# *Verbesina encelioides* [(Cav.) Bentham & Hooker fil. ex Gray] ssp. exauriculata [Robinson & Greenman]

[Illustration of *V. encelioides* by L. Hamilton in Parker, 1972. Small inset is of the winged achene (seed).]

Other Latin names: *Ximenesia encelioides*

Common names: Golden Crownbeard, Crownbeard, Wild sunflower
Girasolcito, Yellowtop, Anil del Muerto

*Verbesina encelioides*, a member of the Asteraceae (Sunflower) family (formerly the Compositae family), is an erect annual (Wagner 1990) commonly seen to heights of 1 to 5 feet (0.3 to 1.66 meters) (Ball et al. 1951, Robbins et al. 1951; Parker 1972).

Leaves of *Verbesina encelioides* are toothed or lobed (Everist 1957; Parker 1972), and have two distinct growth patterns: lower leaves are opposite and triangular, while the upper leaves are alternate and lanceshaped (Everist 1957, Wagner et al. 1990). Both upper and lower leaves feature fine white hairs on the underside (Everist 1957). These fine white hairs are also present on the stem of *Verbesina encelioides*, which grows from a taproot system (Parker 1972).

Flower heads are found on elongated stalks (Parker 1972), and resemble small sunflowers, 1-2 inches (2.5 cm - 5.1 cm) in length (Everist 1957). Flower heads can either be solitary, or in clusters of up to 3 heads (Everist 1957; Wagner et al. 1990). The single "flower" is more accurately referred to as a "head", and is composed of two different types of flower structures: 1) that of the ray-florets, which appear as the petals, and 2) that of the disc-floret, which is in the center of the flower head (Hylander and Johnston 1954; Gardner et al. 1956). The ray-flowers surrounding the center are approximately 0.5 inches (1.25 cm) long, yellow to bright-yellow in color, and number 12-15 per head (Ball et all. 1951, Wagner et al. 1990). The center disc flower, the site of eventual seed formation, is also yellow and comprised of many tubular structures (Hylander and Johnston 1954; Campell 1987).

Seeds (achenes) of *V. encelioides* are grayish-brown, flat, and winged along the margins (Parker 1972). Seed size ranges between 5.4mm to 6.7mm by 3.1mm to 3.66 mm (approx 0.25 inches by 0.15 inch) (Kaul and Mangal 1987). As with the leaves and stalk of *V. encelioides*, the seeds are also covered with fine hairs (Parker 1972).

*Verbesina encelioides* is differentiated from the garden sunflower by the opposite leaves on the lower part of the plant, as well as significantly smaller flower heads (Everist 1957).

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|---|---|---|---|
| Federal Noxious Weed? | N | Hawaii State Noxious Weed? | N |
| Federal Seed Act? | N | Hawaii State Seed Act? | N |

Native to where: The native range of *Verbesina encelioides* is generally considered to be North and South America, specifically Mexico and the southwestern United States of Texas, Arizona (Rydberg 1922, Torrey and Gray 1969; Tutin et al. 1976;Wagner et al. 1990; Menard 1997).

However, it should be pointed out that there exists some discrepancies as to the true native range of *V. encelioides.* Rydberg (1922) suggests the native range also includes Montana, while The United States Geological Survey lists and describes *V. encelioides* on its webpage for "Native Wildflowers of the North Dakota Grasslands (1999). A private gardening company in New Mexico, which 'specializes in drought tolerant native plants and seeds' lists *Verbesina encelioides* on their website (Plants of the Southwest Website 1999). In "An Illustrated Guide to Arizona Weeds", author Parker (1972) describes *V. encelioides* as a weed introduced from 'Old World'. European authors point to the origins of the plant being from North America (Tutin et al. 1976). Authors in California seem to agree that *V. encelioides* is not native to their state (Robbins 1951, CalFlora website 1999), yet in "Weeds of California", Robbins (1951) further suggests that *Verbesina*

*encelioides* was introduced from the eastern United States.

Native climate: *Verbesina encelioides* can encompass a variety of habitats, temperatures, and elevations. In its 'native' range (throughout Mexico, Arizona, and North Dakota), the plant is found from 0 feet to elevations of up to 9,000 feet (USGS website). Open areas and disturbed habitats appear to be ideal habitat for the plant (Woodward 1972; USGS website; CalFlora website).

Biology and Ecology: Water needs: *Verbesina encelioides* does not require large amounts of water (Al-Farraj 1990), and is considered a drought tolerant plant (AZ Dept. of Water Resources website). Once established, the plant requires watering only once a month (AZ Dept. of Water Resources website).

Reproduction: *Verbesina encelioides* propagates by seeds, which have shown to be able to survive under a wide range of climatic conditions including droughts and high temperatures (Kaul and Mangal 1987). The plant demonstrates an efficient ability for both self and cross-pollination (Kaul and Mangal 1987).

Germination success appears to be affected by a variety of factors, including habitat, soils type, soil moisture and soil depth. In researching the germination of *V. encelioides,* Kaul and Mangal (1987) found the ideal growing conditions to be the following:

*Habitat*: Maximum germination occurred with seeds from plants of 'open and sand dune areas'. Seeds from these areas were also found to be greater both in size and weight when compared to those from shadier and less dry habitats.

*Soil Moisture*: Soil moisture of 21% proved optimal. Germination success decreased with either an increase or decrease of this optimal moisture level.

*Seed depth*: Highest germination levels were seen with seeds at the surface, (i.e., no soil depth), but seeds were still able to germinate when placed in up to 2.5cm of soil depth.

Flowering: Generally, the highest levels of flowering occur during the late summer, in the warmer months after significant rains (Parker 1972; Goel 1987; Niethammer pers. com). The specific months in which flowering will occur can vary slightly depending on location of the plant:

-In the Northwestern Hawaiian Islands, flowering is seen throughout the year, with the highest levels of flowering observed from early April through November. A drought period in the summer months will result in the slowing down of the flowering, but this appears to be only a short-term effect until the rains return. There is also a general, but not complete, die-off in late December through January (all from Niethammer pers. com).

-In Arizona, flowering is observed in April through December, with the highest level of flowering in the late summer months (Parker 1972).

-In North Dakota, the plants flower July through September. (USGS website)

-In India, flowering is observed from August through October (Goel 1987).

Seed Dispersal: Seeds are easily dispersed by light winds; however, a large portion of the seeds will generally remain under or nearby the parent plant. (Niethammer, pers. com; author's pers. obs.). Once in the soil, the seeds typically take 14-30 days to germinate (Clothier, in litt.).

Seed Banks: Seeds of *Verbesina encelioides* are numerous. In a small-scale study on Midway Atoll, a single flower head yielded 300-350 seeds (Niethammer pers. com.).

Value to Humans: Horticultural. Though not widely touted ornamentally, there are a few companies in the Southwestern United States (specifically in New Mexico and Texas) that promote the planting of *Verbesina encelioides* for its fast-growing abilities, its bright colors, and the plant's drought resistant qualities (Plants of the Southwest website; Kings Creek Gardens website). Additionally, the Arizona Department of Water Resources has the species listed on its "Official Regulatory List of Low Water Use and Drought Tolerant Plants" as a recommended plant for landscaping usage due to its low water requirements (AZ Department of Water Resources website).

Medicinal: Medicinal uses of *Verbesina encelioides* appear to be limited and not widely documented. However, M. Moore, the Director of the Southwest School of Botanical Medicine refers to the plant's anti-

inflammatory action for use with both gum sores and as well as in a hemorrhoid treatment (Ledlow in litt.) Earlier medicinal uses are thought to have been practiced by the North Dakota Hopi Indian tribe, utilizing *Verbesina encelioides* for the treatment of spider bite symptoms (USGS website).

Problems:

Crop Pest Weed: Though considered native to Texas, peanut farmers in that state consider *Verbesina encelioides* a "troublesome" weed due to its ability to quickly infest fallow peanut fields, as well as for the potentialof livestock ingesting toxins within the plant (detailed below) (Grichar and Sestak 1998). As a result, the Texas Peanut Producers Board have led the way in supporting research for herbicidal control of the plant.

Plant Toxicity / Economic Losses of Herds:
*Nitrates:* Early research efforts focusing on the toxicity of *Verbesina encelioides* pointed to the plant's potentially high levels of nitrates as the toxic agent (Schmutz et al.1968; Kingsbury 1964). These potentially toxic nitrate levels were classified as a high poisoning threat for grazing sheep and cattle (Kingsbury 1964; Schmutz et al.1968;).

*Galegine:* Subsequent studies in Australia and Argentina (Keeler et al. 1986; Keeler et al. 1992; Lopez et al. 1996) pointed out that the pathological effects observed from *V. encelioides* poisoning corresponded to the levels of the toxic component galegine in the plant, not the nitrate levels as previously thought. After galegine was accepted as the principal toxic agent in *Verbesina encelioides*, additional research was done in the United States concluding that the plant "can clearly be classified as poisonous plant material, with the potential to pose a hazard to livestock during periods of forage shortage" (Keeler et al. 1992).

Signs of low does galegine poisoning in livestock from ingestion of *Verbesina encelioides* include dullness and anorexia (Lopez et al. 1996). More serious poisoning can result in death due to severe lesions on the internal organs as well as internal hemorrhaging (Lopez et al. 1996).

The mild signs referred to above occurred within animals ingesting 5.0g of *V. encelioides* per 1kg of body weight (5.0g/kg), while the severe signs were observed at 6.3g/kg (Lopez et al. 1996). Signs of poisoning did not appear in animals that were fed less than 3.2g of the plant per 1kg of body weight (3.2g/kg). Results from Lopez's study in Argentina (1996) led to the classification of V*erbesina encelioides* as one of the most toxic plants in its region, due to possibility of livestock poisoning from grazing.

While ingestion has proven to be toxic, many references also point out that it is rarely eaten by herds unless other feed options are depleted or when *Verbesina encelioides* is mixed in with the hay or other feed (Everist 1957; Keeler et al. 1986; Lopez et al. 1996). Lopez et al. also suggested that recovery from the toxic effects of *V. encelioides* was possible once the plant was removed from the livestock's diet. In related studies, Keeler et al. (1986) observed no long-term cumulative effects of *Verbesina encelioides* ingestion.
It should be emphasized that toxicity has resulted only from direct ingestion of *Verbesina encelioides*, and contact poisoning has not been documented or suggested, as of yet.

Habitat Degradation:
At Midway Atoll and Kure Atoll, both in the Northwestern Hawaiian Islands, *Verbesina encelioides* presents a significant problem of habitat degradation for seabirds and native plants as summarized below:

1. *Decrease of potential nesting habitat:* In field reports from Kure Atoll, researchers VanderWerf and Rohrer (1997) noted that thick infestations of *Verbesina encelioides* contained few nests of any seabird species, while areas that had been recently cleared of the weed had extensive nesting of the both Laysan and Blackfoot Albatross, as well as Christmas and Wedge-tailed Shearwaters. Similarly in 1998 field reports, Smith and Woodside hypothesized that areas that had been previously treated for the control of *Verbesina encelioides* would be more accessible for nesting sites; during their research they subsequently found higher nesting activity in these treated areas than in non-treated areas.

*2. Inhibition of native plant growth:* The aggressive and dominant growth abilities of *Verbesina encelioides* prevents the growth of less aggressive native plants such as *Scaveola sericea* (Naupaka) and *Ipomea pescaprae* (Beach Morning Glory) (Niethammer pers. com.; author's pers. obs.) These and other native plants are important for long-term habitat of nesting seabirds.

Allelopathic effects of *Verbesina encelioides* have also been noted and attribute to its dominant coverage and success in inhibiting native plant growth (Goel 1987).

*3. Wildlife entanglement / entrapment*: Where growth of *Verbesina encelioides* is especially thick, the plant can entangle and/or entrap both ground nesting and burrowing chicks. D. Smith, Hawaii DLNR Wildlife Manager reports observations of Christmas Shearwater and Laysan Albatross species entangled amongst the weed (pers. com). If not directly entangled, excessive growth around a nesting site can greatly hinder and/or preclude a chick's ability to fledge (Smith pers. com).

Control Methods, General:

Texas:
Due to its negative affects on the yields of the peanut crop, *Verbesina encelioides* has been the focus of intensive research sponsored by Texas Peanut Producers Board. Their research focuses on large-scale herbicidal control of the plant in and among peanut fields (Grichar and Sestak 1998, 1999).

Northwestern Hawaiian Islands:
*Midway Atoll:*
Assistant Refuge Manager, Ken Niethammer, reports that the US Fish and Wildlife Service (USFWS) has utilized both mechanical and herbicidal control methods since early 1997. They have also developed a plan to designate those areas which are priority removal sections, as well as specifically which areas will be hand pulled, mowed, and/or sprayed. The labor force for *V. encelioides* eradication at Midway Atoll consists primarily of a USFWS volunteer crew of approximately 5 individuals, involved mainly with the manual pulling of the weeds for roughly 5 hours a week each. Two additional USFWS staff members devote much of their workweek to both herbicidal and mechanical control efforts of *Verbesina encelioides*.[1,2]

*Kure Atoll:*
Dave Smith, Wildlife Manager for Hawaiian Department of Land and Natural Resources, which oversees Kure Atoll, has been investigating the most efficient control methods for *Verbesina encelioides* since 1996 (Menard 1997; pers. com 1999). Through experiments with comparison plots, Smith has compared various mechanical (hand pulling and use of the "weed whacker") and herbicidal applications. Smith is also intentionally leaving some areas untouched. Not only is this for control reasons with the research plots, but Smith also suggests the hypothesis that there may be an eventual natural die-off or a leveling-out due to nutrient depletion or completion of an "eruptive phase" (Smith pers.com).

Australia: Efforts in Australia utilize both chemical and mechanical methods of chipping and / or hand pulling of the plant (Everist 1957).

Control Methods, Specific Strategies:

Mechanical Methods:
At Midway Atoll, Niethammer (pers. com) estimates that in areas with thick *Verbesina encelioides* growth, manual removal efforts must be repeated at least three times. These repeated removal efforts should be at monthly intervals, and more frequent during flowering periods. The major reason for the repeat of effort is due to the fact that the soil is disturbed with the pulling of *V. encelioides*; this then essentially creates prime

[1] By late 1998, labor efforts were significantly increased with the addition of a approximately 6 individuals from the cooperating agent at Midway Atoll. Each of these new crewmembers worked approximately 24 hours a week, employing both herbicidal and mechanical control efforts.

[2] By 2000, manpower resources devoted to the control of *V. encelioides* had been reduced by the cooperating agent. As of 2002, the agreement between USFWS and the cooperating agent had been severed, with little if any resources left at the Atoll devoted to the control of *V. encelioides.*

habitat for the many seeds that are dispersed during the removal process. Niethammer further emphasizes that even after covering an area three times, monthly follow-up is needed to spot check the area for re-sprouting.

The following specific suggestions regarding mechanical removal methods and suggestions are compiled from Midway Atoll, through personal experience and conversations with Niethammer:

1. *Flower head removal*: Ideally, when *V. encelioides* is found in small patches, the flower heads should first be manually removed and disposed of in sealed bags. This prevents making a new seed bed in the disturbed soil. However, in large infestations, this is not practical or logistically feasible, and thus these areas will certainly require the extra follow-efforts referred to above.

2. *Taproot removal*: Care should be taken with the manual pulling of *Verbesina encelioides* to ensure that the entire taproot is removed. For most of the plants, this is accomplished relatively easily by pulling from the base of the weed, right at ground level. In taller and thicker plants, or with plants that have been mowed, roots can be more resistant to removal and will require extra attention and effort to ensure the entire taproot is removed without breaking off.

3. *Disposal of weeds:* Once an area is manually weeded, it is possible for the pulled weeds to root back into the soil, especially if there are heavy rains soon thereafter. For this reason, it is advised to remove the pulled weeds from the site altogether. However, as this is not always logistically feasible, the second option is to make piles of the pulled weeds, so as to congregate the potential re-growth into limited area.

4. *Mowing efforts* are also employed on large flat fields at Midway Atoll. Niethammer points out that while mowing will not kill the plant, it can be effective in preventing flowering, and subsequent dispersal of seeds. As in hand pulling, once an area is mowed, it must be maintained or the plants appear to come back hardier.

5. *Continual monitoring* efforts are vital in controlling *Verbesina encelioides* due to the apparent high seed dormancy period and ease of establishment of new seeds. Incidental observations (Niethammer pers. com.) have shown re-sprouting in areas that have been kept free of *Verbesina encelioides* for over 3 years.

Unlike Midway, which has a year-round labor force for controlling the *Verbesina encelioides*, efforts at Kure Atoll are restricted to approximately two months a year, with a crew of 1-3 individuals (Smith pers. com). Due to this limited labor force, Smith reserves removal by manual hand pulling only for relatively small patches or those areas considered sensitive due to seabird nesting or native vegetation (Menard 1997, Smith pers. com).

Using results of studies at Kure comparing the most effective control methods, Smith has now also focused his manual efforts on first cutting the foliage back, primarily through the use of a "weed whacker", in preparation for herbicidal application (Menard 1997). Without first cutting back the foliage, it has been found that the canopy structure appears to block access of the herbicide to the smaller plants below (Menard 1997).

Chemical Control Efforts:

On Midway, herbicidal efforts have been primarily reserved for large open areas containing limited nesting activity (Niethammer, pers. com; author's pers. obs.). For these areas, "Rodeo" is mixed at a rate of 1.5-2.0 oz. per gallon of water, according to labeling. Niethammer typically applies one to two herbicidal applications, and follows up with manual spot-checking for new growth. By employing the use of herbicide first, mechanical efforts, which require a significant larger labor force, can be reduced from 3 - 4 coverages of an area to 1 - 2 coverages (Niethammer pers. com). Niethammer is also looking into additional herbicidal options and increased usage, and specifically hopes to start focusing on the use of pre-emergence herbicides (pers. com 1999).

On Kure Atoll, due to the limited labor force previously discussed, Smith has employed herbicidal applications as the primary control method for *Verbesina encelioides* (Smith pers. com). For areas of

*Verbesina encelioides* without native plants or grasses, a combination of "Roundup" with Garlon 3A is applied (Smith pers. com). In areas where *Verbesina encelioides* is mixed within native vegetation, such as *Scaevola seriacea* (Naupaka), Smith has found effective control can be accomplished through a 2% percent "Round-up" solution alone. As pictured in the photo below, this method appears to kill the *Verbesina encelioides* while the native *Scaveola seriacea* remains alive (Smith and Woodside 1998):

*Photo: Dave Smith*

Kure Atoll: Application of two percent "Round-up" solution to an area containing mixed growth of both *Verbesina encelioides* and native *Scaevola seriacea*. The dead foliage in the foreground and background is the *V. encelioides*, while native *S. seriacea* remains alive and appears healthy.

In 1998, Liesemeyer and Polhemus (1999) began additional trials on Kure Atoll using a 2% solution of only Garlon 3A in areas where *V. encelioides* is mixed within native grasses. Initial results have been promising: within 24 hours of application, there was significant withering of the *Verbesina encelioides* without any noticeable detrimental effects on the adjacent native grasses. One week later, though not yet completely killed, the *Verbesina encelioides* continued to whither and yellow. Further follow-up not made that season due to the limited stay of personnel on the island. However, additional follow-up was to be a focus of the upcoming 1999 field season (all above results from Liesemeyer and Polhemus 1999).

At Kure, the continued approach to controlling *Verbesina encelioides* will be to first cut the foliage back, and then follow with herbicidal spraying (Menard 1997; Smith and Woodside 1998). There is a need to spray again after the first signs of re-growth, which is approximately 1-2 months after initial treatment (Menard 1997). Regardless of the method used (manual or herbicidal) Smith also emphasized that one control attempt is not sufficient and that a combination and repeat of efforts will be necessary (pers. com.).

Texas is another location of intensive management efforts for *Verbesina encelioides*. In 1992, the Texas Peanut Producers Board sponsored researchers Grichar and Sestak for a three-year study focusing on post-emergence herbicidal control of *V. encelioides* in peanut fields (Grichar and Sestak 1998). A second study, in 1994-1995 by the same researchers, focused on pre-emergence control herbicides (Grichar and Sestak 1999). Both studies yielded promising results:

*Post-emergence Control:* In their study, Grichar and Sestak (1998) found the most effective control of *V. encelioides* was accomplished with the post-emergence herbicides (POST) of Bentazon, lactofen, pyridate, 2,4-Dichlorophenoxy butanoic acid (2, 4-DB), and 2,4-DB with either pyridate or acifluorfen (herbicides not listed in any order). In this study, the authors defined effective control as a rate of 90% or better over the three- year testing period. (Full results are listed in tables in appendix A and B).

The following post-emergence herbicides provided inconsistent control or damage to the peanut plant (Grichar and Sestak 1998):

1. Bromoxynil
   -stunted peanut growth and sustained damage on the peanut plant
2. Impazapic
   - inconsistent control with varying rainfall
3. Imazethapyr
   - inconsistent control with varying rainfall
4. Acifluorfen
   -inconsistent control when not combined with 2,4-DB

The inconsistent control of both ima zapic and imazethapyr may be explained by results of previous research of Richburg et al. (1995, in Grichar and Sestak 1998), in which they suggest that applications of the post-emergence herbicide must be applied when the plant is less than 4cm (1.6 inches) in height. In Grichar and Sestak's study, post-emergence herbicidal applications were applied when the *Verbesina encelioides* plants were 15cm (6.0 inches) tall.

*Pre-emergence Control:* In their later study on pre-emergence (PRE) and pre-plant incorporated (PPI) herbicidal control, Grichar and Sestak (1999) found that "Ethalfluralin applied preplant incorporated (PPI) followed by imazapic or lactofen (Post) provided 100%" control of *Verbesina encelioides*.

Control of 90% or better was also seen with Ethalafluralin PPI combined with the pre-emergence oxyfluorfen (Grichar and Sestak 1999). Methods of application for this study were as follows (Grichar and Sestak 1999):

PPI herbicides: mixed into the soil by a tractor-driven power tiller to a depth of 5-7 cm.
PRE herbicides: applied immediately after the peanut crop was planted
POST herbicides: applied 3 weeks after the peanut crop was planted

Limited documentation was found on pre and post emergence herbicidal treatment efforts in locations other than Texas. Australia has treated *Verbesina encelioides* with post-emergence applications of 2,4-D, as well as the herbicide, M.C.P.A; both are listed at a rate of 1 lb. per acre (Everist 1957). In California, the general treatment of annuals calls for the spraying of 2,4-D or a "preparation of sodium dinitro-cresol of ninitro-phenol" (Ball 1951).

Other Control Options:

*Salt water:* A preliminary, short-term study was done at Midway Atoll demonstrating the effects of excessive seawater on the growth of *Verbesina encelioides* (author unknown, unpublished). This preliminary study showed that browning occurred on the plants that had direct exposure to copious amounts of seawater poured onto the plant. However, no follow up was done to determine if the plants were killed or if the browning was just temporary.

*Controlled burns:* No research has been done on the use of controlled burns, but in areas such as the Northwestern Hawaiian Islands, this is not a feasible option due to year-round bird populations (Niethammer pers. com).

*Biocontrol:* No documentation could be found regarding bio-control efforts for *Verbesina encelioides* as of this writing.

History: In Hawaii, the earliest recorded observations of *Verbesina encelioides* were made by Hillebrand on Maui in the mid 1800's (Carr website). Documentation of the presence of *Verbesina encelioides* in the Northwestern Hawaiian Islands was made in October 1959, at Kure Atoll (Woodward 1972). It is thought to have come on the tires of bulldozers doing work with the military (Smith pers. com.).

Invasive attributes: A number of characteristics aid in the aggressive qualities of this plant including: ability to withstand drought, ability to handle a wide range of growing conditions, rapid growth, allelopathic effects on other plants, high seed production and dispersal ability, high periods of seed dormancy, and high germination rates (Kaul and Mangal 1987; Grichar and Sestak 1998; Niethammer pers. com.; Smith pers. com.; AZ Dept. of Water Resources website).

Invaded ecosystem Attributes:

*Verbesina encelioides* has a wide range of habitats in which it can invade, with varying degrees of severity:

- North India: *V. encelioides* is considered a dominant weed (Kaul and Mangal 1987).
- Saudi Arabia: in lowland habitats, which are composed of open sand plains with limited water resources, there is a covering of 5-15% *Verbesina encelioides*. The plant is considered dominant and naturalized (Zayed and El-Karemy 1989).
- Argentina: *V. encelioides* is extensively distributed throughout the country (Lopez et al. 1996).
- Europe: *V. encelioides* is considered naturalized and scattered throughout its range (Tutin et al. 1976).
- Australia: *V. encelioides* has been introduced into the country and the weed is widely distributed along "stock routes and grazing areas in areas of southern and Central Queensland" (Everist 1957, Keeler et al. 1986).
- United States: *V. encelioides* is reported in 24 states, the majority of which do not claim the plant as being native. (Rydberg 1932; Shelter and Skog 1978; Keeler et al. 1992; USGS website)

Considered to be naturalized throughout the Hawaiian Islands (Wagner et al. 1990), large populations of *Verbesina encelioides* can be found in Hawaiian habitats that are similar to its native habitat. This includes areas of predominantly dry climates, most likely at sea level elevation, and in sandy soil of open or disturbed areas (Woodward 1972; USGS website; CalFlora website; Menard 1997; Niethammer pers. com; Smith pers. com; author's pers. obs). Though most likely to be found at sea level in Hawaii, *V. encelioides* can encompasses a range from sea level to 2,805 meters (Wagner et al. 1990).

The plant's highly invasive characteristics appear predominant in portions of the Northwestern Hawaiian island chain, where *Verbesina encelioides* has become a widespread and aggressive weed on both Midway Atoll and Kure Atoll (Smith pers. com; Niethammer pers. com; author's pers. obs.). At Midway Atoll, Niethammer estimates that the main island, Sand Island, has 80% of its 1200 acres inhabited by some levels of *Verbesina encelioides*. Nearby Eastern Island, at 350 acres, also has large patches of the weed, but Niethammer notes that the populations are not as large or tall, possibly due to less optimal soil.[3] On Kure Atoll, Smith estimates that approximately 50% of the island has some level of *Verbesina encelioides* growth (pers. com). The heaviest infestations appear on areas previously disturbed through clearing or mowing during the construction of a US Coast Guard LORAN station (Smith pers. com).

Control Summary:

The key elements in dealing with *Verbesina encelioides* are 1) the plant must be prevented from flowering, 2) existing seeds in the soils must be killed, and 3) efforts must be long term. Additionally, replanting of the area with native plants is essential for long-term habitat management and to prevent leaving an open, disturbed area for which the *Verbesina encelioides* can invade.

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[3] As of 2001, Niethammer noted that over the last few years, the Eastern Island plants appear to be more robust. He attributes this likely to be due to soil buildup from decaying material of previous generations of *V. encelioides* plants (pers. com).

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USGS site, "Native Wildflowers of the North Dakota Grasslands", with description and background information of *Verbesina encelioides*. (Photo image included)

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Photo: Midway Atoll, author hand pulling *Verbesina encelioides* which surrounding Laysan albatross chick in lower left corner.

*Appendix A:* Results of Post-emergence Herbicides on *Verbesina encelioides*. Table is taken from Grichar and Sestak's paper entitled, "Golden Crownbeard Control with Postemergence Herbicides", 1998.

**Late-season Control of *Verbesina encelioides* in Peanut Fields with Postemergence Herbicides, 1992-1995**

| | | Percentage of Control for *V. encelioides* | | | | |
|---|---|---|---|---|---|---|
| | | 1992 | 1994 | | 1995 | |
| Treatment | Rate kg/ha | Field B % | Field A % | Field B % | Field A % | Field B % |
| Nontreated Check | - | 0 | 0 | 0 | 0 | 0 |
| Acifluorfen | 0.42 | 93 | - | 100 | - | 80 |
| Acifluorfen | 0.56 | 95 | 100 | 100 | 55 | - |
| Acifluorfen + 2,4-DB | 0.56 + 0.28 | 95 | - | 100 | - | 98 |
| Acifluorfen + bentazon | 0.28 + 0.56 | 85 | 88 | 100 | 60 | 90 |
| Bentazon | 1.12 | 96 | - | - | - | 100 |
| Bromoxynil | 0.28 | - | 100 | - | 66 | - |
| Imazapic | 0.04 | 93 | 78 | 90 | 43 | 28 |
| Imazapic | 0.05 | 97 | 75 | 100 | 40 | 27 |
| Imazapic | 0.06 | 94 | 60 | 93 | 60 | - |
| Imazapic | 0.07 | 92 | 87 | 100 | 38 | 27 |
| Imazethapyr | 0.05 | 90 | - | 83 | - | - |
| Imazethapyr | 0.07 | 95 | 67 | 87 | 35 | 7 |
| Lactofen | 0.28 | 95 | 100 | 100 | 80 | 94 |
| Pyridate | 0.50 | 92 | - | 100 | - | - |
| Pryidate | 1.00 | 94 | 100 | 100 | 98 | 88 |
| Pyridate + 2,4-DB | 0.50 + 0.28 | 95 | - | 100 | 100 | - |
| Pyridate + 2,4-DB | 1.00 + 0.28 | - | 100 | - | 100 | 92 |
| 2, 4-DB | 0.28 | 91 | 90 | 100 | 100 | 98 |

*Field A and Field B refer to field locations and Charlotte and Pearsall, Texas.
*Field B had heavier infestations of *V. encelioides* in 1994 and 1995 than in 1992.
*In 1994 and 1995, Field A received limited rainfall (12.5mm) for 30 days after application of postemergence herbicide.
*All postemergence applications were applied when the *V. encelioides* had a height of approximately 15 cm.

*Appendix B:* Breakdown of Herbicide Treatments Referred to in the Preceding Table (appendix A):
(This table is a direct copy of work from Grichar and Sestak (1998))

| Common name | Chemical name | Rate | Adjuvant |
|---|---|---|---|
| | | kg/ha | |
| Acifluorfen | 5-[2-chloro-4-(trifluoromethyl) phenoxy]-2-nitrobenzoic acid | 0.42, 0.56 | Crop oil concentrate[a] (1% v/v) |
| Acifluorfen + bentazon | A mixture of 159 g acifluorfen and 320 g bentazon/L[b] | 0.28 + 0.56 | Crop oil concentrate (1% v/v) |
| Acifluorfen + 2,4-DB | - | 0.56 + 0.28 | Crop oil concentrate (1% v/v) |
| Bentazon | 3-(1-methylethyl)-(1*H*)-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide | 1.12 | Crop oil concentrate (1% v/v) |
| Bromoxynil | 3,5-dibromo-4-hydroxybenzonitrile | 0.28 | None |
| Imazethapyr | 2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid | 0.05, 0.07 | Nonionic surfactant[c] (0.25% v/v) |
| Imazapic | (±)-2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-methyl-3-pyrindine- carboxylic acid | 0.04, 0.05, 0.06, 0.07 | Nonionic surfactant (0.25% v/v) |
| Lactofen | (±)-2-ethoxy-1-methyl-2-oxoethyl 5-[2-chloro-4-(trifluoromethyl) phenoxy]-2-nitrobenzoate | 0.28 | Crop oil concentrate (0.5% v/v) |
| Pyridate | *O*-(6-chloro-3-phenyl-4-pyridazinyl)*S*-octyl carbonothioate | 0.5, 1.0 | Crop oil concentrate (1% v/v) |
| Pyridate + 2,4-DB | - | 0.50 + 0.28, 1.0 + 0.28 | Crop oil concentrate (1% v/v) |
| 2,4-DB | 4-(2,4-dichlorophenoxy)butanoic acid | 0.28 | Crop oil concentrate (1% v/v) |

[a]Agridex, a crop oil concentrate containing 83% paraffin based petroleum oil and 17% polyoxyethylated polyol fatty acid and polyol fatty acid ester (Helena Chemical Company, Memphis, TN).
[b]A premix marketed as Storm (BASF Corp., Parsippany, NJ).
[c]X-77, a nonionic surfactant containing alkylanylpolyethylene glycols, free fatty acids, and isopropanol (Valent USA, San Ramon, CA).