INDRODUCTION

The significant and sometimes devastating effects of air pollutants on vegetation have long been recognized. India contributes about 10 million tonnes of air pollutants in the form of particulates, sulphur dioxide, carbon monoxide and hydrocarbons (Khoshoo, 1989). The air pollutant causing the maximum damage is sulphur dioxide which can cause adverse effects on vegetation affecting the major physiological and biochemical processes that may lead to growth and yield reductions in plants (Malhotra and Khan, 1984).

In Kerala State, though atmospheric pollution is not a widespread problem, it is becoming a matter of great concern in areas of industrial activity. Coconut (*Cocos nucifera L.)*, the most important perennial tree crop of Kerala, which plays a major role in its economy, is the major tree crop in and around factories of the state. In view of this, the present study was designed to assess the effect of the industrial atmospheric pollutant, sulphur dioxide on tree crops such as coconut. The study aims at elucidating the effects of sulphur dioxide pollution on the various leaf constituents and the nut characters of the coconut palm.

MATERIALS AND METHODS

The area around the Travancore Titanium Products at Trivandrum district of Kerala State, concerned with the manufacture of titanium dioxide using the locally available mineral sand ilmenite and concentrated sulphuric acid through the sulphate process was selected as the experimental site. Since coconut dominates the tree crops in the area and due to its added importance as an oil seed crop, the study was conducted on coconut palms near the factory. Chemical analysis of leaves and nuts were made to assess the extent of damage caused by sulphur dioxide pollution. Leaves and nuts of the affected and healthy palms were sampled from five radial distances of 250, 500, 1000, 1500 and 2000m from the factory to have a comparative study of the toxic effects of this pollutant. Control samples from palms of the same age were collected at a distance of 5000m from the same radii around the factory. The fourteenth leaf was taken as the index leaf for analysis. Concentration of leaf nutrients like nitrogen, phosphorus potassium, calcium, magnesium, and sulphur, the leaf pigments and the nut characters like weight of mature husked nuts, weight of shell per nut, fresh meat per nut, copra and oil content were determined to assess the extent of damage caused by sulphur dioxide pollution.

RESULTS

Coconut palms close to the source of pollution showed a high degree of chlorosis and necrosis of leaves accompanied by malformation of young leaves.

Nutrient content

Nitrogen content of palms at a distance of 1km from the factory was significantly lower when compared to control palms whereas the contents of phosphorus and potassium were markedly reduced up to 2 km (Table 1). This may be due to an increase in respiration of plants resulting from sulphur dioxide exposure leading to decreased adenosine triphosphate (ATP) levels which invariably results in a build up of adenosine diphosphate (ADP). As ATP levels fall in a cell, cessation of nitrogenase activity occurs, resulting in decreased nitrogen fixation (Conn and Stumpf, 1976). Reduction in phosphorus content could be due to sulphur accumulation, its interference in mineral absorption and other physiological and biochemical processes (Agrawal *et al*. 1989). Decrease in potassium content may be due to the release of K^+ from leaves or due to a reduction in the uptake of potassium (Jurat and Schuab, 1988).

Table 1. Nutrient content of palms with increasing distance from the pollution source

Distance from the factory (m)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Total sulphur (%)	Sulphate sulphur (%)
250	1.360	0.024	0.235	1.100	0.156	1.731	0.364
500	1.704	0.024	0.268	1.298	0.253	0.964	0.196
1000	1.944	0.029	0.428	1.439	0.266	0.681	0.129
1500	2.130	0.034	0.522	1.516	0.285	0.604	0.111
2000	2.256	0.036	0.644	1.735	0.287	0.439	0.079
5000	2.584	0.047	0.846	2.009	0.311	0.202	0.037
CD(0.05)	0.468	0.005	0.155	0.215	NS*	0.386	0.079

*NS: not significant

There was a clear decrease in the calcium content of leaves with proximity to the pollution source with significant difference observed upto 1500m but no significant difference was observed in the magnesium content. The decrease in calcium content may be due to its leakage from the leaves.

The total sulphur content showed remarkable increase as distance from the factory decreased with the values being 1.731 per cent at 250m and 0.202 per cent at 5000m. Atmospheric sulphur dioxide may enter plants through stomata as gaseous sulphur dioxide or as sulphite ions (SO_3^{2-}) which may diffuse through the cell wall and penetrate the outer cell membrane (Hallgren, 198). Sulphate sulphur also showed marked increase upto 500m from the pollution source since a major portion of sulphur dioxide entering the plant is converted to sulphate. Thus increase in sulphate sulphur may have resulted from the conversion of sulphur which was absorbed through the stomata into sulphate.

Plant pigments

Significant reduction was observed in the concentration of total chlorophyll, chlorophyll ‘a’, chlorophyll ‘b’, and total carotenoids (Table 2) of leaves. The chlorophyll contents were affected up to 2000m while the carotenoid contents were affected only up to 1500m from the pollution source. The decrease in chlorophyll content may be due to an inhibition of chlorophyll synthesis or due to its destruction (Shimazaki *et al.* 1980).

Table 2. Leaf pigment concentration of the coconut palm (mg g^{-1} fresh leaf)

Distance from the factory (m)	Total carotenoids	Total chlorophyll	Chlorophyll ‘a’	Chlorophyll ‘b’
250	0.051	0.187	0.101	0.086
500	0.091	0.348	0.222	0.126
1000	0.135	0.569	0.392	0.177
1500	0.207	0.773	0.530	0.243
2000	0.221	0.972	0.699	0.273
5000	0.270	1.492	1.051	0.441
CD(0.05%)	0.059	0.316	0.321	0.094

Nut characters

No significant influence of sulphur dioxide pollution was noticed in the weight of husked nuts, the weight of shell per nut or the weight of fresh meat per nut (Table 3). But a significant reduction in copra and oil contents was observed in palms near the pollution source.

Table 3. Nut characters of the coconut palm

Distance from the factory (m)	Weight of husked nut (g)	Weight of shell per nut (g)	Weight of fresh meat per nut (g)	Weight of copra per nut (g)	Copra content %	Oil content %
250	451.60	119.80	208.70	104.80	49.81	54.22
500	455.20	127.30	226.20	125.20	55.59	56.48
1000	396.50	108.10	202.70	110.30	54.29	55.50
1500	403.20	115.60	216.80	124.60	57.31	60.64
2000	420.80	118.20	229.40	135.90	59.18	66.46
5000	462.10	134.70	255.00	170.70	66.60	71.86
CD(0.05%)	NS	NS	NS	36.82	6.82	7.97

Copra content was only 49.81 per cent for palms at 250m while it increased to 66.60 per cent for the control palms at 5000m from the pollution source while the oil content was 54.22 per cent and 71.86 per cent at 250 and 5000m respectively. A reduction in copra content was noticed up to 2000m while for oil content the effect was only upto 1500m from the source of pollution. The reduction in oil content may probably be due to the oxidation of lipids by sulphur dioxide (Shimazaki *et al*. 1980).

CONCLUSIONS

The study confirms that when plants are exposed to sulphur dioxide, they absorb sulphur through the foliage to toxic levels and lead to plant injury in the surrounding area. The adverse effects of sulphur dioxide existed up to 1500 to 2000m from the pollution source.

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