TUMBLEWEEDS OF CALIFORNIA: WHO, WHAT, WHERE AND HOW?

Debra Ayres[1], Fred Ryan[2], Fred Hrusa[3], and Pat Akers[3]

UC Davis, USDA, CDFA

Variety of forms of *S. tragus*

Abstract: Tumbleweeds are noxious large summer annuals that impede traffic, create fire hazards, and are the alternate host for the beet leafhopper (*Circulifer tenellus*) that can carry the virus causing curly-top of sugarbeets, tomatoes, melons and other crops. Russian thistle, Salsola tragus, has spread widely throughout the U. S. since its introduction in the 1800s. Barb-wire tumbleweed, *Salsola paulsenii*, has been known for decades from the transmontane regions. A third *Salsola* species, referred to here as Type B, was recently recognized as occurring widely throughout low elevation cismontane California. Two additional *Salsola* taxa termed Type C and "lax", were found in the southern San Joaquin Valley and western Mojave Desert. Our goals were to develop keys to identify these five taxa, to determine whether the groups were genetically distinct using DNA markers, to map the distribution of the four taxa that occur north of the Tehachapi, and to determine the relationships among the taxa using microsatellite DNA markers. A principle components analysis based on morphological traits distinguished the five taxa. Both RAPD and ISSR DNA markers clearly separated the 5 groups genetically. *S. tragus* and Type B were widespread in the central valley and coast ranges, while 'lax' and Type C were found primarily around Bakersfield and in the western Mojave. Microsatellite analyses suggested that Type C is an interspecific hybrid between *S. tragus* and Type B, and that "lax" is a complex hybrid involving *S. tragus*, Type B, and *S. paulsenii*. California tumbleweeds were the subject of previous biocontrol attempts in the 1970s which were not successful and efforts are currently underway to identify more agents. For this reason, and due to the potential invasiveness of hybrids (e.g. *Spartina*), recognition of these distinct taxa is important.

Uniform morphology Type B

WHO….

Plants from all taxa were grown from seed in a common garden at the CDFA facility in Sacramento. Morphological measurements were analyzed by principal components analysis which sorted the taxa into 5 groups; key characters were then determined and developed into a taxonomic key by Dr. Fred Hrusa, CDFA.

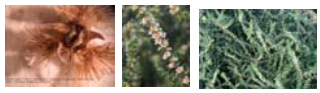
At least some mature perianths with distinct wings. These gen. 5 in number, the smallest two (minor wings) sometimes highly reduced.

A. Perianth (not the wings) at maturity forming a sharp spinose tip. Minor wings small, triangular pointed. All fruits forming wings. Plant stiff and very spiny at maturity. Desert regions.

S. paulsenii

AA. Perianth (not the wings) at maturity +/-soft, not forming a sharp spinose tip. Fruits all winged or some fruits not winged. Deserts and cismontane regions. B.

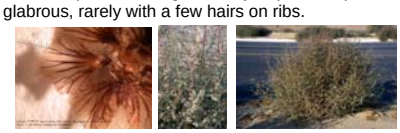
B. In mature plants, lower fruits not forming wings. Minor wings with distinct narrow lamina, distal portion not broadened at summit. Stem hairs restricted to ribs.



S. tragus

BB. Generally all fruits eventually forming wings, rarely a few at very base minutely winged only. C.

C. Individual minor perianth wings broadly expanded (the ratio of length to width +/- 1). Stems gen. glabrous, rarely with a few hairs on ribs.



Type B

CC. Individual minor perianth wings not broadly expanded, often less than 0.5 mm (length/width ration obviously > 1). D.

D. Stems hairy, minor perianth wings often highly reduced, nearly obsolete, or linear with a sharp point (length/width ratio >> 1). Venation of a minor wing not visible except maybe a single vein in the middle. Plants stiff and spiny at maturity, similar to *S. paulsenii*.

***Salsola* "lax"**

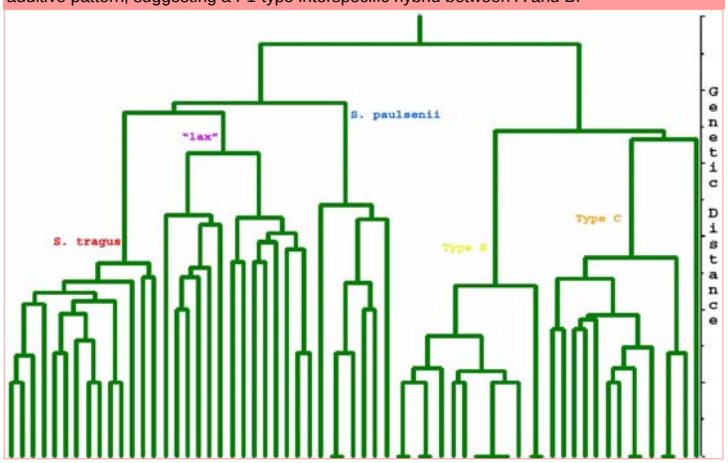
DD. Stems sparsely hairy or glabrous. Minor perianth wings variable, gen. broadly oblanceolate or obovate, the distal portion often wider than the limb, but the length/width ratio > 1. Venation of a minor wing gen. with several veins in the distal portion.

Type C

WHAT….

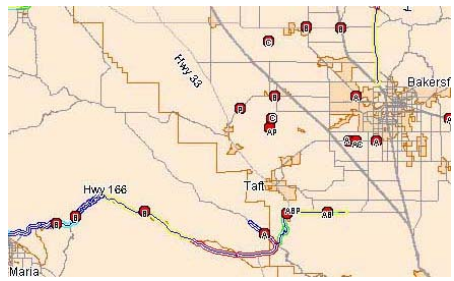
Each individual was genetically phenotyped for 25 RAPD and 43 ISSR DNA fragments scored as present or absent (1 or 0). Genetic distance between individuals was calculated as Euclidean distance. The relationships among individuals were portrayed using UPGMA clustering.

Each morphologically discrete group was also genetically distinct. *Salsola* "lax" contained fragments specific to *S. tragus*, Type B, and *S. paulsenii* suggesting a complex hybrid involving all three species. Type C contained fragments specific to Type A and Type B, in an additive pattern, suggesting a F1-type interspecific hybrid between A and B.



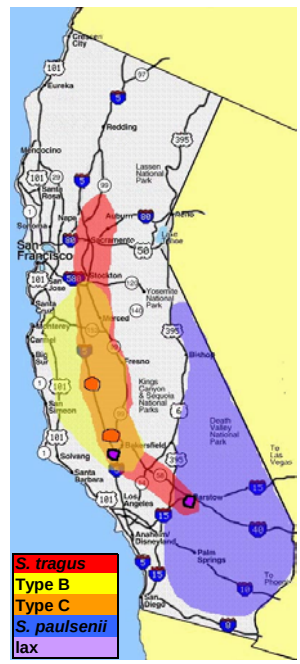
WHERE….

Locations of *S. tragus*, Type B, Type C, and *Salsola* lax were mapped on survey trips in 2002-03. The actual ranges of *S. tragus* and Type B are more extensive; *S. tragus* extends to the top of the Sierra and into Washington State (at least); Type B has been found as far east as Phoenix, AZ. In September 2005, large numbers of lax were found in western Nevada, the eastern Mojave, around Mono Lake and in the Owens Valley, occurring with both *S. paulsenii* and *S. tragus*.



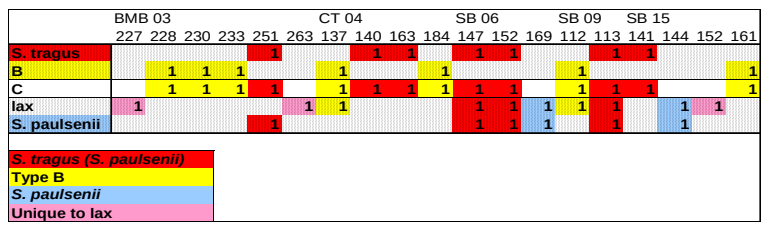
The area around Bakersfield/Taft is the center of all things tumbleweed and contains all taxa except *S. paulsenii*. Key to map above:

A = *S. tragus* B = Type B C = Type C P = lax

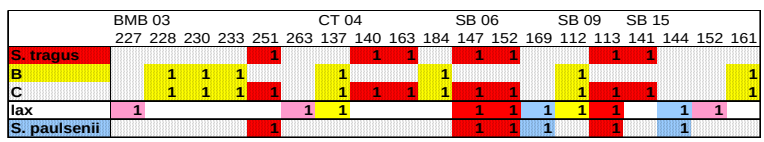


HOW….

Each taxon had a distinctive microsatellite allelelic pattern. *Salsola tragus*, Type B, and *S. paulsenii* contained species-specific alleles that we used to examine affiliations in Type C and lax. Type C contained an additive pattern of *S. tragus* and Type B alleles suggesting a F1-type hybrid between the two species.



Lax contained alleles from *S. tragus*, *S. paulsenii*, Type B and had unique allelles, suggesting a complex hybrid involving all 3 species



Conclusions and Questions remaining:

1. Recently Type B was identified, using morphological features and molecular markers, as *Salsola kali* var. *austroafricana* from South Africa. Type B specimens are in the CDFA collection from at least as early as 1963. What was the introduction route for this species into California? Are there biocontrol agents from South Africa or Australia that would be effective in California?

2. RAPD, ISSR, and microsatellites confirm that Type C is a F1-type hybrid between *S. tragus* and Type B. Type C plants exhibit some genetic variation, in accord with variation patterns in the parental species. *S. tragus* contains 36 chromosomes, and Type B contains 18 chromosomes; a F1 hybrid would be expected to have 27 chromosomes. Type C had 54 chromosomes in a preliminary study. Further, plants of Type C produce viable seed. Taken together, this evidence strongly suggests that Type C is a new allopolyploid species that arose at least two times via chromosomal doubling of F1 hybrids between *S. tragus* and Type B. If so, many questions occur regarding its habits, life history, potential for invasion, and efficacy of biocontol agents.

3. *Salsola* lax is a complex hybrid involving at least *S. tragus*, Type B and *S. paulsenii*. It was first described in 1970. Its genetic patterns are not strictly additive among the 3 species as it lacks some markers specific to each species. It is diverse genetically, and contains markers not found in the 3 parental species. Could these unique alleles represent the contribution of another species or a lack of sampling intensity of the parental species? Further molecular work is needed to address these questions. Many questions remain regarding its habit, invasion ability, etc. as for Type C, above.

We thank UCIPM for funding this research, and Alex Lee, Heather McGray, and Christina Sloop for lab and data analysis. Photo credits: F. Hrusa – fruit; Pat Akers - plants