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Notes on new *Ruellia* L. (Acanthaceae) species on Guam*

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Abstract—Since the 1970s only one *Ruellia* species (*Ruellia blechum* L.) has been reported from Guam. A few recently introduced *Ruellia* species have become established over the island but have not been identified or documented. In this paper, we add four *Ruellia* species (*Ruellia prostrata* Poir., *Ruellia simplex* C.Wright, *Ruellia tuberosa* L., and *Ruellia ciliatiflora* Hook.) to Guam's weed list, most of which appear highly aggressive in our urban environment. These Guam *Ruellia* can be differentiated using the key and photos we provide. We also briefly discuss mechanisms that could contribute to the "success" of these plants.

Introduction

Guam, an island of 210 square miles (544 km^2) in the West Pacific, is a U.S. territory and home to three military bases. Military and commercial cargo transported via airplanes and shipping vessels arrive daily, providing stable channels for foreign species relocating to Guam. Consequently, invasive species (such as those presented here) have been a major environmental and economic issue that local biologists and residents have to battle. Meanwhile, an influx of new exotic species is constantly pressuring established urban or suburban communities as well as native ecosystems, some of which are extraordinary invaders on Guam.

One primary obstacle in managing introduced species is that new species introduced to Guam are not sufficiently documented, even for some highly invasive ones. Without knowing what they are, researchers cannot investigate their introductory pathway, ecological roles, adaptation, or strategize management plans. The non-native *Ruellia* L. on Guam is such an example (Fig. 1). Plants in this genus are herbaceous and most have showy lavender flowers. Their petals delicately wrinkle, resembling the popular petunia (*Petunia* Juss.). Despite its attractive flowers, *Ruellia* contains species that are highly invasive. For example, *Ruellia simplex*, the Mexican petunia, has been ranked in Invasion Category 1 by the Florida Exotic Pest Plant Council (UF/IFAS Center for Aquatic and Invasive Plants).

Until now, only one species of the genus, *Ruellia blechum* L. (synonym: *Blechum pyramidatum* Urb.), was documented as present in Guam (Stone 1970, Fosberg et al. 1979, Raulerson 2006, McConnell & Gutierrez 2006). But to date, we account for five *Ruellia* species/cultivar: *Ruellia blechum*, *Ruellia prostrata*, *Ruellia simplex*, *Ruellia tuberosa*, and *Ruellia ciliatiflora*. The latter four

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species are commonly sighted throughout the island but have not previously been reported on Guam. Since recent weed surveys did not capture any of these four species (McConnell & Gutierrez 2006, Reddy 2011), they probably were uncommon or did not exist on Guam before 2006.

The purpose of this paper is to document the five current *Ruellia* species on our island and distinguish them using a key and photos. We also provide an estimate of when these species possibly became established on Guam, based on our observations and previous plant surveys. Finally, we discuss potential mechanisms that might contribute to the success of invasive plant species in our urban ecosystem, using *Ruellia* as an example.

Five *Ruellia* species on Guam, 2023

On Guam, known *Ruellia* species are all herbaceous plants. The genus can be easily recognized by their opposite leaves, didynamous stamens, and 5-lobed trumpet-shaped flowers. Flowers are pale pinkish, purplish to bluish lavender (-colored), varying from species to species. The corolla is often wrinkly and showy, resembling ornamental petunias. The five *Ruellia* species that occur on Guam today can be distinguished using the key below.

1. Flowers arranged in terminal spikes with stacked, leaflike bracts. Corolla less than 1.5 cm in diameter..... *R. blechum*

1'. Inflorescence axillary cymes and/or terminal panicle. Corolla is more than 2 cm in diameter.

2. Plant prostrate..... *R. prostrata*

2'. Plant erect

3. Plant 2 feet or taller, typically 3-4 feet tall..... *R. simplex*

3'. Plant less than 2 feet in height

4. Axillary cymes, no terminal inflorescence..... *R. tuberosa*

4'. Axillary cymes with a dominating terminal panicle..... *R. ciliatiflora*

Ruellia blechum (Fig. 2), commonly known as the "Green Shrimp" plant, can be easily identified by a chain of stacked bracts like those on the Shrimp plant (*Justicia brandegeeana* Wassh. & L.B.Sm.). Flowers are small compared to the other four species. It is native to the New World tropics (POWO 2023). Its first record from the Pacific Islands was from Fiji in 1921 (Whistler 1995). Its occurrence in Guam was first documented by Stone (1970). Then Fosberg et al. (1979) published that *R. blechum* was found throughout the Mariana Islands and the Caroline Islands. Later, McConnell & Gutierrez (2006) listed it as a common weed on Guam with photographs. Our observations in recent years show populations of this species are only found in shaded areas and small populations are vulnerable to habitat alterations as a few small, scattered populations on UOG campus have disappeared in the past few years after typhoon, or grass cutting, or tree trimming.

We collected the specimens of this species and deposited them at GUAM Herbarium as: GUAM 157519, GUAM 157520.

Ruellia prostrata (Fig. 3), commonly known as the "Bell Weed". It can be distinguished from other (erect) *Ruellia* by its creeping habit. This plant has showy flowers of pale pink-lavender color, the corolla is often larger than its leaf when growing in full-sun. It only flowers in the morning, the corolla falls off after 9-10 AM. It is found in lawns throughout the island. For any early birds who take a morning walk in their yard, *R. prostrata* is quite pleasant.

This species is native to the Paleotropical realm (most to Africa and India), and introduced to Hawaii, Samoa, Cook Island, Pohnpei, and Kosrae (Pacific Island Ecosystems at Risk). It was first recorded from the Pacific Islands (Hawaii) in 1944 (Whistler 1995). Josekutty et al. (2002) reported it from Kosrae (observation of 1998-2001), which is possibly its first record in Micronesia. This species was observed by the author upon moving to Guam in 2014. It is also a common weed on Saipan today, mentioned by botanist Ana Agulto (personal communication). Space et al. (2003), Raulerson (2006) and Space et al. (2009) marked no observations of this species on Guam. It is possible this species was established on Guam after 2008 (and before 2014).

Specimens collected: GUAM 157521, GUAM 157522.

Ruellia simplex (Fig. 4), known as "Mexican Petunia", is the tallest of the *Ruellia* species found on Guam. A sterile cultivar of this species is commonly planted as an ornamental, which displays stunning lavender flowers every day. You can conveniently purchase this plant from local nurseries on the island. It can be easily propagated by cutting and it occasionally produces viable seed. It has not been observed escaping from home gardens, but owners of this plant should take precautions about its ability to spread. Wild (fertile) *Ruellia simplex,* with pink flowers, is highly invasive and has become common in Saipan (Fig. 4) and the Solomon Islands (Tanaka et al. 2020). Plant lovers should restrain themselves from bringing seeds of *R. simplex* to Guam or other islands.

The sterile cultivar was made available in 2012 (Freyre et al. 2014), therefore, its initial introduction to Guam was after 2012. The author observed it planted in a school garden in 2014, and it has become much more popular today.

Specimens collected: GUAM 157523, GUAM 157524.

Ruellia tuberosa (Fig. 5), also known as "Popping Pod", is easily recognized by the intense lavender hue of its large, flashy flowers. Some populations have flowers with a tint of blue, a rare color found on Guam. This species can be seen along roadsides or in concrete cracks such as in parking lots and pavement edges. Although found throughout the island, it does not seem as frequent or aggressive as *R. prostrata* or *R. ciliatiflora*.

Native to the New World tropics, *R. tuberosa* was previously documented from Palau in 2003 (Space et al. 2003). The author observed this plant in 2014 on the campus of the University of Guam. It is possible it was not common or not yet introduced to Guam before 2006 (Raulerson 2006, McConnell & Gutierrez 2006). It is a common weed in Saipan today as well (notes from Mrs. Ana Agulto).

Specimens collected: GUAM 157525, GUAM 157526.

Lastly, ***Ruellia ciliatiflora*** (Fig. 1), the "Hairyflower Wild Petunia", is a species complex (*Sensu* Daniel et al. 2021, synonym: *Ruellia nudiflora*) that awaits further biogeographic and phylogenetic study for species delineation. This species complex is naturally distributed in the New World tropics (POWO 2023). Today on Guam, plants form a cover over the roadside (Fig. 1), appearing much more aggressive than any other species mentioned above. Morphologically, *R. ciliatiflora* is mostly like *R. tuberosa*, but they are easy to distinguish: *R. ciliatiflora* has a terminal inflorescence, while *R. tuberosa* lacks such (Fig. 5). There is also a significant difference in corolla size (*R. ciliatiflora* has a smaller corolla) and *R. tuberosa* has a darkened throat of the floral tube (Fig. 6).

It appears that *R. ciliatiflora* is a recent introduction to Guam. The author first observed this species in 2019 near Ladera Tower in Mangilao Village. Today it is common throughout the island, mostly along roadside in grassy areas and concrete cracks in residential areas. It is astonishing how fast this plant has spread over Guam. In Saipan, this species was first observed in 2015, and is now widespread (Mrs. Ana Agulto, pers. comm.).

Specimens collected: GUAM 157527, GUAM 157528.

Results and Discussion

Given the frequent *Ruellia* introductions in recent years and their rapid spreading over the island, it is critical to understand what traits have made their invasion successful. Although our goal in this paper is not to test any invasion mechanisms (Gioria et al. 2023), we would like to outline our hypotheses and reasonings in preparation for future studies. First, ***climate change*****:** *Ruellia simplex, R. tuberosa* and *R. ciliatiflora* are three closely related species (Manzitto-Tripp & Daniel 2023). Compared to the brutal summer of the southern US where these three *Ruellia* species naturally occur, Guam's tropical heat is only mild with temperature below 34˚C. But the island has experienced steady temperature rise since the 1940s (no climate data before 1945). Average temperature increased 1.7 ˚C from 1945 to 2022 (unpublished notes from Ms. Maeyah Soberano). It is possible that heat-tolerance is the winning nature of those successful *Ruellia* in our urban ecosystem. On the other hand, warming might also have caused the populations of *R. blechum* to retreat to cooler, shaded area, explaining its decline. Second, ***concrete breakers*****:** We found *R. prostrata, R. tuberosa*, and *R. ciliatiflora* are extraordinary pioneer species that can establish in concrete cracks or the edges of concrete structures (Figs. 1, 3, 5). In addition, concrete corners, like the base of a curb, shelter weeds from grass cutting. It is likely that the weedy *Ruellia* take advantage of this protected niche. Third, ***phenotypical plasticity*****:** *R. ciliatiflora* is the most recent introduction to Guam among all the *Ruellia* but appears to be the most successful one. Within a few years since the first sighting, it appears to have become the most common *Ruellia* species on the island. *R. ciliatiflora* is a species complex with a wide distribution in the New World tropics and large morphological variation, and it contains many synonyms of species with controversial species boundaries (Daniel et al. 2021). Broad habitat and phenotypical plasticity may underlie the success of this species (Gioria et al. 2023). Finally, ***other biological features***: On Guam, weeds with showy flowers of vibrant blue-purple are rare. Could the ability to attract pollinators make these newcomers thrive and outcompete other Guam weeds? In addition, *Ruellia* species produce large quantities of tiny seeds with explosive dispersal manner, which likely aid in their invasiveness by landing and establishing in concrete cracks and dispersing far or spreading fast.

In conclusion, this report highlights several recently introduced, highly aggressive *Ruellia* species. Like *Ruellia*, there are a few other species that are rapidly changing Guam urban landscapes. However, it remains unclear whether these shifts are due to new introduction pathways, significant local climate change, or other factors. The impact of these exotic species on local agriculture and native forests has yet to be assessed. To address these questions and implement effective invasive species management, it is crucial to regularly monitor and share data on exotic species, while also updating the diversity baseline. We encourage scholars and citizen scientists to continue reporting new weeds to local and Federal agencies, making observations on iNaturalist, and discussing species that have disappeared from the island.

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Figures 1-6

Fig. 1. *Ruellia ciliatiflora* at roadside and in parking lot (top corner), Guam.

Fig. 2. *Ruellia blechum* on Guam. Inflorescence is a spike with “Shrimp-Plant” like bracts (top left).

Fig. 3. *Ruellia prostrata* in lawn and parking lot curb (top corner) on Guam.

Fig. 4. *Ruellia simplex* sterile cultivar (left) on Guam and fertile *Ruellia simplex* (right, photo by Ana Agulto) in Saipan.

Fig. 5. *Ruellia tuberosa* in a parking lot (left), *Guam; R. tuberosa* (A in the right) is distinguished from *Ruellia ciliatiflora* (B) by its exclusively axillary inflorescence, contrasting with the latter's predominantly terminal inflorescence pattern.

Fig. 6. *Ruellia ciliatiflora* (left) has corolla smaller than *Ruellia tuberosa* (right). *R. tuberosa* is also characterized by a distinct dark-throated corolla tube.