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Observations on *Zizania texana* (Texas wildrice), an endangered species

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TERRELL, E. E. (Plant Taxonomy Lab., Plant Genetics and Germplasm Inst., U.S. Dept. Agric., Beltsville, MD 20705), W. H. P. EMERY (Dept. Biol., Southwest Texas State Univ., San Marcos, TX 78666) and H. E. BEATY (Temple Junior Coll., Temple, TX 76501). Observations on *Zizania texana* (Texas wildrice), an endangered species. Bull. Torrey Bot. Club 105: 50–57. 1978.—*Zizania texana* is restricted to 2.4 km of the upper San Marcos River in southcentral Texas. Physical and chemical characteristics of the San Marcos River are unusual, being characterized by alkaline or neutral pH and water temperature varying only ca 5 C annually. Taxonomic comparison of *Z. texana* with *Z. aquatica* and *Z. palustris* showed several important morphological differences; these were maintained in cultivation, although *Z. texana* lost its streaming, submersed habit. *Zizania texana* is geographically isolated from all other *Zizania* taxa by at least 640 km. Viable seed obtained in cultivation produced 500 new clones. Human disturbances have affected *Z. texana* adversely. Survival depends on continued water purity and abundant flow from Spring Lake, source of the river. We are attempting to preserve the habitat and to transplant cultivated clones to other localities in central Texas.

Texas wildrice, *Zizania texana* Hitchcock, is of special interest because of its rarity and its problematical relationship to other species of *Zizania*. Curiosity about the validity of the species led the senior author to visit its native habitat in September 1973, in company with the junior authors, who had published previously on the species. Subsequently, we accumulated data concerning ecology, distribution, morphology, taxonomy, and response to cultivation.

Zizania texana is restricted to a 1.5 mile (2.4 km) length of the headwaters of the San Marcos River, within the city limits of San Marcos (population ca. 20,000), Hays County, southcentral Texas. Formerly, the species occurred also at the headwaters of the river in Spring Lake, but it has been destroyed there.

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Historical background. The first documented collection of *Zizania texana* was by G. C. Nealley in August, 1892 (U.S. National Herbarium sheet 979361). It is labelled *Z. aquatica,* thus Nealley may not have suspected it to be different. A later collection by Ena A. Allen on July 10, 1921 (US 1611456) was labelled *Z. texana* apparently by A. S. Hitchcock long after its collection. Both of these collections came from the San Marcos River.

The discovery and recognition of *Z. texana* as a distinct species was by W. A. Silveus, an attorney and amateur botanist living in San Antonio, Texas. In a letter (preserved with the holotype in the U.S. National Herbarium) dated April 4, 1932, Silveus wrote to Agnes Chase, U.S. National Herbarium, regarding one of his collecting trips: "I travelled about 180 miles yesterday and got only one grass—is too dry—then the frost nipped them off.

"At San Marcos near a road crossing I found a great deal of *Zizania palustris,* but it was growing in an unexpected way from what I had read about it. The San

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Marcos River arises a short distance above this crossing, and as a rule the flow is about constant, the stream is about 40 ft wide and has lots of water—the current rapid.

"This grass was growing in water from 1–4 ft deep mostly some distance from the bank—the plant prostrate on or just under the surface of the water, and in many of the plants the flowering part of the culm 1–2 ft above the water, the stem geniculate where it left the water, and sometimes rooting at that place. The leaves were as much as 5 ft long, about 8–10 mm wide at the base and 15–20 mm above, . . .

". . . I could understand if the river should rise suddenly and cause this grass to become prostrate on the water, but this stream has a pretty steady flow all the time. . . . I had expected to find it [*Zizania*] along the margins of the stream growing more or less like *Zizaniopsis.*"

A subsequent letter (Nov. 7, 1932) to Mrs. Chase noted, "I came home by San Marcos and took another look at *Zizania* and found it still blooming. It blooms from April to Nov. anyway and the man at the pump station on the bank of the lake says it blooms all year if warm. He says they clean it out and [it] comes up again immediately. It covers several acres on lake and along stream below."

A third letter from Silveus, with comments similar to the above, and apparently sent to A. S. Hitchcock, was quoted by Hitchcock (1933) in connection with his original description of *Z. texana.* Silveus's book (1933) on the grasses of Texas summarized general information about *Z. texana* and included an excellent photograph of the plant in its native habitat. This original photograph accompanies the holotype specimen and is reproduced here (Fig. 1), courtesy of the Smithsonian Institution.

The type collection of *Z. texana* is in the U.S. National Herbarium: *W. A. Silveus 518,* April 1932, floating in San Mar-

Fig. 1. Original photo by Silveus. *Zizania texana* in San Marcos River.

cos River near San Marcos, Hays Co., Texas (Holotype US 1537174; isotype US 1720531). It may be inferred from Silveus's letter of April 4 that the type collection was gathered on April 3, 1932.

Ecology and distribution. The upper San Marcos River is a rapidly-flowing, usually clear river, some 5–15 m wide and up to ca 4 m deep. For the first few kilometers the river flows mostly over a firm gravel bottom with many shallow ripples alternating with deep pools. Its relative narrowness and swiftness give it the aspect of a northern trout stream. Accumulated flow records for the fifteen years ending in 1971 show that the water velocity averages 157 cu ft/sec. (U.S. Dept. of Interior 1967–1971; Beaty 1972). The water temperature as it issues from the springs is constant at 21.5 C. At the lower end of the wildrice habitat a range of temperature from 25.5 C in August to 20.4 C in February has been recorded. The water tends to be alkaline or neutral due to the limestone source: reported pH in San Marcos Springs is 6.9–7.8 (Texas Water Devel. Board 1968). Two readings taken during the present study were pH 7.4 and 7.9.

Spring Lake (altitude 189 m) was created over fifty years ago by the damming of the San Marcos River not far below the springs which form its source. The springs discharge 200 million gallons of water daily from the Edwards limestone where it is faulted against the Pecan Gap Chalk. Due to the clarity of its water, Spring Lake is now the site of a major tourist attraction, Aquarena Springs, Inc., featuring glass-bottomed boat rides and a submarine theater.

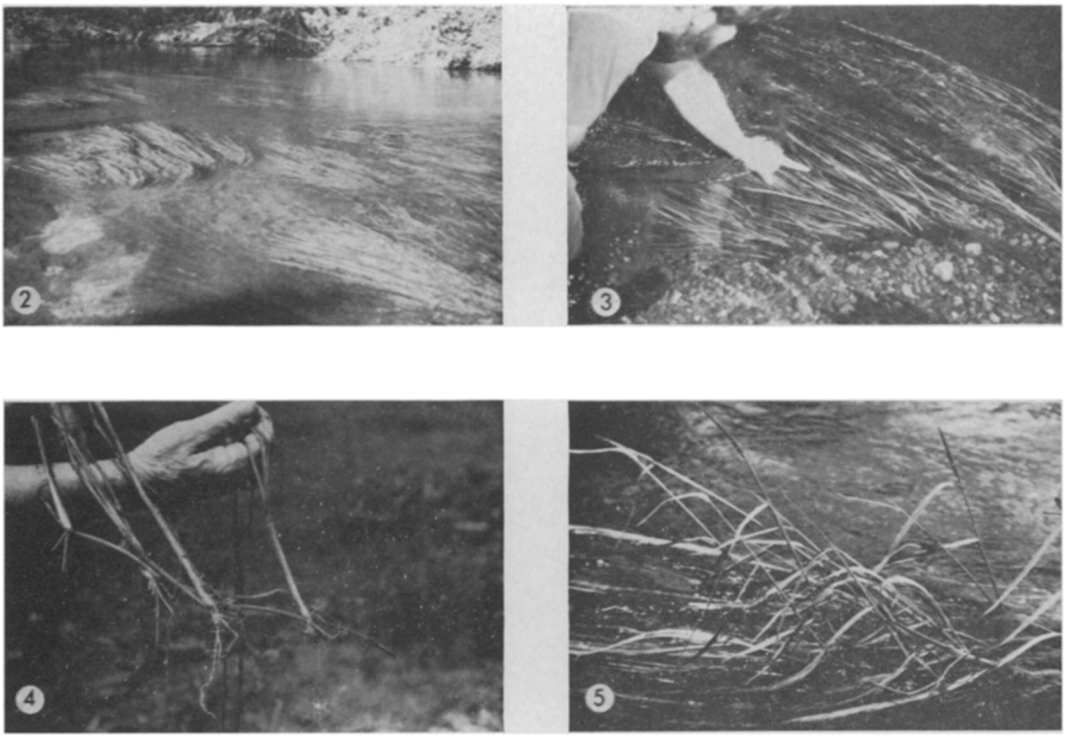
At the time it was discovered *Z. texana* was very abundant in the San Marcos River, in contiguous irrigation ditches, and in Spring Lake, requiring considerable effort by the irrigation company to keep the luxuriant growth under control (Silveus 1933). Thirty four years later its abundance had been drastically reduced. Emery (1967) found only one plant in Spring Lake, no plants in the uppermost 0.8 km of the San Marcos River, and scattered plants in the next 2.4 km. In 1970 Emery surveyed the lower reaches of the river by boat, but he did not find any wildrice.

In 1976 Emery again checked on the abundance of wildrice in the upper parts of the river. Utilizing a floating frame one meter square to measure the area of vegetative dominance, he found that wildrice plants covered 1,131 m^2 of river habitat. The highest concentrations were in the extreme upper and lower segments of the 2.4 km length of the river. He did not find any wildrice in Spring Lake.

Plants of *Z. texana* form large clumps or masses which are firmly rooted in the gravel bottom of the river (Figs. 2, 3). Culms and leaves are completely immersed and long-streaming in the swift current. Plants are geniculate and produce roots from the lower nodes (Fig. 4). Silveus's description (1933) and his photograph (Fig. 1) indicate that formerly, when there was less human disturbance, culms and panicles projected as much as one meter above the water. At the present time, however, flowering plants are rarely seen, and when present, do not extend very far above the surface (Fig. 5). Plants often grow in the swiftest currents of the shallow areas near the middle of the river. Other plants are in water 2–3 m deep, and the streaming leaves remain below the surface, the clear water allowing passage of sufficient light for photosynthesis.

In the upper 0.4 km of the portion of the river inhabitated by the wildrice, associated species include *Potamogeton illinoensis* Morong, *Vallisneria americana* Michx., *Sagittaria platyphylla* (Engelm.) J. G. Sm., and *Hydrilla verticillata* (L. f.) Royle. Throughout most of the remaining 2.0 km of the habitat the Texas wildrice is most frequently in isolated clumps, and competition from other species is of minor importance.

The origin of *Z. texana* poses interesting but difficult problems. In view of its morphological differences we suppose that *Z. texana* evolved its differences over a substantial period of time. It may have evolved in geographic isolation, as there are no other populations of any *Zizania* taxon in Texas. The nearest populations of *Z. aquatica* are in southern Louisiana, about 400 miles (640 km) to the east. Like other southeastern Coastal Plain populations of *Z. aquatica,* these plants are quite different morphologically from *Z. texana.* They are giant grasses to 4 m high, with only their lower culms immersed and with leaves 3–5 times broader than those of *Z. texana.* The nearest populations of *Z.*



Figs. 2–3. Immersed plants of *Zizania texana* in San Marcos River.
Figs. 4–5. *Zizania texana:* plant taken from San Marcos River showing rooting at lower nodes; plant with immature inflorescences growing in San Marcos River.

palustris are several hundred miles to the north and northeast, in Missouri, Kansas, and Arkansas.

Morphology and taxonomy. The following description of *Z. texana* includes data from Hitchcock (1933), Silveus (1933), and Correll and Johnston (1970) as well as our present findings.

Perennial aquatic, immersed, culms and leaves long-streaming in river currents with only inflorescence emergent, or in slow currents with upper culms and leaves emergent. Culms many, decumbent, geniculate, rooting at lower nodes (Fig. 4), stoloniform, to 3 m long (reported sometimes 5 m by Silveus 1933) when immersed, 1–2 m when partly emersed, basal sheaths yellowish or straw-colored. Ligules usually dark basally, whitish distally, 4–12 mm long, 2–5 mm wide, caudate-acuminate or acuminate. Leaves linear, immersed ones soft and flexible, to ca 1 m long, to 13(–20) mm wide (reported to 25 mm wide by Silveus 1933), aerial leaves rather stiff, tapering to caudate apices. Panicles 16–31 cm long, 1–10 cm wide, with staminate branches below, pistillate branches above. Staminate branches ascending or somewhat spreading, to 10 cm long, pedicels 1–9 mm long, the terminal expanded articulation ca 0.3 mm in dia. Pistillate branches appressed or ascending, to 7 cm long, pedicels 1–7(–13) mm long, the terminal expanded articulation 0.5–0.9 mm in dia. Staminate spikelets ovate or oblong, 6.5–11.0 mm long, 1.2–2.0 mm wide, glabrous to pubescent or scaberulous; lemma and palea similar, thin, acute to short caudate-acuminate. Anthers six, linear, yellow, 3.2–7.0 mm long. Mature pistillate spikelets 9.0–12.5 mm long, 1.2–1.8 mm wide, lemma and palea adnate along margins, somewhat thickened and leathery, light brown, greenish, or basal half greenish, distal half whitish, somewhat lustrous, tapering gradually to terminal awn 9–35 mm long and scabrous or hispidulous with scattered prickle hairs, these slightly denser and longer at base of awn. Aborted pistillate spikelets 7.5–12.0 mm long, 0.7–

1.2(–1.5) mm wide. Caryopses (as grown in cultivation) 4.3–7.6 mm long, 1.0–1.5 mm wide, cylindrical, widest near middle and gradually tapering to slightly rounded ends, only 1/2–3/4 as long as lemma and palea, black, brown, or greenish, linear scutellum 1/2–3/4 as long as caryopsis.

In this paper we use the common name "wildrice," following Correll and Johnston (1970). We follow Dore (1969) in recognizing as distinct species *Z. aquatica* L. (southern wildrice) and *Z. palustris* L. (northern wildrice). The former is concentrated along the Atlantic Coastal Plain westward to Louisiana, and extends into southern New England and westward into Wisconsin. The latter is in New England, eastern Canada, and Great Lakes region westward into Manitoba. Northern wildrice has long been known as an Indian food (it usually has larger grains than southern wildrice) and has recently been brought into cultivation in Minnesota and Canada as a new crop. Another species, *Z. latifolia* (Griseb.) Turcz. ex Stapf, is native to eastern Asia.

Little has been known previously about the taxonomic status of *Z. texana*. Dore (1969) called it a "dubious species" and suggested that its underground parts might have been confused with the rhizomes of *Zizaniopsis miliacea* (Michx.) Doell & Aschers. Dore (letter to Terrell, 26 Nov. 1974) explained that some years ago after he had requested plants of *Zizania texana* from a Texas correspondent, he was sent rhizomes which grew into *Zizaniopsis miliacea*.

During the present study Emery found *Zizaniopsis miliacea* along banks of the San Marcos River and at two sites immersed in the river, with streaming culms and leaves. One plant was grown to maturity from rhizomes. Emery found that *Zizaniopsis miliacea* may be distinguished vegetatively from *Zizania* by its bluish coloration, leaf anatomy, and large rhizomes. Terrell & Robinson (1974) noted differences also in the arrangement of the stellate cells in the leaf sheath, and after comparing *Zizania* and *Zizaniopsis* in several important reproductive and vegetative characters concluded that they belonged in separate subtribes.

Taxonomic comparisons of *Z. texana* with other *Zizania* species are limited here to a tabular comparison and brief discussion, pending the completion of more definitive studies. We consider *Z. texana* a good species as its differs in several characters (Table 1). We grew *Z. texana* side-by-side with *Z. aquatica* and *Z. palustris*

Table 1. Comparison of three American taxa of *Zizania*.*

	texana	*palustris* var. *palustris*	*aquatica* var. *aquatica*
Duration	Perennial	Annual	Annual
Plant height (m)	1–2	1–2	2–4.3
Habit	Immersed, prostrate, varying to erect and mostly emergent	Usually 25–75% emergent	Usually 70% or more emergent
Leaf width (mm)	7–13(–20)	4–14	Usually 10–53
Pistillate infl. brchs. (at maturity)	Appressed	Appressed	Wide-spreading
Ligule (upper) shape	Caudate-acuminate or acuminate	Rounded, truncate, or somewhat acuminate	Rounded, truncate or somewhat acuminate
Spikelet length (mm)	9.5–12.5	10–20	7.5–21
width (mm)	1.2–1.7	1.7–2.1	1.0–1.8
Lemma, palea: texture	Somewhat leathery	Leathery	Papery
Margins attached	Rather tightly	Tightly	Loosely, sometimes separating
Prickle hairs	Scattered	In lines	Scattered
$\frac{\text{Caryopsis length}}{\text{Spikelet length}} = \%$	50–70	70–90	80–90

* Excluding *Z. aquatica* var. *brevis* (see text) and *Z. palustris* var. *interior* (Fassett) Dore (*Z. aquatica* var. *interior* Fassett). Latter may be hybrid of *Z. aquatica* and *Z. palustris*.

in a greenhouse tank at Beltsville, Maryland, and in an outdoor sluice at San Marcos, Texas. In cultivation *Z. texana* changed from a prostrate, immersed plant to an erect, emergent one, but significant differences were maintained in spikelet and inflorescence characters, leaf width, and plant height.

The lemmas and paleas of *Z. texana* bear scattered prickle hairs like *Z. aquatica,* whereas *Z. palustris* has these hairs in lines. The textures of the lemmas and paleas in *Z. texana* are more or less intermediate to those in *Z. aquatica* and *Z. palustris* (Table 1). In *Z. texana* spikelets from cultivated plants in Texas and Maryland (different clones) the mature caryopses are only 50–70% as long as the lemma and palea; in *Z. aquatica* and *Z. palustris* the caryopses occupy nearly all of the spikelet. The panicle of *Z. texana* is rather similar to that of *Z. palustris* in having appressed pistillate branches (visible in Fig. 1), rather than the long, widely-spreading ones of *Z. aquatica. Zizania texana* is also similar to *Z. palustris* in having narrow leaves and relatively low stature. *Zizania texana* is the only perennial American species, but it remains to be determined how strongly perenniality is influenced by the warm, more or less constant temperature in the San Marcos River. *Zizania texana* is somewhat similar vegetatively to *Z. aquatica* var. *brevis* Fassett, an endemic of the St. Laurence estuary in Quebec, but spikelet and inflorescence characters of var. *brevis* are similar to these of *Z. aquatica* var. *aquatica.* The chromosome number in *Z. texana* is $n = 15$ or $2n = 30$ (Brown 1950), which is the same as that reported for *Z. aquatica* and *Z. palustris.*

Emery has obtained data (unpublished) on amino acid content in *Z. texana* grains. It will be interesting to compare these data when published with those already known for protein and lysine in *Z. aquatica, Z. palustris,* and *Z. latifolia* (Terrell and Wiser 1975) and for other amino acids in *Z. palustris* (as *Z. aquatica*) by Oelke (1976).

Observations in cultivation. Three small clumps of *Z. texana* collected from the San Marcos River were brought to Beltsville, Maryland by Terrell in September 1973, where they were transplanted into large plastic pots containing greenhouse potting soil. They were then placed in a 1×3 m tank of tap water and were maintained with a few cm of water over the soil surface in the pots. The water in the tank was regulated at a constant temperature of ca 23 C and was kept circulating (but not aerated) by an electric pump. Water was replaced at monthly or bimonthly intervals.

By December 1973, only one of the three plants had survived. This plant, instead of growing immersed as in nature, produced several erect, aerial culms up to 1 m high. The plant flowered abundantly from January 1974 through the summer of 1974, and resembled the aerial culms shown in Fig. 1, but was somewhat less robust. The plant was eventually divided into four. In autumn-winter, 1974, these plants were attacked by two-spotted mites (*Tetranychus urticae* Koch) and were considerably weakened. By January, 1975, the plants were dead. It is suspected that the mites were not entirely responsible for their demise; environmental factors may not have been favorable for growth.

During 1974 about 80 seeds were obtained from self-pollination of the plants in the greenhouse. These seeds appeared to be of normal size compared to others in the herbarium of the Patuxent Wildlife Research Center, Laurel, Maryland. Some seeds germinated, but consistently failed to survive after reaching a few cm length. A few seedlings grown in San Marcos River water also died. Further attempts were made in 1975 and 1976 to grow *Z. texana* in the greenhouse tank at Beltsville, but even in the presence of supplemental light the seedlings died. We concluded that *Z. texana* needed special requirements not adequately met at Beltsville; seedlings of *Z. aquatica* and *Z. palustris* were grown to maturity under these same conditions.

In 1975 Emery moved four clones of *Z. texana* from its river habitat to a constant temperature, artesian, spring-fed sluice on the campus of Southwest Texas State University in San Marcos, where it was possible to regulate both the velocity and depth of the water. The four clones produced vigorous growth and abundant foliage. Their growth form was dramatically altered. The decumbent culms and submerged leaves characteristic of the river clones changed to erect culms with emergent aerial leaves. Inflorescences

formed, and cross fertilization of the numerous florets produced more than 1,500 seeds during the summer of 1975. As with other wildrice species, freshly harvested seeds appeared to have an extended dormant period. When seeds were placed in spring water and refrigerated at 3 C, 105 days were adequate to break the dormancy. Germination varied from 60–100%. The dormancy of Texas wildrice appeared to be related in part to the permeability of the pericarp. Germination (usually less than 50%) may be obtained soon after harvest by either puncture or scraping of the pericarp away from the embryo (cf. Simpson 1966, and Woods and Gutek 1974).

Seeds were germinated in petri dishes filled with tap water. The water was changed daily. Seven to ten days after germination the seedlings were transferred to pots containing river gravel. The pots were kept immersed a few cm below the water surface and care was taken to prevent currents that would disturb the seedlings. By the end of August, 1976, about 500 sexual clones of *Z. texana* had been cultured in this way.

Aspects of conservation. *Zizania texana* was proposed as an endangered species in the list published in the Federal Register (U.S. Fish and Wildlife Service 1976). We believe this designation to be a realistic one. The location of *Z. texana* within the city limits of San Marcos has made protection difficult. Emery (1967) in discussing the decline of the wildrice mentioned some disturbing factors: (1) the regular mowing of aquatic vegetation in Spring Lake to render the lake more attractive to tourists allows floating masses of cut vegetation to move downriver and damage or break off the exserted inflorescences of the wildrice; this interferes with pollination and reproduction by seed, (2) city workers periodically plough or harrow the river bottom in accessible locations to rid it of clogging vegetation, (3) two commercial enterprises selling exotic aquatic plants for home aquaria disturb the river and lake vegetation, (4) raw sewage is discharged into the river whenever the capacity of the city's sewage system is exceeded. Emery (1977) reported that ten years later the impact of these factors had significantly abated, but there had not been any reproduction from seed or any significant vegetative spread from existing clones.

The wildrice is particularly vulnerable to chemical changes in its aquatic milieu. An additional threat is the ever-present possibility of accidental pollution by runoff of locally-applied herbicides or pesticides.

The best means of preserving the species is by preserving the habitat intact and undisturbed. Education of the public may help in this regard through talks, newspaper reports, and articles such as the one by Beaty (1975). We would discourage the casual collecting of *Z. texana* by botanists and others.

A partial management alternative is transplantation to other localities. Clones transplanted to Salado Creek, Bell County, central Texas, have so far been successful. Emery's program of cultivation in a spring-fed sluice is intended to permit relocation without encroaching on native populations. More than 100 clones of nursery-grown wildrice were transplanted in 1976 to locations in central Texas. Transplantings to Spring Lake were eaten by the introduced mammal,, Nutria, (*Myocastor coypus* (Molina). It is hoped that transplantings elsewhere, especially to barren sections of the San Marcos River, can ultimately succeed. In the introduction effort, we are faced with some of the same pressures causing the decline of the native populations and with the very restricted physiological and ecological requirements of Texas wildrice. Data now being accumulated may lead to a better assessment of the vital requirements of the species.

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