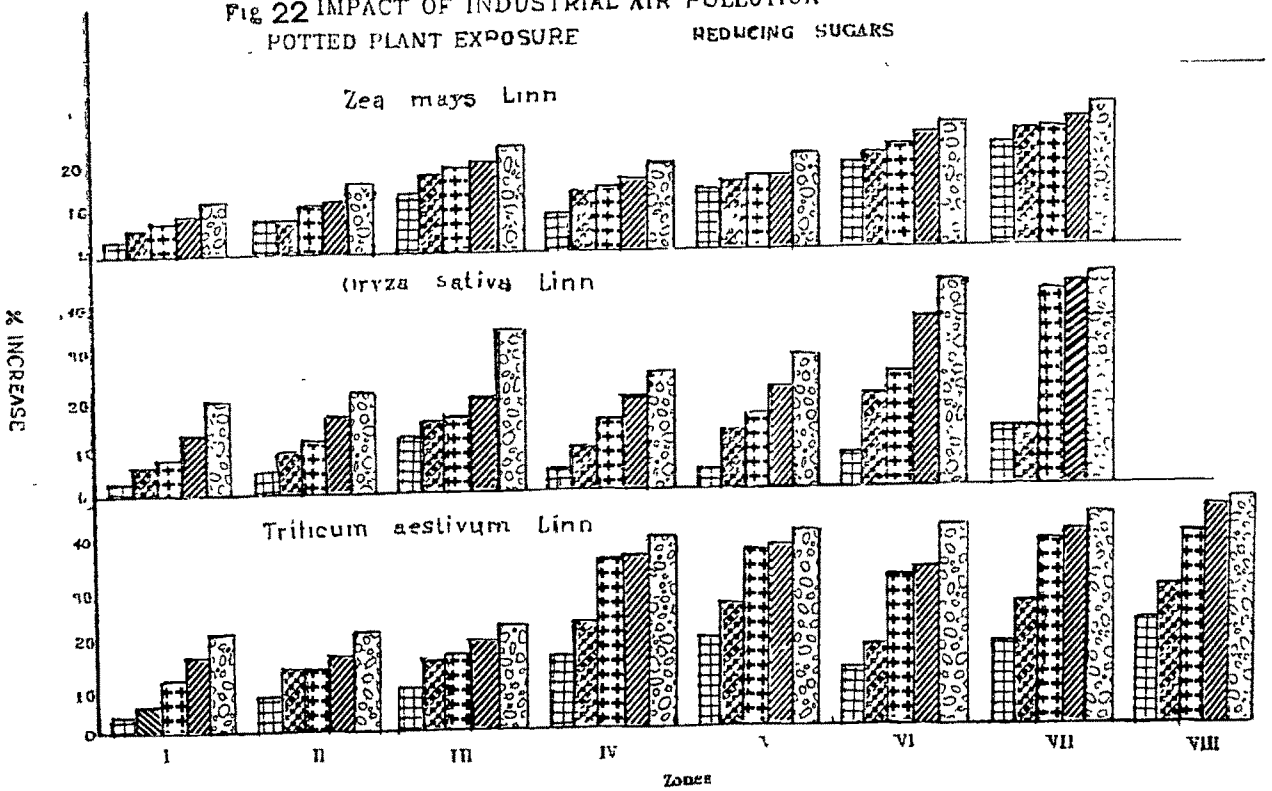
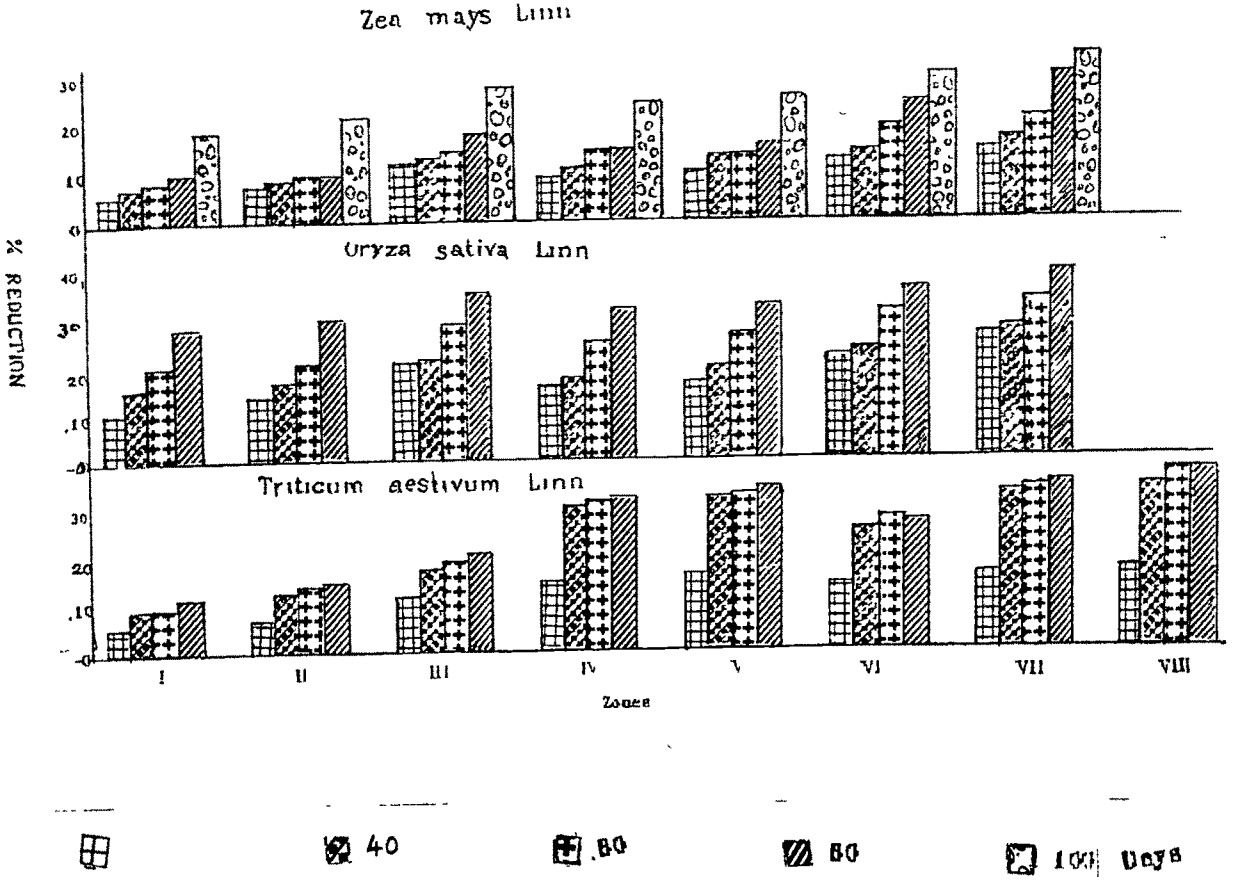


Fig 20 IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE ASCORBIC ACID



12.37 & 10.64 percent reduction respectively at the same age Fig.19; Table 26).

### 3.3.1.15 Sulphur

Gradual increase in foliar sulphur was recorded upto 100 days at all the zones over reference plants. Maximum accumulation of sulphur (2.10 times more than reference) was recorded at zone V at 100 days. The zones VI, VII, VIII, IV, III, II & I depicted 1.98, 1.85, 1.12, 0.85, 0.72, 0.61 & 0.56 times increase over reference at 100 days (Fig.23, Table 24).

### 3.3.1.16 Chloride

Higher degree of chloride accumulation was recorded at zones II & VIII as compared to reference while no significant difference in chloride content at other zones was recorded with respect to reference. The accumulation at zone VIII was 1.27 times and at zone II was 0.27 times more than reference (Fig.24, Table 27).

### 3.3.1.17 Yield

Reduction in all growth and biochemical parameters resulted in reduction in grain yield. The maximum reduction (88.82%) was recorded in grain yield at zone VIII at harvest. The zones VII, V, IV, III, II & I recorded 83.79, 85.55, 72.70, 61.78, 37.63, 36.41 & 24.28 percent reduction respectively (Fig.25, Table 28).

### 3.3.2 *Oryza sativa* Linn (Paddy)

This crop was grown at all the zones except at zone VIII during monsoon. Various growth and biochemical

Fig 19 IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE ——PROTEIN

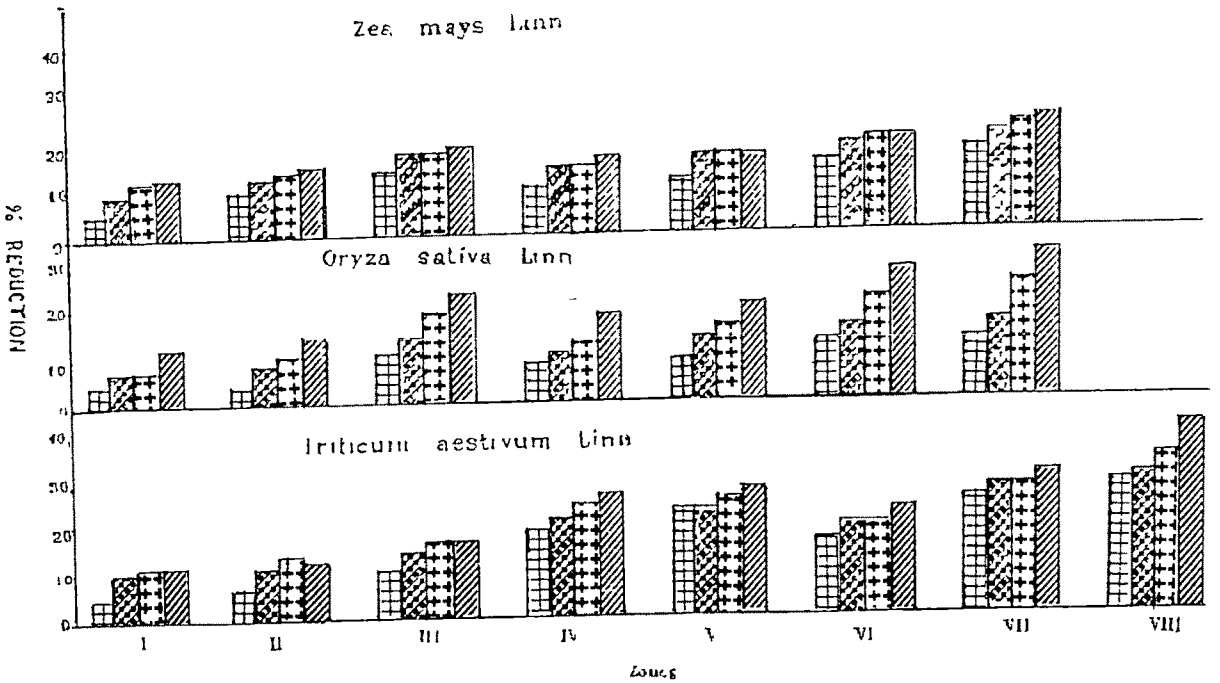
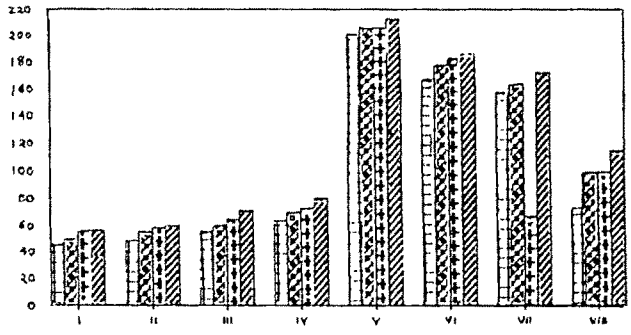
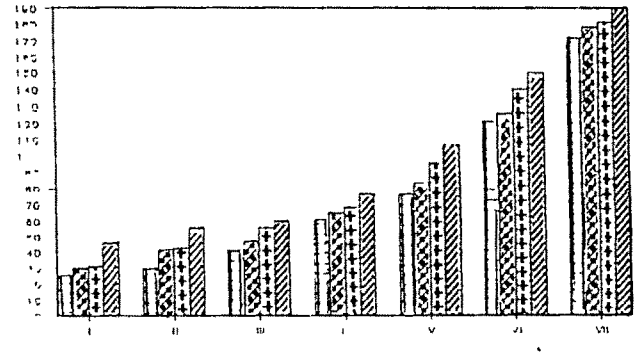


Fig 23 IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE SULPHUR

Triticum aestivum Linn



Oryza Sativa Linn



% INCREASE

Zea mays Linn

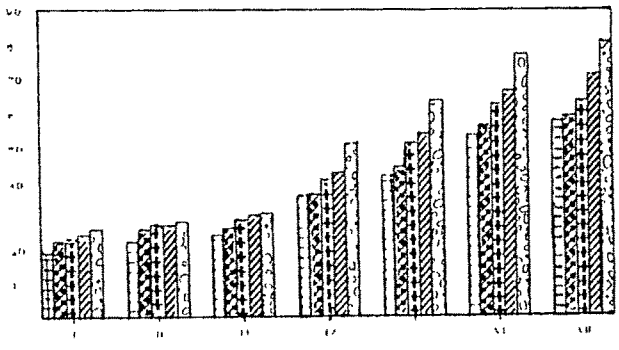
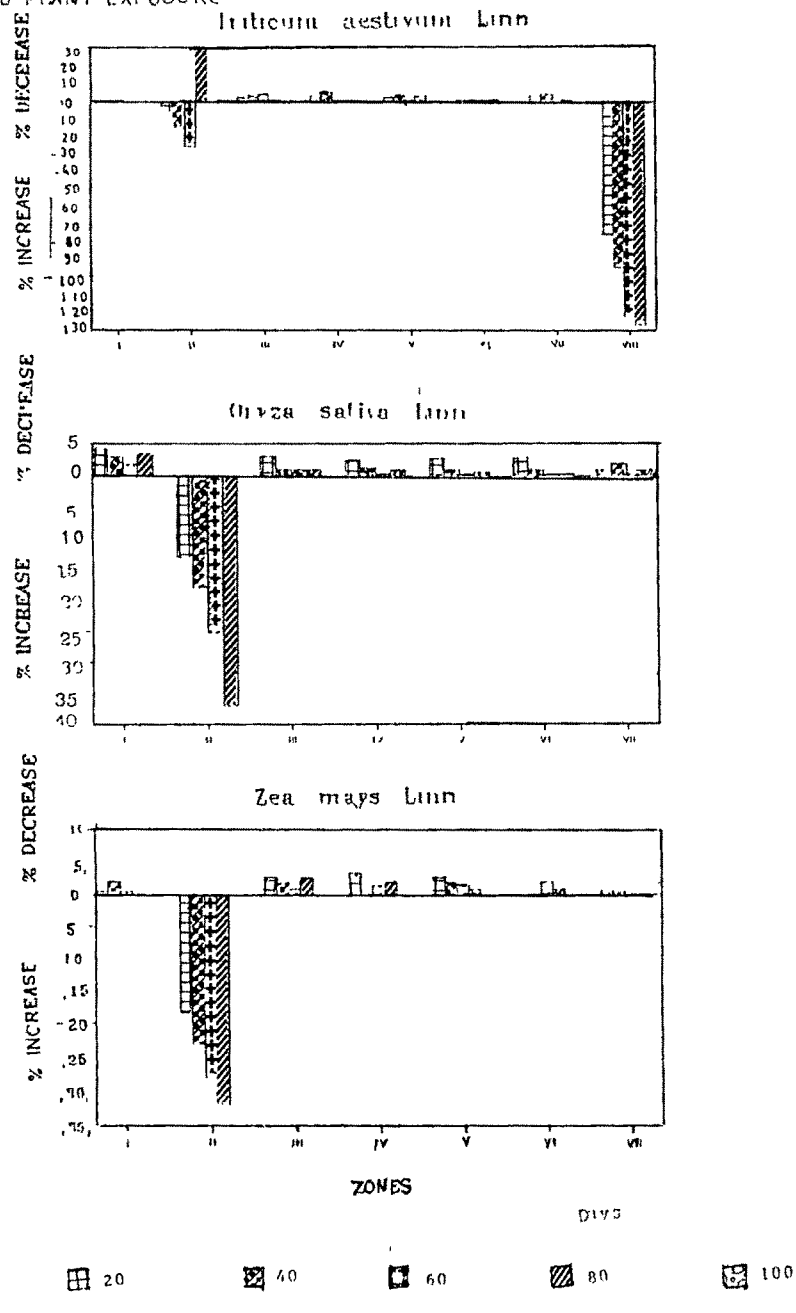


Fig 24 IMPACT OF INDUSTRIAL AIR POLLUTION
POTTED PLANT EXPOSURE CHLORIDE



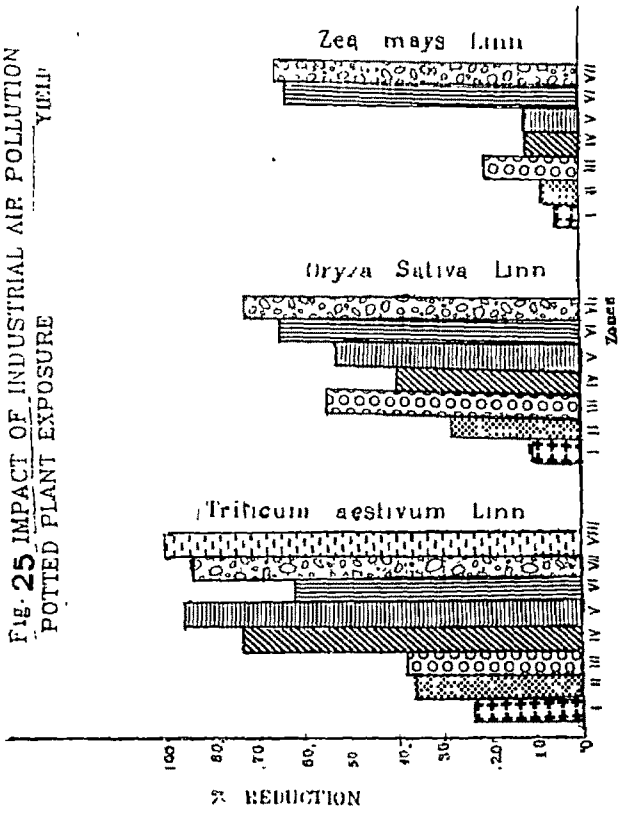



Fig. 25 IMPACT OF INDUSTRIAL AIR POLLUTION ON YIELD POTTED PLANT EXPOSURE

parameters were recorded at 20, 40, 60 & 80 days. At 100 days biomass accumulation, sugar content and pollutant accumulation were recorded. The damage recorded was more at zones III, VI & VII (windward) and less at zones V, VI, II & I (leeward). The zone I showed less damage. The maximum damage was recorded at 80 days and minimum at 20 days at all the zones as compared to reference plants.

**Growth Studies**

**3.3.2.1 Root length**

Maximum reduction (41.01%) in root length was recorded at 80 days at zone VII. The zones VI, III, V,IV,II & I depicted 39.57, 34.77, 30.94, 25.18, 23.74 & 19.43 percent reduction respectively over reference samples at the same age (Fig.10; Table 11).

**3.3.2.2 Shoot length**

Gradual increase was recorded upto 80 days. The highest percentage reduction (47.73) was recorded at 80 days at zone VII. The zones VI, III, V & IV, II & I recorded 46.12, 31.58, 29.99, 17.93, 9.90 & 9.01 percent reduction respectively over reference samples at 80 days (Fig.11; Table 12).

**3.3.2.3 Number of leaves**

The number of leaves increased upto 80 days. The maximum reduction in number of leaves (50.0%) was recorded at 60 days at zone VII. The zones VI, III, V, IV, II & I depicted 44.83, 39.66, 32.76, 22.41, 18.97 & 17.24 percent reduction respectively at the same age (Fig.12; Table 13).

### 3.3.2.4 Total leaf area

The maximum percentage reduction (47.38) was recorded at zone VII at 80 days. The zones VI, III, V, IV, II & I recorded 46.47,36.30, 30.08, 28.15, 27.22 & 26.81 percent reduction respectively at 80 days (Fig.13; Table 14).

### 3.3.2.5 Injury Index

Chlorotic and necrotic patches were observed at tips & margins of the leaves at zones III, VI & VII. The maximum injury index (27.9%) was recorded at 80 days at zone VII, which was followed by zones VI (22.4%) and III (19.9%) respectively over reference samples (Table 15).

### 3.3.2.6 Foliar epidermal structure

Epidermal study was conducted of samples from reference and polluted zone VII. The zone VII was selected for the present study due to high pollutant concentration of $SO_2$ & $NO_x$ during monsoon. Maximum damage recorded in all the parameters was at 80 days, hence foliar tissues of 80 days old plants were studied. Stomatal frequency was reduced by 12.21 % and epidermal cell frequency was increased by 22.49% as compared to reference sample. Stomatal index was reduced by 21.39% as compared to reference samples at 80 days (Table 16).

### 3.3.2.7 Biomass

Gradual increase in biomass accumulation was recorded upto 100 days. The maximum reduction (44.30%) was recorded at zone VII at 100 days over reference samples. The zones VI,

## Explanation for Plate No.1

Visible symptoms Recorded On Species

A. Triticum aestivum Linn

B Zea mays Linn

C Spikes of wheat

D Spikes of paddy

Symptoms : Chlorosis, necrosis and marginal burning are seen Spikes of wheat and paddy of polluted and reference zones showing grains filled, partly filled and empty Spikes, without grains.

Plate 1

A

B

C

D

III, V, IV, II & I depicted 34.63, 26.07, 19 69, 18.94, 8.39 & 7.60 percent reduction respectively at the same age (Fig.14; Table 17).

### 3.3.2.8 Relative growth rate (RGR)

The maximum RGR values were recorded during 80-100 days. The maximum percentage reduction (68.49) in RGR values was recorded at zone VII between 80-100 days. The zones III,VI V, IV, II & I recorded 43.58, 29.42, 22.09, 17.87,10.3 & 9.01 percent reduction respectively at the same age (Fig.15; Table 18)

### 3.3.2.9 Net assimilation rate (NAR)

Maximum NAR was recorded between 60-80 days at all the zones. The maximum reduction (87.20%) was recorded during 60-80 days at zone VII. The zones VI, III, V, IV, II & I recorded 86.58, 64.10, 57.03, 50.63, 46.85 & 43.15 percent reduction respectively over reference samples (Fig.16; Table 16)

### Biochemical studies

### 3.3.2.10 Chlorophyll

**Chlorophyll -a:**

Gradual increase in chlorophyll content was recorded upto 60 days and then showed decrease. Maximum percentage reduction (41.37) was recorded at zone VII at 80 days. The zones VI, III, V, IV, II & I depicted 41.07, 36.96, 34.70, 26.81, 19.83 & 14 20 percent reduction respectively over reference samples at the same age (Fig.17; Table 20).

Chlorophyll-b:

Maximum reduction in chlorophyll-b (36.84%) was recorded at 80 days at zone VII over reference samples. The zones VI, III, V, IV, II & I depicted 35.29, 26.01, 24.45, 19.64, 17.58 & 8.77 percent reduction respectively at the same age (Fig.18; Table 21).

### 3.3.2.11 Total soluble sugars

Gradual increase in soluble sugars was recorded upto 100 days. Maximum reduction (30.35%) was recorded at zone VII at 100 days.The zones VI, III, V, IV, II & I recorded 29.75, 23.64, 20.47,13.28, 11.77 & 10.13 percent reduction respectively over reference samples at the same age (Fig.21; Table 22).

### 3.3.2.12 Reducing sugars

Maximum increase (43.64%) was recorded at zone VII at 100 days. The zones VI, III, V, IV, II & I recorded 42.37, 34.32, 27.12, 24.15, 20.76 & 18.6 percent increase respectively over reference samples at 100 days (Fig.22; Table 23).

### 3.3.2.13 Ascorbic acid

Ascorbic acid was increased upto 80 days. Maximum reduction (38.54%) was recorded at zone VII at 80 days. The zones VI,III, V, IV, II & I depicted 35.52, 34.76, 32.24, 31.99, 29.97 & 27.70 percent reduction respectively at the same age as compared to reference samples (Fig.20; Table 25).

### 3.3.2.14 Protein

Gradual increase in protein content was recorded at all zones upto 80 days. Maximum reduction (30.29%) was recorded at zone VII at 80 days. The zones VI, III, V, IV, II & I recorded 26.49, 23.16, 20.09, 16.87, 13.80 & 12.32 percent reduction respectively at the same age (Fig.19; Table 26).

### 3.3.2.15 Sulphur

Gradual increase in sulphur accumulation was recorded upto 100 days. Maximum increase in sulphur accumulation (1.96 times increase over reference sample) was recorded at zone VII at 100 days. At the same age the zones VI, V, IV,III, II & I recorded 1.56, 1.10, 0.80, 0.69,0.61 & 0.51 times increase respectively over reference samples (Fig.23: Table 24).

### 3.3.2.16 Chloride

Maximum chloride accumulation (0.37 times more than reference) was recorded at zone II. Significant difference with reference samples was not recorded at other zones (Fig.24; Table 27).

### 3.3.2.17 Yield

Maximum reduction in grain yield (71.14%) was recorded at zone VII. The zones VI, III, V, IV, II & I recorded 64.06, 53.85, 52.26, 38.80, 27.95 & 9.55 percent reduction respectively over reference samples (Fig.25; Table 28).

### 3.3.3 *Zea mays* Linn (Maize)

Maize crop was not grown at zone VIII (leeward). This crop recorded less damage compare to other two crops paddy & wheat. Growth, biochemical & yield parameters were recorded at different zones. Higher reduction was recorded at zones III, VI & VII (windward) and lesser damage at I, II, IV & V (leeward). The reduction or increase was recorded in percentage at all the zones as compared to reference samples.

**Growth Studies**

**3,3,3.1 Root length**

Maximum reduction (12.77%) was recorded at 80 days at zone VII over reference samples. The zones VI, III, V, IV, II & I recorded 12.36, 10.73, 10.4,10.18, 9.82 & 9.46 percent reduction respectively over reference at the same age (Table 11).

**3,3.3.2 Shoot length**

Gradual increase was recorded in shoot length till 80 days. Maximum percentage reduction (19.88) was recorded at zone VII at 80 days. The zones VI, III, V, IV, II & I depicted 19.03, 14.93, 12.76, 10.83, 8.43 & 6.65 percent reduction respectively over reference samples at the same age (Fig.11; Table 12).

**3.3.3.3 Number of leaves**

The percentage reduction in total number of leaves recorded at zone VII & VI was 38.46 at 60 days. The zones III & V showed 34.62 and at the zones IV, II & I recorded 30.77 percent reduction respectively over reference samples at the same age (Fig.12; Table 13).

### 3.3.3.4 Total leaf area

Gradual increase in total leaf area was recorded till 100 days. Maximum reduction (26.62%) was recorded at 100 days at zone VII. The zones VI, III, V, IV, II & I recorded 23.19, 21.25, 15.36, 12.41, 10.85 & 9.42 percent respectively over reference samples at the same age (Fig.13, Table 14).

### 3.3.3.5 Injury Index

Maximum injury index (19.4%) was recorded at 80 days at zone VII which was followed by zones VI (9.8%) and zone III (7.4%) respectively as compared to reference samples. All other zones did not show any visual foliar damage (Table 15).

### 3.3.3.6 Biomass

Gradual increase in above ground biomass was recorded upto 100 days at all the zones. Maximum reduction (34.31%) was recorded at zone VII at 100 days. The zones VI, III, V, IV, II & I recorded 32.79, 31.35, 28.73, 9.45, 8.94 & 7.86 percent reduction respectively over reference samples at 100 days (Fig.14, Table 17).

### 3.3.3.7 Relative growth rate (RGR)

RGR recorded increase upto 80 days. Maximum reduction (17.76%) was recorded at zone VII during 40-60 days as compared to reference.The zone VII depicted at 80-100 days 16.73% reduction. It was followed by zones VI, III, V, IV, II & I recorded 14.90, 13.98, 10.92, 10.44, 10.61 &8.46 percent reduction respectively at the same over reference samples(Fig.15; Table 18).

### 3.3.3.8 Net assimilation rate (NAR)

Maximum reduction (66.60%) was recorded during 40-60 days at zone VII. The zone VII during 80-100 days was recorded 46.64 percent reduction. It was followed by zones VII, VI, III, V, IV, II & I i.e. 46.20, 45.93, 32.04, 31.33, 22.48 & 20.70 percent reduction respectively duriong 80-100 days as compared to reference samples (Fig.16; Table 19).

**Biochemical studies**

### 3.3.3.9 Chlorophyll

**Chlorophyll-a:**

The increase in chlorophyll-a was recorded upto 80 days. Maximum reduction (37.54%) was recorded at 100 days at zone VII. The zones VI, III, V, IV, II & I recorded 29.84, 21.84, 18.31,14.11,12.96 & 12.82 percent reduction respectively as compared to reference samples at the same age (Fig.17; Table 20).

**Chlorophyll-b**

It exhibited lesser reduction than chlorophyll-a at all zones at all ages. The maximum percentage reduction (22.73) was recorded at zone VII at 100 days. The zones VI, III, V, IV,II & I depicted 19.07, 11.48, 10.52, 7.28, 6.86 & 6.37 percent reduction respctively over reference samples at 100 days (Fig.18, Table 21).

### 3.3.3.10 Total soluble sugars

Gradual increase in total soluble sugars was recorded upto 100 days. Maximum reduction (26.86%) was recorded at 100

days at zone VII. The zones VI, III, V, IV, II & I recorded 23.83, 21.69, 18.13, 16.14, 9.71 & 8.20 percent reduction respectively over reference samples at the same age (Fig.21, Table 22).

### 3.3.3.11 Reducing sugars

The highest increase (29.50%) was recorded at zone VII at 100 days. The zones VI, III, V, IV, II & I recorded 26.36, 21.97, 20.29, 17 57, 14.23 & 11.05 percent increase respectively over reference samples at the same age (Fig.22; Table 23).

### 3.3.3.12 Ascorbic acid

Increase in ascorbic acid was recorded upto 100 days. The highest reduction (34.48%) was recorded at 100 days at zone VII. The zones VI, III, V, IV, II & I recorded 31.03, 28.16, 26.44, 25.29, 21.91 & 18.54 percent reduction respectively at 100 days as compared to reference samples (Fig.20; Table 25).

### 3.3.3.13 Protein

Increase in protein at all zones was recorded upto 80 days. Maximum reduction (23.94%) was recorded at 100 days at zone VII. The zones VI, III, V, IV, II & I recorded 20.24, 19.65,18.49, 17 81, 16.04 & 14.17 percent reduction respectively over reference samples at 100 days (Fig.19; Table 26).

### 3.3.3.14 Sulphur

Gradual increase in sulphur accumulation was recorded upto 100 days. Maximum increase in sulphur accumulation (0.81

times increase over reference) was recorded at zone VII at 100 days. The zones VI, V, IV, III, II & I recorded 0.77, 0.64, 0.51, 0.31, 0.28 & 0.23 times increase respectively over reference samples at 100 days (Fig.23; Table 24).

### 3.3.3.15 Chloride

Maximum accumulation of chloride in foliar tissues (0.32 times increase over reference) was recorded at zone II at 100 days. No significant difference in chloride content at different zones were recorded as compared to control (Fig.24; Table 27).

### 3.3.3.16 Yield

Maximum percentage reduction of grain yield (64.59) was recorded at zone VII. The zones VI, III, V,IV, II & I recorded 63.16, 20.30, 10.54, 10.24, 7.60 & 3.60 percent reduction respectively over reference samples at the time of harvest (Fig.25; Table 28).

## 3.3.4 Statistical Analysis of the Data

Two way analysis of variance was done for two crops of the same season paddy and maize for three parameters viz. total leaf area, biomass and chlorophyll-a content using two factors (species and zones). The calculations were done with 8 readings of each parameter. The results for total leafarea, biomass and chlorophyll were highly significant with interaction of species x zone which depicted the behaviour of same species was different at different zones.

Friedman test was also done for paddy and maize crops for its total leaf area parameter which depicted, paddy was

much more sensitive than maize.

Correlacion for different parameters viz, total leaf area,biomass, chlorophyll, sulphur and yield was done of wheat crop. It was observed that all parameters were positively correlated with each other and sulphur was negatively correlated with each parameters. To find out the dependency of yield on sulphur accumulation , correlation coefficient showed negative correlation between sulphur and yield. F values were recorded at 0.05 % level. The calculated values are higher than table values. Hence the F values were highly significant (Table 29).

## 3.4 ARTIFICIAL FUMIGATION

In order to determine the effect of single air pollutant ($SO_2$) under simulated conditions, present experiment was conducted. Potted plants were exposed intermittently to 0.2 ppm of $SO_2$ for 2 hours on alternate days (from 7 to 100 days) with 46 hours of recovery period. The reduction was recorded in all parameters except sulphur and reducing sugars over reference sample (Unexposed plants). The plants showed maximum sensitivity at 80 days. Percentage increase or decrease in various parameters has been shown in Figs.

### 3.4.1 Triticum aestivum Linn.(Wheat)

#### 3.4.1.1 Morphological parameters

Maximum percentage reduction in root length (21.22), shoot length (30.70, number of leaves (14.98), total leafarea (28.49) and maximum leaf injury index (18.77%) was recorded at 80 days as compared to the reference samples. Biomass accumulation depicted maximum reduction (33.03%) at 100 days.

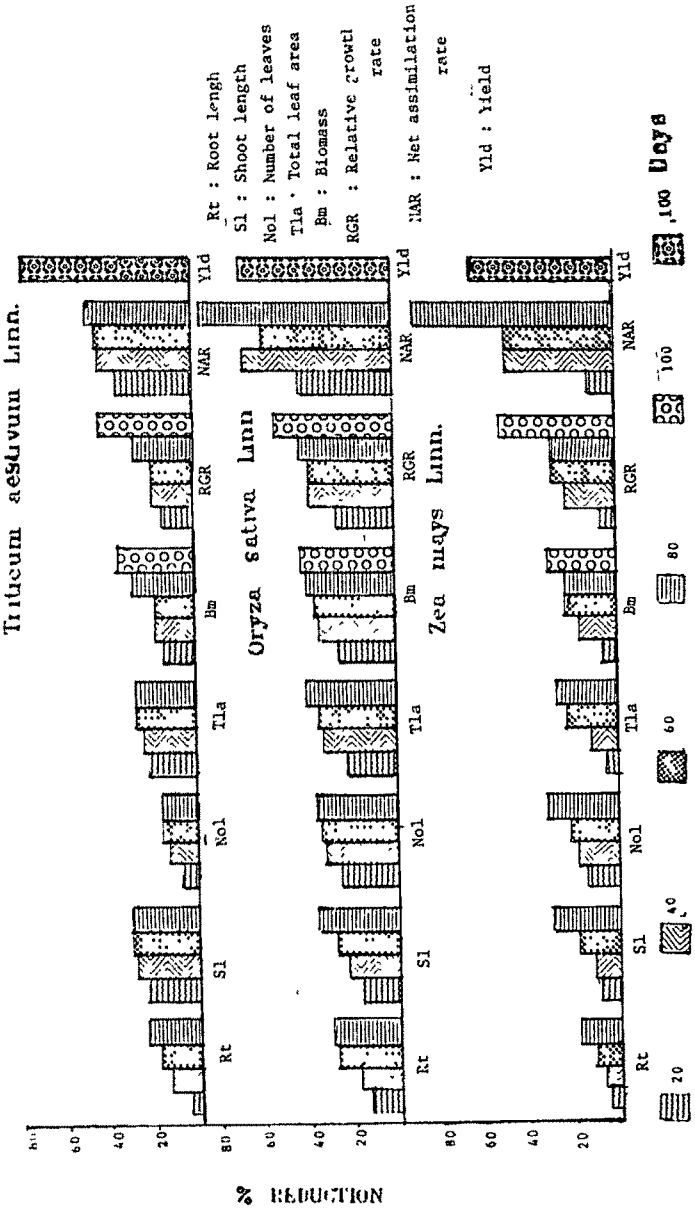



Fig 26 IMPACT OF $SO_2$ FUMIGATION

RGR and NAR recorded 42.07 & 47.57% respectively at 80 days. The pH of the soil of exposed bags reduced from 7.3 to 6.5 at 80 das (Fig.26; Table 30).

### 3.4.1.2 Bio-chemical parameters

The maximum reduction in chlorophyll-a (36.70%),Chlorophyll-b (29.02%), protein (31.73) and ascoprbic acid (34.58%) was recorded at 80 days in exposed plants as compared to reference samples. The highest reduction in soluble sugars (29.39%) was recorded at 100 days in exposed plants. The maximum increase (1.25 times) was recorded in sulphur and reducing sugars (30.83%) of exposed plants over reference samples at 100 days. Increase in the sulphur (0.29 times) in soil of the exposed plants was recorded at 100 days (Fig.27; Table 30.2).

### 3.4.1.3 Yield

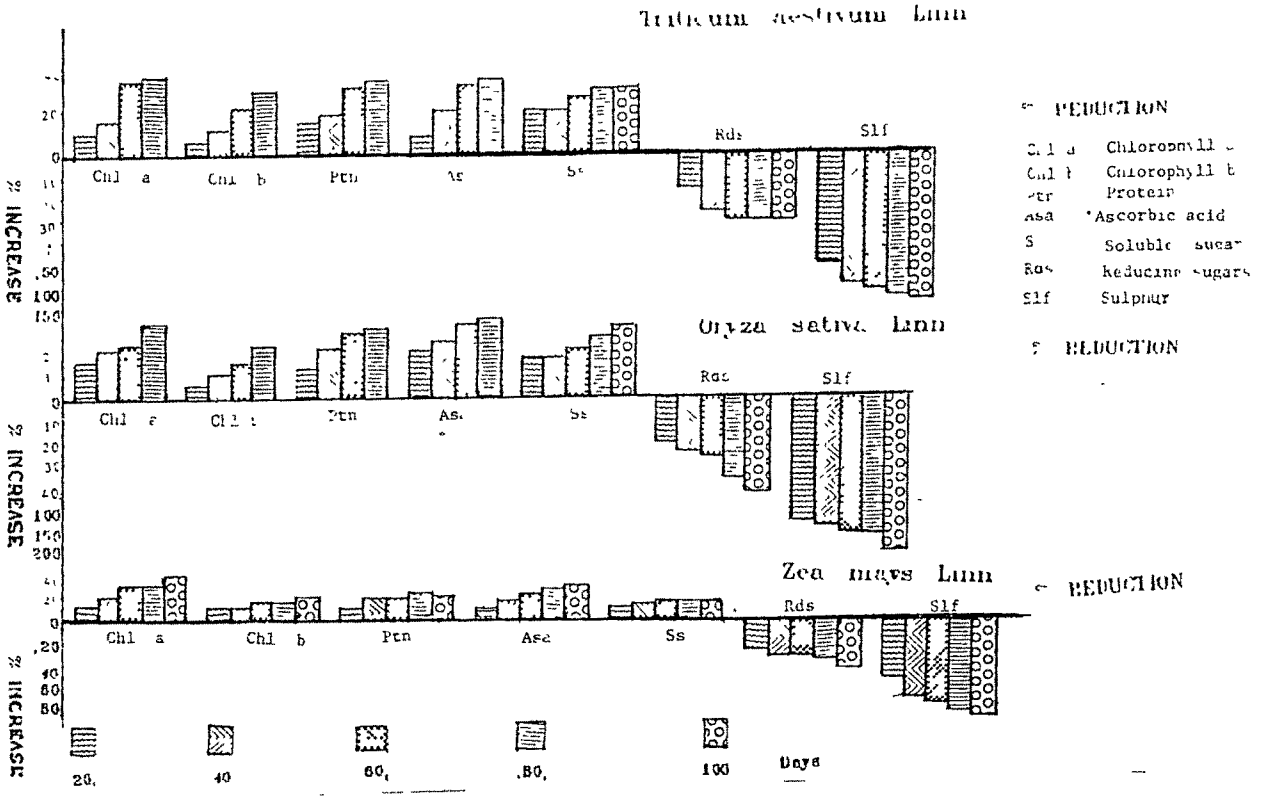
At harvest grain yield reduction recorded was 75.01 percent (Fig.26; Table 33 ).

### 3.4.2 *Oryza sativa* Linn (Paddy)

### 3.4.2.1 Morphological parameters

Maximum reduction in root length (30.79%) shoot length (35.83%), number of leaves(35.27%) and total leafarea (39.02%) was recorded at 80 days in the exposed plants. Number of tillers were reduced by 37.50 % in exposed plants at 80 days. Maximum reduction in biomass accumulation (42.74%) was recorded at 100 days. RGR and NAR recorded 52.28 & 87 50 percent reduction respectively (Fig.26; Table 31.1).

Fig 27 IMPACT OF $SO_2$ FUMIGATION



### 3.4.2.2 Biochemical parameters

The highest percentage reduction in chlorophyll -a (34.46), chlorophyll-b (25.21), ascorbic acid (35.87) was recorded at 80 days. Total soluble sugars in exposed plants recorded maximum reduction (32.73%) at 100 days. The maximum increase in sulphur accumulation (2.05 times) and reducing sugars (42.56%) was recorded at 100 days. The sulphur accumulation in soil was recorded maximum (33.33%) at 100 days over reference samples (Fig.27; Table 32.2).

### 3.4.2.3 Yield

Maximum percentage reduction in grain yield was 67.39 (Fig.26, Table 33.0).

### 3.4.3 *Zea mays* Linn. (Maize)

### 3.4.3.1 Morphological parameters

The highest percentage reduction in root length, shoot length, number of leaves, total leafarea and leaf injury index recorded was 18.87, 27.31, 25.93, 26.92 & 15.75% respectively at 80 days. Gradual increase in biomass accumulation was recorded upto 100 days. Maximum percentage reduction (29 83) in dry biomass accumulation was recorded at 100 days. RGR calculated on the dry weight basis was recorded maximum reduction (50.36%) during 80-100 days. NAR calculated on the total leaf area basis recorded highest reduction (89.93%) between 60-80 days (Fig.26; Table 32.1).

### 3.4.3.2 Biochemical parameters

Chlorophyll-a, Chlorophyll-b, soluble sugars, ascorbic

acid and protein exhibited 39.27, 19.14, 15.71, 33.78 & 25.25 percent reduction respectively at 100 days. Maximum percentage increase (41.60) in reducing sugars was recorded at 100 days.The maximum increase in sulphur content in foliar tissues and in soil (0.89 & 0.27 times increase respectively) was recorded at 100 days (Fig.27; Table 32.2).

### 3.4.3.3 Yield

The grain yield of the exposed plants was 63.61% less than unexposed plants (Fig.26; Table 33.0).

## 3.5 MITIGATION OF POLLUTION DAMAGE

Foliar tissues of plants represent an efficient pollutant trapping device. To mitigate the effect of pollutants different chemicals viz. ascorbic acid and urea were foliarly sprayed.

### 3.5.1 Under Simulated Conditions

Ascorbic acid was used as mitigating agent under simulated conditions. Three different concentrations 0.005M ($T_1$) 0.0075M ($T_2$) and 0.01M ($T_3$) aqueous solutions were used. One set of plants was kept unexposed to $SO_2$ and untreated with ascorbic acid solutions (reference) to know the effect of ascorbic acid in $T_1$,$T_2$, $T_3$ sets under unexposed conditions. Percentage increase over reference samples (UEUT) was recorded in all the parameters. Another set of plants was exposed to $SO_2$ but untreated with ascorbic acid. This set was considered as reference for three sets of Trreated and

Exposed ($T_1E$, $T_2E$ & $T_3E$) plants. The percentage recovery except sulphur was recorded in all the parameters with respect to reference sample (UTE).

**A. Unexposed plants**

3.5.1.1 Triticum aestivum Linn.(Wheat) Var.J-24

Plants treated with ascorbic acid ($T_1$, $T_2$ &$T_3$)at regular interval of 20 days to 100 days and unexposed to $SO_2$ showed increase and better growth compared to plants of untreated and unexposed reference plants (UTUE).

**i. Morphological parameters**

Maximum increase in root length, shoot length, number of leaves, total leafarea was 9.59, 26.32, 29.52 & 17.52 percent respectively in $T_3$ plants over reference sample at 80 days. maximum increase in biomass accumulation (30.47%) was recorded at 100 days. RGR and NAR recorded maximum increase 42.34 & 72.37 percent in $T_3$ plants during 80-100 days and 60-80 days respectively (Table 34 to 40).

**ii. Bio-chemical parameters**

Maximum percentage increase in chlorophyll-a, chlorophyll-b, and protein recorded was 34.33, 25.87 & 22.39 respectively at 80 days. Ascorbic acid and soluble sugars recorded maximum increase 26.37 & 21.06 respectively in $T_3$ plants at 100 days. The sulphur content was decreased maximum by 24.80% in $T_3$ plants at 100 days (Table 41 to 46).

**iii. Yield**

The increase in yield at harvest in $T_1$, $T_2$ and $T_3$ plants was 22.93, 69.88 & 46.20% respectively (Table 47).

3.5.1.2 Oryza sativa Linn (Paddy) Var.Guj.17

Maximum increase in all parameters except sulphur was recorded in $T_3$ plants over reference (UTUE) plants.

**i. Morphological parameters**

The maximum increase in root length, shoot length, number of leaves, total leafarea recorded was 14.26, 14.46, 13.79 & 20.73 percent respectively at 80 days. The highest increase in biomass accumulation (20.78%) was recorded at 100 days. RGR and NAR were recorded maximum increase 23.90 & 20.00 percent respectively in $T_3$ plants during 80-100 & 60-80 days (Table 34 to 40).

**ii. Bio-chemical parameters**

The maximum increase in chlorophyll-a, chlorophyll-b and protein was 27.85, 19.68 & 20.46 percent respectively at 80 days. Ascorbic acid and soluble sugars increase at 100 days were 18.79 & 35.56 percent respectively. Sulphur content was decreased by 17.14 percent in $T_3$ plants over reference at 100 days (Table 41 to 46).

**iii. Yield**

The increase in yield at harvest in $T_1$, $T_2$ & $T_3$ plants was 18.30, 38.89 & 40.47 percent respectively (Table 47).

3.5.1.3 Zea mays Linn(Maize) Var. American sweet corn.

**i Morphological parameters**

Maximum increase in root length, shoot length, number of leaves was recorded 24.42, 6.49 and 16.67 percent

respectively at 80 days. The total leafarea was increased by 16.40 percent over reference samples at 100 days. Maximum increase in biomass accumulation (19.42%) was recorded at 100 days in $T_3$ plants. RGR and NAR were recorded maximum 30.67 & 70.02 percent increase respectively during 80-100 (Table 34 to 40).

**ii. Bio-chemical parameters**

The maximum increase in chlorophyll-a, chlorophyll-b and protein recorded was 18.92, 15.67 & 16.12 percent respectively over reference samples at 80 days. Ascorbic acid and soluble sugars recorded maximum increase 24.44 & 28.14 percent respectively at 100 days. Maximum reduction in sulphur content was recorded 14.57 percent at 100 days (Table 41 to 46).

**iii. Yield**

The increase in yield (at harvest) over reference in $T_1$,$T_2$ & $T_3$ plants was 5.41, 10.46 & 12.9% respectively (Table 47).

**B. Exposed plants**

The plants treated with ascorbic acid and exposed to $SO_2$ depicted better growth with lesser damage compare to untreated and exposed plants (UTE). The recovery in all the parameters and decrease in sulphur was minimum in $T_1E$ (0.005M) and maximum in $T_3E$ (0.01M) plants.

3.5.2.1 Triticum aestivun Linn (Wheat) Var.J-24

First treatment (ascorbic acid) was given to 20 days old plants. Observations were recorded from 20-100 days at a regular interval of 20 days.

**Morphological parameters**

The maximum recovery in root length, shoot length, number of leaves and total leafarea recorded was 9.84, 19.25, 25.0 & 22.08 percent respectively at 80 days in $T_3E$ plants. The biomass was recovered maximum (22.50%) in $T_3E$ plants at 100 days. The percentage recovery in RGR and NAR was recorded maximum 65.72 & 86.97 percent during 80-100 days and 60-80 days in $T_3E$ plants respectively (Fig.28 to 30; Table 34 yo 40).

**ii. Bio-chemical parameters**

Maximum recovery in chlorophyll-a, Chlorophyll-b and protein was 30.70, 20.55 & 22.09 percent in $T_3E$ plants at 80 days respectively. Ascorbic acid and soluble sugars recorded 29.63 & 25.68 percent increase respectively at 100 days in $T_3E$ plants at 100 days (Fig.31 to 33, Table 41 to 46).

**iii. Yield**

The percentage recovery in $T_1E$, $T_2E$ & $T_3E$ plants was 31.05, 52.73 & 56.40 percent respectively over reference (Fig.34; Table 47).

**iv Cost-benefit ratio**

The cost benefit ratio was 1:0.96, 1:1.2, 1:1.1 in $T_1E$, $T_2E$, $T_3E$ treatments respectively.

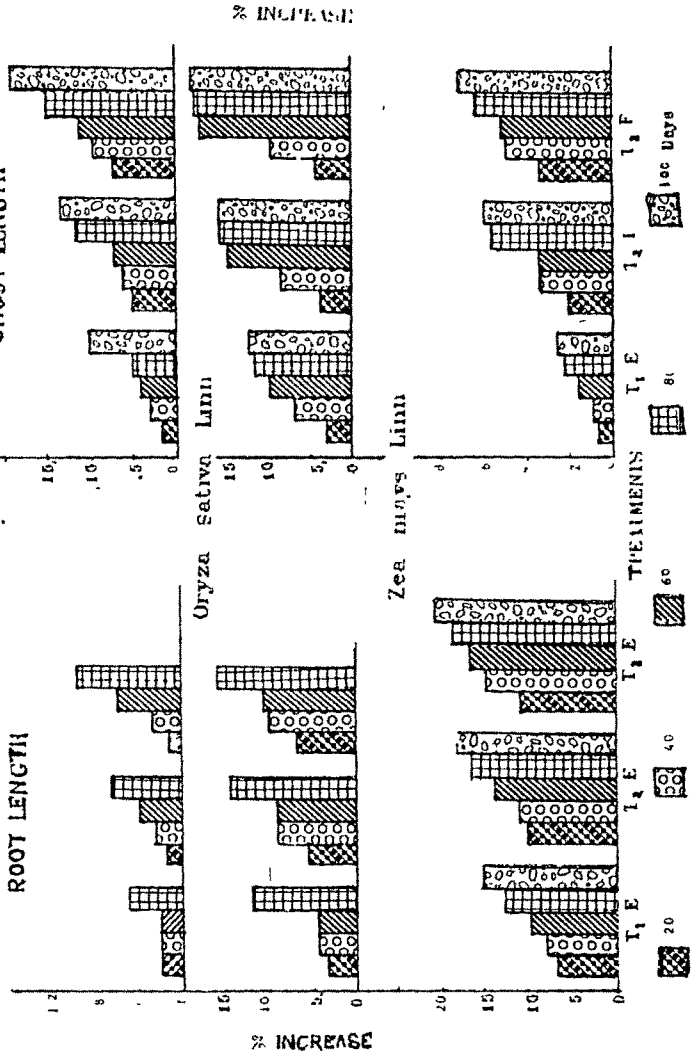
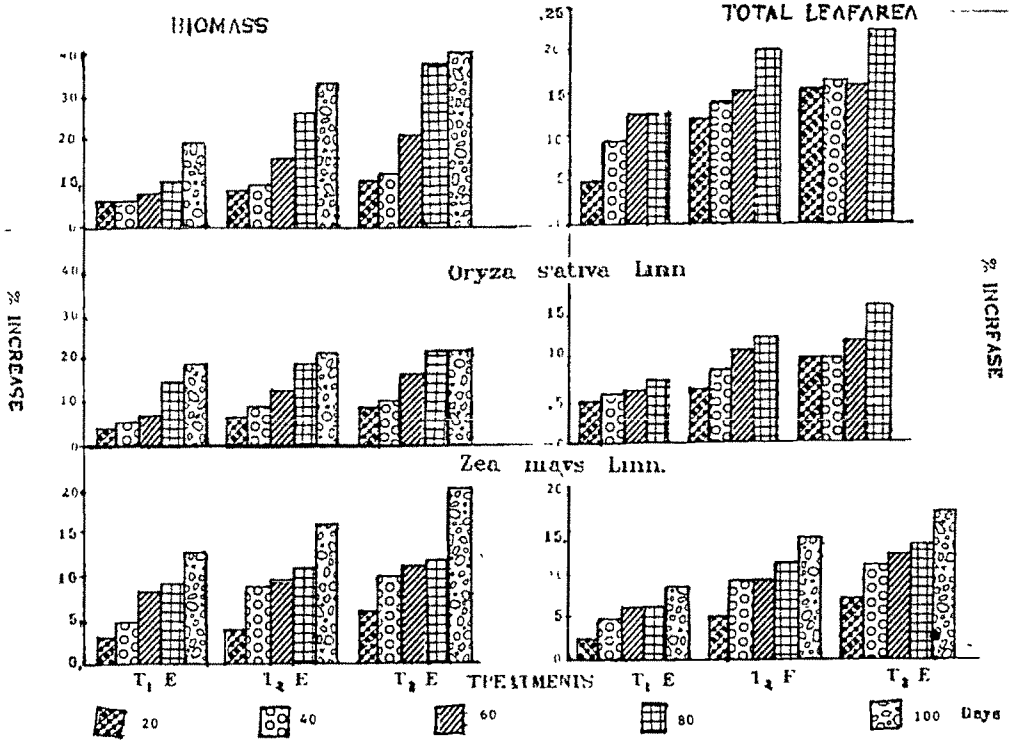



Fig 28 MITIGATION OF $SO_2$ FUMIGATION
Under Simulated Conditions

Fig 29 MITIGATION OF $SO_2$ FUMIGATION

Under Simulated Conditions

Triticum aestivum Linn



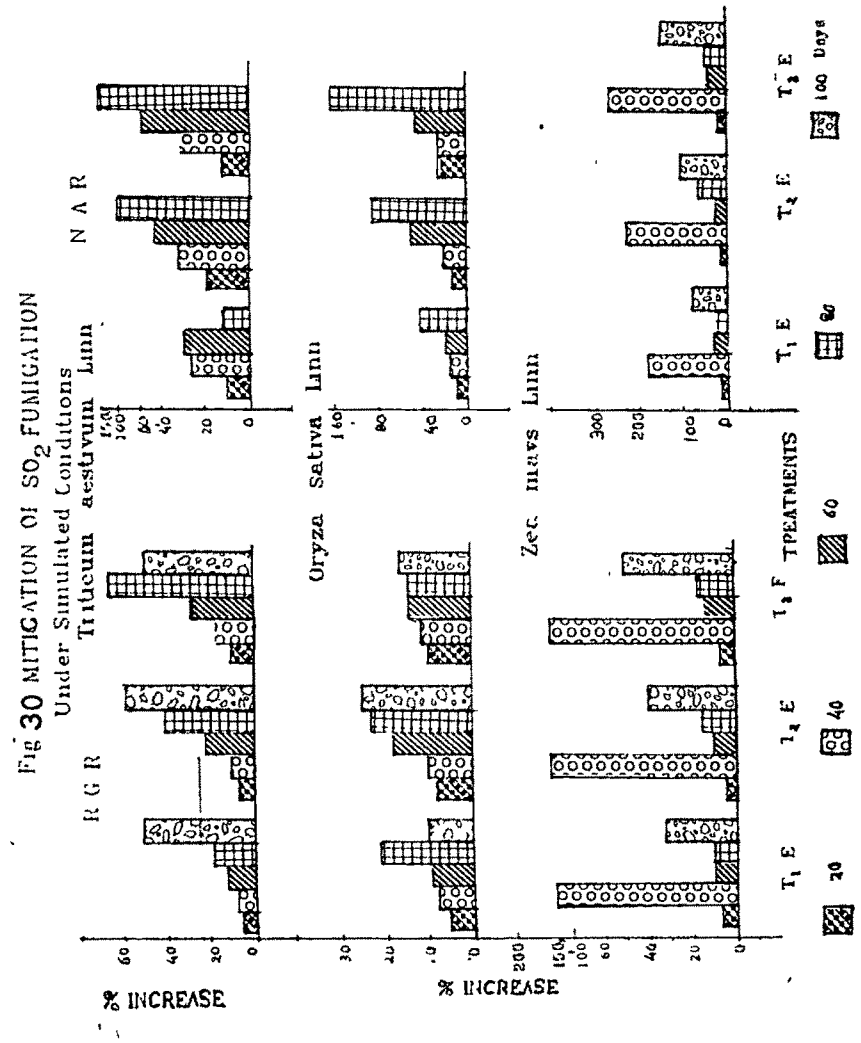


Fig 30 MITIGATION OF $SO_2$ FUMIGATION
Under Simulated Conditions
Triticum aestivum Linn
Oryza Sativa Linn
Zea mays Linn
N A R
R G R
% INCREASE
% INCREASE
$T_1$ E
$T_2$ E
$T_3$ F
TREATMENTS
20
40
80
100 Days

3.5.2.2 Oryza sativa Linn. (Paddy) Var.Guj-17.

**i. Morphological parameters**

Maximum recovery in root length, shoot length, number of leaves and total leafarea recorded was 16.25, 17.59, 15.56 &17.37 percent respectively at 80 days in $T_3E$ plants. The maximum percentage recovery (22.50) in biomass accumulation ws recorded in $T_3E$ plants at 100 days. The RGR and NAR recorded 25.71 & 23.85 percent recovery in $T_3E$ plants during 80-100 days and 60-80 days respectively (Fig.28 to 30; Table 34 to 40).

**ii. Bio-chemical parameters**

Maximum recovery in chlorophyll-a, chlorophyll-b and protein was 30.70, 20.55 & 22.09 percent respectively over reference samples at 80 days: The highest recovery in ascorbic acid and soluble sugars was 44.35 & 27.06% respectively at 100 days in $T_3E$ plants. The sulphur recorded maximum decrease in foliar tissues (28.06%) at 100 days in the same set of plants (Fig.31 to 33; Table 41 to 46).

**iii. Yield**

The percentage recovery in $T_1E$, $T_2E$, $T_3E$ plants was 22.90,43.31 & 57.33 respectively over reference plants (UTE) at the harvest (Fig.34; Table 47).

**iv. Cost-benefit ratio**

The cost/benefit ratio was 1:1.33, 1:1.6 & 1:1.6 in $T_1E$ $T_2E$, $T_3E$ treatment respectively over reference samples (UTE).


Fig 31 MITIGATION OF $SO_2$ FUMIGATION
Under Simulated Conditions
CHLOROPHYLL – a

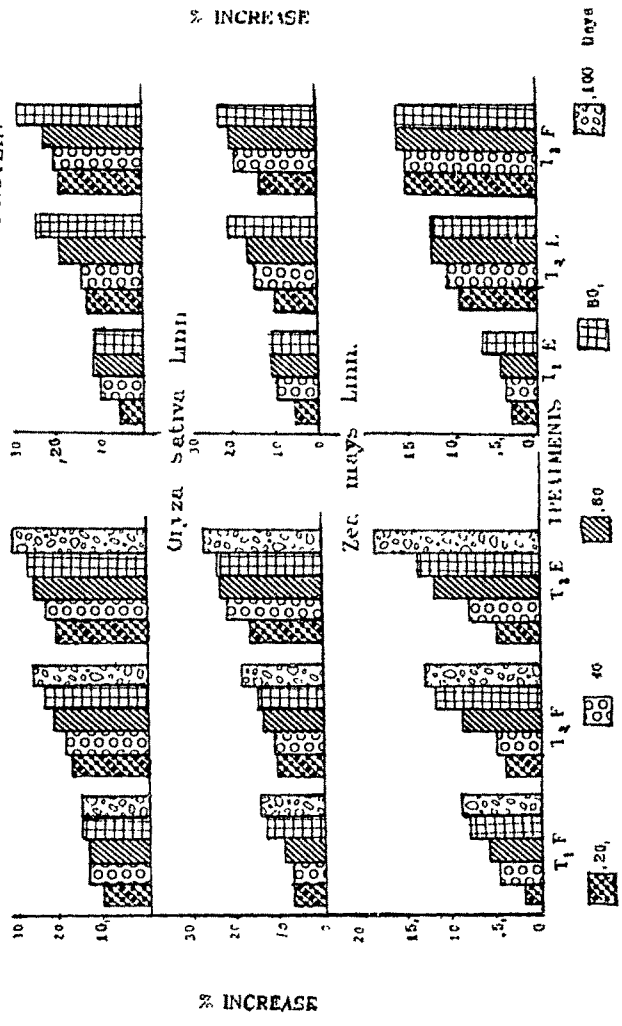



Fig 32 MITIGATION OF $SO_2$ FUMIGATION ..
Under Simulated Conditions

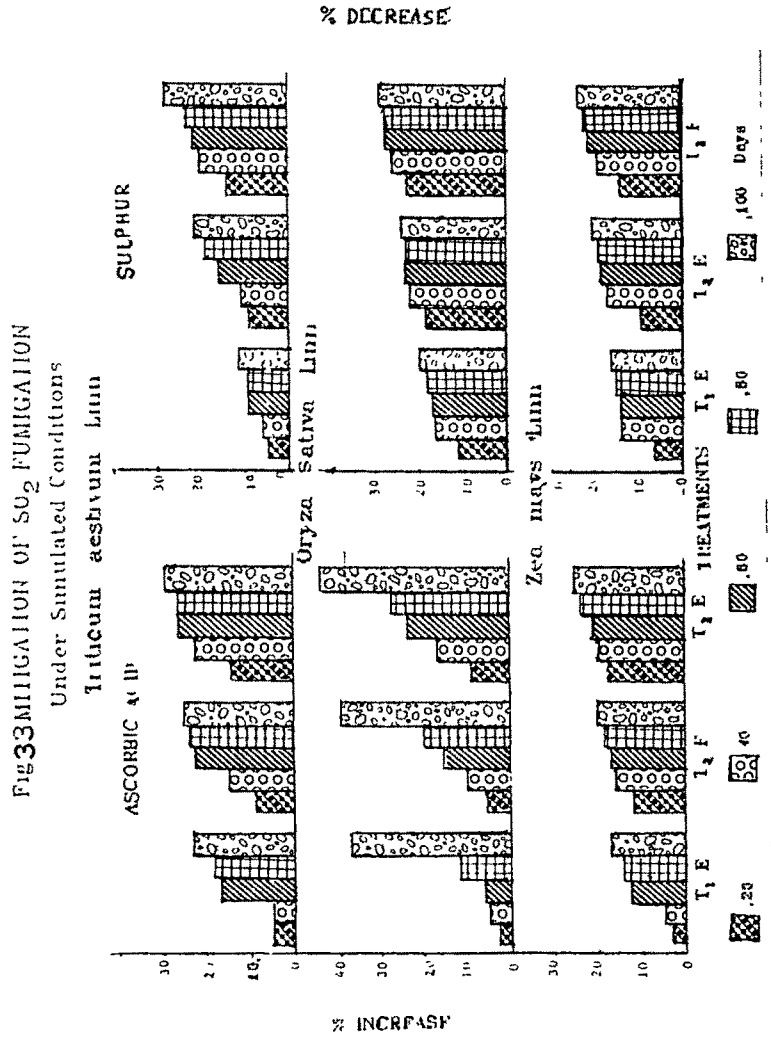



Fig 33 MITIGATION OF $SO_2$ FUMIGATION
Under Simulated Conditions

3.5.2.3 Zea mays Linn. (Maize) Var.American sweet Corn.

**i. Morphological parameters**

The maximum recovery in root length, shoot length, number of leaves, total leafarea recorded was 18.99, 6.52, 20.0 & 13.19% respectively in $T_3E$ plants over reference at 80 days. The maximum recovery in biomass recorded was 20.17 percent at 100 days in $T_3E$ plants. RGR and NAR recorded maximum revoery 56.46 & 33.57 percent respectively during 80-100 & 60-80 days (Fig.28 to 30; Table 34 to 40).

**ii. Bio-chemical parameters**

The maximum recovery in chlorophyll-a, chlorophyll-b and protein was 21.45, 15.36 & 16.20 percent respectively in $T_3E$ plants at 80 days. Ascorbic acid and soluble sugars recorded maximum recovery 24.44 & 18.63 percent respectively at 100 days in $T_3E$ plants. Sulphur recorded maximum decrease 22.63% in the same set of plants over reference at 100 days (Fig. 31 to 33, Table 41 to 46).

**iii. Yield**

The maximum percentage recovery in grain yield recorded was 27.59 in $T_3E$ plants. It was followed by 24.92 & 22.53 percent respectively in $T_2E$ and $T_1E$ plants at the harvest (Fig.34; Table 47).

**iv. Cost-benefit ratio**

The cost benefit ratio was 1:1.7, 1:1.44 & 1:1.2 in $T_1E$,$T_2E$, $T_3E$ treatments respectively over reference samples (UTE).

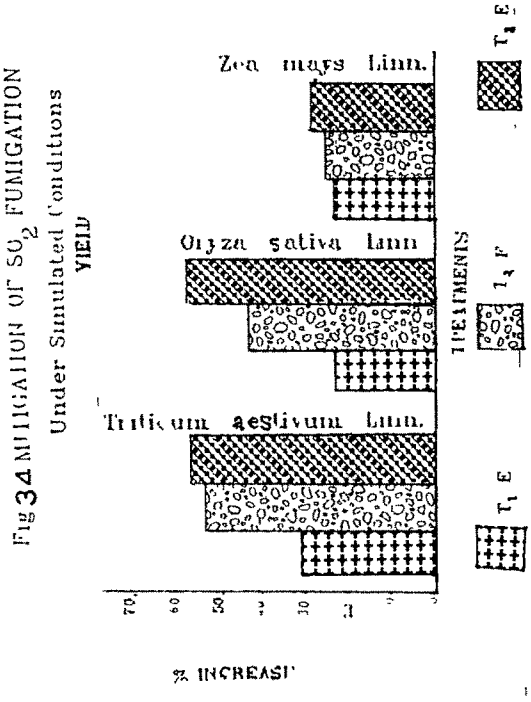



Fig 34 MITIGATION OF $SO_2$ FUMIGATION
Under Simulated Conditions
YIELD

### 3.5.3 Under field conditions

Experiments were conducted on field grown crop plants. Different concentrations of ascorbic acid .005M, .01M & .02M and urea 0.16M, 0.32M, 0.64M solutions were foliarly sprayed in the respective sets. With all the six treatments increase in different parameters except sulphur and reducing sugars was recorded with reference to untreated and exposed (UTE) plants. All the results recorded increase or decrease in percentage at the respective ages with the reference plants.

#### 3.5.3.1 Triticum aestivum Linn.Sonalika

Five sprays of each chemical (ascorbic acid and urea) were sprayed at an interval of 20 days. All the treated plants recorded better growth compared to untreated and exposed plants. The increase in all parameters in all treated plants over reference was recorded by percent recovery.

**Morphological parameters**

**i. Root length**

The maximum recovery in root length of $A_1$,$A_2$,$A_3$; $U_1$, $U_2$, and $U_3$ treatments was 7.19, 27.45, 21.57; 28.10, 39.22 & 48.37 percent over reference (UTE) plants at 80 days respectively (Fig. 35; Table 48.1).

**ii. Shoot length**

The maximum recovery in shoot length of $A_1$, $A_2$, $A_3$; $U_1$, $U_2$, & $U_3$ treatments was 26.57, 36.71, 35.94; 26.96,

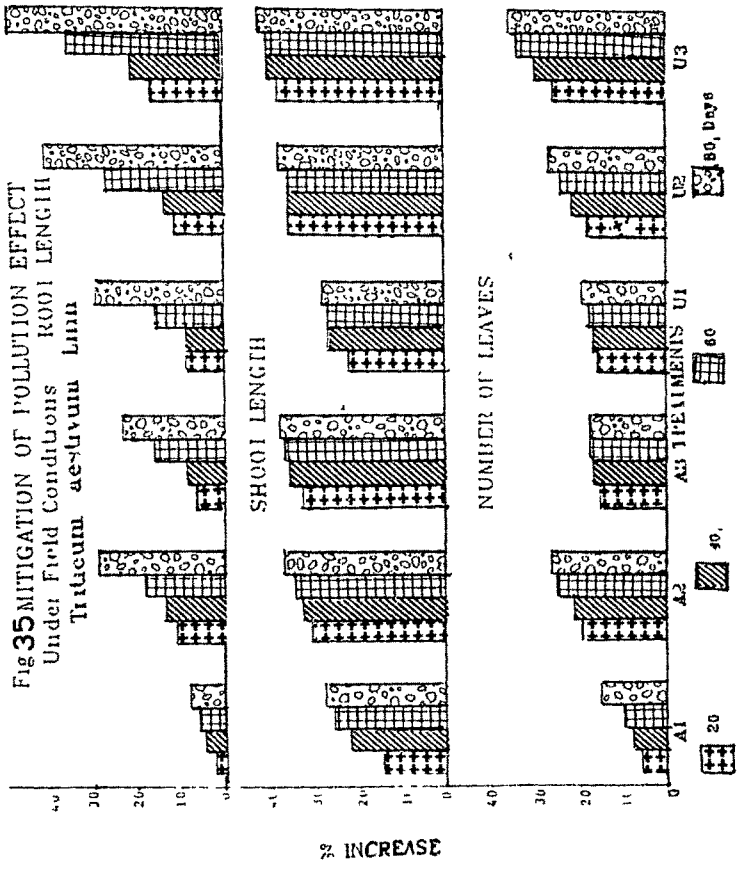


Fig 35 MITIGATION OF POLLUTION EFFECT
Under Field Conditions ROOT LENGTH
Triticum aestivum Linn
SHOOT LENGTH
NUMBER OF LEAVES
% INCREASE
A1
A2
A3 TREATMENTS U1
U2
U3
20
40
60
80, Days

36.84, 40.56 percent over reference plants respectively (Fig.36; Table 48.2).

**iii. Number of leaves**

The maximum recovery in $A_1$,$A_2$, $A_3$; $U_1$,$U_2$ & $U_3$ was 15.0, 26.0. 16.67; 16.67, 25.00 & 33.33 percent at 80 days over reference plants respectively (Fig. 35; Table 48.3).

**iv. Total leafarea**

The highest recovery in total leafarea of $A_1$, $A_2$, $A_3$; $U_1$, $U_2$, & $U_3$ treatments recorded was 14.69, 25.29, 21.38; 15.17, 22.42 & 25.27 percent at 80 days respectively (Fig.36; Table 49.1).

**v. Injury index**

Untreated plants showed visible injury from 20 days onwards. Maximum injury index (17.9%) was recorded at 80 days in UTE plants. In ascorbic acid treated plants visible injury was recorded after 50 days. The sets of $A_1$, $A_2$, $A_3$; $U_1$, $U_2$, & $U_3$ exhibited 10.4, 7.9, 5.0; 8.6, 4.2 & 0.0 percent injury index at 80 days as compared to reference (UTE) plants respectively. No damage was recorded in $U_3$ set of plants over reference plants (Table 49.3).

**vi. Biomass**

The maximum recovery in biomass accumulation of the plants of $A_1$, $A_2$, $A_3$; $U_1$, $U_2$, $U_3$ treatments was 11.56, 18.44, 15.00; 12.50, 15.94, 26.56 at 100 days respectively (Fig.36; Table 49.2).

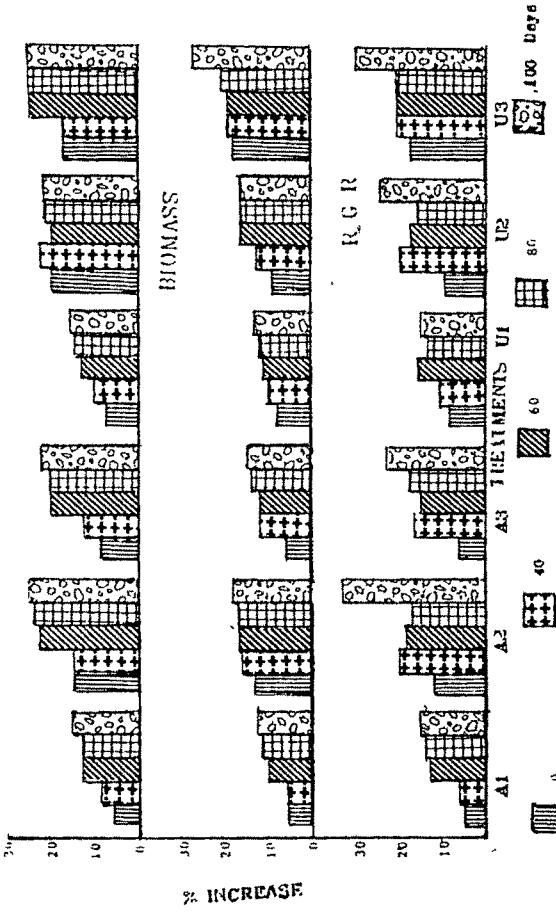



Fig. 36 MITIGATION OF POLLUTION EFFECT
Under Field Conditions TOTAL LEAFAREA
Trifolium aestivum Linn

**vii. Relative growth rate**

The maximum recovery in RGR of $A_1$, $A_2$, $A_3$; $U_1$, $U_2$,$U_3$ treatments was 14.20, 31.76, 21.50; 14.40, 24.26 & 28.92 percent respectively during 80-100 days over reference plants (Fig.36; Table 50.1)

**viii Net assimilation rate**

The maximum recovery in NAR of $A_1$, $A_2$, $A_3$; $U_1$, $U_2$,$U_3$ treated plants recorded was 29.73, 48.65, 43.24; 29.73, 43.74 & 51.35 percent during 60-80 days respectively (Fig.37; Table 50.2).

**Biochemical parameters**

**ix Chlorophyll**

Chlorophyll-a:

The maximum recovery in chlorophyll-a of $A_1$,$A_2$,$A_3$; $U_1$,$U_2$, $U_3$ treatments was 15.76, 35.47, 26.11, 20.69, 32.02 and 40.39 percent over reference at 80 days respectively (Fig.37; Table 51.1).

Chlorophyll-b:

The maximum recovery in chlorophyll-b of $A_1$,$A_2$,$A_3$; $U_1$,$U_2$,$U_3$ treatments was 8.89, 27.78, 20.0 ; 10.0, 22.22 & 27.78 percent at 80 days respectively (Fig.37; Table 51.2).

**x Total chlorophyll**

Maximum recovery in total chlorophyll of $A_1$,$A_2$, $A_3$; $U_1$,$U_2$,$U_3$ treatments was 8.72, 15.21, 10.58; 8.91, 15.21 & 21.34 percent at 80 days respectively (Fig.38; Table 51.3).

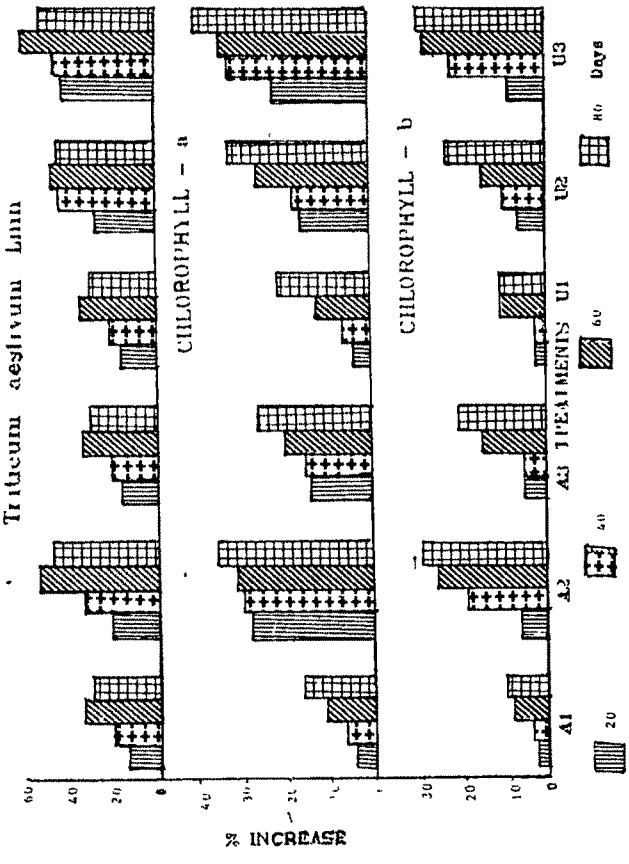



Fig 37 MITIGATION OF POLLUTION EFFECT
Under Field Conditions NAR
Triticum aestivum Linn

**xi. Total soluble sugars**

Maximum recovery in soluble sugars of $A_1$,$A_2$, $A_3$; $U_1$,$U_2$, $U_3$ treatments recorded was 13.06, 35.48, 24.76; 17.54, 25.49 & 36.94 percent at 100 days respectively (Fig.39; Table 52.2).

**xii. Reducing sugars**

The maximum decrease in reducing sugars recorded in $A_1$,$A_{21}$, $A3$; $U_1$, $U_2$, $U_3$ was 10.58, 18.27, 12.16; 13.75, 15.00 & 16.88 percent respectively at 100 days (Fig.39; Table 52.3).

**xiii. Protein**

Maximum recovery in protein of $A_1$, $A_2$, $A_3$;; $U_1$, $U_2$, $U_3$ plants recorded was 9.07, 19.19, 14.09; 10.47, 17.09 & 21.34 percent respectively at 80 days (Fig.38; Table 50.3).

**xiv. Ascorbic acid**

The highest recovery recorded in $A_1$,$A_2$,$A_3$; $U_1$,$U_2$,$U_3$ treatments was 17.65, 30.89, 25.82; 6.54, 15.03 & 19.28 percent at 80 days respectively (Fig.38; Table 52.1).

**xv. Sulphur**

The maximum decrease in sulphur recorded in $A_1$, $A_2$, $A_3$; $U_1$, $U_2$, $U_3$ was 13.33, 17.16, 15.04; 15.46, 17.30 & 18.30 percent respectively at 100 days (Fig.39; Table 53).

**xvi. Yield**

The percentage recovery in $A_1$, $A_2$, $A_3$; $U_1$, $U_2$, $U_3$ recorded was 20.67, 43.10, 31.50; 25.19, 37.02 & 55.58 as

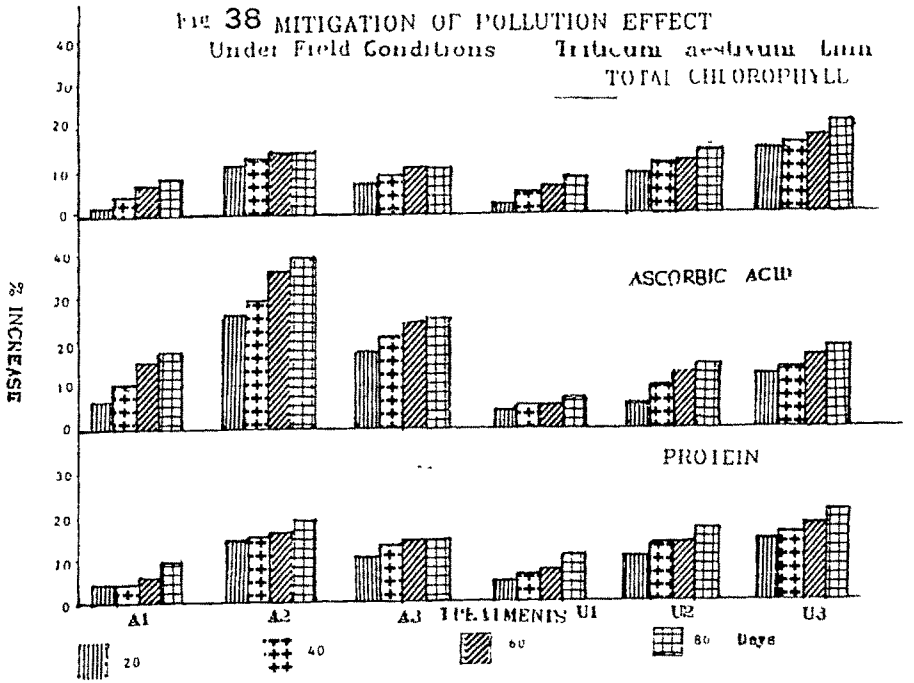


Fig 38 MITIGATION OF POLLUTION EFFECT
Under Field Conditions
Triticum aestivum Linn
TOTAL CHLOROPHYLL
ASCORBIC ACID
PROTEIN
% INCREASE
40
30
20
10
0
A1
A2
A3
TREATMENTS
U1
U2
U3
20
40
60
80
Days

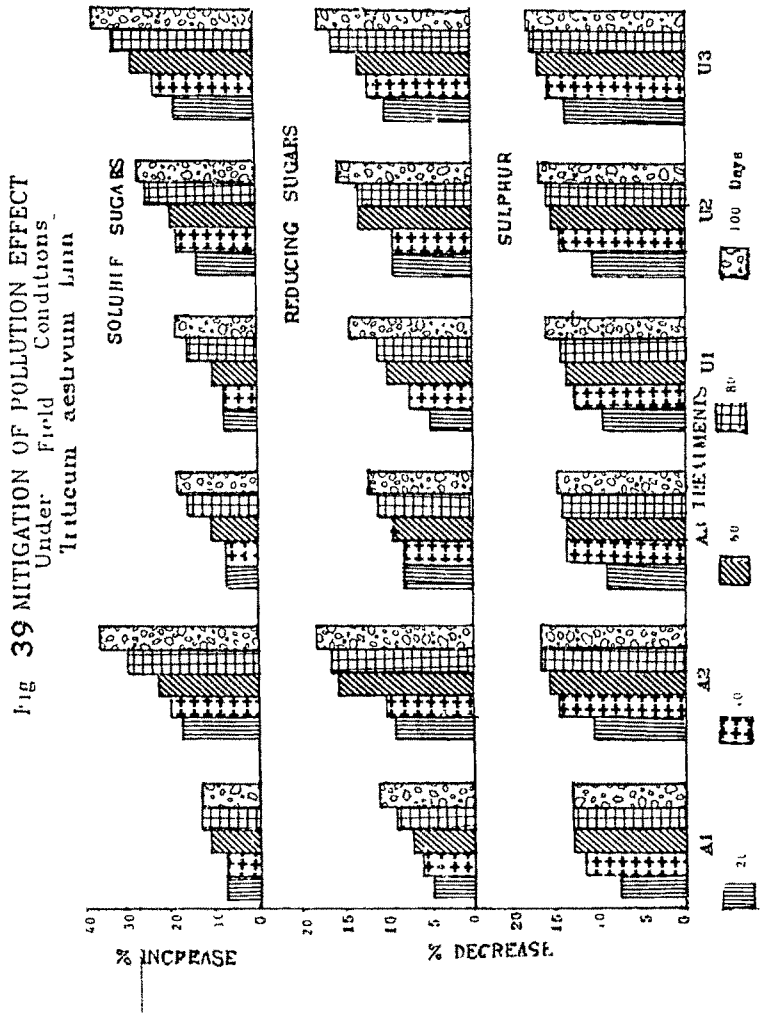
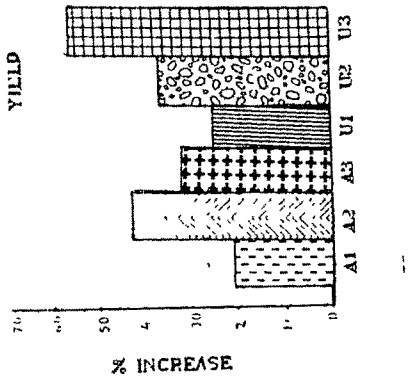



Fig 39 MITIGATION OF POLLUTION EFFECT
Under Field Conditions
Triticum aestivum Linn

Fig 40 MITIGATION OF POLLUTION EFFECT
Under Field Conditions
Triticum aestivum Linn



compared to untreated plants (Fig.40; Table 53).

**Cost benefit ratio**

The cost benefit ratio was 1:1.26, 1:1.05, 1:0.73; 1: 2.45, 1:1.85, 1:1.46 in $A_1$,$A_2$, $A_3$; $U_1$, $U_2$, $U_3$ treatments respectively.In all the treatments, $U_1$ (0.16 M urea) treatment gives maximum profit.

Among treatments of both the chemicals, it was found that there was a linear progressive recovery in all the parameters with urea treatments $U_1 < U_2 < U_3$ while in ascorbic acid treatment, the recovery was reduced in third treatment($A_1 < A_2 > A_3$).