Solanum viarum Dunal

Tropical Soda Apple Pest Risk Assessment

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I. Taxonomy, synonymy, common names

Solanum viarum Dunal, or tropical soda apple (TSA), is a member of the economically important family Solanaceae. Consisting of 75-90 genera and more than 2,500 species, this family includes many species used for ornaments, food and drugs. The diverse genus *Solanum* includes about 1400 species of shrubs, herbs and trees.

Synonyms for *Solanum viarum* include:

Solanum khasianum var. *chatterjeeanum* Sen Gupta, Bull. Bot. Surv. India 3:413. 1961.
S. chloranthum DC., Pl. Rar. Jard. Geneva 47, tab. 13. 1826, *non* Spreng., 1824.
S. viridiflorum Schldl., Linnaea 19:292. 1847, *non* Ruiz & Pavon,1799. (Nee, 1991)

Solanum viarum has been misidentified as *S. khasianum* (=*S. aculeatissimum)* (Nee, 1991) and *S. reflexum* (Morton, 1976). According to Nee, (1991), most reports in the literature of *S. khasianum* are probably misidentifications of plants of *S. viarum* (Nee, 1991).

Besides tropical soda apple, *S. viarum* is sometimes called "sodom apple".

II. Description

Tropical soda apple is a perennial, much branched, prickly shrub. One to two meters tall at maturity, TSA is among the non-tuberous solanums. The stems, leaves, flower stalks, and calyxes have broad-based white to yellowish prickles up to 12 mm long (Mullahey et al, 1993). Stems, petioles, pedicels, and calyxes have short, dirty white or grayish-white gland hairs (Babu and Hepper, 1978).

Stems are herbaceous, basally woody, and covered with short, straight, slender prickles mixed with stout, compressed, hooked or strongly recurved prickles (Sen Gupta, 1961) (Babu and Hepper, 1978).

Leaves are alternate with shapes varying from ovate, ovate-cordate, acute or subobtuse. Shallowly or sometimes deeply divided into 6-8 broad pointed lobes, with secondary lobation, the leaves have prickly veins and and petioles. The upper leaf surface is clothed with soft hairs (resulting in a velvety sheen), while the undersides have 4- or 5-rayed stellate hairs. The leaves are 10-20 cm. long by 6-15 cm. wide.

Flowers are borne 1-4 together on stems below the leaves (Mullahey *et al*, 1993) and have 5, white, recurved petals. The 5, cream-colored stamens surround the pistil. After fertilization, the superior ovary is completely exposed with a persistent, sparsely prickled calyx attached.

The ovary is densely puberulent (covered with short, soft hairs) when young, (one of its most distinctive characteristics); young fruit are minutely puberulent. The hairs are not always evident with a 10x hand lens (Nees, 1991).

Fruits are glabrous, globose berries, pale green with darker green or white streaks, turning yellow at maturity. Eighty to ninety percent of the fruits' dry matter consists of seeds, the remaining ten to twenty percent is pericarp. The pulp of the berries is a narrow band, mucilaginous and pale green at maturity (Coile, 1993). About 2 to 3 cm. in diameter, each fruit can contain 150 to 413 seeds. Each healthy plant may bear about 125 berries (Mullahey *et al*, 1993).

The watermelon-like mottling on young fruit and the yellow mature fruit are distinguishing characteristics.

Seeds are small (2.2 to 2.8 mm. in diameter), light red-brown to brown, compressed, and covered with a gelatinous layer. One hundred air-dried seeds weigh about 0.2 grams.

Roots do not penetrate deeply but spread horizontally (Chandra & Srivastava, 1978).

III. Distribution

Originally native to Paraguay, northeast Argentina, Uruguay, and eastern Brazil (Nee, 1991), S. viarum has spread into other parts of South and Central America, and has been introduced in the Caribbean, West Indies, Nepal, India and Africa (Coile, 1993). Chandra & Srivastava (1978) also report introduction into North Burma and China. Nee (1991) expects TSA to occur in other subtropical areas as well.

IV. Uses

Much of the literature on TSA concerns its cultivation as the richest source of solasodine, a nitrogenous analogue of diosgenin (Goswami et al 1986). The gelatinous layer surrounding the seeds contains this glyco-alkaloid (Saini, 1966). Solasodine is used as the important starting material for synthesis of cortisone and other steroid drugs. These drugs have been shown to be effective in cancer treatment, domestic contraceptive formulations, treatment of patients with Addison's disease, rheumatic arthritis, and as anabolic agents (Chandra and

Srivastava, 1978).

In 1984, the estimated world production of diosgenin was 1,000 tons (Sahoo & Dutta, 1984). Mexico is the largest producer of diosgenin, producing 750 tons annually. The diosgenin requirement of India in 1983-1984 was around 241.8 tons.

Dried berries of TSA currently sell in India for approximately 15 cents a pound. The processed berries are exported to manufacturers in both Italy and France, who produce a product of apparent value in fertility drugs. Sales of the manufactured product go for about $73.00 USD per pound (Moulthrop, 1994, personal communication).

V. Physiology

Solanum viarum is an herbaceous perennial which can persist where winters are mild (Coile, 1993). Flowering and fruit production occur throughout the year, but are concentrated from September through May in Florida (Mullahey and Colvin, 1993). TSA can be cultivated under a wide range of agroclimatic conditions, but fails to thrive under extreme climatic conditions (Kaul and Zutshi, 1982).

Temperature: Growth and development is best under sunny, moderate conditions where maximum and minimum temperatures are about 35 and 20 degrees C. respectively (Kaul and Zutshi, 1982). Frost severely damages TSA leaves (Chandra & Srivastava, 1978; Mullahey, personal observation).

Water: TSA prefers an average annual rainfall of 70-200 cm. Increasing water stress (deprivation) results in lower plant height, but the number of leaves and fruits is not significantly reduced. Water stress enhances fruit ripening and shortens the life cycle, allowing the plant to adapt to drought conditions (Yaniv et al 1984). TSA cannot tolerate much waterlogging. During extended periods (greater than three weeks) of standing water, plant death can occur (Sahoo & Dutta, 1984).

Soil: TSA prefers well drained sandy loam soils of high organic matter content. It has grown well in saline alkaline soil up to soil pH 9 (Chandra & Srivastava, 1978). Red lateritic soil is suitable, clay soil is not (Sahoo and Dutta, 1984).

Germination: Seed germination is dependant on temperature, light, and age of seed (Mullahey and Colvin, 1993). Alternating the temperature increases germination significantly. Light stimulates germination, independent of temperature, with light sensitivity occurring 3 to 5 days after imbibition. The stimulating effect of washing the seeds suggests the presence of a germination inhibitor (Vicente, 1974).

Pingle & Dnyansagar,(1979.) experienced considerable difficulty germinating seeds of *Solanum viarum* during the course of their cytogenetic study. Germination varied from 12 to 74 percent, and in most cases did not exceed 58 percent. Occasionally seeds remained dormant in the soil for months, while the usual dormancy was found to be only one month.

In Florida, Mullahey and Colvin (1993) report germination has occurred from seeds planted 3.25 inches into the ground. The depth of planting required to inhibit germination is unknown. Seed germination is highest (95%) for 5 month old seeds followed by a gradual decline to zero at 25 months.

VI. History of domestic introduction

The earliest herbarium record in Florida was collected from Glades County in 1988. David Hall, who identified the specimen, believes it has been there since 1981 or 1982 (personal communication to N. Coile, 1993).

TSA was observed on a cattle ranch in Hendry County (southwest Florida) as early as 1987. In 1990, the identity of the infestation was confirmed as *S. viarum* (Mullahey et al, 1993).

Based on a mail survey conducted by Dr. Mullahey in Florida, TSA occurs on at least 388,000 acres in 27 Florida counties (Mullahey, 1994). This includes mostly improved pasture and rangeland (Coile, personal observation) and in over 30,000 acres of woodland and pasture hammocks (Westbrooks, 1993). TSA has also been observed in ditch banks, citrus groves, sugarcane fields, watermelon fields, and along roadsides (Coile, 1993).

The Florida Department of Agriculture listed TSA as a state noxious weed effective February 27, 1994 (Coile, 1993, personal observation).

TSA is not known to occur elsewhere in the United States.

VII. Associated pests

In India, the fungus *Fusarium oxysporum* causes a wilt disease (Chandra and Srivastava, 1978) (Sahoo and Dutta, 1984). Also in India, aphid attack is prominent at the seedling sage. Root rot and wilt disease are reported but are not very serious (Kaul and Zutshi, 1982).

After finding naturally infected *S. viarum* growing in Brazil, Vicente and Chagas (1979) suggested TSA may be reservoir of potato virus Y (PVY) . The virus resembled PVY in its symptoms on indicator plants, physical properties and morphology. Unnamed viruses causing mosaic disease are mentioned by various sources (Chandra and Srivastava, 1978) (Sahoo & Dutta, 1984) (Kaul and

Zutshi, 1982).

In Florida, no incidence of severe plant defoliation or death from insect feeding have been reported. Occasionally plants appear stressed and display symptoms associated with plant pathogens (Mullahey, et al, 1993).

VIII. Rating elements of risk model

Estimate probability of pest spreading beyond colonized area. **HIGH - VC[1]**

Livestock and wildlife (deer, raccoons, feral hogs) eat the berries, then seed is spread via feces. Fruit production occurs throughout the year in Florida (primarily September through May). Averaging 413 seeds per fruit and 125 fruits per plant, numbers of seeds per plant can exceed 50,000, with an average 75% germination rate. With the high germination rate of seeds and prolific seed production, TSA can spread rapidly (Mullahey et al, 1993).

TSA seeds are spread by man through movement of infested sod, hay, grass seed, and cattle (Mullahey and Colvin, 1993).

TSA can thrive even in marginal lands and compete successfully with other weeds and undergrowth (Kaul and Zutshi, 1982).

Birds have not been observed feeding on the fruits and may not be vectors (Coile, 1993).

TSA is difficult to control because of its prickly nature and tendency to form huge patches (Coile, 1993). New plants can emerge from roots, which have buds capable of regenerating new shoots (Mullahey and Colvin, 1993). Mullahey (1994) observed shoot emergence from three and six inch root fragments buried up to four inches below the soil surface. New shoots also emerge from the crown of a mowed TSA plant.

In one population of *S. khasianum* var. *chatterjeeaum*, three types differing in growth habits were observed (Saini, Mukherjee, and Biswas, 1965). No other natural development of strains or races has been reported.

Attempts to cross TSA with 22 other species were unsuccessful. Interspecific hybridization failed even with species showing close morphological relation (Chandra & Srivastava, 1978) (Zutshi, 1968).

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[1]Please see Appendix B, page 12, for explanation of codes.

No studies have been conducted yet to predict the potential range in the United States. The incidence of this plant in Florida has been highest in the south (Mullahey and Colvin, 1993). Based on reports of frost-induced mortality, TSA might be limited to Hardiness Zones 9-11 in the United States (including Florida, Hawaii, the southernmost parts of South Carolina, Georgia, Alabama, Mississippi, Louisiana, Texas, and parts of Arizona, California, Oregon and Washington.)

Estimate economic impact if established. **HIGH-VC**

With prickly foliage unpalatable to livestock, this noxious weed can infest a pasture or rangeland in one-two years resulting in lower stocking rates (Mullahey and Colvin, 1993).

Of 3.5 million acres of improved pastures in Florida, TSA currently infests about 11 percent. Considering an acre of improved pasture in Florida generates revenues of about $200/year (1 cow/2 acres), Westbrooks (1993) estimates TSA is already causing cattle production losses of $28.4 million/year. Additional losses of cattle to heat stress are due to TSA infestation of hammocks where cattle congregate to escape the sun. Total costs and losses to the cattle industry now attributable to TSA amount to over $44 million per year. This represents an annual loss of almost 4.4 percent to the $1 billion cattle industry in Florida (Westbrooks, 1993).

Repeated herbicide applications are necessary to control TSA. Costs may prohibit some ranchers from making multiple applications (Mullahey, Cornell, and Colvin, 1993). According to Mullahey, current control costs with herbicides and mowing are $40.00/ acre. This amounts to $16 million/ year, if fully implemented. If TSA is eliminated, re-establishment of pasture grasses costs an additional $75-150 /acre (Westbrooks, 1993).

Because of its prickly nature, rapidly expanding range, and tendency to form huge, dense patches, TSA has potential for major economic impact on agricultural fields, orange groves and pastures (Coile, 1993).

Estimate environmental impact if established **HIGH-RC**

Oak hammocks, cypress heads and other natural areas are at risk because of displacement of native components of these natural ecosystems. In pastures, TSA replaces native and preferred forage plants (Coile, 1993).

Other natural areas at risk include public lands such as state and national parks, wilderness areas, and state and national forests (Westbrooks, 1994).

Repeated applications of herbicides are required to eliminate TSA from a pasture (Mullahey, Cornell, and Colvin, 1993).

Estimate impact from social and/or political influence. LOW-MC

Bitter alkaloids of the solanine type (eg., solasodine) are poisonous to humans. An adult would have to ingest at least 10 berries before showing symptoms of poisoning, and would have to consume around 200 berries for a lethal dose (Frohne & Pfander, 1983).

The Florida State Cattlemen's Association is concerned over the spread of TSA, and has met to discuss control. Ranchers affirm TSA is killing the grass their cows need to eat (Fretz, 1993). However, if the weed is listed as a Federal Noxious weed and a quarantine is imposed, restrictions on the movement of cattle, hay, and other potential vectors will not be welcomed by cattlemen.

Solanum viarum has genes for resistance to shoot- and fruit-borer, an attribute lacking in eggplant. But efforts by plant breeders to incorporate this characteristic in eggplant have proved futile (Sharma, et al, 1984)). Should the species be listed as a Federal Noxious weed, importation and use of TSA germplasm for plant breeding research would require a permit.

IX. Pest Risk Potential Rating (low, medium, high) HIGH

This calculation is based on the high rating for spread potential, and the high ratings for economic and environmental consequences of establishment.

X. Summary and discussion

Until its introduction into Florida, tropical soda apple was little known as a troublesome weed. Most of the literature on the species prior to 1993 concerned its cultivation for the production of the pharmaceutical chemical solasodine. However, since 1990, TSA has caused serious problems in many perennial grass pastures and natural areas of Florida (Mullahey and Colvin, 1993.) TSA's rapid increase is a threat to the cattle industry in South Florida and other southern states. Recognizing its

potential as an economically important noxious weed, Agricultural Research Service scientists are initiating studies on TSA life cycle, control methods and potential range prediction.

TSA meets the definition of Federal Noxious Weed in every aspect; it is of foreign origin, not widely distributed in the United States, and it can directly and indirectly injure crops, other useful plants, livestock, and other interests of agriculture.

XI. Recommendations

1. Because of the significant potential economic and environmental impact, APHIS should list *Solanum viarum* Dunal in the regulations under the Federal Noxious Weed Act.

2. APHIS should develop genetic fingerprinting tests to determine species for seeds of *Solanum* spp. If TSA is listed under the Federal Noxious Weed Act, APHIS will be authorized to prohibit the importation of TSA. Imported crop seeds and other commodities may be held, re-exported, or treated unnecessarily if APHIS is unable to distinguish non-weedy or indigenous species of *Solanum* from the FNWA-listed species.

3. APHIS should conduct surveys within TSA's predicted range to determine distribution.

4. The New Pest Advisory Group should evaluate pest management alternatives for current infestations.

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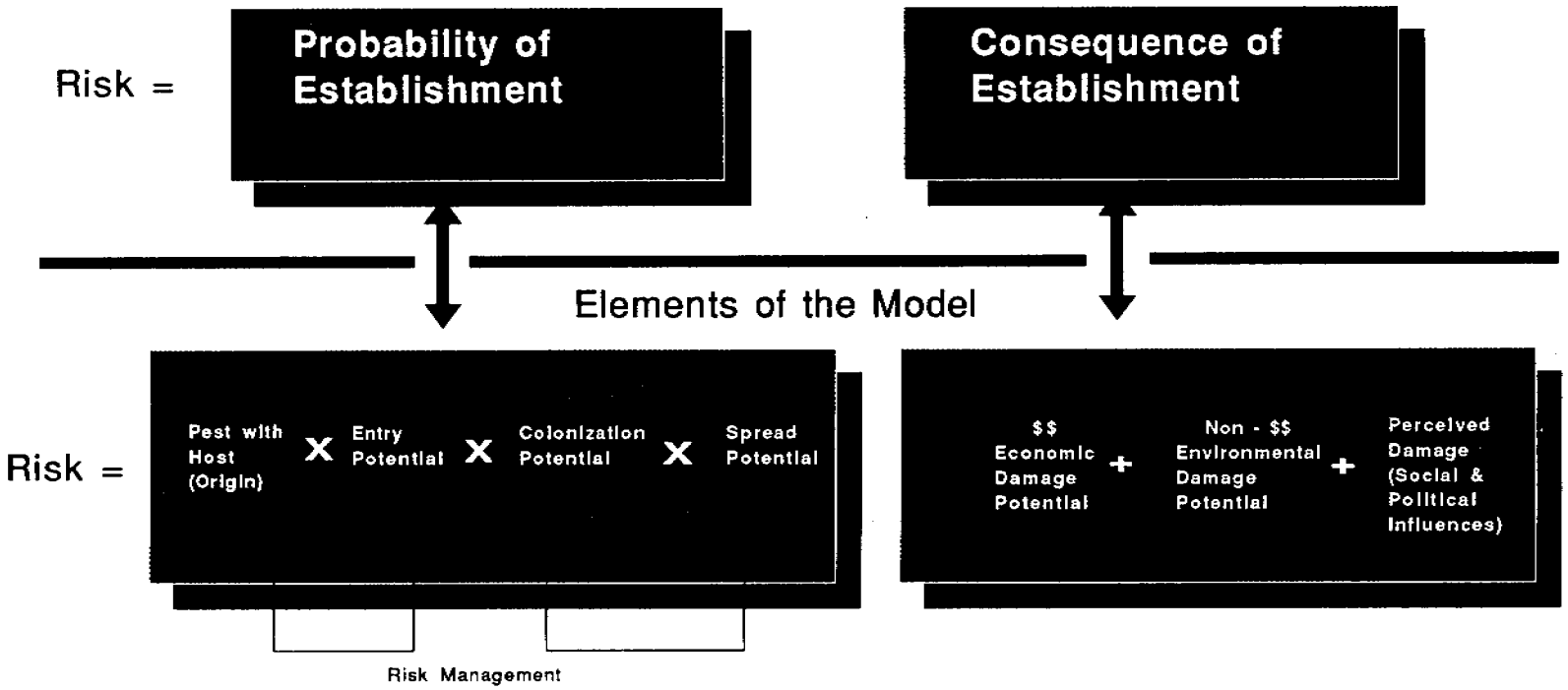
Pest Risk Assessment Model

Standard Risk Formula



- For model simplification the various elements are depicted as being independent of one another
- The order of the elements in the model does not necessarily reflect the order of calculation.

Appendix B

UNCERTAINTY CODES TO INDIVIDUAL ELEMENTS

Uncertainty Code	Symbol	Description
Very Certain	VC	As certain as I am going to get
Reasonably Certain	RC	Reasonably certain
Moderately Certain	MC	More certain than not
Reasonably Uncertain	RU	Reasonably uncertain
Very Uncertain	VU	A guess