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NOTES ON A HYBRID COLONY OF *AGAVE PARRYI* VAR. *HUACHUCENSIS X AGAVE PALMERI* (AGAVACEAE) IN SOUTHEASTERN ARIZONA

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ABSTRACT

We report a small colony of hybrid agave plants from the Ciénega Ranch in southeastern Arizona that appear to be the result of a natural cross between *Agave parryi* var. *huachucensis* and *A. palmeri*, the only two agave species found in the area. The hybrids appear to reproduce via rhizomes and are intermediate in flowering time and in most morphological characteristics to those of the putative parents. Pollen staining revealed 79% non-abortive pollen and 21% abortive pollen. However, the hybrids display reduced fertility with only an average of 4.4 mature seeds per fruit and a mature seed germination rate of only 6%.

Hybridization is believed to play an important role in the evolution of the genus *Agave*. In fact several economically and ethnobotanically important species (e.g., *A. fourcroydes* Lem., *A. sisalana* Perrine, and *A. mapisaga* Trel.) are hypothesized to be of hybrid origin (Gentry 1982; Pinkava & Baker 1985). One mechanism that helps many hybrid agaves persist is clonal reproduction by rhizomes. In Arizona multiple species are reported to hybridize and two of these hybrids, *A.* x *arizonica* Gentry & J.H. Weber (*A. chrysantha* Peebles x *A. toumeyana* var. *bella* Breitung), *A.* x *ajoensis* W.C. Hodgs. (*A. simplex* (Gentry) Salywon & W.C. Hodgs. x *A. schottii* var. *schottii* Engelm.), have even been given formal taxonomic recognition and are available in the horticultural trade (Hodgson 1999; Reveal & Hodgson 2002). With the aim of further documenting the extent, distribution, and characteristics of interspecific hybridization within the genus, we detail our findings of a previously unreported natural hybrid.

In May 2016, a hybrid colony of *Agave parryi* var. *huachucensis* (Baker) Little x *A. palmeri* Engelm. was located on the Ciénega Ranch in the Sulphur Springs Valley, Cochise County, in southeastern Arizona. Ciénega Ranch is located southeast of the Dos Cabezas Mountains, northwest of the Chiricahua Mountains, and east of Hwy 186. The hybrid colony, which is dispersed over an area of approximately 7 meters by 5 meters, contains 7 large and about 12 smaller individuals (Figs. 1, 2). These hybrid plants seem to be reproducing asexually mainly, if not solely, via the production of rhizomes. Just 4 meters south of the hybrids a larger colony of over 50 adult individuals of *A. parryi* var. *huachucensis* extends over an area of approximately 60 meters by 40 meters. We found no evidence that the establishment of the hybrid colony is associated with habitat disturbance or an ecological transitional zone.

The number of hybrid plants has decreased by almost half since their discovery in 2016, probably as a result of severe drought and unusually prolonged high summer and fall temperatures in 2020. However, two clones from the colony (*Hodgson et al. 30809*) are now in the living collection at the Desert Botanical Garden in Phoenix.

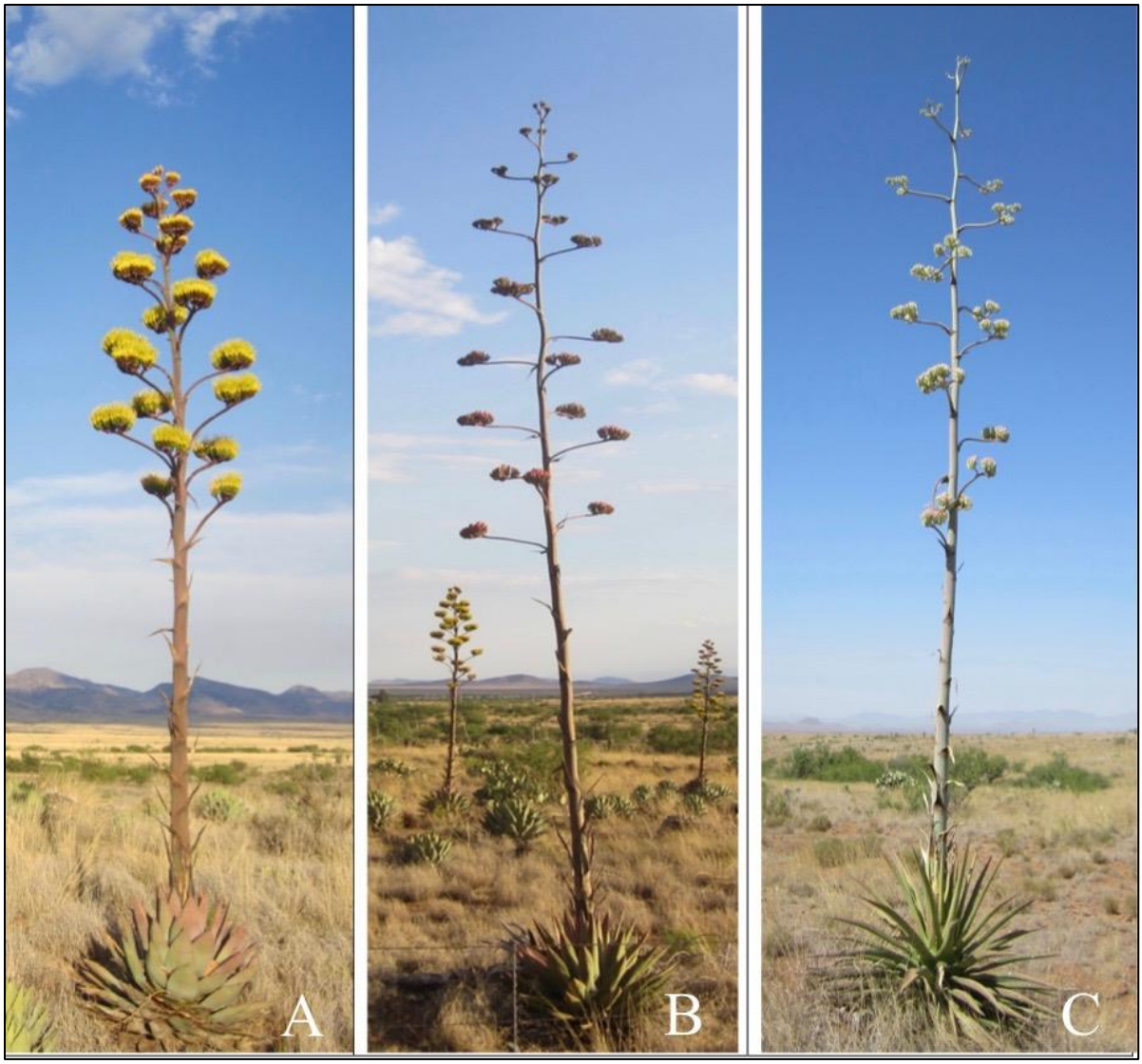

Figure 1. Habit photos. (A) *Agave parryi* var. *huachucensis*. (B) *Agave parryi* var. *huachucensis x A. palmeri* (foreground). (C) *Agave palmeri*. Photos by C. Roll, 1 June 2016 (A & B), and 21 June 2016 (C).

Plants were flowering in both the hybrid and *Agave parryi* var. *huachucensis* colonies. The relatively short and thick flower stalks of var. *huachucensis* were in full bloom with bright yellow flowers. The hybrid plants had taller and more slender stalks with pinkish-green buds, but none was open. The two colonies could be readily distinguished at that time based on these and other characters. Scattered individuals of *A. palmeri* were present in the area and some were developing flowering stalks but were not yet in flower. The nearest flowering *A. palmeri* plant is approximately 600 meters from the colonies. We did not see evidence of introgression between parents and hybrid.

Agave parryi var. *huachucensis* is typically clonal, reproducing vegetatively via rhizomes, which often leads to the formation of dense clusters of plants. For example, one dense colony of var. *huachucensis*, documented during a floristic survey of the nearby Pat Hills, is approximately 50 meters in diameter and comprises hundreds of individual plants. The colony on the Ciénega Ranch appears to be an old colony — it is not a tight aggregation of plants but instead a sprawling, and perhaps dissipating, population. We presume that most individuals within this population cluster are genetically

identical. A population genetics study on three populations of var. *huachucensis* in southern Arizona reported very low genetic diversity within similar lowland populations (Parker et al. 2014).

Figure 2. Hybrid colony of *Agave parryi* var. *huchucensis* x *A. palmeri* on right foreground with larger *A. parryi* var. *huachucensis* colony on the left. Photo by C. Roll, 25 May 2016.

Herbarium vouchers were made of individuals representing *Agave parryi* var. *huachucensis*, the putative hybrid, and *A. palmeri* and were deposited at the University of Arizona Herbarium (ARIZ), Desert Botanical Garden Herbarium (DES), Arizona State University Herbarium (ASU), and/or New Mexico State University Herbarium (NMC).

Morphology

Floral measurements following Gentry (1982) were recorded from 20 flowers including from vouchered flowering specimens (*Roll 2082, 2094, CR0026*, and *Hodgson et al. 30808, 30809,* and *30810*) and are summarized in Table 1. The average measurements of the flower parts of the hybrid plants were mostly intermediate between the parent taxa. However, the inner and outer tepal lobe and anther length of the hybrid flowers exceeded that of both parent taxa.

Table 1. Comparison of the average flower part measurements from fresh flowers of *Agave parryi* var. *huachucensis*, the hybrid *A. parryi* var. *huachucensis* x *A. palmeri*, and *A. palmeri*. Measurements following Gentry (1982): o – ovary body length; n – neck length; t – tube length; fi – filament insertion measured from the bottom of the tube; s – tepal lobe length (both inner and outer tepals); f - filament length; a – anther length; tl – total length. All measurements in millimeters.

	o	n	t	fi	s(outer)	s(inner)	f	a	tl
A.parryi var. *huachucensis*	27.6	6.6	7.4	6.7	20.0	18.7	47.9	19.4	60.9
Hybrid	29.1	4.8	12.7	8.7	20.1	19.4	57.0	24.4	66.0
A. palmeri	33.5	2.8	13.0	9.8	18.3	16.8	59.5	22.3	67.0

Figure 3. Flower longitudinal cross-sections. (A) *Agave parryi* var. *huachucensis*. (B) *Agave parryi* var. *huachucensis x A. palmeri*. (C) *Agave palmeri*. Photos by C. Roll, 2016.

Figure 4. Flowers at anthesis. (A) *Agave parryi* var. *huachucensis*. (B) *Agave parryi* var. *huachucensis x A. palmeri*. (C) *Agave palmeri*. Photos by C. Roll, 2016.

The flowers of *Agave parryi* var. *huachucensis* are strikingly bright yellow, with yellow tepal lobes and yellow or yellow-green filaments, anthers, styles and stigmas (Figs. 3, 4). This contrasts sharply with the coloration of the other parent taxa at the Ciénega Ranch as *A. palmeri* has cream to pale green shading to pink tepal lobes, brownish-green to maroon filaments, light brownish-green anthers, bright maroon style and green-brown stigma. The flower parts of the hybrid reflect the coloration of both parents, having tepal lobes that are light green shading to maroon or even a vivid pink, deep maroon filaments, bright yellow anthers and pale green style and stigma with a hint of maroon (Figs. 3, 4).

When the hybrid colony was revisited on 2 July 2020, only 11 small plants and 2 large hybrid plants were still alive, with one large plant flowering and one small plant appearing almost dead. Although there were still many *Agave parryi* var. *huachucensis* plants in the larger colony, their number appeared to have slightly decreased and none of the plants was flowering. Other colonies of *A. parryi* var. *huachucensis* in the adjacent area also were found to have no flowering stalks.

Measurements were made in 2020 of hybrid flower stalk length and circumference (at 1.5 m above the ground), leaf width, and leaf length. Length and circumference measurements were taken from the flowering stalks of 20 plants, including plants that flowered in 2020 and plants that flowered in past years (Table 2). The hybrid measurements are intermediate between the parent taxa for flowering stalk length, leaf width, and leaf length. The stalk circumference in the hybrid plants was slightly smaller than that of either parent taxon.

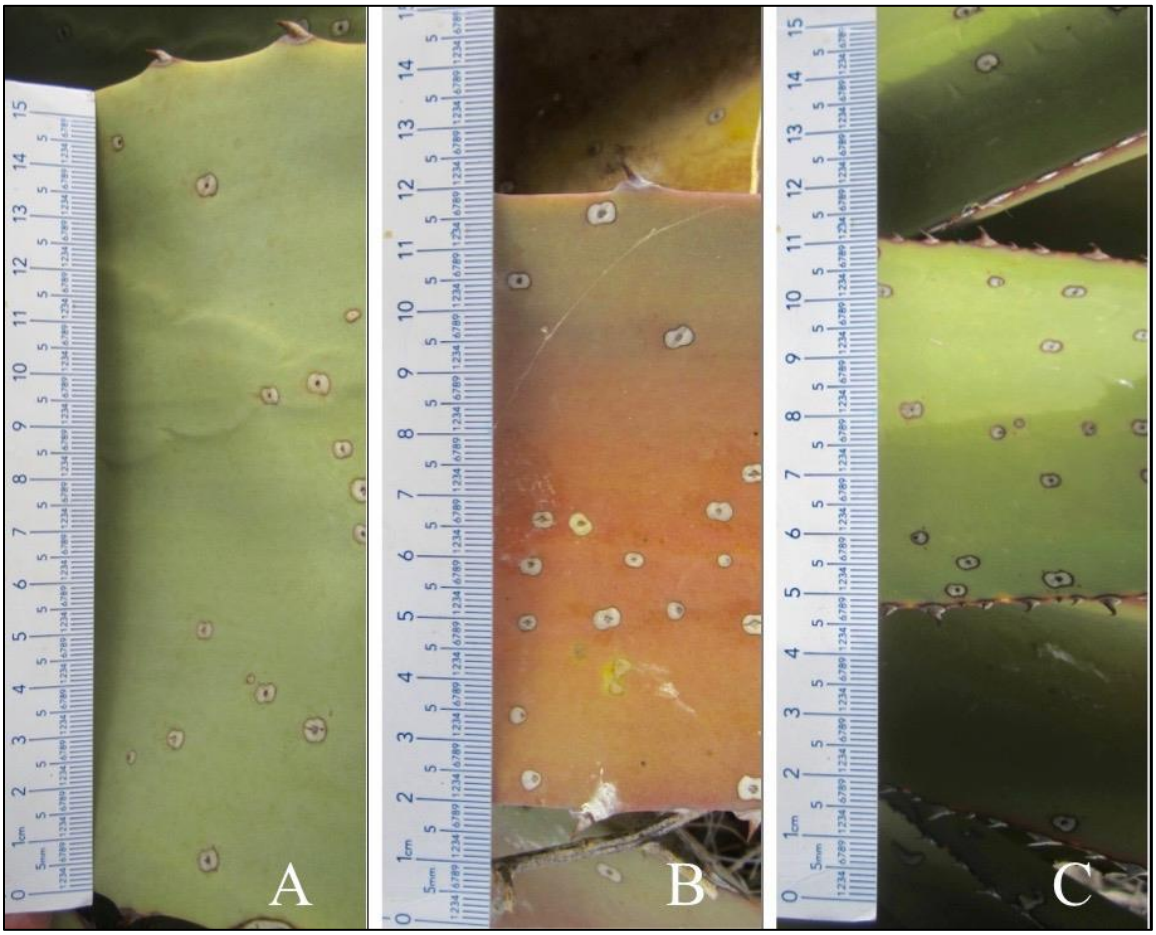

Figure 5. Leaf widths. (A) *Agave parryi* var. *huachucensis*. (B) *Agave parryi* var. *huachucensis x A. palmeri*. (C) *Agave palmeri*. Photos by C. Roll, 2020.

Table 2. Comparison of the average flowering stalk length, stalk circumference, leaf length and leaf width of *Agave parryi* var. *huachucensis*, the hybrid *Agave parryi* var. *huachucensis x A. palmeri*, and *A. palmeri*. Measured July 2020.

	A. parryi var. *huachucensis*	Hybrid	*A. palmeri*
Stalk length	4.5 m	5.9 m	6.1 m
Stalk circumference	23.0 cm	22.3 cm	22.9 cm
Leaf width	14.4 cm	11.3 cm	6.4 cm
Leaf length	35.4 cm	49.1 cm	68.6 cm

The measured narrowness of *Agave palmeri* leaves is somewhat reflective of the "rigid but somewhat guttered" leaves as described by Gentry (1982). The leaves of *A. parryi* var. *huachucensis* are what Gentry (1982) described as being "rigid, thick, nearly plane." The leaf width of the hybrid plants is intermediate between the parent taxa, but the spacing of the marginal teeth is more similar to that of *A. parryi* var. *huachucensis* (Fig. 5).

Phenology

The flowering period of the hybrid plants is intermediate between that of its parent taxa (Table 3). In 2016, *Agave parryi* var. *huachucensis* began flowering on about 16 May in the Pat Hills. The colony at the Ciénega Ranch was in full bloom by 25 May. The first flowers of the hybrid opened on 4 June while the first open flowers of *A. palmeri* at the Ciénega Ranch were observed on 22 June.

Table 3. Flowering periods of *Agave parryi* var. *huachucensis*, the hybrid *A. parryi* var. *huachucensis x A. palmeri*, and *A. palmeri* observed at the Ciénega Ranch in 2016.

May 1----May 15----June 1---- June 15----July 1----July 15----Aug 1----Aug 15	
Agave parryi var. *huachucensis*	**I**---------->
Hybrid	**I**---------->
Agave palmeri	**I**---------->

Genetic features

While *Agave palmeri* is reported to be a diploid (2*n* = 60) (Pinkava & Baker 1985), to our knowledge, no chromosome counts have been documented for *A. parryi* var. *huachucensis*. However, *A. parryi* var. *couesii* (Engelm.) Kearney & Peebles is reported to be a tetraploid (2*n* = 120) (Pinkava & Baker 1985). If var. *huachucensis* is also a tetraploid and it is assumed that the hybrid would be intermediate of the parental taxa, it would be a triploid (2*n*=90).

To gain insight into whether the hybrid displays reduced male fertility, we stained pollen obtained from an anther on specimen *Hodgson 30809* (DES 00087063) with cotton blue to determine the frequency of abortive (non-stained) vs. non-abortive pollen (stained). Out of 476 pollen grains observed, 366 (77%) were normal-sized and stained, 82 (17%) were normal-sized and unstained, 7 (2%) were mico-pollen and stained, and 21 (4%) were micro-pollen and unstained. In total, 79% of the pollen was non-abortive and 21% was abortive. The presence of abortive pollen and micro-pollen is an indication of meiotic irregularities which can be associated with hybridization.

On 27 July 2020, the sole flowering hybrid plant had produced 24 fruits, with some absciscing prematurely and falling to the ground. A total of 20 fruits were collected from the ground between 27

July and 25 August. On 25 August, 4 fruits remained on the plant and were dehiscing normally with seeds spreading in the wind. The 20 fallen fruits had an average length of 44.0 mm and an average width of 18.8 mm. These fruits contained a total of 87 mature black seeds that averaged 6.7 mm long x 4.9 mm wide. The most mature black seeds observed within a single fruit was 14, and the average number of mature black seeds per fruit was 4.4.

To determine if the hybrid produces viable seed, 50 mature black seeds were planted in a small pot in a greenhouse at Desert Botanical Garden on 28 August 2020. By 14 September, 3 of the 50 seeds (6%) had germinated, with no further germination after that date. Although the germination rate for the hybrid seed is low, these hybrid plants apparently have the ability to persist by vegetative means and also by viable seeds.

No plants of *Agave parryi* var. *huachucensis* flowered in 2020 in the area of the hybrids, thus either the seeds were formed apomictically or by self-pollination or else by pollination by an early blooming *A. palmeri* plant from over 0.5 km away.

ACKNOWLEDGEMENTS

Josiah Austin, owner of the Ciénega Ranch, has generously allowed us to explore the botanical diversity of his property and his trust and friendship are truly appreciated. His good stewardship of his land is also appreciated. We thank the Desert Botanical Garden for its continued support of botanical exploration and Steve Blackwell for sowing the hybrid seed and caring for the seedlings.

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