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AIR POLLUTION ACCLIMATION POTENTIAL OF *CARISSA CARANDAS* L.

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PANDEY J, and AGRAWAL M. *Air pollution acclimation potential of* Carissa carandas *L.*. BIOTRONICS 22, 25–33, 1993. Transplants of *Carissa Carandas* L. were kept at selected study sites of Varanasi city over a period of 2 years. Plant health was assessed by measuring eight growth indices including height, basal diameter, number of branches, number of leaves, leaf area, canopy height, canopy area and biomass (leaf, shoot, root, and total). Changes in plant parameters were compared with the status of ambient air quality. The transplants were affected differently at different zones depending upon the level of air pollution in the area. Although the existing air pollution load reduced total plant biomass, the functional importance shifted from below to above ground plant parts where foliage assume predominance. The study shows acclimation potential of *C. carandas* plants against the imposed pollution stress.

Key Word: *Carissa carandas* L.; transplants; air pollution; acclimation; leaf injury.

INTRODUCTION

Air pollution is one of the major environmental factors that limit plant performance, specially in urban industrial areas. In most parts of India the concentrations of various phytotoxic pollutants are increasing at a high rate which often exceed the toxic limit (*10, 14, 15, 16, 17, 18, 24*). Sulphur dioxide, nitrogen dioxide, ozone and suspended particulates have been found to be among the most phytotoxic pollutants in the urban atmosphere (*18*). Individual effects of pollutants on plants have been extensively investigated (*13, 19, 21*). General plant responses to SO_2 and O_3 exposure include reductions in photosynthesis (*12*), leaf conductance (*26*), leaf area and number (*6*), dry matter accumulation and grain yield (*1*).

The ambient environment of urban industrial areas generally contains several pollutants and the plants growing in such areas are exposed to many pollutants in their different combinations. It is possible to study the overall effect of a large number of pollutants as total pollution load by measuring unfavourable changes in plants. This can be done either through plants growing in their natural habitats, or through transplant studies. Transplant studies offer a more direct approach because in this case various edaphic and biotic factors can be successfully controlled. It provides a better basis for the quantification of the effects and validity of comparisons.

Some plant species posses certain degree of acclimation against air pollutants (*8, 21*). Air pollution acclimation enables the plants to resist the effects of imposed pollution stress. Our study provides evidence that *Carissa carandas* plants develop greater propensity for the photosynthetic unit to acclimatise under air pollution atress.

MATERIALS AND METHODS

Study Area

The present study was conducted in the urban environment of Varanasi. The city of Varanasi (25° 18′ N lat. and 83° 01′ E long., 76.19 m above sea level) with a population density of about 10, 26, 467 is located in the eastern Gangetic plain of Indian subcontinent. The climate of the area is tropical monsoonic, with three distinct seasons, summer (March to June), rainy (July to October) and winter (November to February), with annual average 24℃ temperature, 60% relative humidity and 1,000mm annual precipitation. The first half of the summer season experience strong hot dry winds and high temperature, while second half is generally hot and humid. During summer, the day time temperature ranges from 30 to 42℃ and the day light duration from 10 to 14 hours. During rainy season which accounts for 90% of total annual rainfall, the maximum temperature ranges from 24 to 36℃ and the relative humidity from 70 to 95%. Temperature varies between 10 to 25℃ in winter season and night temperature sometimes drops below 6℃.

The soil of the region is alluvial (sandy loam) and usually light brown in colour, having a slightly alkaline pH range (pH 7.3 to 7.6). The vegetation mainly comprises of artificial plantation interspersed with seasonally growing weeds and perennial shrubs. The air quality status of Varanasi is projected in Table 1.

For the purpose of the present study the city was divided into five zones and five microsites were selected in each zone. This was done on the basis of pollution sources and structure of build up areas (*18*). Continuous air quality monitoring was done by using High Volume Samplers (HVSs) located at 1.5 to 3.0 m above ground level, in the city at each microsite. Total suspended particulates were trapped on a glass-fibre filter paper attached to the hopper of HVS. Gaseous pollutants such as SO_2, NO_2 and O_3 were scrubbed separately in tetrachloromercurate, NaOH (0.1 N) and buffered KI (0.1 N), respectively, at 2-h intervals. These absorbing solutions were analysed colorimetrically for SO_2 (*25*), NO_2 (*11*) and O_3 (*4*) pollutants, respectively. The data were presented as 24-h average and 2-h peak concentrations, and expressed as $\mu g\ m^{-3}$.

Experimental Design

The plant species selected for this study is found in and around the city of Varanasi. *Carissa carandas* is a spiny shrub that bears edible acidic berries which are pickled. Uniform size of six months old saplings (1 pot^{-1}) were planted in the earthen pots of 30 cm diameter filled with well manured garden soil (pH 7.2 ; organic carbon, 0.86% ; total N, 0.09% ; available P, 0.005% ; exchangeable K, 0.1% ; cation exchange capacity, 15.4 meq (100 g^{-1}) and were allowed to stabilize for a period of four weeks. Thereafter ten sets of each species (7 months of plant age) were kept at each study site. To maintain constant soil moisture and an adequate nutrient supply, pots were uniformly watered thrice in a week during dry seasons and were supplied with manure twice in a year at the rate of 250 g per pot.

Plant Sampling and Analysis

Sampling were done at four month intervals on the dates December 8, 1988 (9 months of plant age) ; April 8, 1989 (13 months of plant age) ; August 8,1989 (17 months of plant age) ; December 8,1989 (21 months of plant age) ; April 8, 1990 (25 months of plant age) ; August 8, 1990 (29 months of plant age) and December 8, 1990 (33 months of plant age) . Initially, parameters like plant height, number of leaves, number of branches, basal diameter, canopy area, etc., were recorded for all individuals. At the end of the experiment (on December 8, 1990) plants were harvested for the determination of leaf area and above and below ground biomass.

Leaf area was measured with a portable leaf area meter (LI–COR, USA). Plant leaves were closely examined for lesions, if any, in terms of chlorosis, necrosis, bronzing, etc., and the injury was quantified as percentage of leaf area injured using planimeter (Type KP–27, Koizumi, Japan). For biomass determination, whole plants were separated into leaf, shoot and root. Samples were thoroughly washed and kept in oven at 80℃ till the constant weight was achieved. The relative total biomass of species (*RTB*) was calculated as:

$$RTB = \frac{(TB)^{P}}{(TB)^{C}}$$

Where $(TB)^{P}$ is the mean total biomass at zone Ⅰ, Ⅱ, Ⅲ, and Ⅳ in question and $(TB)^{C}$ is the mean total biomass at zone Ⅴ. Since the transplants kept at zone Ⅴ accumulated the highest total biomass, *RTB* expresses the proportional loss in total biomass of a species at a given polluted site. Root: shoot ratio was also calculated.

RESULTS

On the basis of air quality data the urban area of Varanasi can be ranked from maximum pollution load to a minimum as Ⅰ > Ⅱ > Ⅲ > Ⅳ > Ⅴ (Table 1). Since the concentrations of all the pollutants are lowest at zone Ⅴth, the data for this zone was used as the reference for comparing the changes in different

Table 1. Annual 24-h average air pollutant concentrations ($\mu g\ m^{-3}$) in different zones of Varanasi city. Values in parentheses represents 2-h peak concentrations.

Year	Pollutants	I	II	III	IV	V
1989	SO_2	66(234)	59(205)	48(176)	47(150)	15(37)
	NO_2	51(159)	50(125)	38(94)	46(105)	19(39)
	O_3	45(169)	44(149)	33(105)	24(116)	14(36)
	TSP*	305(733)	280(694)	231(540)	239(534)	143(265)
1990	SO_2	79(238)	74(203)	52(181)	50(159)	15(39)
	NO_2	59(159)	51(119)	43(101)	45(117)	19(42)
	O_3	48(149)	50(159)	41(105)	38(110)	16(30)
	TSP*	336(1056)	323(892)	258(610)	217(543)	126(215)

*Total suspended particulates.

Table 2. Per cent of leaf area injury in transplants kept at different zones of Varanasi city.

zone	Plant age (months)						
	9	13	17	21	25	29	33
I	—	4.5	2.0	12.0	10.4	4.6	17.8
II	—	3.8	—	10.6	10.0	3.9	17.2
III	—	—	—	4.0	2.0	—	7.5
IV	—	—	—	1.0	—	—	3.2
V	—	—	—	—	—	—	—

parameters obtained at other zones.

The transplants kept at zones I, II, III and IV showed visible leaf injury in the form of bifacial chlorotic and necrotic symptoms. The maximum per cent leaf area injury was observed at zone I followed by II, III and IV (Table 2).

Plant heights were lower in zones receiving higher pollution load as compared to the plants kept at zone V (Table 3). The per cent reductions in plant height were 52.9, 48.6, 40.0 and 4.3 at zones I, II, III and IV with respect to the plants at zone V after 26 months of exposure. The plant basal diameter also declined for the plants kept at zones I, II, III and IV when compared with the plants at zone V. Canopy height was markedly reduced at polluted sites and at zones I, II, III and IV the respective reductions were 55.1, 52.9, 27.8 and 4.4% with respect to the plants at zone V after 26 months of exposure. The number of leaves and branches gradually increased in the

Table 3. Agewise changes in plant height, basal diameter and canopy height of transplants kept at different zones of Varanasi city.

Plant age (months)	Plant height(cm)					Basal diameter(cm)					Canopy height(cm)				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
9	16.8	12.5	9.0	15.5	9.5	0.21	0.12	0.16	0.12	0.12	15.3	10.5	8.0	13.7	8.0
13	18.0	14.5	12.0	19.0	14.5	0.22	0.19	0.33	0.39	0.15	16.2	12.2	10.5	17.0	13.0
17	21.5	25.0	27.0	42.5	42.5	0.26	0.28	0.56	0.56	0.40	18.7	22.0	24.7	40.2	41.0
21	24.0	26.0	30.0	44.0	44.0	0.35	0.36	0.59	0.60	0.45	21.2	23.0	27.7	41.7	42.5
25	26.0	26.0	32.0	44.5	45.0	0.36	0.36	0.65	0.60	0.65	23.5	23.0	29.5	42.0	43.0
29	31.5	35.5	39.5	65.0	68.5	0.41	0.62	0.95	0.79	0.80	29.0	31.5	37.7	63.0	66.5
33	33.0	36.0	42.0	67.0	70.0	0.45	0.62	0.95	0.80	0.85	30.5	32.0	40.2	65.0	68.0

Table 4. Agewise changes in number of branches, number of leaves and canopy area of transplants kept at different zones of Varanasi city.

Plant age (months)	Number of branches ($plant^{-1}$)					Number of leaves ($plant^{-1}$)					Canopy area (cm^2)				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
9	4	4	4	3	4	33	25	38	45	38	50	51	60	92	101
13	10	12	11	9	20	94	105	78	120	110	108	120	120	146	144
17	50	26	35	54	23	538	585	244	231	186	577	882	780	1293	1359
21	82	72	54	67	56	624	600	448	200	215	1361	760	1000	1400	1400
25	98	84	68	77	59	610	576	350	212	270	1100	816	950	1416	1460
29	150	156	129	115	84	1200	1300	1050	658	570	1875	1175	2055	2090	2050
33	165	160	135	124	96	1140	1105	970	612	560	1950	1200	2000	1895	2050

plants at zones IV, III, II and I relative to the plants at zone V (Table 4). However, both the leaf area of individual leaf and the total leaf area $transplant^{-1}$ were maximum in plants at zone V. Similar effect was observed for canopy area also (Table 4).

Leaf biomass was found to decrease with increasing pollution load. The values of the total leaf biomass were 4.3, 4.5, 5.1, 5.8 and 6.6 g $plant^{-1}$, respectively at zones I, II, III, IV and V after 26 months of exposure (Fig 1). The root: shoot ratio also showed a decreasing trend with increasing pollution load. The transplants kept at zones I, II, III and IV showed significant reduction in total plant biomass (Fig 1). Decrease in relative total biomass (*RTB*) indicated total biomass loss of 30.5% at the most polluted zone I as compared to the plants at zone V after 26 months of exposure. At zone II, III and IV, the respective losses in total biomass were 29.0, 19.8 and 17.9 per cent.

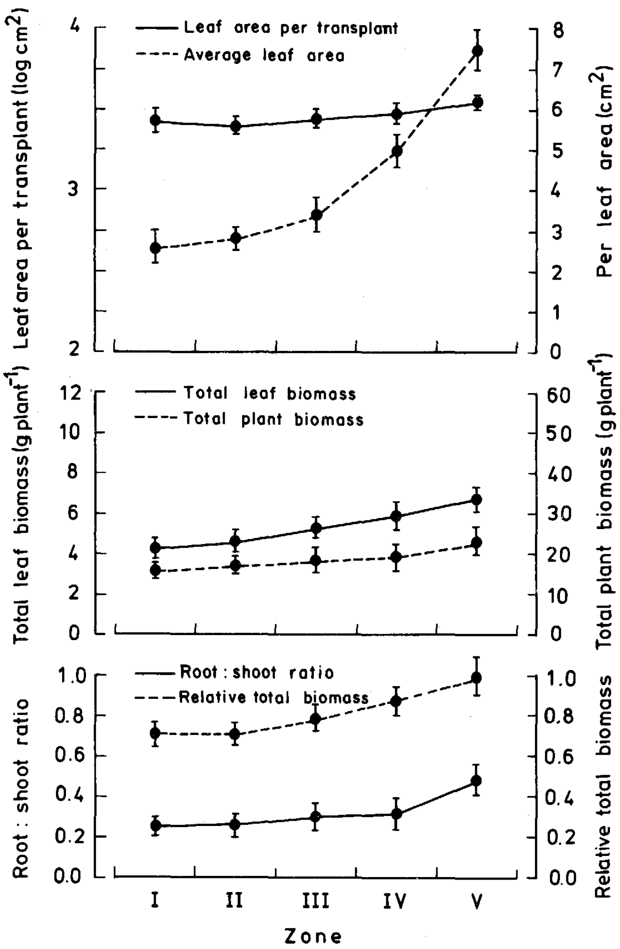

Fig 1. Leaf area per transplant, average leaf area, leaf biomass, total biomass, relative total biomass and root: shoot ratio of different transplants kept at different zones of Varanasi city (Values are mean ± S. E., n=10).

DISCUSSION

The results of this study indicate that transplants kept at zones I, II, III and IV were unfavourably affected. The visible leaf injury symptoms observed in the present study were in the form of bifacial chlorotic and necrotic symptoms. This may be an interactive response of the dust deposited on foliar surfaces and the simultaneous absorption of various gaseous pollutants. It may be suggested that in the presence of variety of pollutants, specific injury symptoms may coalesce giving rise to an unspecific appearance. Severity in foliar injury during winter was probably due to high levels of SO_2, NO_2 and TSP in winter months.

Reduction in plant height, basal diameter, canopy height, canopy area and total plant biomass at zones I, II, III and IV reflect the adverse effects of urban air pollution on plants. The magnitude of growth reduction was maximum at zone I receiving maximum pollution load. In the present study, the transplants were maintained at similar edaphic and climatological conditions, therefore, the observed differences in plant growth performance are mainly due to the atmospheric pollutants. Cohen and Ruston (*5*) and Bleasdale (*2*) also observed significant growth depressions in *Lactuca sativa* and *Lolium perenne* plants, respectively at polluted urban sites compared to relatively clean sites in U.K.

Although, in plants at zone I, II, III and IV the number of leaves increased compared to the plants at zones V, the total leaf area transplant^{-1} declined resulting in a net decrease in photosynthetic area vis-a-vis plant growth. Reduced photosynthetic leaf area has been found to reduce photosynthetic capacity of plants in several studies (*3, 6, 23*). Changes in number of leaves, leaf biomass, and root : shoot ratio indicated the relative importance of resource allocation pattern in the plant's ability to acclimatize. A significant increase in number of leaves can be attributed to acclimatory changes under pollution stress condition. Held *et al.* (*8*) have also reported a similar response in radish plants against ozone stress. This increase may be due to the allocation of relatively more photosynthate towards the leaf production. Further, Cell elongation is more sensitive to stresses such as water stress, radiation effects, etc., than photosynthesis and cell division (*9*). Consequently, leaf elongation may cease when stress is imposed, carbohydrate reserve accumulates and new leaves continue to be initiated. Reduction in total leaf area (with respect to the plants kept at zone V) inspite of increase in number of leaves is due to a significant reduction in the area of the individual leaf (Fig. 1). Low RSR values at zones receiving higher pollution load, further indicate that *C. carandas* plants respond to the existing pollution load by retaining a major part of its photosynthate to above ground plant parts. Thus a low RSR value in which functional importance (resource allocation) shifts from below to above ground plant parts where foliage assume predominance, was associated with high pollution load. On the other hand, a high RSR at unpolluted zone (V) was a normal pattern, where a proportionate shift towards root growth has occurred.

In the present study, although, many parameters were used to measure the effects of urban air pollution on transplant growth, two of them mainly provides a gross measure of pollution stress Vs plant performance, i.e., the relative total biomass (stressed/control) and the number of leaves per plant. The former is a final result of total assimilation after respiration. Since the transplants kept at zone V accumulated the highest total biomass, this ratio expresses the proportional loss in total biomass of a species at a given polluted site. Injury due to air pollution stress not only reduces photosynthesis but also increases respiration (*12, 22*) and thus leads to depression of plant biomass. Number of leaves per plant is a contributing factor in total biomass. The leaf production in this species responds characteristically to the existing air pollution stress. Reduction in leaf photosynthetic capacity alters allocation patterns in a manner that favours the production of new leaves over new roots (*27*). This response is a consequence of the greater propensity for the photosynthetic units (leaf) to acclimatize under stress. The leaves which are main site of pollutant injury get priority over the roots in the partitioning of assimilates. Plants exposed to low concentrations of ozone showed growth reductions, but leaf turnover increased (*20*). A greater proportional carbon allocation to leaves should result in a greater proportional dry weight accumulation. But in the present study this greater allocation was used for the production of new leaves, instead of increasing the leaf area and leaf biomass. This may be due to photosynthetic acclimation of *C. carandas* plants to existing pollution load. The young expanding leaves are found to be more resistant to pollutants as compared to fully expanded mature leaves (*7*). Therefore, increased number of leaves is considered an adaptive response as there is a saving in carbon acquisition by increasing the leaf number.

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