ELEMENT STEWARDSHIP ABSTRACT
for

Lippia nodiflora

Mat-grass
or
Garden Lippia

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ELEMENT CODE

STEWARDSHIP ABSTRACT RESPONSIBILITY

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NAME

LIPPIA NODIFLORA; also classified as *PHYLA NODIFLORA*

COMMON NAMES

Garden Lippia, Mat-grass

DESCRIPTION

The following description of *Lippia nodiflora* combines the published information contained in Munz and Keck (1973), Robbins *et al*. (1951), and Bailey (1922).

Lippia nodiflora Michx. [*Zappania nodiflora* Moldenke; *Lippia filiformis* Schrad.] A prostrate perennial with extensively creeping, up to 1 m-long stems which root at the nodes. Plants matted, more or less woody near base, cinereous-strigillose; leaves opposite, verticillate, pale green, narrow-oblanceolate to -obovate, entire to toothed, 1-2 cm long (including short petiole), more or less acute at apex. Leaves are broadest above the middle part, serrate with the teeth pointing forward. Spikes are ovoid, mostly 5-10 mm long, 6 mm thick. The flowers are rose-purple to nearly white and are in spikes or heads on slender auxillary peduncles, mostly 1.5-3.0 cm long. The corolla tube is cylindrical with the upper part of the corolla bilobate, 4-5 mm long. The calyx is small, about 1 mm long, lobes shorter than the tube, and bicleft. There is a single pistle. The fruit is a dry drupe enclosed by the calyx. It is globular or indistinctly bilobular and forms two nutlets. Bracts are ovate, about as long as the corolla tube, with glabrous or nearly glabrous hyaline margins. Flowering period is May to October.

Munz and Keck (1973) have placed *L. nodiflora* close to *L. incisa* Tides on morphological grounds, while Robbins *et al.* (1951) have argued that it is more closely related to *L. lanceolata* Michx. *Lippia nodiflora* has been transferred back and forth from the genus *Phyla* several times, with no conclusive evidence of its proper placement. Since most specialists have continued to use *Lippia*, we have continued this practice.

HABITAT

Lippia nodiflora is a member of the family Verbenaceae; the genus of herbs and shrubs is used horticulturally for their blooms and as a ground cover. There are more than 100 species in the genus.

Bailey (1922) wrote this description of *L. canescens*, now thought to be a variety of *Lippia nodiflora* (Munz and Keck 1973):

> In California, Arizona, Mexico, and Australia, the plant is now an important ground-cover or lawn plant. The many thousands of acres thus covered are said all to have come from plants secured in a twelve-ounce box from the Botanic Garden in Rome by F. Francischi, of Santa Barbara, in 1898.--Culture by Francischi: It thrives in any soil, no matter how poor, rapidly covering the ground with a very dense matting. It will smother all weeds in short time, and the more trodden upon the better it grows. It requires much less water than other lawn plants... It will stand severe heat and many degrees of cold, and can easily be established in sloping grounds. It will never be difficult to eradicate, having no underground runners. Have the ground well worked and pulverized, leveled and rolled, if possible. No manure is recommended. It seeds very sparingly or not at all... Each (2 square inch sod planted) contains many joints, and from each joint runners and roots soon appear that will branch out in every direction and will anchor it in the ground, rooting again as they run...Occasional rolling will be of advantage. Frequent walking over it will have the same effect.

Native to South America, *Lippia nodiflora* grows throughout the world. It is widely distributed in the tropics and grows in cooler climates but may be excluded wherever temperatures drop below freezing several times per year. Karadge *et al.* (1983) reported *Lippia nodiflora* growing luxuriently where few other weeds were growing in the saline barren fields of Maharashtra State in India. Tomas-Barberan *et al.* (1987) described it as a maritime plant based on collections of specimens from Spain, Malaysia and Saudi

Arabia. *L. nodiflora* is also found in Yugoslavia (Pulevic, 1976) and also is found as a weed in shaded mountainous coffee plantations in Cuba (although this may be *L. lanceolata* or *L. insisa;* Cairo *et al.*, 1985). Rahman and Alam (1980) reported *L. nodiflora* to be found both on sunny dry slopes and shady moist plains such as in crop fields, grasslands, and roadsides in Bangladesh.

In the United States, *L. nodiflora* is widely distributed across the continent. It grows on the wet banks of lowlands from the Central Valley of California east to the Atlantic Ocean (Mason, 1969). It grows in sandy soil in Georgia (Bailey, 1922), and in marshes at the mouth of the Pearl River in Louisiana (White and Simmons, 1988). In California it is found especially in the Sacramento-San Joaquin Delta region (Robbins *et al.*, 1951), and Munz and Keck (1973) report that it is well-established in more or less moist places in central and southern California.

The species is highly valued for holding levees against erosion (Jepson, 1911). Robbins *et al.* (1951) described it being used as a ground cover where grasses do not flourish due to the absence of irrigation water.

Lippia nodiflora has also been recommended as a ground cover in Arizona. Johnson (1973) writes that it is able to grow in full sunlight to shaded areas. Soil preparation and suggested care included a combination of breaking up compacted soil layers, adding peat moss, redwood soil amendment, compost, manure, fertilizer, and irrigation. He reported that the leaves will brown after the temperature drops several degrees below freezing, and that the plant will be killed at about 5°F.

L. nodiflora is often found growing in saline soils. Berghen (1990) considers it halophilic and reports it growing in association with *Kyllinga peruviana* in temporarily-inundated maritime sand dunes of the Casamance country in southern Senegal. The sandy soil had a pH of 8.0 to 8.8 at the onset of the dry season following the rains. In saline barren fields of Maharashtra State in India *Lippia* was found growing "luxuriently" where there were few other weeds (Karadge *et al.*, 1983).

Sharma et al. (1983) reported that *L. nodiflora* was found to be an indicator of "supraoptimal" concentration (24-43.5%) of calcium sulphate in the form of monoclinic gypsum. Pure populations of *L. nodiflora* grew in areas of the gypsum substrata in Rajasthan, India. The presence of high calcium sulphate concentrations in the soil therefore might be regarded as having high potential for invasibility in regions where it has been introduced. *Lippia nodiflora* is also listed among species growing on monazite-bearing soils (Hewamanna *et al.*,1987).

BIOLOGY-ECOLOGY

The literature on the ecology of *L. nodiflora*, especially as a weedy species, is nonexistent, and most of what we know has come from studies of the plant in the Jepson Prairie Preserve, Solano County, California. This section describes some of the information we have accumulated over the past year. The invasive *L. nodiflora* became established in Olcott Lake and other areas of the Preserve by 1975. The invasion of this species may be a threat to rare species associated with the vernal pools at the Preserve. State or Federally listed rare or endangered species at Jepson Prairie include *Elaphrus viridis* (Delta Green Ground Beetle), *Tuctoria mucronata* (Solano grass), *Neostapfia colusana* (Colusa grass), *Legenere limosa*, *Downingia humilis* (Dwarf or Least Downingia), *Allocarya hystriculus* (Bearded Popcorn Flower), *Cuscuta howelliana* (Bogg's Lake Dodder), *Cyzicus californicus* (a clam shrimp), *Branchynecta* sp. (a fairy shrimp), and *Fritillaria liliacea* (Prairie bells). Of these, the principal threats are to the Delta green ground beetle (because of habitat modification) and to Colusa and Solano grass (competition for habitat).

At the Jepson Prairie Nature Conservancy Preserve, the distribution of the species is highly discontinuous. The vast majority of the *Lippia* plants are found in areas with limited biomass in other vegetation, and not in upland prairie grasslands. Large populations are found in the bed of Olcott Lake, a saline playa, and on the banks of the Calhoun Cut, which is a saline, tidal branch of the Sacramento-San Joaquin Delta. Many *Lippia* individuals are found in upland areas adjacent to the Lake and also along sheep trails near Calhoun Cut. *Lippia* has also been reportedly found in an Olcott Lake outflow channel along the northern edge adjacent to the railroad corridor.

At Jepson Prairie three subpopulations of *Lippia nodiflora* were apparent, characterized by physical habitat and floral differences:

1. Individuals found along the roadside bissecting Olcott Lake (Cook Lane) are found mixed with the annual vegetation and are most prominent along the margin of the road. Our observations in 1991 indicated that this population exhibited a long reproductive period, commencing flowering earlier in the season and lasting almost as long as plants in the lake bed. Floral densities were high only at the road margin and were low otherwise.

2. Plants in the lake bed typically began flowering much later, probably due to the time required for the lake bed to dry out, than the roadside population. Flowering

continued to a later date. Many individuals in this population exhibited high floral densities during that period.

3. The population around the periphery of the lake and around the shores of emergent islands within the lake characteristically had short reproductive periods starting earlier in the season than elsewhere and ending earlier in the season as well. This population typically has low floral densities.

Although our evidence is preliminary, we have made a number of observations which may prove to be important determinants to the distribution and abundance of *Lippia nodiflora*.

The species is extremely plastic in growth form and morphology, even within the same individual. Morphological characteristics also appeared to be associated with the floral density and period. Smaller individuals and larger mats seemed to produce flowers in lower densities and for shorter durations than well-established mid-sized clones.

It appears that as plants get older and larger, they fragment, creating a mat composed of separated vegetative clones that are indistinguishable as individuals. These mats tend to occur along the shoreline in Olcott Lake, especially along the northern and western shores and some island shorelines. In these areas, the shorelines slope more gradually than in other areas, creating conditions in which evaporation of the lake will proceed more quickly.

Mat-like growths of *L. nodiflora* may be found growing amongst dense *Eleocharis* at the lowest elevations of the lake bed. These might be seedlings or fragmented individuals; it was not possible to tell. Some patches of *L. nodiflora* in the lower lake bed appear to be medium-sized individuals which have not fragmented.

The plants at Jepson Prairie exhibit great morphological diversity in relation to their local environment. The largest differences are exhibited by those plants in areas open to full sun compared to those found under heavy canopies of annual plants. In open areas of the lakebed, the plant leaves were typically smaller (length < 10 mm), with relatively high leaf-hair densities, and short internodal lengths (ca. 2-15 mm), resulting in low-growing, compact plants. In contrast, the plants found amongst tall grasses had longer leaves (lengths ca. 10-20 mm) and longer internodal stem lengths (ca. 6-50 mm). Leaf widths were typically half the length. The smaller leaves had a higher density of hairs than the larger leaves. Rhizomes under canopies tended to be elongate and clambering upon grass blades. Heavily-shaded leaves along the rhizomes were larger and with low leaf-hair densities. Rahman and Alam (1980) have documented similar trends in *Lippia* in Bangladesh. These morphological reactions are typical of reactions to lower ambient light, as seen in plants growing under a canopy but reaching the roadside or other open area where a competitive canopy was reduced. In these situations, plant morphologies were similar to plants found in open areas, as might be expected. Nevertheless, the morphological plasticity seen in the response of individuals is remarkable and indicates the importance of light to this species.

Growth in *L. nodiflora* clearly is sensitive to competition for light from tall grasses. Soil moisture may, however, be more limiting than light and is possibly even more limiting to younger plants. Although this conclusion requires further justification, evidence of soil moisture is found throughout the literature and in our own observations. The populations along Cook Lane, where competition is the greatest but soil moisture persists well into June, appeared to maintain green leaves the longest, and they renewed growth earlier than others. The high levels of soil moisture may permit *L. nodiflora* to exploit the environment when the annuals begin to senesce.

With the exception of Calhoun Cut, most *L. nodiflora* are confined to in the Olcott Lake area. The upper margin of *Lippia* growth in the Olcott Lake area is restricted by competition with grass, although demarcations are often indistinct. Dispersal of *Lippia* into the lower levels of Olcott Lake may be slowed in association with the inundation period and water depth. A comparison can be made between the two smaller pools on the east side of Cook Lane and the larger lake area on the west side of the road. The standing water in both east-side pools receded sooner than in the west-side lake. The northern east-side pool had *Lippia* throughout the entire lakebed. The extensive lakebed growth may be explained either by a shorter inundation period or shallower standing water. It may also be due to the smaller aerial extent, thus allowing for cover by *Lippia* in a shorter time period. The southern east-side pool, in contrast to both other pools, had extremely little *Lippia* growth, and the reasons for this are speculated about later in this abstract (see RESEARCH NEEDS).

A small number of further observations may prove to be important to ecology and control. *Lippia* mats hold soil well, and larger mats are easily seen to be elevated relative to the surrounding lake bed, especially in the western portion of the lake. This may enable the species to begin growth earlier in the season as the water level retreats, and over the long term may lead to soil accretion in areas of the lake bed, the formation of islands, and invasion by upland vegetation. The drought years from 1987-

present may have enhanced the establishment and survival rates of *Lippia* at deeper lake levels. Preliminary results from vegetation transects indicate that there are both positive and negative correlations between *Lippia* and other plant species, although we have not established the significance of this analysis. Finally, seed dispersal may be facilitated by floatation on the lake surface and burial in the bottom sediments as the lake recedes. The significance of dispersal remains unknown.

LITERATURE ON THE BIOLOGY AND ECOLOGY OF *LIPPIA NODIFLORA*

L. nodiflora grew best in the dry winter season in a 1 km^2 ponding basin in western India characterised by summer flooding (avg. 660 mm ppt y^{-1}), and warm (20-40°C) temperatures, alternating with winter drying and cooler, but not freezing (2-30°C) temperatures (Sankhla and Vyas, 1982). The average daily relative humidity ranged from 45% to 75% through the year. The tank holds perennial water in 1/3 of its areal extent. *L. nodiflora* was most productive during the winter months when most of the other 21 species present were least productive. It was also the most productive on an annual basis, 85 $gm^{-1}m^{-2}y^{-1}$, leading to its dominance of the community. Johnson (1973) reported that the leaves of *Lippia* will brown after the temperature drops several degrees below freezing, and that the plant will be killed at about 5°F. These limits suggest that temperatures do not limit the species at the Jepson Prairie Preserve.

Diseases reported to affect *Lippia* include southern blight, nematodes and crown galls. Insects reported found on *Lippia* include ants, cutworms, leafhoppers, Rhodes-grass scale, sod webworms, and white grubs. Weeds reported to associate with *Lippia* include Bermuda grass, clover, nutsedge, oxalis, annual bluegrass, brome, and spotted spurge (Johnson, 1973).

Lippia nodiflora may have an allelopathic effect on surrounding plants. Extracts and steam volatiles of *Lippia nodiflora* were found to inhibit lettuce seedling growth, and radish seed germination. Sesquiterpenes and monoterpenes were identified in extracts of the plant and indicated as potential allelochemicals (Elakovich, 1987).

Rahman and Alam (1980) identified differences between sunny area and shady moist area plants. Sunny slope plants exhibited smaller internode lengths, smaller leaf size, smaller stem circumference, patches of hypodermal sclerenchyma, a higher cortex to pith ratio, smaller cells, and lower relative water contents than the shady moist plain specimens. The shady moist plain specimens had a few layers of hypodermal chlorenchyma, possibly to adapt to low light intensity. In their transplant study, many differences were found to be non-persistent: hypodermal layer cells, internode lengths, cortex to pith ratio, and relative water content. There were also persistent differences. The most important one perhaps was that a difference remained in drought tolerance associated with the habitat conditions of the transplants' original locations. Rahman and Alam (1980) suggested that the differences in drought tolerances were possibly related to retained differences in the density of lamina hairs, stem circumference, and perhaps physiological differences such as cell sap concentration.

Kausal and Tripathi (1984) found some characteristics common to some Verbenaceae species they studied, and this included *L. nodiflora*. Stomata were more frequent on the lower leaf surface, and were predominantly anomocytic, or diacutic type, and rarely of anisocytic type. The epidermal cells were sinuous, wavy to straight-walled and glandular and non-glandular trichomes were present on foliar and floral parts.

L. nodiflora was found to effectively hold soil, water and nutrients, and increase porosity on a 13° slope (Ambasht, 1984). The species had a 93.8% soil conservation value, high nitrogen and organic carbon conservation, and 74% water conservation value (soil infiltration of applied water; compared to 18% for the bare soil). The retention of clay and silt particles was proprtionately higher for *L. nodiflora* than for bare soil, thus altering the soil composition. The significance of these findings for areas where *L. nodiflora* is introduced is unclear; however, they supported the hypothesis that the topography, vegetation, hydrology and nutrient flow all may be altered as a consequence.

There are indications that *L. nodiflora* productivity is enhanced by increased soil salinity up to the tolerance level. A study that was done for the purpose of finding salt-tolerant crop varieties (Karadge, 1983) found that total plant biomass increased somewhat in the roots but especially in the leaves, and decreased in the stems with increasing salinity from equal amounts of NaCl and $CaCl^2$ (1.8 mmhos=control, 6.0 mmhos, 12.5 mmhos, and 17.0 mmhos). Total nitrogen was increased in all plant parts. Calcium absorption and translocation were increased. Starches and soluable sugars were increased, with starches increasing more in the root parts. Succulence increased with salinity especially in the leaves, evident in increased leaf thickness. It was suggested that the sugars, nitrogen metabolism, and increased calcium uptake probably play a primary role in adaptation to saline conditions in this species. Although proline concentration was not increased, it was suggested as playing a secondary role in adapting to the saline conditions. Polyphenols and chlorophylls were both reduced, even with small increases of NaCl. Potassium uptake was not affected. *Lippia* growth appeared to decrease only at the highest salinity level tested.

L. nodiflora was found to grow well in fresh and intermediate tidal marshes in subtropical Louisiana, but not in the brackish marsh (White and Simmons, 1988). Mean salinities and mean conductances were as follows: a) freshwater marsh - 0.3 ppt, 470 μmhos; b) intermediate marsh - 1.8 ppt, 1670 μmhos; and c) brackish marsh - 1.6 ppt, 1805 μmhos. Possible aided by storm driven salt-water intrusion, *L. nodiflora* competed with and sometimes dominated *Vigna luteola*, creating an intertwined mat covering the intermediate marsh. This may have accounted for the reduced *Sagittaria lancifolia* productivity, followed by *Spartina patens* dominance. *L. nodiflora* productivity was significant in the freshwater marsh; however, it was inferior to the more productive growth of *Vigna luteola, Sagittaria lancifolia, Panicum gymnocarpon, Peltandra virginica,* and *Polygonum sagittatum.* In the brackish marsh *Spartina patens* dominated, creating barely penetrable mats that effectively excluded *L. nodiflora*.

L. nodiflora was found to spread vigorously by runners and form a non-random distribution of single-species patches in a 50^{+}-year-old excavated seasonal pond in western India (Billore and Mehta, 1975). Additionally, three negative associations were found between *L. nodiflora* and the other species present (*Gnaphalium indicum, Polygonum plebejum,* and *Crypsis aculeata*). No investigation of the ecological mechanism was made in this study.

Kumar and Dutt (1989) studied *L. nodiflora* to gain insight into evolutionary processes due to its successful and rapid colonising ability in diverse habitats. They suggested that *L. nodiflora* colonizes primarily by vegetative propagation combined with a secondary mechanism of facultative auto-allo-breeding, predominantly selfing, and involving a high seed set. A non-synchronous maturation and dehiscence of protandrous posterior and anterior anthers, along with epipetalous stamens, and hairy corolla throats, possibly allows for both autogamous and allogamous pollination, mediated by small bees or ants. *L. nodiflora* has 32 diploid chromosomes in a symmetrical karyotype (Chouhary and Roy, 1983). The high chiasmata per nucleus and per bivalent ratios, 32.4 and 1.8 respectively, are taken to indicate predominant self-pollination. In-breeding variability is maintained through a high number of chiasmata whereas out-breeding genetic variability comes from cross-pollination enabling a lower number of chiasmata. Because of the characteristics of zygomorphic protandrous flowers, and high chiasmata frequency, They speculated that the breeding mechanism for *L. nodiflora* is one of facultative auto-allobreeders, predominantly selfing. *L. nodiflora* seems to grow in clonal patches, at least in open areas. This tendency, coupled with the findings by Gary et al. (1980) of an insignificant pollen take by honey bees extensively using *Lippia* for nector, may further indicate the tendency of selfing. Horticulturally, vegetative propagation is considered the best approach for establishment of *Lippia* (Johnson, 1973).

Sahu and Santra (1989) found a significant response of *L. nodiflora* to air pollution. They found an increase in the trichome frequency as well as length. They also found a reduction in stomatal frequency and pore area in glabrous leaves contrasting with an increase in pubescent leaves. The stomatal size itself did not significantly change.

ELEMENT OCCURRENCE QUALITY DETERMINATION

N/A

THREATS

L. nodiflora is considered to be a serious threat to three of the rare species at Jepson Prairie's Olcott Lake (*Tuctoria mucronata, Neostapfia colusana, Elaphrus viridis*). For further information, see BIOLOGY-ECOLOGY.

LAND PROTECTION SPECIFICATIONS

N/A

RECOVERY POTENTIAL

N/A

BIOLOGICAL MONITORING NEEDS

An accurate survey of the Olcott Lake area should be made to establish a data baseline and to determine the current distribution and abundance of *L. nodiflora*. Second, the importance of seedling establishment in the dispersal of the species should be examined in greenhouse and laboratory studies. At present, we do not know if seed production is important to the species, or if seed germination has special requirements. If seedling establishment is important, attention should be paid to the potential importance of dispersal by animal vectors and by patterns of surface flow when the area is flooded. This information is critical to predicting the rate of spread into areas occupied by the two endangered plant species in the vicinity. Finally, behavioral studies on the foraging behavior of the Delta green ground beetle in *Lippia* stands should be studied, as it remains conjecture that continued growth of *L. nodiflora* will lead to the reduction of the beetle population.

BIOLOGICAL MONITORING PROCEDURES

A 1 m^2 Daubenmire quadrat was used along permanent transects established on lake-to-upland ecotones, and open lake bed areas. Lake-to-upland transects were located near islands and the lake shoreline. A long-lake, cross-section belt transect was established using a 5 m^2 quadrat. In all transects, the quadrats were sampled continuously. In all but the cross-lake transect the procedure was to sample until no more *L. nodiflora* was encountered in the quadrat for 5 meters.

Measurements taken were: (1) cover of *Lippia*, (2) cover of all other vegetation, dead or alive, (3) "brown class" of *Lippia* (a measure of senescent or dry material, with four percentage ranges we created to aid in quickly and, hopefully, accurately estimating dead or dying material cover), (4) linear spread of *Lippia*, as measured by a 1-meter-wide line intercept of *Lippia* anywhere along the one m running width (ie., the plants didn't have to be continuous themselves...they only had to be spotted somewhere along the width held perpendicular to the running transect tape measure); gaps in continuity for less than 5cm were ignored, and a 5 meter break meant the transect run was over, and (5) number of *Lippia* flowers and presence/absence of *Lippia* seedheads and buds.

The transects were marked using 2' pieces of rebar covered on the top with a ball of duct tape to prevent injury, a duct tape flag, and permanent marker. Also used for stakes were 12"-18" redwood stakes where rebar might be considered dangerous to hikers. The rebar was preferred because they were invulnerable to sheep or other curious animals, and would not decay in water.

Lakebed markers were made as follows:

All patches and lakebed transect markers were tagged using white-coated mason jar covers, 6" steel nails, and a black china marker. All treated patches were temporarily flagged with colored plastic tape to facilitate treatments. Patches subsequently were flagged with steel wire stakes with aluminum (at ground level to enable use of a metal detector if neccessary) and plastic flagging for the duration of the inundation period to facilitate relocating them in the spring.

All points were measured (compass direction, distance, and helpful descriptions) off permanent poles, fenceposts, stakes, and so on and also placed on a map. It was helpful to measure the points off two different points, and to also describe the location.

BIOLOGICAL MONITORING PROGRAMS

ECOLOGICAL STUDY

Representative transect sites were established in Olcott Lake to run the duration of the research period. Factors used to locate the transects included presence of *L. nodiflora*, general alignment with water-inundation-period gradients in Olcott Lake, and presence of competing vegetation.

Estimating the establishment potential of *L. nodiflora*, as well as the need to control it when it is not directly threatening rare and endangered species will be accomplished by analyzing sampling data on the rate and mode of *Lippia* dispersal.

RESEARCH NEEDS

1. A new treatment regime is in the process of being developed to meet the objective of controlling *L. nodiflora* at the Jepson Prairie Nature Conservancy Preserve.
2. Research into the role sheep may play in *Lippia* dispersal, and also in its control may be useful in determining future grazing plans at the Jepson Prairie Nature Conservancy Preserve.

RESEARCH NEEDS COMMENTS

1. As of October, 1991, it became apparent that all herbicidal treatments and mechanical treatments thus far had failed to kill the *L. nodiflora* plants (see MANAGEMENT NEEDS COMMENTS section). Extensive consultation with Monsanto will be in order to determine whether continued experimentation with glyphosate (Roundup) is best. Further consultation with weed specialists in UCD Weed Control Extension will help determine other potential avenues of control.

2. The northern pool east of the road has *Lippia* clones extensively throughout the entire lake bed. The southern pool east of the road has almost no *Lippia* present even though it is growing moderately well along the road adjacent to both the north and south pools. The visual differences between the pools are that the southern pool is largely devoid of intact mud flakes. These are still present in both the northern pool, and

the larger west-side lake. The reason for the loss of flakes appears to be due to the trampling from sheep present only in the southern pool, and the wind, or both. The thickness of the flakes, and also the soil composition, may also be different in the different pools. Animal vectors of various kinds may also be responsible for the spread of *Lippia* seeds, transporting them by foot by walking across the plants and sticky mud during moist rainy seasons. The region also may have been flooded so thoroughly as to carry the floating seeds from the slough system to Olcott Lake. *Lippia* is not presently found in an adjacent similar large playa lake northwest of Olcott Lake.

RESEARCH PROGRAMS

OBJECTIVE

The primary objective is to determine the most effective strategy of controlling *L. nodiflora* in areas where it may be a threat to rare and endangered species. In pursuit of this objective, three goals are:

1. Find the most effective treatment(s) for *L. nodiflora* while minimizing damage to threatened species.

2. Estimate the potential for establishment of *L. nodiflora* in habitats of rare and endangered species.

3. Determine if *L. nodiflora* will need to be controlled if it is not directly threatening State- and Federally-listed species.

EXPERIMENTAL DESIGN

A. **TREATMENTS**

1. Glyphosate (Roundup) in 1% and 2% concentrations applied in a close spray to stratified-randomly selected patches of *L. nodiflora*.

2. Glyphosate (Roundup) in 8% and 12% concentrations applied by sponge (wick-on method) to stratified-rendomly selected patches of *L. nodiflora*.

3. Scraping of patches (severing stems from shoots) by means of a hula hoe.

4. An untreated control group.

B. **TIMING OF TREATMENTS**

1. Treatment in mid-June

2. Treatment in mid-July

C. TREATMENT BLOCKS

Blocks were established for the two treatment times consisting of 100 randomly-chosen patches of *L. nodiflora*, for a total of 200 patches. An additional 42 patches were randomly chosen for the wick-on treatment added on in July. The patch sizes ranged less than 0.10 m to more than 3.0 m in diameter. The majority of patches were located within a band 15 meters on either side of the high-water mark in west Olcott Lake, where *L. nodiflora* appeared to have its greatest abundance. This area includes the habitat for the Delta Green Ground Beetle. The remainder of patches were distributed throughout the lake interior, mostly near the lake "islands." Known locations of *Tuctoria mucronata* and *Neostapfia colusana* were excluded from patch selection with the exception of one control.

D. MEASUREMENTS

Measurements taken in each patch included 1) floral phase and density; 2) patch size; 3) total cover; 4) green cover (to determine top kill); 5) lake location; and 6) presence of other vegetation. Measurements will continue to be made to one year following the treatments to determine effectivness. These will include measurements of clonal regrowth, and covariates as listed above.

E. PROCEDURES

1. MECHANICAL TREATMENTS

The mechanical treatment consisted of severing the stems at the soil surface by scraping with a stirrup hoe while not removing the material from the site. 50 patches were treated this way, half in June and half in July.

2. HERBICIDAL TREATMENTS

The herbicide, glyphosate (Roundup), formulated in concentrations of 1% and 2%, was applied with a close-range backpack sprayer using a large spray tip and kept at low pressure to minimize drift. Each treatment level and time consisted of 25 randomly-selected patches for a total of 50 patches treated with the herbicide in June and 50 patches in July.

The wick-on treatment consisted of a sponged-on application of 8% and 12% concentrations of Roundup, applied to 15 patches each. A measured amount of solution was applied to each patch, based on the patch size, and covering the entire patch surface. An additional exploratory treatment was made to attempt to determine differences in the manner of sponged-on applications.

RESEARCH PROGRAMS: COMMENTS

The research is still in progress. Any new experimental treatments will not be able to be conducted until the spring or summer of 1992 after the rainy season and drying of Olcott Lake.

MANAGEMENT NEEDS

These depend upon the outcome of the research program and will be considered in detail then.

MANAGEMENT NEEDS: COMMENTS

Roundup initially appeared to be more effective earlier in the season, and prior to or during the flowering phase. The 2% solution appeared more effective than the 1% solution, based on top kill. Neither appeared to be completely effective, however, and by late October most treated patches were developing new leaves, regardless of herbicide concentration or method of application. The choice of surfactant and time of treatment are major considerations that are currently being examined. We have not excluded another herbicide or combination of treatments, although glyphosate still appears to be the superior choice.

As with the spray treatments both wick-on treatments proved ineffective by late October. The wick-on method of treatment may be easier than the spray procedure and also may be less contaminating to the soil. This may prove to be an effective alternative when winds are persistant.

Scraping of *Lippia* with a hula hoe at the ground level appears to be, in itself, largely ineffective. It may be effective against very small individuals, or in combination with other treatments. It may be the only available treatment in the *Tuctoria mucronata* areas, or where conditions prohibit herbicidal treatments. Any substantial remaining rhizomes will probably resprout, however, so digging all the roots up is preferable where possible. Digging up *Lippia* in the lake bed of Jepson Prairie will be very difficult due to the extent and location of growth. The habitat of the Delta Green Ground Beetle would be disrupted, and the procedure would be extremely intrusive to the lakebed soil structure.

Our experience indicates that eradication of *L. nodiflora* is likely to be very difficult. The species thrives in environments required by the endangered species it threatens without an obvious treatment that will guarantee its eradication. Further work on the control of garden lippia is essential.

MANAGEMENT PROCEDURES

HERBICIDAL

RESEARCH PROGRAM OUTCOME: In progress

LITERATURE:

A single postemergence application of diuron (5 kg/ha) and paraquat (2 liters/ha) was found to have good control of weeds, including amongst them *L. nodiflora* (although there is reason to believe this may be *L. lanceolata* or *L.incisa* by Munz and Keck's description, for 60 days in an arabica coffee plantation in Cuba (Cairo et al., 1985).

MECHANICAL

RESEARCH PROGRAM OUTCOME: In progress

LITERATURE:

Johnson (1973) recommended plugs or sprigs for establishment of *Lippia* as ground cover. Therefore scrapings should possibly be regarded as a source for re-establishment. After establishment, clippings are considered a vector for fungal spread (Johnson, 1973), and so this also should be considered in any mechanical control method, since increased fungal activity may also adversely affect desirable vegetation.

BIOCONTROL

LITERATURE:

L. nodiflora is listed as a host of a powdery mildew in Cuba, although it is analyzed as only having been slightly affected by the mildew. The potential of these fungi as a biological weed control is analysed (Gonzalez, 1984).

MANAGEMENT PROGRAMS

N/A

MANAGEMENT PROGRAMS COMMENTS

Ted Foin and Ron Unger (1991-2) are currently conducting research at Jepson Prairie Nature Conservancy Preserve south of Dixon, California as outlined in the RESEARCH section of this report.

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SUMMARY OF STEWARDSHIP NEEDS

Lippia nodiflora is a prostrate perennial, spreading vigorously by runners and often forming monodominant patches. Though vegetative propogation seems to predominate, it may also produce viable water-dispersed seeds whose importance remains unknown. Mat-grass is a hardy plant, drought tolerant, perhaps capable of allelopathic effects, and growing better when trampled upon. With simultaneous light and soil moisture limitations, however, the plants appear to be somewhat restricted, as in very dry grasslands. *Lippia* holds soil well, and clones became elevated relative to the surrounding lake bed in a seasonally-flooded playa pool at Jepson Prairie. This tendency may result in topographical changes and an altered vegetation pattern.

Native to South America, it now grows throughout the world. It is widely distributed in the tropics, and perhaps is excluded where temperatures drop below freezing several times per year. Rapidly covering the ground with a dense matting and able to hold soil well, it has often been used as a ground cover and for erosion control in levees. It is able to grow in many soils, and it does best in somewhat saline conditions.

Widely distributed in the U.S., *L. nodiflora* is found on sunny, dry, open areas to shady, moist plains such as in river banks, irrigation channels, crop fields, grasslands, roadsides, vernal pools, tidal marshes, sand dunes, orchards, and washes.

The rhizomatous perennial may be a threat to rare species associated with the vernal pools at the Preserve. State- or Federally-listed rare or endangered species at Jepson Prairie include: *Elaphrus viridis* (Delta Green Ground Beetle), *Tuctoria mucronata* (Solano grass), *Neostapfia colusana* (Colusa grass), *Legenere limosa*, *Downingia humilis* (Dwarf or Least Downingia), *Allocarya hystriculus* (Bearded Popcorn Flower), *Cuscuta* *howelliana* (Bogg's Lake Dodder), *Cyzicus californicus* (a clam shrimp), *Branchynecta* sp. (a fairy shrimp), and *Fritillaria liliacea* (Prairie bells).

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