Differential Resistance Among Crape Myrtle (*Lagerstroemia*) Species, Hybrids, and Cultivars to Foliar Feeding by Adult Flea Beetles (*Altica litigata*)

Raul I. Cabrera², James A. Reinert, and Cynthia B. McKenney¹

Horticultural Sciences, Texas A & M University Research & Extension Center, 17360 Coit Road, Dallas, TX 75252-6599

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Abstract. Field (choice) and laboratory (no choice) studies were conducted to evaluate the susceptibility of 12 crape myrtle (*Lagerstroemia*) cultivars, representing two species and their interspecific hybrids, to feeding damage by the flea beetle (*Altica litigata* Fall). The results indicate that as a group, the *L. indica* L. cultivars were more susceptible to attack and significant herbivory damage by *Altica* beetles, whereas all the *L. fauriei* Koehne cultivars and most of the interspecific *L. indica* × *fauriei* hybrids were resistant. Significant differences in feeding damage were observed between the new and older leaves in the susceptible hybrid ‘Biloxi’ and *L. indica* ‘Whit IV’, but not in the rest of the cultivars. Mineral nutrient content differences were observed between species with *L. indica* cultivars having a significantly contrasting nutrient status profile compared with the *L. fauriei* and interspecific hybrid cultivar groups. The results indicate that the factors influencing *Altica* flea beetle-feeding preferences and damage are inherited and therefore will allow the implementation of pest management practices that minimize damage and optimize chemical control strategies. In addition, opportunities may exist for breeding and selection efforts that could lead to superior cultivars with insect resistance.

The genus *Lagerstroemia* L. is native to Southeast Asia and comprises between 50 and 80 species, most of which are concentrated in tropical latitudes (Cabrera, 2004; Egolf and Andrick, 1978; Pooler, 2003). Of these, however, less than 10 species have been cultivated as ornamental plants, in particular *L. indica* L., *L. fauriei* Koehne, *L. subcostata* Koehne, and *L. speciosa* Pers. (Pooler, 2006b). Breeding and selection efforts in the United States, and specifically at the U.S. National Arboretum, have been instrumental in the development of modern cultivars that have the typical lengthy flowering period during the summer months and a diversity of flower colors as well as disease (powdery mildew) resistance, cold-hardiness, showy exfoliating bark, and a range of sizes (from 40 cm to greater than 6 m) and growth habits (Pooler, 2003; 2006b). All these traits have led to a wide distribution and use of crape myrtles throughout southeastern U.S. gardens (Byers, 1997; Egolf and Andrick, 1978) and its categorization as a “naturalized” U.S. plant (Everett, 1981).

Attesting to this status, in 1997, the common crape myrtle, *L. indica*, was designated as the official shrub for the state of Texas (Resolution 14, 75th Texas State Legislature).

The ruggedness and low-maintenance requirements of crape myrtles both in production and in the landscape have also been associated with relatively low insect and disease pressures. The very few insects that may regularly affect the appearance and performance of crape myrtles include aphids (*Tinocallis kahawaluokalani* Kirkaldy), Japanese beetle (*Popillia japonica* Newman), Florida wax scale (*Ceroplastes floridensis* Compsock), azalea bark scale *Acanthococcus azaleae* Comstock), and several species of flea beetles (*Altica* spp.) (Byers, 1997; Egolf and Andrick, 1978; Mizell and Knox, 1993). In recent years, there have been numerous reports by nursery growers of sudden and severe damage to young crape myrtle plantings by the *Altica* flea beetle with some reports of it becoming a serious pest in containerized nursery production throughout the southeastern United States (Braman and van de Mark, 2001; Pettis et al., 2004). A number of cultivated and weedy plants in the *Oenothera*, *Calylophus*, and *Ludwigia* (primrose) family and *Lythracea* (loostrife) family are the most common hosts for the primrose flea beetles (*Altica litigata* Fall) with both adults and larvae damaging the foliage in these plants (Center et al., 2002; McKenney, Reinert, and Cabrera, unpublished data;

Schultz et al., 2001). However, only the adult flea beetles have become a pest on crape myrtles, where substantial populations of this insect can suddenly appear and severely damage and defoliate young and containerized plants (Byers, 1997; Pettis et al., 2004). To date, there have been only limited and anecdotal reports of extensive flea beetle damage to landscape-established crape myrtles.

We report on the differential resistance of containerized liners of crape myrtle species and cultivars to a severe attack of flea beetles in a nursery setting, which was followed by a no-choice feeding trial in the laboratory to verify flea beetle-feeding preference.

Materials and Methods

Nursery choice feeding study. Rooted liners from 12 cultivars, all of standard size (greater than 6 m or greater than 20 ft) at maturity representing two *Lagerstroemia* species and their interspecific hybrids (*L. indica*, *L. fauriei*, and *L. indica* × *L. fauriei* hybrids) were acquired in early May 2002. Background information on these cultivars is provided in Table 1. The liners were transplanted on 27 May to No. 4 (12-L) plastic containers holding a 2 peat : 1 pine bark : 1 sand (by volume) growing medium amended with 3 kg·m⁻³ dolomitic limestone, 0.6 kg·m⁻³ of the micronutrient fertilizer Micromax (Scotts Co., Marysville, OH), and 0.6 kg·m⁻³ of the wetting agent Aquagro (Aquatrols Corp. of America, Paulsboro, NJ). The plants were manually irrigated with a complete nutrient solution based on the water-soluble fertilizer Peter’s Excel Cal- Mag 15-5-15 (Scotts Co.) adjusted to provide a nitrogen concentration of 100 mg·L⁻¹. The plants were placed in gravel beds lined with landscape fabric in an outdoor research nursery at the Texas A & M Research and Extension Center in Dallas, TX. There were a total of five completely randomized blocks that included one plant of each cultivar per block. Plants of the cultivar ‘Sacramento’ (*L. indica*), which were acquired the previous season and were growing in 12-L containers, became heavily infested ≈29 May with *Altica litigata* Fall flea beetles (Center et al., 2002) emigrating from nearby fields having large wild and cultivated populations of evening primroses (*Oenothera* spp.). On 30 May, one severely flea beetle-infested ‘Sacramento’ plant was placed in the middle of each block of the recently transplanted crape myrtle cultivars. Additional *Altica* beetles were collected from other infested plants and scattered evenly over the plants to increase the infestation potential of the plants in the experiment. Thereafter, data were taken for 4 d on the number of beetles per leaf (average of three leaves per plant) and leaf damage (percent of leaves damaged on each plant). The observations were made separately in older and newer leaves. Older leaves were those considered to be fully developed (i.e., fully expanded), whereas new leaves were those found in the tips of the growing shoots (tender, still in expansion). Two observers made each rating,

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¹Current address: Department of Plant and Soil Science, Texas Tech University, Lubbock, TX 79409.

²To whom reprint requests should be addressed; e-mail r-cabrera@tamu.edu

which were then averaged per plant. Ten weeks after the end of this study, mineral analyses were performed in recently matured leaves collected from plants not exposed to the beetles. The nutrient analyses were done at the Louisiana State University AgCenter Soil Testing and Plant Laboratory with nitrogen measured by dry combustion in a Leco CN analyzer (LECO Corp., St. Joseph, MI) and the rest of plant essential elements done by inductively coupled plasmaspectroscopy in HNO₃-H₂O₂ tissue digests.

Laboratory no-choice feeding study. Recently matured leaves were taken from terminal shoots of a pest-free block of plants containing seven of the *Lagerstroemia* cultivars used in the previous study. These leaves were used to bioassay the flea beetle adults in a no-choice laboratory experiment. The plants from which the leaves were taken were grown and culturally managed the same as in the previous study. Two freshly excised leaves of each cultivar were placed in feeding chambers consisting of 90 × 20 mm (diameter × height) plastic petri dishes. Each dish was fitted with two water-saturated filter paper discs (75 mm diameter). During the experiment, water was added to the filter paper as needed to keep it saturated to help maintain leaf turgidity. Active adult flea beetles were taken from a colony of field-collected flea beetles, and five beetles were introduced into each petri dish. These beetles had been held in the laboratory for 10 d without any food or water before placement on the leaves in each feeding dish. Dishes were placed on a laboratory bench (21 ± 2 °C, 45 ± 10% relative humidity, and 14-h light : 10-h dark photoperiods with standard fluorescent lighting). The feeding chambers were arranged in a randomized complete block design with six replicates. Feeding damage (scored as percent of leaf area damaged in estimated 5% intervals) and beetle mortality were assessed daily for 6 d. Three observers rated the damage each day and the ratings were averaged.

Data analysis. Analyses of variance, orthogonal contrasts and mean separation procedures were performed using SAS software (SAS Institute, 2007). For statistical analyses of leaf damage percentage data in both experiments, data were transformed by taking the arcsine of their square root (Gomez and Gomez, 1984). Untransformed data are reported.

Results

Nursery choice feeding study. The flea beetles in the heavily infested 'Sacramento' plants in the midst of each block of crape myrtle liners were observed to immediately disperse to the liners. Within 24 h, significant cultivar differences were observed with respect to the average number of beetles per leaf (Fig. 1). One and 3 d after the introduction of the flea beetle-infested 'Sacramento' plants, all the *L. indica* cultivars, 'Whit IV' (Red Rocket), 'Whit II' (Dynamite), 'Carolina Beauty', and 'Dallas Red', showed the highest flea beetle population densities, a

combined daily average of 7.4 beetles per leaf. Conversely, all the *L. fauriei* cultivars, 'Kiowa', 'Townhouse', and 'Fantasy', had the lowest number of beetles per leaf, averaging less than 1 by day 3. The hybrid cultivars 'Natchez', 'Basham's Party Pink', and 'Tuscarora' had similar beetle numbers as the *L. fauriei* cultivars, except 'Biloxi', which had beetle numbers similar to the *L. indica* cultivars.

The percentages of leaves showing feeding damage after 3 d basically mirrored the observed number of beetles per leaf (Fig. 2) with 'Whit II' (Dynamite), 'Carolina Beauty', and 'Dallas Red' showing damage in greater than 90% of both their older and new foliage. These were followed by 'Whit IV' (Red Rocket), which, within the *L. indica* group, was the cultivar showing the least

damage with 45% and 79% leaf damage to old and new leaves, respectively. Most of the *L. fauriei* and hybrid crape myrtles had little (less than 10%) to no leaf damage, except the hybrid 'Biloxi', which had 98% and 17% feeding damage in its older and younger leaves, respectively. Analyses of variance and orthogonal contrasts of cultivars grouped according to species confirmed that *L. indica* cultivars were the most significantly infested and damaged by the flea beetles (data not shown).

Ten weeks after the end of this study, mineral analyses were conducted in recently matured leaves collected from liners (plants) not exposed to the beetles. The delay in conducting the tissue analyses was the result of the need to have sufficient leaf tissue mass to perform the analyses. Although it is

Table 1. Crape myrtle species and cultivars used in the *Altica* beetle nursery choice feeding study.^z

<i>Lagerstroemia</i> species	Cultivar name and abbreviation ^y	Flower color	Origin/breeder
<i>L. indica</i>	Carolina Beauty (CarolB)	Light red	Dailey's Nursery, SC
<i>L. indica</i>	Dallas Red (DallRd)	Red	Troup Nursery, TX
<i>L. indica</i>	Whit II aka Dynamite™ (Dynmt)	Cherry red	Dr. Carl Whitcomb, OK
<i>L. indica</i>	Whit IV aka Red Rocket™ (RdRkt)	Bright red	Dr. Carl Whitcomb, OK
<i>L. indica</i>	Sacramento ^x	Pink	Chopin Nurseries, LA
<i>L. fauriei</i>	Fantasy (Fntsy)	White	NCSU Arboretum
<i>L. fauriei</i>	Kiowa (Kiowa)	White	US National Arboretum
<i>L. fauriei</i>	Townhouse (Twnhs)	White	NCSU Arboretum
<i>L. indica</i> × <i>fauriei</i>	Bashams Party Pink (BPPnk)	Lavender	B. Basham & L. Lowrey (TX)
<i>L. indica</i> × <i>fauriei</i>	Biloxi (Biloxi)	Pink	US National Arboretum
<i>L. indica</i> × <i>fauriei</i>	Natchez (Ntchz)	White	US National Arboretum
<i>L. indica</i> × <i>fauriei</i>	Tuscarora (Tscrdr)	Dark pink	US National Arboretum

^zAll these cultivars are classified as "standard" size when mature (4.5 m or greater) with the exception of the dwarf Sacramento (less than 3 m).

^yAbbreviation (in parentheses) used in figures.

^xOne-year-old plants of this cultivar, heavily infested with primrose flea beetle (*Altica litigata*), were used to infest plants in each experimental block.

Fig. 1. Flea beetle (*Altica litigata*) infestation (number per leaf) in liners of selected crape myrtle cultivars growing outdoors in No. 4 (12-L) containers. Values shown are means of three leaves from each of five plants with cultivar means separation according to Duncan's multiple range test ($P < 0.05$).

Fig. 2. Mean percentage of leaves damaged by flea beetle (*Altica litigata*) feeding in liners of selected crape myrtle cultivars growing outdoors in No. 4 (12-L) containers. Older leaves were those considered to be fully developed (i.e., fully expanded), whereas new leaves were those found in the tips of the growing shoots (tender, still in expansion). Values shown are means of five plants. Capital and lowercase letters were used for old and new leaves, respectively, to show cultivar mean separation according to Duncan's multiple range test ($P < 0.05$).

acknowledged that nutrient concentrations may have changed significantly over time, our attention was directed to an assessment of the overall nutrient profile differences in the species and cultivar groups and not specifically on actual concentrations of specific cultivars. Although nutrient concentration differences were indeed observed among individual cultivars (data not shown), grouping and statistical analyses by species (Table 2) showed that the *L. indica* cultivars had an overall and significantly contrasting nutrient status profile compared with the *L. fauriei* and hybrid cultivar groups. Significant leaf nutrient concentrations were found for nitrogen ($P = 0.075$) and phosphorus, potassium, boron, magnesium, and zinc ($P \leq 0.05$).

Laboratory no-choice feeding study. Like in the previous trial, significant differences in leaf feeding damage were found among cultivars. The greatest feeding damage was observed in *L. indica* 'Dallas Red', which steadily increased over time up to 46% by day 5 (Fig. 3). In addition, this cultivar was the only one that had no dead beetles in its feeding chambers. In general, the beetles

initially fed only on one leaf, but once they damaged it $\approx 25\%$ to 33% , they began feeding on the other leaf. Conversely, less than 1% leaf feeding damage was observed in the *L. fauriei* cultivars ('Kiowa', 'Fantasy', and 'Townhouse') after 5 d, and 10% to 17% of the beetles were dead by this time, presumably as a result of starvation because the beetles had not fed for 15 d, including the 10 d of no feeding before the laboratory study was initiated.

Within the hybrid cultivar group 'Basham's Party Pink' and 'Tuscarora' had very little leaf damage after 5 d (less than 1%) and beetle mortality rates of 33% and 10%, respectively. 'Natchez' also had little feeding damage by the beetles, 7% to 10% after 5 d, and it was mostly observed as undersurface leaf tip or margin nibbling. Similar to the previous nursery choice trial, 'Biloxi' was the hybrid cultivar showing the greatest leaf feeding damage, 28% by day 5, albeit it had produced beetle mortalities similar to the other hybrids (16.7%).

Although mean comparisons of the beetle mortality data at day 5 were not significant

when compared among all cultivars, orthogonal contrasts showed that 'Dallas Red' was significantly different from the group of hybrid cultivars ($P = 0.05$).

Discussion

In both the field choice study and the no-choice laboratory study, grouping of cultivars by species revealed a significant and damaging flea beetle-feeding preference on *L. indica* cultivars and herbivory resistance in all cultivars of *L. fauriei* and most of the interspecific hybrids (Figs. 1 and 2; Table 2). Our results are comparable to those presented by Pettis et al. (2004), who reported data from flea beetle choice trials done in commercial nurseries after they had outbreaks of *Altica*, plus other no-choice laboratory and controlled studies. For their outdoor choice trials, they evaluated beetle feeding on plants of different cultivars, phenological sizes (dwarf to standard), plant ages (months up to 3 years), and container sizes (12 to 95-L containers). From these trials they reported that, in general, the *L. indica* cultivars had the highest levels of feeding damage, and the least damage was found in those with *L. fauriei* parentage (namely the *L. indica* $\times$ *L. fauriei* hybrids). Braman and van de Mark (2001) also reported similar results in no-choice studies with caged flea beetles on crape myrtle cuttings.

Our study included the three commercially available pure *L. fauriei* cultivars, 'Fantasy', 'Townhouse', and 'Kiowa' (Byers, 1997), and their performance leads to the contention that the flea beetle resistance trait observed in the majority of the interspecific hybrids was acquired from this parent species. Most of the hybrids trace their pedigree to one common *L. fauriei* parent, USDA PI 237884 (Byers, 1997; Pooler, 2003), and thus it may be presumed that many of the genotypical and phenotypical variations observed in the hybrids are likely to be more associated with the *L. indica* parents or other *Lagerstroemia* species (i.e., *L. amabilis*, *L. limii*) (Pooler, 2006b).

An analysis of the hybridization crosses and pedigrees of all the 24 interspecific hybrids released by the U.S. National Arboretum (Egolf, 1981a, 1981b, 1986a, 1986b, 1987a, 1987b, 1990a, 1990b; Pooler, 2006a; Pooler and Dix, 1999) plus the chance hybrid 'Basham's Party Pink' (Byers, 1997; Egolf and Andrick, 1978) coupled with all the

Table 2. Average leaf nutrient concentrations in crape myrtle cultivars grouped by species.^z

Species	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Iron	Boron	Manganese	Zinc
			(%)					(mg·kg ⁻¹)	
<i>L. indica</i>	2.60 a	0.31 a	1.98 a	1.79 b	0.48 a	92 a	81 a	523 a	116 a
Hybrids	2.64 a	0.27 a	1.68 b	2.08 a	0.51 a	96 a	51 b	382 b	69 b
<i>L. fauriei</i>	2.80 a	0.28 a	1.74 b	1.34 c	0.45 a	80 b	47 b	198 c	73 b
Contrast				<i>L. indica</i> vs. hybrids plus <i>L. fauriei</i>					
Pr > t	0.075	0.027	<0.001	0.270	0.985	0.288	<0.001	<0.001	<0.001
Parameter estimate	-0.024	0.067	0.528	0.156	0.001	8.6	63.3	465	90.5

^zData were taken 10 weeks after concluding the flea beetle (*Altica litigata*) feeding studies. There were four, four, and three cultivars for *L. indica*, interspecific (*L. indica* $\times$ *L. fauriei*) hybrids, and *L. fauriei*, respectively, with eight replicates per cultivar. Means within a column followed by different letters are significantly different according to Duncan's multiple range test ($P < 0.05$).

Fig. 3. Cumulative mean percentage of leaf area damaged by flea beetle (*Altica litigata*) feeding on detached leaves in petri dishes under laboratory conditions (no-choice feeding study). Values shown are means of six replicates. Vertical bar are least significant different values ($P \leq 0.05$) for cultivar comparisons for each day. Cumulative beetle mortality data at day 5 are shown next to the cultivar legends.

currently available flea beetle resistance data, including our study, brings up the general observations that many of the taller cultivars and others with more complex hybridization schemes seem to have more flea beetle herbivory resistance. For instance, and rather interestingly, the semidwarf cultivars ‘Hopi’, ‘Pecos’, and ‘Zuni’ plus the standard-sized ‘Biloxi’, which have been previously reported as the only hybrids to show some susceptibility to powdery mildew (Hagan et al., 1998), have been rated also as susceptible or moderately susceptible to damage by *Altica* flea beetle (Pettis et al., 2004; our data in Figs. 1, 2, and 3). Analyzing their pedigrees, the commonality of these four cultivars is related to their dwarf *L. indica* parents (‘Dwarf Red’, ‘Dark Red’, ‘Low Flame’, and ‘Alba Nana’) and simpler hybridization crosses. There are other flea beetle-resistant crape myrtle hybrids that share up to two of these *L. indica* parents (i.e., ‘Arapaho’, ‘Chickasaw’, ‘Pocomoke’, ‘Tonto’), but their pedigrees (hybridization schemes) are more complex, involving other medium to standard-sized *L. indica* parent cultivars/selections and even other *Lagerstroemia* species (i.e., *L. limii* in ‘Arapaho’). Although further genetic studies using controlled hybridizations are necessary to test the genetic basis of these observations, they also merit further attention and consideration by horticulturists and entomologists.

As reported previously, ‘Biloxi’ was the only hybrid cultivar in our studies showing significant flea beetle damage and it was also reported as susceptible in one of the nursery trials (25-L containers) of Pettis et al. (2004). Perhaps as remarkable were the significant

differences in feeding damage observed between the new and older leaves in ‘Biloxi’ (Fig. 2) and *L. indica* ‘Whit IV’ (Red Rocket). This differential feeding suggests significant changes or transitions in physical, biochemical, or physiological conditions as leaves age that affect *Altica* feeding preference on crape myrtle cultivars that are inherently susceptible to herbivory damage by this beetle. It has been postulated that changes in plant development affect the nutritional and defense qualities of a plant and could produce tissues with altered palatability or resistance to herbivores (Kearsley and Whitham, 1989; Schoonhoven et al., 2005). In line with this hypothesis, reports of *Altica* beetle damage on crape myrtles have been limited to young, rapid-growing plants (liners) under intensively managed nursery conditions, but not in mature, landscape-established plants. Cabrera and Devereaux (1999) previously reported that the intense fertilization and irrigation management of nursery-grown crape myrtles yield plants with vigorous (“soft”) growth and high leaf nutrient concentrations (i.e., lower C : N ratio) that are significantly different in the same plants once they are transplanted and established into a landscape with minimum maintenance. Studies with other plants and beetle species indeed confirm that fertilization and irrigation management differentially affects plant nutrition and chemistry and the degree of insect preference and herbivory damage (Lower et al., 2003). Recent literature indicates that, in general, abiotic stresses on woody plants adversely affect the performance of chewing insects (Koricheva et al., 1998; Schoonhoven et al.,

2005) and that fertilization almost always decreases tree resistance to herbivore insects (Hermes, 2002; Schoonhoven et al., 2005).

Regarding tissue nutrient status, the studies of Pettis et al. (2004) were not able to show correlations between leaf nutrient concentrations with *Altica* feeding damage in crape myrtles. Because nutrient concentrations were measured over 2 months after flea beetle herbivory resistance was assessed in our nursery choice feeding study, it is not possible to compare insect damage and plant nutrient correlations with those performed by Pettis et al. (2004). Nevertheless, our leaf mineral analyses data (Table 2) showed significantly contrasting nutrient profile differences between the *L. indica* cultivar group and the rest of the *L. fauriei* and hybrid cultivars. Although it is well known that the nutrient status of plants, particularly nitrogen, affects growth, development, and defense chemistry, the relationship between the total concentration of a mineral nutrient and insect-feeding preference or degree of damage is unclear and even conflicting (Beanland et al., 2003; Hargrove et al., 1984). Furthermore, most of these studies have focused on the link between individual plant nutrients and susceptibility to herbivory and have not considered the importance of more realistic multiple mineral–nutrient interactions. Some authors are embracing a mineral balance hypothesis that proposes that imbalances in the concentration and proportion of certain minerals impair primary or secondary metabolism to the point of enhancing a plant’s insect susceptibility and the developmental performance of insect herbivores (Beanland et al., 2003). Unfortunately for crape myrtles, as with most ornamental and horticultural crops, in-depth studies with information and reference values of nutrient ratios that optimize plant growth, physiological performance, and defense mechanisms are lacking. Detailed studies are needed to link the integral nutrient status of a plant (i.e., nutrient concentration and ratios) with functional physiological/biochemical processes and the synthesis of metabolic products conferring resistance to insect damage (Schoonhoven et al., 2005).

In summary, our studies confirm the differential resistance of crape myrtle (*Lagerstroemia*) species and hybrids to herbivory damage by the flea beetle (*A. litigata*). The field and laboratory results indicate that as a group, cultivars of *L. indica* are more susceptible to attack and significant damage by primrose flea beetles, whereas *L. fauriei* cultivars and most of its interspecific hybrids with *L. indica* and other species are resistant. These results furthermore strongly suggest that the factors influencing flea beetle-feeding preferences are inherited and therefore offer the opportunity to help breeders and horticulturists to refine breeding and selection efforts to generate superior cultivars with insect resistance. The horticultural implications of these results are significant because they will allow growers to implement pest

management practices that minimize damage and optimize chemical control strategies.

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