USDA Animal and Plant Health Inspection Service
Plant Protection and Quarantine

Uromyces transversalis
Assessment of the Risk of Introduction
Recommendations for Risk Mitigation
for _Gladiolus_ spp. Cut Flowers and Propagative Material from Mexico

A Qualitative, Organism-Based Pathway Risk Assessment

Gladiolus

http://doityourself.com/gardenmaint/hrdzon5.htm

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Executive Summary

This organism-based pathway risk analysis evaluates the likelihood and consequences of *Uromyces transversalis* (Gladiolus rust) being introduced into the United States via *Gladiolus spp*. cut flowers and nursery stock imported from Mexico. The analysis finds that both the probability of introduction and the consequences are **High**. Ongoing, high-levels of interceptions of the disease in cut flowers from Mexico indicate that current requirements for Mexico are inadequate. Stronger measures are recommended to reduce or eliminate the prevalence of the disease in Gladiolus cut flowers imported from Mexico.

A. Introduction

1. Request for the analysis

This organism-based pathway risk analysis has been prepared in response to *Ad Hoc* request No. 29 from Dr. Cathy Enright, Phytosanitary Issues Management (PIM) through Ron Sequeira, National Science Program Leader for Risk and Pathway Analysis, Center for Plant Health Science and Technology (CPHST). PIM requested that the analysis:

- evaluate the likelihood and consequences of *Uromyces transversalis* being introduced into the United States via *Gladiolus* sp. cut flowers and nursery stock imported from Mexico; and
- recommend any new restrictions that may be needed for cut flowers and nursery stock as pathways for this pest.

2. Methodology

This analysis is qualitative. Estimates of the probability and consequences of introduction are expressed in the qualitative terms of High, Medium, or Low rather than in numerical terms, such as probabilities or frequencies. The details of the methodology and rating criteria are elaborated in the Guidelines for Pathway-Initiated Pest Risk Assessment, Version 5.02 (USDA-APHIS-PPQ, 2000). The analysis addresses the likelihood of introduction where introduction is entry resulting in establishment (IPPC, 2002).

3. Initiating Event

The rust fungus *Uromyces transversalis* was intercepted on Gladiolus cut flowers from Mexico in August 2004 at ports in California and Texas. The Animal and Plant Health Inspection Service (APHIS) Offshore Pest Information System reported that the infected cut flowers were apparently grown in "Tenancingo Ejido de Mexico" in the State of Puebla (OPIS 2005).

APHIS requested information on the presence of Gladiolus rust in Mexico (SAGARPA Letter #12993 dated December 15, 2004 (Raya 2004)). APHIS' request was predicated on the confirmation by Dr. Mary Palm of *Uromyces transversalis* on interceptions submitted by Charles J. Payne on September 13, 2004 (ARS-GRIN database).

The national plant protection organization of Mexico (SAGARPA) informed APHIS that Gladiolus rust, caused by the fungus *Uromyces transversalis*, was present in some fields in the states of Morelos, Puebla and Mexico. Subsequent surveys found the disease in the main Gladiolus production areas of the states of Mexico, Michoacan, Morelos, Puebla, Guerrero, Oaxaca, Sinaloa, and Veracruz (Enright 2005).

SAGARPA also informed APHIS that phytosanitary production, pest management, inspection and certification programs were in place to avoid shipping infested host material to the United States. The organism continues to be intercepted routinely in both cargo and baggage from Mexico since 2004 (see Table 1).

Table 1. Interceptions of *Uromyces transversalis* on *Gladiolus spp*. cut flowers from Mexico (2004-2005) by month*

Month	No. of interceptions
August 2004	2
September 2004	15
October 2004	78
November 2004	93
December 2004	36
January 2005	20
February 2005	26
March 2005	11
April 2005	7
May 2005	8
June 2005	3
July 2005	1
August 2005	6
September 2005	2
	Total 307

***PIN 309 database; accessed 9-23-2005

Table 2. Interceptions of *Uromyces transversalis* on *Gladiolus* sp. cut flowers from Mexico by State (2004-2005)

State	No. of interceptions
Arizona	16
California	26
Texas	265
	Total 307

*PIN 309 database accessed 9-23-2005

4. Regulatory Status

U.S. plant quarantine regulations currently require that a phytosanitary certificate (PC) accompany all *Gladiolus spp*. cut flowers, plants, bulbs and nursery stock from Mexico. An additional declaration (AD) is required stating that "The *Gladiolus spp*. in this shipment have been inspected and found free of *Uromyces transversalis*".

5. Pathways

The known pathways for the entry or spread of *U. transversalis* into the U.S. are cut flowers and propagative material in baggage and cargo. Interceptions from Mexico at ports in Arizona, California, and Texas confirm that cut flowers are the major pathway from Mexico.

6. Taxonomy, Biology, and Distribution of *Uromyces transversalis (Thüm) G. Winter.* See Appendix 1.

B. Assessment of the Consequences of Introduction

1. Climate-Host Interaction

Gladiolus plants are grown commercially in the field and in greenhouses in the United States. Large scale production of plants (mainly to be sold as bulbs and cut flowers) exists in numerous states. The plants are commonly used as indoor ornamentals throughout the country and are widely grown outdoors in USDA Hardiness Zones 7-10 (see USDA Plant Hardiness Zones; Appendix 2, Map 2). The availability of both suitable hosts and suitable climate throughout the U.S. result in a rating of **High** for this element of the analysis.

2. Dispersal Potential

The local spread of Gladiolus rust occurs mainly by air distribution of urediospores which are produced in prolific quantities on aerial portions of the plant and disperse easily in wind or if lightly brushed. Urediospores develop quickly and continuously under suitable conditions. Aloj et al. (1981) reported that urediospore germination occurred between 5 and 25°C, being optimal at 15°C. Infection of Gladiolus plants was most severe between 10 and 20°C, when leaves were wet for 12 h, and only slight between 10 and 15°C for 6-9 h wetting and at 25°C for 12 h wetting. The period of infection and incubation varied from >20 days at 10°C to 8-10 days at 25°C (CABI 2003).

Long-distance spread of the disease is augmented by the movement of infected plants and cut flowers. Due to the latency period between infection and the expression of symptoms, plants or cut flowers may appear healthy at harvest but later manifest the disease, especially when harvested in the early stages of an outbreak or where fungicides are being used to reduce the prevalence of the disease.

Dispersal potential is rated **High** because the disease can reproduce and spread rapidly when producing urediospores.

3. Economic Impact

Ferreira and Nevill (1989) found that the use of fungicides was necessary to ensure a marketable crop of corms. Marketable inflorescences were harvested only from plots treated weekly with fungicides.

Although the disease is present in most countries that are trading partners of the United States, it is absent from much of Europe. Restrictions on U.S. exports of Gladiolus plants and flowers to Europe would be anticipated if the disease were to become established in the United States. An anticipated increase in the use of fungicides would be another negative impact for U.S. growers.

The economic impact is rated as **High** because potentially significant negative impacts would be anticipated for yield, quality, and trade.

4. Summary Assessment of the Consequences of Introduction:

The consequences in this case are based on the ratings for three key elements. In each instance, the analysis resulted in ratings of **High**. The overall estimate of the consequences of introduction is therefore also **High**.

C. Assessment of the Likelihood of Introduction

The likelihood of introduction is a function of the quantity and frequency of the commodity imported annually and the pest opportunity, which consists of five criteria that consider the potential for a pest's survival along the pathway to establishment (USDA 2000).

1. Volume and frequency of imports

The total number of shipments of Gladiolus cut flowers from Mexico was 2,071 in 2004 and 843 in 2005 (PQ 280 database). This represents a total of 29,699,235 stems of Gladiolus cut flowers (Tanner, 2005). APHIS considers this to be a very substantial volume and therefore rates this sub-element of the assessment **High**.

2. Likelihood of surviving post-harvest procedures

This sub-element is to estimate the ability of the pest to survive harvesting, handling, processing, and phytosanitary or other treatment in the country of origin. Examples include culling, washing, chemical treatment, and cold storage. It is assumed that a minimal amount of postharvest handling, such as removing most soil residue and culling for obvious pest or other damage, is performed on Gladiolus cut flowers, bulbs, and plants.

Diseased stems are likely to be culled if lesions are present because although the yellow/orange/brown uredinia are microscopic, they are also prolific and easily spotted against the green color of the leaf. Handling and washing may remove some of the bright spores and make the detection of the disease more difficult. Washing would not be expected to negatively affect the survival of the organism due to hyphae being internal. Lesions and contamination on other parts of the plant may be invisible. Recently infected plants or plants treated with fungicides are less likely to have visually detectable signs at the time of harvest. No postharvest treatments are known to be applied to *Gladiolus* sp. from Mexico.

Careful culling at harvest and curing packing may help to reduce the number of diseased stems, but will do nothing to reduce the survival of the disease in infected material that has not yet shown signs of the disease or where signs have been masked by fungicide treatments. A substantial amount of infected material would be expected to escape post-harvest processing. Infected material would be expected to produce viable urediospores, and continue producing viable spores until the host material was completely dead and dry or destroyed. This sub-element is therefore rated **High**.

3. Likelihood of surviving shipment

Infected stems continue producing lesions and viable urediospores as long as the plant material is live. The conditions for shipping Gladiolus cut flowers are generally conducive to preserving the freshness and extending the shelf-life of the flowers. The temperatures and humidity under these conditions also promote the survival of the fungus since spores survive and germinate on corms, rhizomes, flowers, leaves and stems between 5 and 25^0 C (Aloj *et al.* 1981). It is therefore anticipated that Gladiolus rust will survive shipment and this sub-element is also rated **High**.

4. Likelihood of escaping detection at the Port of Entry

Symptoms are as for a typical rust; yellowish-brown (uredinia) or blackish-brown (telia) pustules on the leaves, either solitary or aggregated. The uredinia are the first to develop and these produce the characteristic minutely verruculose, yellowish, urediniospores. The telia develop later and produce the thick-walled, yellowish-brown, pedicellate, teliospores (CABI 2003).

Uredinia (across the width of the leaf) and telium (dark)
- BPI 863538, ELP TX 66823

All bulbs and cut flowers from Mexico are subject to inspection on arrival. The probability that a pathogen is detected at the port of entry is a function of the presence of visible symptoms or signs and the level of inspection sampling. Because many pathogens are microscopic and well concealed, they have a high probability of escaping detection but *Uromyces transversalis* can be fairly visible. The dusty yellow/orange/brown color of the spores is especially visible on leaf surfaces making it easy to detect when sporulating. The difficulty is that not all infected material may have sporulating lesions at the time of inspection. As a result, a substantial amount of infected material may pass undetected, especially if it has already been culled for obvious symptomatic stems and/or treated with a fungicide to suppress sporulation. For this reason, the likelihood that the disease will escape detection is **High**.

5. Likelihood of being moved to a suitable habitat

This sub-element considers the geographic location of likely markets and the chance that the commodity will be moved to locations suitable for pest survival. Ornamental plants and cut flowers imported into the United States typically arrive at multiple ports and are distributed according to market demand. Gladiolus plants and cut flowers are popular among consumers in the United States. Widespread acceptance means that markets exist in all parts of the United States, and infested cut flowers and plant parts are certain to arrive in areas that are suitable for the survival of the disease.

The fungus occurs in East Africa in Zones 7-12 (see Appendix 2, Map 1). Based on establishment and spread potential demonstrated in other areas, it is predicted that the disease could easily establish and spread in all but the hottest and coldest areas of the United States. *U. transversalis* is therefore assigned a **High** rating in this sub-element.

6. Likelihood of contact with host material

This sub-element considers the likelihood that the disease can come in contact with host material for reproduction. Susceptible host material is widely prevalent throughout most of the United States, especially considering that Gladiolus is a common landscape plant in home gardens.

The likelihood of exposure is increased substantially by two common practices: (1) the disposal of old or poor quality material in compost piles near gardens; and (2) the placement of fresh infected material in outdoor areas near gardens (e.g., cemeteries). Direct contact of infected material with a susceptible host is not necessary because the spores are aerially distributed. As a result, this sub-element is also rated **High**.

7. Summary Assessment of the Likelihood of Introduction:

The overall likelihood of introduction (entry and establishment) and spread of Gladiolus rust is estimated to be **High** based on the composite ratings for each sub-element in this aspect of the analysis. It is noted that the detectability of the rust due to the visibility of spores on leaf surfaces somewhat reduces the likelihood of escaping detection for some proportion of fresh material, but not all. The propensity of the fungus to be present without signs, especially in fresh, newly infected plants and plants treated with fungicides, means that a substantial amount of infected material without visible signs would be expected to escape detection.

D. Conclusion: Pest Risk Potential

The Pest Risk Potential is a summation of the estimates for the Consequences of Introduction and Likelihood of Introduction. Pest Risk Potential is an estimation of the risk associated with importation in the absence of prescribed mitigation measures. According to the template document, *Guidelines for Pathway-Initiated Pest Risk Assessments, Version 5.02* (USDA, 2000), port of entry inspection provides sufficient phytosanitary security for pests assigned Low Pest Risk Potentials, while specific phytosanitary measures may be necessary for Medium Pest Risk Potentials and are strongly recommended for High Pest Risk Potentials. In this case, all estimates are **High**, and therefore the overall Pest Risk Potential is also **High**.

E. Recommendations

Prior to October 20, 2004 and before the confirmation that *U. transversalis* was present in Mexico, cut flowers required only inspection at the port of entry, bulbs required a Phytosanitary Certificate, and plants required a Phytosanitary Certificate and Post-entry Inspection.

Based on interceptions of *U. transversalis* at ports in Texas, APHIS has required a phytosanitary certificate with an additional declaration stating that "the *Gladiolus* spp. in this shipment have been inspected and found free of *Uromyces transversalis."* This requirement applies to all cut flowers, plants (bulbs), and nursery stock of *Gladiolus* spp. from Mexico, and was effective beginning Wednesday, October 20, 2004.

The continuing high number of Gladiolus rust interceptions in cut flowers associated with both baggage and cargo indicates that current mitigations are not effectively reducing the pest risk potential from Mexico. Due to the high Pest Risk Potential for Gladiolus rust, it is recommended that strengthened measures be put in place.

Options include:

a) prohibition of all *Gladiolus spp*. material (cut flowers <u>and</u> propagative material) from <u>all</u> areas where *Uromyces transversalis* is known to occur;

b) prohibition of cut flowers from all areas where *Uromyces transversalis* is known to occur, and strengthened certification for propagative material (e.g., the potato program for *Globodera rostochiensis*, the geranium program for *Ralstonia solanacearum* Race 3, Biovar 2 or the program for *Monilina fructigena* on fruit);

c) prohibition of cut flowers from all areas where *Uromyces transversalis* is known to occur, and continue with current certification and post-entry requirements for propagative material;

d) strengthen certification requirements for cut flowers, and continue with current certification and post-entry requirements for propagative material;

e) increased inspection intensity at the port of entry and/or at origin.

A phytosanitary treatment is not an alternative because no effective treatment currently exists for either field or post-harvest application to eliminate the fungus from material for export. The prevalence of the disease in export material may be somewhat reduced by field applications of fungicides and careful culling procedures, but the experience to date has shown that this regime does not adequately reduce the amount of infected material that is shipped from Mexico. In fact, the fungicide applications may actually be increasing the risk of introduction by masking and delaying symptom expression.

Likewise, pest-free areas or pest-free places of production are not identified as alternatives. Such measures may be a possibility where free-areas are separated by large distances or physical barriers and adequate regulatory safeguards can be put in place to prevent introduction of the disease. A program of this nature would be difficult because the disease spreads easily via aerial distribution of spores. No such program has been proposed so this possibility is not considered viable at this time.

Continuing interceptions of the disease in shipments of cut flowers from Mexico indicates that current measures for cut flowers are inadequate. There is however, no evidence to suggest that current measures for propagative material are failing. Strengthening measures for propagative material as suggested by options (a) and (b) is therefore less easily justified based only on the experience to date with Mexico. Additional analysis would be required to reconsider the risk associated with propagative material from all current sources.

Options (d) and (e) are essentially strengthening the intensity of existing measures. Aside from the obvious resource issues associated with these approaches, they also do not completely address the underlying practical and biological difficulties associated with excluding infected material from export shipments based only on inspection and certification. Both options have a strong potential element of human variability which is compounded by the tendency for the disease to be difficult to detect in some stages of infection and development.

Increasing the effort devoted to certification and inspection programs would be expected to result in some reduction in the prevalence of the disease in export material (depending on the magnitude and quality of the effort) but it is unlikely to result in only clean material being shipped because all infected material will not be symptomatic.

Option (c) is therefore the preferred option based on the results of this analysis. This option strengthens restrictions on cut flowers, where the risk is currently highest, without adding restrictions to propagative material, where there is no evidence of increased risk.

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Appendix 1

UROMYCES TRANSVERSALIS
GLADIOLUS RUST

[Based on review of CABI Data Sheet by Bob Schall, January 6, 2005]

PREFERRED NAME: *Uromyces transversalis* (Thum.) G. Winter (1884)

TAXONOMIC POSITION

Domain:	Eukaryota
Kingdom:	Fungi
Phylum:	Basidiomycota
Class:	Urediniomycetes
Order:	Uredinales
Family:	Pucciniaceae

OTHER NAMES USED

Uredo transversalis Thüm. 1876. Flora 59:570.
Uredo transversalis Thüm. 1876.
Uromyces freesiae Bubák 1900
Uromyces watsoniae P. Syd. & Syd. 1910.
Uromyc.

COMMON NAMES

English: Gladiolus rust, rust of Gladiolus, rust: *Gladiolus* spp.
French: rouille du Gladiolus, rouille du glaïeul

NOTES ON TAXONOMY AND NOMENCLATURE

There are two species of *Uromyces* causing rust on *Gladiolus*. The other species, *Uromyces gladioli*, can be distinguished from *U. transversalis* by its larger teliospores with a longer pedicel. In addition, the two rusts are said to infect different species of *Gladiolus*.

HOST RANGE

Primary hosts: *Gladiolus* hybrids (sword lily)
Secondary hosts: *Crocosmia*

Affected Plant Stages: Vegetative growing stage.
Affected Plant Parts: Leaves.

GEOGRAPHIC DISTRIBUTION

The distribution map includes records based on specimens of *U. transversalis* at herb. IMI (CABI Bioscience, Egham, UK).

List of countries

Europe
France: restricted distribution (IMI, 1996; EPPO, 2003)
Italy: restricted distribution (Pisi & Bellardi, 1994; IMI, 1996; EPPO, 2003)
Luxembourg: absent, formerly present (EPPO, 2003)
Malta: restricted distribution (IMI, 1996; Herb. IMI; EPPO, 2003)
Netherlands: absent, intercepted only (EPPO, 2003)
Portugal: absent, formerly present (EPPO, 2003)
Spain: restricted distribution (IMI, 1996; EPPO, 2003)
United Kingdom: absent, intercepted only (EPPO, 2003)

Africa
Kenya: present, no further details (IMI, 1996; Herb. IMI; EPPO, 2003)
Malawi: present, no further details (IMI, 1996; Herb. IMI; EPPO, 2003)
Mauritius: present, no further details (Herb. IMI; EPPO, 2003)
Morocco: eradicated (Viennot-Bourgin, 1978; IMI, 1996; EPPO, 2003)
South Africa: restricted distribution (IMI, 1996; Herb. IMI; EPPO, 2003)
Tanzania: present, no further details (IMI, 1996; Herb. IMI; EPPO, 2003)
Zambia: present, no further details (Herb. IMI)
Zimbabwe: present, few occurrences (IMI, 1996; Herb. IMI; EPPO, 2003)

Western Hemisphere
Brazil: restricted distribution (Pitta et al., 1981; IMI, 1996; Herb. IMI)
Sao Paulo: present, no further details (EPPO, 2003)
Martinique: present, few occurrences (IMI, 1996; EPPO, 2003)

Oceania
Australia: present, few occurrences (EPPO, 2003)
Queensland: present, no further details (EPPO, 2003)
South Australia: present, no further details (EPPO, 2003)
Victoria: present, no further details (EPPO, 2003)

BIOLOGY AND ECOLOGY

Aloj et al. (1981) reported that urediospore germination occurred between 5 and 25°C, being optimal at 15°C. Infection of Gladiolus plants was most severe between 10 and 20°C, when leaves were wet for 12 h, and only slight between 10 and 15°C for 6-9 h wetting and at 25°C for 12 h wetting. The period of infection and incubation varied from >20 days at 10°C to 8-10 days at 25°C.

Means of Movement and Dispersal

Plant parts liable to carry the pest in trade/transport:

- Bulbs/tubers/corms/rhizomes: spores; borne externally; invisible.
- Flowers/inflorescences/cones/calyx: spores; borne externally; invisible.

- Leaves: spores, hyphae; borne internally; borne externally; visible to naked eye.
- Stems (above ground)/shoots/trunks/branches: spores, hyphae; borne internally; borne externally; visible to naked eye.

Plant parts not known to carry the pest in trade/transport:

- Bark
- Growing medium accompanying plants
- Seedlings/micropropagated plants
- Roots
- True seeds (inc. grain)
- Wood.

ECONOMIC IMPACT

Ferreira and Nevill (1989) found that corm yield was adversely affected by rust, and weekly applications of bitertanol or triadimefon were necessary to ensure a reasonable yield. Marketable inflorescences were harvested only from plots treated weekly with fungicides; internode length on flower spikes was closely related to the intervals between applications.

SYMPTOMS

Symptoms are as for a typical rust; yellowish-brown (uredinia) or blackish-brown (telia) pustules on the leaves, either solitary or aggregated. The uredinia are the first to develop and these produce the characteristic minutely verruculose, yellowish, urediniospores. The telia develop later and produce the thick-walled, yellowish-brown, pedicellate, teliospores.

MORPHOLOGY

Uredinia amphigenous, solitary or aggregated, minute, 0.3-1.5 µm diameter, round to elongated, yellowish-brown. Urediniospores globose to subglobose or broadly ellipsoid, minutely verruculose, yellowish, 14-26 x 13-19 µm; wall 1.5-2.5 µm thick; pores 6-8. Telia amphigenous, irregularly scattered or aggregated, round to oblong, compact, blackish-brown. Teliospores subglobose to broadly ellipsoid or pyriform, apex rounded or conico-truncate, smooth, yellowish-brown, 20-32 x 14-21 µm; wall 1.5-2 µm thick, 4-8 µm thick at the apex; pedicel hyaline to pale brown, up to 45 µm long; paraphyses yellowish-brown, densely aggregated.

SIMILARITIES TO OTHER SPECIES

There are two species of *Uromyces* causing rust on *Gladiolus*. The other species, *Uromyces gladioli*, can be distinguished from *U. transversalis* by its larger teliospores with a longer pedicel. In addition, there is evidence to suggest that the two rusts infect different species of *Gladiolus*.

DETECTION AND INSPECTION METHODS

Examine leaves and stems and look for yellowish pustules; confirm by examination with the microscope.

CONTROL

Host-Plant Resistance

Resistance appears to be due to a significant reduction in the number of appressoria formed by the fungus on resistant species (for example, *Gladiolus daleni*) compared to the number formed on susceptible cultivars (for example, 'Goldfield') (Ferreira and Rijkenberg, 1991). An evaluation schedule and a standardized artificial inoculation technique have been developed. All cultivars evaluated were susceptible to *U. transversalis*; the most resistant species were *G. daleni, G. ochroleucus, G. papilio, G. tristis* var. *concolor* and *G. tristis* var. *tristis*. Very resistant selections were obtained from the following crosses: *G. alatus* x *G. tristis*; 'Vuurland' x *G. tristis*; 'Campanella' and 'Nymph' x *G. angustus*; and *G. daleni* x *G. carinatus*. The inheritance of resistance from *G. daleni* and *G. tristis* has been described.

Chemical Control

Garibaldi and Aloj (1980) found that systemic fungicides gave better control than preventive chemicals and weekly application of oxycarboxin or benodanil from symptom manifestation till at least appearance of inflorescences gave the best control and are therefore recommended.

Aloj and Garibaldi (1980) found that in glasshouse trials with 61 cultivars, Junior Promm, Summer melody and Blondine appeared resistant.

Pandolfo and Garibaldi (1986) reported that benodanil, bitertanol, fenpropimorf, myclobutanil, propiconazole, S-3308 [?diniconazole], DPX H-6573 [flusilazole] and penconazole + captan gave excellent control in field trials; no phytotoxicity was noted.

Ferreira and Nevill (1989) reported that weekly applications of bitertanol or triadimefon gave significantly better control of U. transversalis than fenarimol and performed better than oxycarboxin, penconazole, EDTA, CuEDTA and DTPA. There was a direct relationship between the number of applications and the incidence of rust.

Rolim et al. (1985) found that weekly sprays with bitertanol, mancozeb and chlorothalonil, gave the best control on the basis of results from field trials against natural infection. Results were evaluated by leaf infection and bulb weight.

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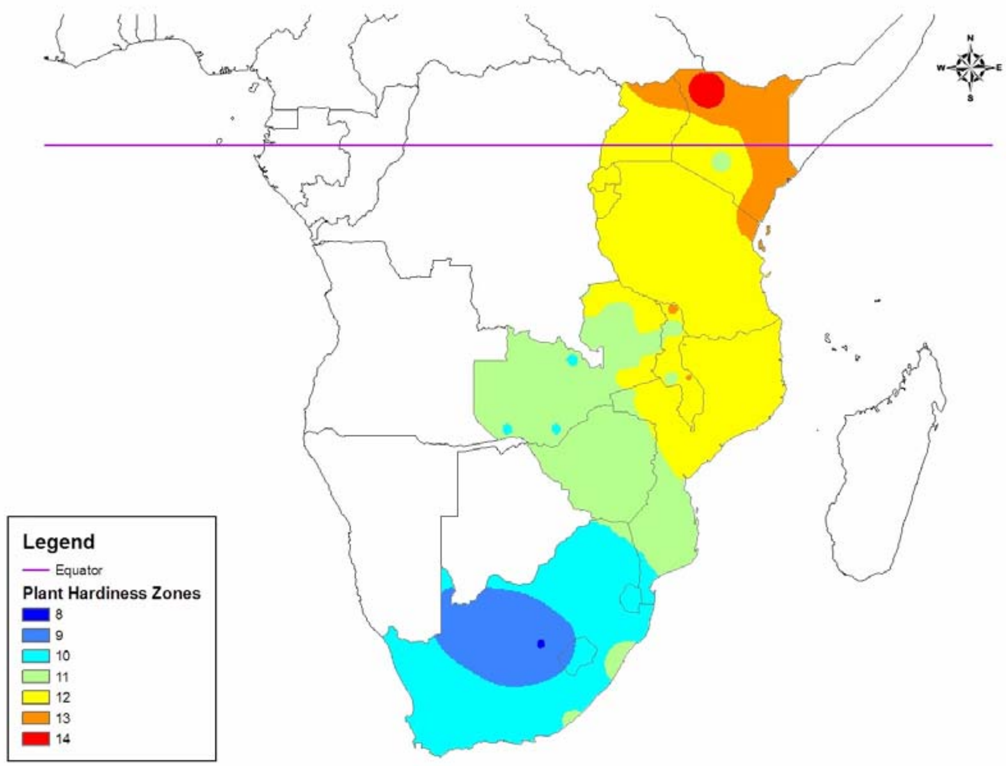
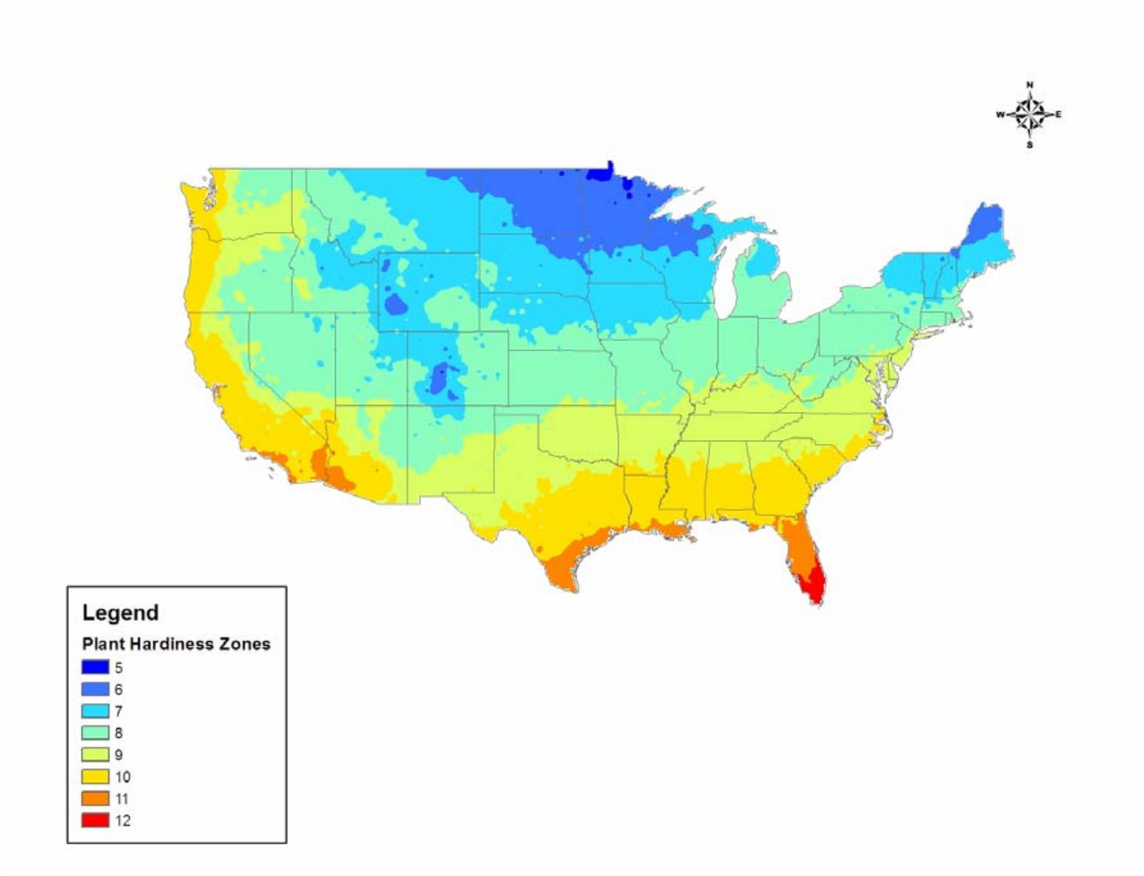
Appendix 2



Map 1. East Africa Plant Hardiness Zones
Global Climate Normals: 1961-1990. World Meteorological Organization. National Climatic Data Center. Asheville, North Carolina.



Map 2. U.S. Plant Hardiness Zones
Climate Atlas of the Contiguous United States: 1961-1990. National Climatic Data Center. Asheville, North Carolina.