



Variation in air pollution tolerance index and anticipated performance index of roadside plants in Mysore, India

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Abstract

Plants develop characteristic reactions and symptoms in response to particular type and level of air pollution. Air pollution tolerance index has been used to rank plant species in their order of tolerance to air pollution. In the present study, the Air Pollution Tolerance Index of five roadside plant species (*Enterolobium saman*, *Muntingia calabura*, *Peltophorum pterocarpum*, *Spathodea campanulata* and *Polyalthia longifolia*) has been evaluated. The Anticipated Performance Index (API) of these plant species was also calculated by considering their APTI values together with biological parameters (Plant habit, Canopy structure, Type of plant, laminar structure and Economic value). Based on these indices, the most suitable plant species for green belt development in urban areas were identified and recommended for long-term air pollution management. Among the plants studied at different sites, *Polyalthia longifolia* was found to be a better tolerant species with an APTI value of 12.21 as compared to other species and *Peltophorum pterocarpum* appears to be less tolerant to air pollutants with an APTI value of 8.16.

Key words

Air pollution tolerance index, Anticipated performance index, Green belt

Introduction

Air pollution is one of the severe problems world is facing today. It deteriorates ecological condition and can be defined as fluctuation in any atmospheric constituent from the value that would have existed without human activity. In recent past, air pollutants, responsible for vegetation injury and crop yield losses, are causing increased concern (Joshi and Swami, 2009). Vehicles represent a major source of air pollutants such as CO, NO₂, SO₂ and particulate matters. Vehicular emissions tend to increase due to increasing number of vehicles. The implementation of appropriate transportation policy by using minimally polluting automobiles, improving combustion system, and planting roadside vegetation could reduce air pollution from motor vehicles. It is a known fact that 60 % of air pollution in city is caused by automobiles only (Gaikwad *et al.*, 2004).

Lack of knowledge about resistant and sensitive species to air pollution has caused the field studies to identify sensitive

and resistant species. Plants are an integral basis for all ecosystems and most likely to be affected by airborne pollution, which are identified as the organisms with most potential to receive impacts from ambient air pollution. Also the effects are often apparent on the leaves which are usually the most abundant and primary receptors of large number of air pollutants. Bio monitoring of plants is an important tool to evaluate the impact of air pollution. Hence, in recent years, urban vegetation has become increasingly important not only for social reasons but also for improving urban air quality (Prajapati and Tripathi, 2008).

Roadside vegetation based on level road structure at 10 and 150 m from road could reduce NO₂ concentration up to 3.5 and 2.3 ppb, respectively. Reduction of NO₂ concentration by the vegetation might be due to the absorption of the pollutant by its canopy and its dispersion into the planting area. Vegetation absorbs NO₂ through gas exchange processes, and then it is assimilated into nitrogenous compounds and used as the plant major compound to increase its growth (Nasrullah *et al.*, 1994).

Different plant species showed a diverse behavior for various pollutants and any plant part could be indifferently used as bio-monitors. Four physiological properties i.e. total ascorbate and chlorophyll content as well as leaf-extract pH and relative water content were calculated as air pollution tolerance index (APTI). The APTI value was used to evaluate the susceptibility level of plants to air pollutants (Mingorance *et al.*, 2007, Singh *et al.*, 1991). APTI is an index that denotes capability of a plant to combat against air pollution. Plants which have higher index value are tolerant to air pollution and can be caused as sink to mitigate pollution, while plants with low index value show less tolerance and can be used to indicate levels of air pollution (Begum and Harikrishna, 2010). APTI is used by landscapers to select plant species tolerant to air pollution (Yan-Ju and Hui, 2008). Screening of plants for their sensitivity/tolerance level to air pollutants is important because the sensitive plants can serve as bio-indicator and the tolerant plants as sink for controlling air pollution in urban and industrial areas (Kuddus *et al.*, 2011).

The objective of present study was to examine the plant species which are tolerant to air pollutants in the urban areas of Mysore, Karnataka. On the basis of APTI and relevant biological characters, the anticipated performance index (API) of various plant species was determined for green belt development.

Materials and Methods

Description of the study area and selection of study sites :

The experimental site Mysore city is situated in Mysore District, in Karnataka State of India. The geographical location of city is 12° 18' 0" N, 76° 39' 0" situated at the base of Chamundi Hills and spreads across an area of 128.42 km². It has an average altitude of 770 m, above mean sea level. The city has an average of temperature 21-34°C during summer and 12 - 30°C during winter. The Control site, University of Mysore (Manasagangotri campus) is located at 12°18'29.45"N, 76°38'18.83"E. It spreads over an area of 739 acres at the western end of Kukkarahalli Lake.

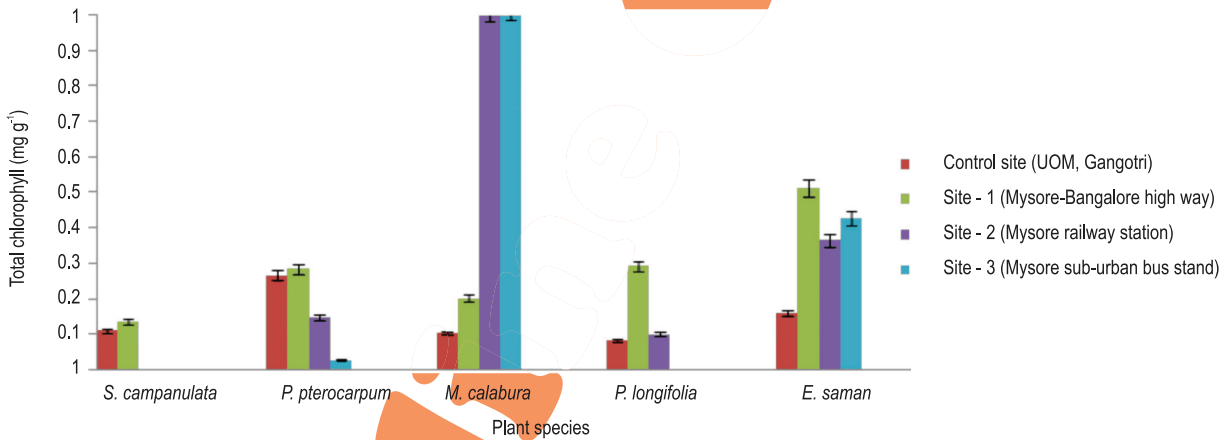


Fig. 1 : Values of total chlorophyll content in fresh leaves of five roadside plant species in Mysore. Values are mean of triplicates ± SD

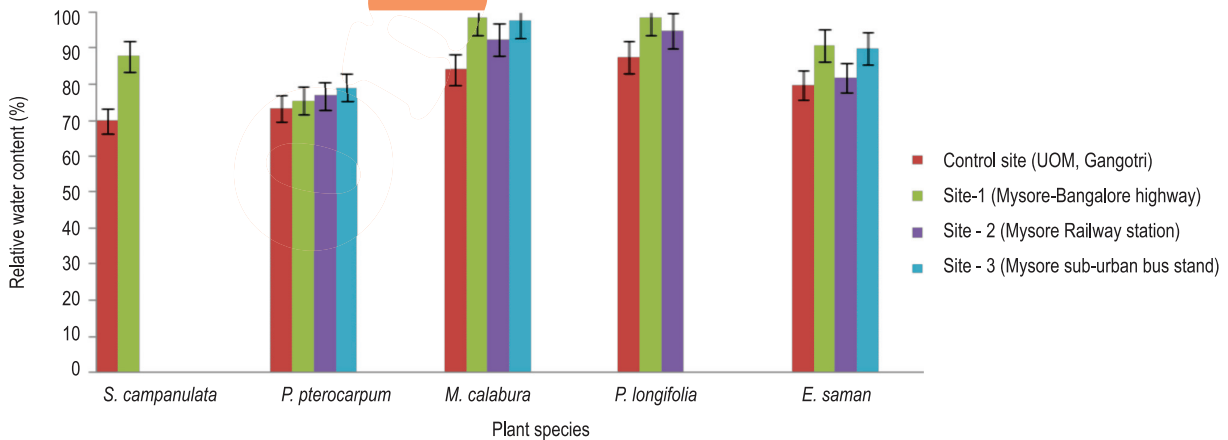


Fig. 2 : Values of relative water content in fresh leaves of five roadside plant species in Mysore. Values are mean of triplicates ± SD

The study area was classified into two zones : control site and experimental site. The leaf samples of *Enterolobium saman*, *Muntingia calabura*, *Peltophorum pterocarpum*, *Spathodea campanulata* and *Polyalthia longifolia* were collected from control site i.e. University of Mysore (Gangotri campus) where there was least disturbance. Same plant species were collected randomly from 3 experimental sites i.e Mysore-Bangalore high way (Site-1), Mysore city railway station (Site-2), and Sub-urban bus stand (Site-3). The experimental sites included busiest traffic area of the city. Fully mature leaves in triplicates were collected during morning hours from the selected evergreen trees of almost same diameter at breast height (DBH) and from the shrubs of almost same height. Utmost care was taken that the samples from each

study site were collected from plants growing in isoecological conditions. Fresh weight of the leaves was taken immediately upon getting to the laboratory and then samples were preserved in refrigerator for further analysis.

Total chlorophyll content : Total chlorophyll content in the leaves was estimated following the method of Chouhan *et al.* (2012). Three grams of fresh leaves were blended and then extracted with 10 ml of 80% acetone and left for 15 min. The liquid portion was decanted into another test-tube and centrifuged at 2,500 rpm for 3 min. The supernatant was then collected and the absorbance was taken at 645 nm and 663 nm using a spectrophotometer.

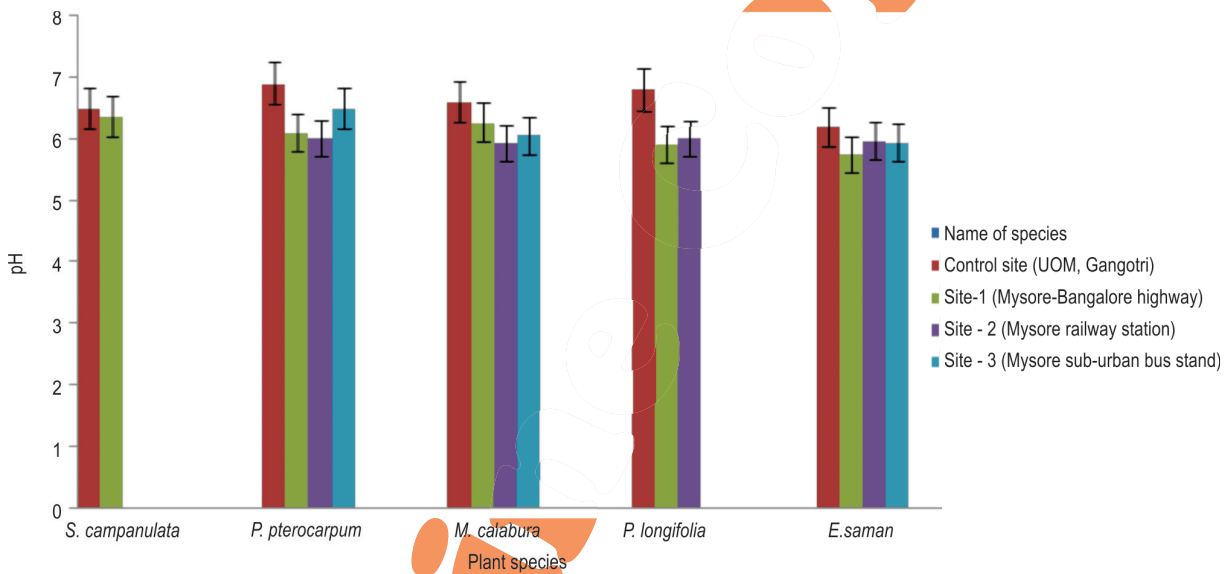


Fig. 3 : Values of pH of fresh leaves of five roadside plant species in Mysore. Values are mean of triplicates ± SD

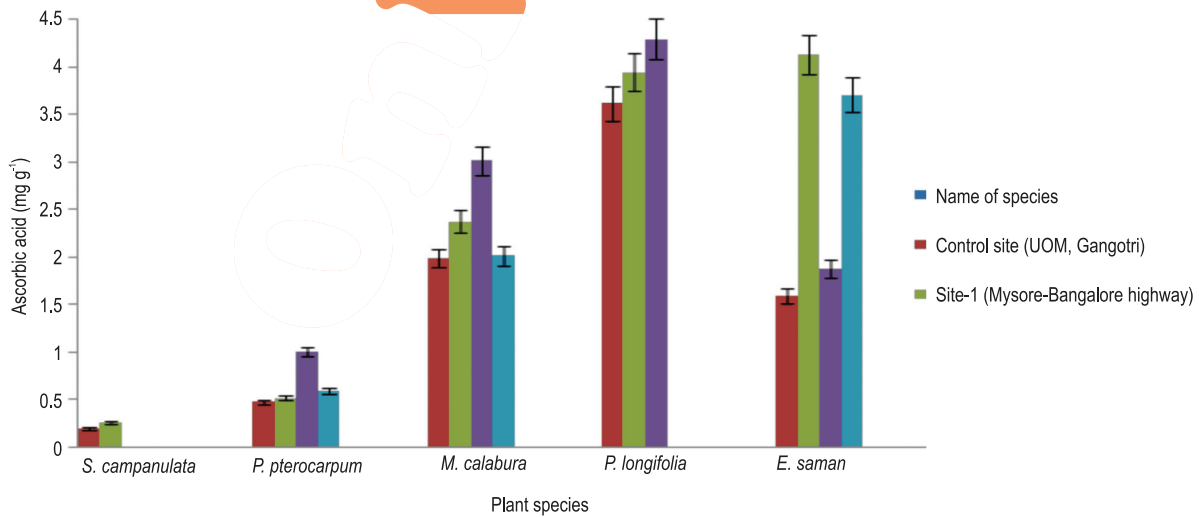


Fig. 4 : Values of Ascorbic acid content in fresh leaves of five roadside plant species in Mysore. Values are mean of triplicates ± SD.

Relative leaf water content (RWC) : Following the method described by Tripathi *et al.* (2009), leaf RWC was determined and calculated. Fresh weight was obtained by weighing the fresh leaves. The leaves were then immersed in water over night, blotted dry and then weighed to get the turgid weight. Next, the leaves were dried overnight in an oven at 70°C and reweighed to obtain the dry weight.

Leaf extract pH : Leaf-extract pH was determined with pH meter. Five grams of a leaf sample was digested and added with 50 ml of deionized water, the obtained suspension was measured with a pH meter after calibrating pH-meter with buffer solution of pH 4 and 9 (Adamsab and Kousar, 2011).

Ascorbic acid (AA) content : Ascorbic acid content (expressed in mg g⁻¹) was measured using spectrophotometric method (Begum and Harikrishna, 2010). One gram of fresh foliage was added to a test-tube containing 4ml oxalic acid – EDTA extracting solution 1 ml of orthophosphoric acid 1 ml tetraoxosulphate (5%), 2ml of ammonium molybdate and 3ml of water., The solution was then allowed to stand for 15 min and absorbance was read at 760nm with a spectrophotometer. The concentration of ascorbic acid in the samples were then extrapolated from a standard ascorbic acid curve.

Statistical analysis : Data were analyzed by one way analysis of variance (ANOVA) using Statistical Program for Social Sciences (SPSS) 11.2 for windows. Linear regression analysis was performed between independent variables total viz. chlorophyll content, pH, RWC, ascorbic acid content and dependent variable such as APTI by using XL STAT (Version 10) software. These scatter plots illustrated the degree of correlation (R²) between the said variables. The air pollution tolerance indices were determined following the method of Singh and Rao (1983). By combining the resultant APTI values with some relevant biological characters (plant habit, canopy structure, type of plant, laminar structure and economic value), the Anticipated Performance Index (API) was calculated for different species (Prajapati and Tripathi, 2008). The criteria of Dali Mondal *et al* (2011) were used for calculating API of different plant species.

Results and Discussion

Muntingia calabura showed highest total chlorophyll content at all the study sites followed by *Enterolobium saman* (Fig. 1). It was found that there was a significant increase in total chlorophyll content compared to control site. It had the highest increase in mean value of total chlorophyll compared to control site (86.27%) followed by *Enterolobium saman* (63.26%), *Polyalthia longifolia* (57.00%), *Spathodea campanulata* (18.67%) and *Peltophorum pterocarpum* (13.04%). Chlorophyll content of plants signifies its photosynthetic activity as well as the growth and development of biomass. It is well evident that chlorophyll content of plants varies from species to species; age of leaf and also with the pollution level as well as with other biotic and abiotic

conditions (Katiyar and Dubey, 2001).

Present study revealed that total chlorophyll content in all the plants varied with the pollution status of study area. It also varied with tolerance as well as sensitivity of the plant species *i.e.* higher the sensitive nature of plant species lower the chlorophyll content. Irrespective of study stations, high level of total chlorophyll observed in *Muntingia calabura* may be due to its tolerance nature (Jyothi and Jaya, 2010).

There was a significant increase in relative water content in leaves of experimental site as compared to control site (Fig. 2). The mean percentage increase in RWC compared to control site (Manasagangotri) was highest in *Spathodea campanulata* (20.37%) followed by *Muntingia calabura* (12.53%), *Polyalthia longifolia* (9.54%), *Enterolobium saman* (8.68%) and *Peltophorum pterocarpum* (5.18%). This shows that *Spathodea campanulata* could be a drought or pollution tolerant than other plants and *Peltophorum pterocarpum* was more sensitive to air pollution. High water content within a plant body helps to maintain its physiological balance under stress conditions such as exposure to air pollution when the transpiration rates are usually high. Relative water content is associated with protoplasmic permeability in cells which causes loss of water and dissolved nutrients, resulting in early senescence of leaves (Agarwal and Tiwari, 1997). Therefore, the plants with high relative water content under polluted conditions may be tolerant to pollutants.

All the plant samples collected from polluted site exhibited pH towards acidic side (Fig. 3), which may be due to the presence of SO₂ and NO_x in the ambient air causing a change in pH of the leaf sap towards acidic site (Swami *et al.*, 2004). The changes in leaf-extract pH might influence the stomata sensitivity due to air pollutants. The plants with high sensitivity to SO₂ and NO₂ closed the stomata faster when exposed to pollutants (Larcher, 1995). A shift in pH of cell sap towards the acidic side in presence of an acidic pollutant might decrease the efficiency of conversion of hexose sugar to ascorbic acid. However, the reducing activity of ascorbic acid is pH dependent being more at higher and lesser at lower pH. Hence higher pH is known to improve tolerance to air pollution, while lower pH show good correlation with sensitivity to air pollution (Yan and Hui, 2008).

Being a very important reducing agent, ascorbic acid also plays a vital role in cell wall synthesis, defense and cell division (Conklin, 2001). Present study showed elevation in the concentration of ascorbic acid with respect to control site in *Polyalthia longifolia*, *Enterolobium saman* and *Muntingia calabura* (Fig. 4). Pollution load dependent increase in ascorbic acid content of all the plant species may be due to increased rate of production of reactive oxygen species during photo-oxidation of SO₂ to SO₃ where sulfites are generated from absorbed SO₂. In the present study, high level of ascorbic acid content in the leaves of *Polyalthia longifolia*, *Enterolobium saman* and *Muntingia*

Table 1 : Air pollution tolerance index (APTI) increase in percentage from the control to experimental sites

Name of species	Site	T.Ch (mg g ⁻¹)	RWC (%)	pH	AA (mg g ⁻¹)	APTI	APTI increase (%)
<i>S. campanulata</i>	ES	0.136+0.084	87.80+ 3.987	6.37+0.284	0.26+0.312	7.12+0.345	20.41
	CS	0.11	69.92	6.5	0.19	8.95	
<i>P. pterocarpum</i>	ES	0.15+0.104	77.2+1.510	6.2+0.212	0.7+0.213	7.66+0.199	6.06
	CS	0.26	73.19	6.9	0.47	8.16	
<i>M. calabura</i>	ES	0.75+0.392	96.21+2.628	6.09+0.136	2.46+0.414	9.74+0.082	13.87
	CS	0.1	84.15	6.6	1.98	11.31	
<i>P. longifolia</i>	ES	0.19+0.095	96.82+1.887	5.96+0.045	4.11+0.175	11.24+5.760	8.01
	CS	0.08	87.59	6.8	3.61	12.21	
<i>E. saman</i>	ES	0.43+0.060	87.55+4.134	5.89+0.099	3.23+0.973	9.01+1.023	16.57
	CS	0.16	79.94	6.2	1.58	10.8	

Table 2 : Anticipated performance index (API) Values of selected tree species

Name of species	Mean APTI	Tree habitat	Canopy structure	Types of trees	Size	Texture	Economic importance	Hardiness	Total+	Grade allotted scoring (%)	API Grade
<i>S. campanulata</i>	++	++	-	-	++	+	++	+	10	62.5	4
<i>P. pterocarpum</i>	++	++	+	-	-	-	-	-	5	31.25	1
<i>M. calabura</i>	++++	+	+	+	-	+	+	-	9	56.25	3
<i>P. longifolia</i>	+++++	++	-	+	+	+	+	+	12	75	5
<i>E. saman</i>	+++	++	+	-	++	-	++	+	11	68.75	4

Table 3 : Assessment of anticipated performance index (API) values of selected tree species

Name of species	Total grade allotted		Assessment	
	+	scoring(%)	API grade	Assessment grade
<i>S. campanulata</i>	10	62.5	4	Good
<i>P. pterocarpum</i>	5	31.25	1	Very poor
<i>M. calabura</i>	9	56.25	3	Moderate
<i>P. longifolia</i>	12	75	5	Very good
<i>E. saman</i>	11	68.75	4	Good

calabura suggests their tolerance towards the pollutants. Low ascorbic acid content in the leaves of *Spathodea campanulata* and *Peltophorum pterocarpum* supports the sensitive nature of these plants towards pollutants particularly automobile exhausts. The increase in level of ascorbic acid reported may be due to the defense mechanism of respective plants (Tripathi and Gautam, 2007; Cheng *et al.*, 2007).

The result of air pollution tolerance index (APTI) calculated for each plant species studied at different sites is mentioned in Table 3. *Polyalthia longifolia* highest APTI value at all experimental sites followed by *Muntingia calabura*, *Enterolobium saman*, *Spathodea campanulata* and *Peltophorum pterocarpum*.

Different plant species show considerable variation in their susceptibility to air pollution. The plants with high and low

APTI can serve as tolerant and sensitive species respectively. Also the sensitivity level of plants to air pollutants differ for herbs, shrubs and trees. With identical values, a tree may be sensitive but a shrub or a herb may be tolerant to a given pollutant. The observations in this study suggest that plants have potential to serve as an excellent quantitative and qualitative indices of pollution. High dust collecting capacity may be one of the reasons for the sensitive plant species studied to become highly susceptible to auto-exhaust pollutants, making reduction or increase of different biochemical and physiological parameters (Singh, 2005). In the present study, among tree species *Polyalthia longifolia*, with highest APTI was found tolerant to automobile pollutants whereas *Peltophorum pterocarpum* was found to be more sensitive than others.

It is evident from the study that each parameter plays a distinctive role in determination of the susceptibility of plants (Singh *et al.*, 1991). But the evaluation of plant responses based on single criterion alone may not be feasible in the complex circumstances of an urban industrial environment where a variety of unspecified pollutants are present. So, combination of variety of parameters can give a more reliable result than that based on only one single biochemical parameter. Thus, combination of four parameters is suggested as representing the best index of susceptibility levels of plants under field conditions (Das *et al.*, 2010).

In the present study, *Polyalthia longifolia* was found as the most tolerant plant to grow along the road sides of urban areas

(Table 4 and 5). It has a dense plant canopy of evergreen like foliage, which may afford protection from pollution stress. Tree species ranked as tolerant and moderately tolerant are considered as ideal candidates for landscaping in the vicinity of polluting industry (Das *et al.*, 2010). The economic and aesthetic value of this tree is well known and it may be recommended for extensive planting as a first curtain. *Spathodea campanulata* and *Enterolobium saman* were judged to be good performers, while *Muntingia calabura* qualified for the moderate performer category. *Peltophorum pterocarpum* was found to be unsuitable as a pollution sink because of its lower anticipated performance but has been planted in industrial areas for its aesthetic value and other economic uses. The latter species are attractive plants that certainly enhance the aesthetic value of urban areas.

The APTI determination provides a reliable method for screening large number of plants with respect to their susceptibility to air pollutants. The method is simple and convenient to adopt under field conditions without adopting any costly environmental monitoring gadgets.

Plants with high APTI values are recommended to be planted along the road sides for sequestration of some toxicants from vehicular pollution while plants with high values of API would help in establishing Green Belt.

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