Chapter-V
SUMMARY AND CONCLUSION

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Current interest in air pollution is centred on the influence of moderate concentrations on crop production, which occur over large areas of agricultural land in industrialised countries of the world. This investigation has been carried out on three cultivars of rice (**Oryza sativa** L.) viz., CO 43, GR 3 and TKM 9 exposed to air polluted environment near a fertilizer plant (Gujarat State Fertilizer Company Ltd., Baroda, India) under two nitrogen and water regimes, in the first year. A second year study was carried out only in cv GR 3 with the treatments of high nitrogen (HN), putrescine, spermidine, spermine, kinetin and ascorbic acid to predispose the air pollution effects. This has been supported by artificial fumigation studies in all the three rice cultivars with SO_2 (0.75 ppm), NH_3 (10 ppm) and NO_2^- (0.3 ppm) singly and in combinations, 2 hrs daily, for 10 days between 21 and 31 days of growth in plants grown in sand-culture. The salient features of the findings and conclusions are highlighted hereunder.

(1) The plant height in the early growth of three cultivars of rice exposed to the polluted environment was reduced equally and sharply but it was minimised at the later stages to varying degrees, reflecting an obvious result of differential response of the cultivars to the chronic air pollutants. The artificial fumigation on rice cultivars also supported the same.

(2) The strategy of the rice plants to overcome the reduction in height under the chronic air pollution involved the greater tiller formation which enhanced the fresh and dry matter accumulation in shoots whenever the climatic factors were conducive. Another important character of adaptability in rice was the increased number of smaller leaves to maintain the photosynthetic leaf area

against the chronic air pollution injuries.

(3) Alternatively the apparent stimulation in most of the growth characters in cv GR 3 under ammonia fumigation could explain the strategy to negate the stress effect, ultimately increasing the grain yield, but other cvs CO 43 and TKM 9 were sensitive to NH_3. NO_2 fumigation was found to be more toxic to cv GR 3 but improved the cvs CO 43 and TKM 9 in the given concentration, providing evidence for differential response of cultivars to specific pollutants.

(4) The present study revealed that the effect of artificial fumigation of SO_2 and NH_3 mixture was antagonistic to the growth of rice plants. The responses of cvs CO 43 and TKM 9 to SO_2 and NO_2 mixture constituted a valuable confirmation of the synergistic sensitive activity. Conversely, cv GR 3 with a reduction to NO_2 and half of its reduction to SO_2 and NO_2 mixture indicated an antagonistic effect.

(5) There was a delay in the panicle initiation of cultivars GR 3 and TKM 9 by 13 days and the delay was 35 days in cv CO 43, when plants were exposed to chronic air pollution stress.

(6) The air pollution led to the production of remarkably higher number of panicles in the rice cultivars but with higher sterility index than the control. A significant increase in the number of panicles and filled grains brought about a remarkable increase in the production of biological and economic yields in the cv GR 3 and to a certain extent in cv TKM 9, at the polluted site. Conversely, in cv CO 43 a considerable increase in the biological yield paralleled with a meagre production in economic yield were resulted at the test site.

(7) The yield performance of the II year results on cv GR 3 did not strictly support the first year study. As there were no abrupt changes in the concentrations of pollutants and there was lesser performance at the control site than the I year study, the possible reasons could be the combined effect of chronic air pollutants and climatic factors, particularly temperature (the year 1986 experienced a worst drought hit in the history of Western India).

(8) Among the studied remedial measures to mitigate air pollution effects, application of high N appeared to be highly effective, particularly to cv GR 3 for amelioration. Water stress in addition to N regimes found to be less effective to cv GR 3 as compared to N alone. Foliar application of chemical protectants - putrescine, spermidine, spermine, kinetin and ascorbic acid were not effective to improve the yield at the polluted site.

(9) The studies on strategic measures adduced the fact that the prime importance should be cultivar selection for any study on air pollution.

(10) The air emissions of the fertilizer plant increased the amount of Chl 'a' Chl 'b' and total Chl at the early stage of growth and decreased them at later stage in all rice cultivars. The reduction was low in the pollution tolerant cv GR 3. In the ambient air exposure studies the increase or decrease in Chl 'a' and Chl 'b' were parallel. Under fumigation of SO_2, Chl 'a' was found to be affected and the percentage of inhibition was less under HN regime. The carotenoids seemed to be less sensitive to SO_2 as compared to chlorophylls. The spermidine application to cv GR 3 modestly increased the Chl 'a' and carotenoids towards ambient air exposures.

(11) The increased endogenous ascorbic acid levels did not strictly point out to the tolerant nature of cultivars to the chronic air pollution of the fertilizer plant. The fumigation studies in rice to SO_2 and SO_2 + NH_3 exposures, indicated the maintenance of the same endogenous level of ascorbic acid as the control, whereas the exposure of other pollutants inhibited it.

(12) The cv GR 3 showed always an increase in the total nitrogen content in the shoot system towards the ambient air exposures, while cvs CO 43 and TKM 9 indicated decrease or marginal increase at the later stages of growth. Fumigation of SO_2 reduced the total nitrogen in cv GR 3. However, the content was increased in cv GR 3 to NH_3 or its combinations and in cvs CO 43 and TKM 9 to NO_2 or its combinations at different N levels.

(13) The total protein content in the cultivars of rice was found to be increased in the polluted environment and the increase was due to the increase in insoluble protein in cv GR 3 and the soluble protein in cvs CO 43 and TKM 9, though both categories of proteins were increased generally in all the cultivars.

(14) The pollution tolerant cv GR 3, based on the yield pattern, accumulated a high amount of free proline in its leaves, particularly under HN, moderately tolerant cv TKM 9 accumulated a moderately high amount of proline, and sensitive cv CO 43 accumulated lesser amount than the control. The fumigation studies also showed more or less same pattern of accumulation of free proline in rice leaves. However, the gradual increase in the contents of quaternary ammonium compounds of polluted site rice plants showed an inverse relation to their tolerant nature.

(15) The endogenous levels of polyamines putrescine, spermidine and spermine were found to be sharply reduced even after the exogenous application in rice plants exposed to ambient air exposure. However, a linear correlation between the total endogenous polyamines with plant height and leaf area were evident independently.

(16) Accumulation of soluble sugars in cv GR 3 during the active growth was less but later increased in plants at the test site. The starch content was increased at early stages but decreased at the final harvest in its shoot portion. In contrast, the pollution sensitive cv CO 43 accumulated mostly a free pool of soluble sugars and highly increased starch content at the final harvest. The accumulation in cv TKM 9 was of latter type but with lesser magnitude.

(17) There was an increase in the glutathione content in all the rice cultivars at the polluted site. The magnitude of increase was higher at later stage than the early one. SO_2 fumigation brought about a high amount of water extractable SH compounds under HN in all the rice cultivars.

(18) The total sulphur content in the shoot portion of rice cultivars was marginally increased at the test site. The fumigation of SO_2 + NO_2 mixture brought about an increased accumulation of sulphur and nitrogen under HN regime. The ambient air exposure also increased the fluoride content of rice plants in their shoots. Nevertheless, the accumulation pattern of both sulphur and fluoride provided no significant variation among the cultivars.

(19) The rice cultivars sensitive to specific pollutants showed a decreased buffering capacity, while the cultivar which was tolerant either increased or

showed no difference in its buffering capacity. The absorption peaks from the spectra of leaves of cv GR 3 were high towards SO_2, NH_3 and NO_2 mixture while they were low in cv TKM 9, as compared to the control. The cv CO 43 showed a sharp decrease in the peak at the HN towards fumigation.

(20) The activity of peroxidase was increased in cv GR 3 and TKM 9 while decreased in cv CO 43 in the polluted site plants under normal N. Water stressed plants of all the cultivars also showed increase at the test site. The inhibited activity of acid phosphatase was minimised under HN regimes of cvs GR 3 and CO 43 in the polluted environment. The activity of polyphenol oxidase was increased under normal N of cvs CO 43 and TKM 9 while it was decreased in GR 3 under air pollution stress. However, responses were opposite under HN. At a later stage all the rice cultivars accumulated higher amount of phenolic compounds in their shoot at the test site. The activity of amylase and phosphorylase was appeared to be promoted in all the cultivars in the polluted environment. The activity of invertase was maximum in the cv GR 3 in the test site and it was remarkably high under normal watered high nitrogen regime. The inhibition in the activity of nitrate reductase (NR) to chronic air pollution was minimum in cv GR 3. Though to the individual fumigation of SO_2, NH_3 and NO_2 the activity was decreased in all the cultivars, cv TKM 9 as response to NO_2, SO_2 + NH_3 and SO_2 + NO_2 showed a slight increase in the NR activity. The decrease was less in cvs GR 3 and CO 43 in their glutamine synthetase activity to NO_2 under low N regime.

(21). The cv GR 3 from the seeds particularly HN regimed I year polluted site plants were evaluated for a subsequent generation at the same site with same regime. The progeny plants became more prone to the polluted environment

at later stages with increased foliar injury, loss in economic yield, destruction in pigments, reduction in leaf relative water content, and increase in the total sulphur and fluoride contents. It was also clear from the progeny study that the evolution of resistance character must be slow in a mixed polluted environment, due to variation in cultivar response to specific pollutants.

It would be reasonable to conclude that among the tested rice cultivars cv GR 3 was found to be suitable to grow at conditions near the fertilizer plant during usual monsoon season with sufficient irrigation. Nevertheless, prevailment of dry season could decrease the performance of this cultivar, indicating a delicate balance between pollution resistance and climatic factors. Further, application of luxury amount of nitrogen, particularly to cv GR 3 would compound the beneficiary effects in the polluted environment. It was also clear that, to be successful, cultivars must be able to divert photosynthates into grain yield both in control and polluted atmospheres. Among the tested biochemical manifestations the amount of polyamines were found to be less in the polluted environment. There are bright chances to implicate the accumulation of free proline content as a biochemical marker of stress tolerance. Although fragmentary, leaf absorption spectra, temperature stability indices, and buffering capacity studies provided an axis as diagnostic tests for air pollution tolerance.

Recommendations for Further Studies and to Farmers

(1) The cv GR 3 of rice is suitable to grow at conditions near the fertilizer plant (emitting chronic SO_2, NO_x, NH_3 and F pollutants) during usual monsoon seasons with high nitrogen application. It is worthwhile to grow the fodder crops in the polluted environment.

(2) The studies on air pollution should involve large number of cultivars, rather than on single cultivar.

(3) A promising avenue on crop research would be the studies on grain filling rates of the plants under the polluted environment to arrive at sink and source relations.

(4) Resistance to air pollutants could be determined directly by screening a number of cultivars, rather than trying to create an adaptive resistance by allowing them to grow for subsequent generations at the same site.

(5) Plant breeders can utilize the greater accumulation of free proline contents in the leaves as one of the biochemical manifestations to mark the stress tolerance.

(6) A focus on interaction of air pollutants with the nutritional status of each crop species would be a reasonable study to point out the utility of atmospheric sources.

(7) Studies on leaf absorption or reflectance spectra, chlorophyll stability index and buffering capacity would be the other promising avenues of pollution research as capable of yielding useful information regarding tolerance / sensitivity in the short term.

(8) The studies on dose-response relationships of air pollution mixture on crops are necessary as the presence of other pollutants accelerate/decelerate the effects in the field of mixed pollutant environment.

(9) To provide an insight about the field environment, it is also inevitable to study the interactions of climatic factors and pollution resistance in plants.

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