Proceedings of the Indiana Academy of Science
(1987) Volume 97 p. 109-113.

Cyanogenesis in Woody Ornamentals

John E. Ebinger and Daniel L. Bergman
Eastern Illinois University, Charleston, Illinois 61920

Introduction

Many plants have the ability to synthesize compounds which are capable of liberating hydrogen cyanide upon hydrolysis. This phenomenon, known as cyanogenesis, has been recognized for more than a century and is not restricted to a particular group of plants. Cyanogenesis has been reported in bacteria, fungi, ferns, gymnosperms, and angiosperms. Among higher plants, these compounds are generally restricted to the leaves but may also occur in other plant organs. Presently cyanide has been reported from more than 2050 species of plants representing about 110 families (Seigler, 1981).

Cyanogenesis is caused by the breakdown of cyanogenic glycosides or cyanolipids in the presence of specific enzymes (β-glucosidases). The amount of cyanide produced depends on several intrinsic (genetics, part of plant, age of plant, and sometimes the sex of the plant) and extrinsic factors (climate, moisture supply, soil fertility, and frost damage) (Kingsbury, 1964). More than 30 different cyanogenic compounds have been reported, but specific compounds have been isolated from less than 200 species (Seigler, 1977). The present study was undertaken to determine the extent of cyanogenesis in common woody ornamentals in the midwestern United States because these compounds may be useful as taxonomic characters, and both the compounds and the plants that contain them are poisonous to both humans and livestock.

Materials and Methods

More than 1000 ornamental woody specimens, representing 37 species, were tested for the presence of cyanogenic compounds, as were herbarium specimens of these species in the Stover Herbarium at Eastern Illinois University (EIU). Each of these specimens were tested for the presence of hydrogen cyanide by the method previously described by Feigl and Anger (1966) and modified by Tantisewie *et al.* (1969). To conduct this test, a small amount of plant material (about 200 mg) is crushed, placed in a vial, and moistened with distilled water. A strip of filter paper impregnated with copper ethylacetoacetate and tetra base (4,4′-tetramethyldiaminodiphenylmethane) is added to the vial so as not to touch the sample, and the vial sealed with a cork. The presence of cyanide is indicated if the filter paper turns a blue color within a 24-hour period. A negative test indicates the specimen does not contain a cyanogenic compound or lacks the enzyme capable of hydrolyzing the cyanogenic compound, or both.

A quantitative determination of cyanide was not made. An indication of the amount of cyanide produced, however, can be made by observing the extent of the color change of the Feigl Anger paper (Dickenmann, 1982). In this study the reaction was considered weak if only part of the paper turned a light blue, moderate if it turned a light to medium blue, and strong if the paper turned a deep blue. According to Dickenmann (1982), the weak reaction contains approximately 2-20 mg of HCN per kg fresh weight, the moderate reaction produces 21-50 mg of HCN per kg fresh weight, and the strong reaction produced more than 50 mg of HCN per kg fresh weight. Voucher specimens are deposited in the Stover Herbarium of Eastern Illinois University (EIU). Nomenclature follows Bailey (1964).

Results and Discussion

The species examined are discussed below, while Table 1 lists all of the species ex-

TABLE 1. Woody ornamentals which tested positive for cyanogenesis during the present study. Also included for each species is the strength of the reaction, the plant part tested, the number of individuals examined, the number of individuals that tested positive for cyanogenesis, and a reference for species that have been reported previously as cyanogenic.

Species	Speed of the reaction[1]	Strength of the reaction[2]	Plant part tested[3]	Number tested	Number cyanogenic	Reference
Aceraceae						
Acer platanoides	S	W/M	F	14	11	This Study
Acer rubrum	S	W	F	9	1	This Study
Apocynaceae						
Vinca minor	S	W	L	45	1	This Study
Buxaceae						
Buxus microphylla	S	W/M	L	10	7	This Study
Calycanthaceae						
Calycanthus floridus	S	M	L	5	1	van Valen (1978)
Celastracaea						
Euonymus alatus	S	W/S	L	55	14	This Study
Magnoliaceae						
Liriodondron tulipifera	F	S	L	120	119	van Valen (1978)
Magnolia acuminata	S	S	P	1	1	This Study
Magnolia soulangeana	S	M	P	3	3	This Study
Magnolia stellata	S	W	P	1	1	This Study
Magnolia virginiana	—	—	P	7	0	—
Oleaceae						
Syringa vulgaris	S	W/S	F	12	5	This Study
Platanaceae						
Platanus acerifolia	F	S	L	23	23	Greshoff (1909)
Platanus occidentalis	F	S	L	158	130	Greshoff (1909)
Rosaceae						
Amelanchier arborea	F	W/S	L	66	61	Seigler (1976)
Amelanchier humilis	F	S	L	8	7	Gibbs (1974)
Amelanchier interior	F	S	L	1	1	This study
Amelanchier laevis	F	S	L	4	4	Gibbs (1974)
Chaenomeles japonica	F	S	L	10	9	Rosenthaler (1926)
Cotoneaster acutifolia	F	W/S	L	10	6	Gibbs (1974)
Cotoneaster adpressa	F	S	L	1	1	Tidwell, *et al.* (1970)
Cotoneaster apiculata	F	S	L	2	2	Tidwell, *et al.* (1970)
Cotoneaster divaricata	F	S	L	16	15	Tidwell, *et al.* (1970)
Exochorda racemosa	F	S	L	1	1	Hagnauer (1971)
Kerria japonica	S	W	L	10	1	Plouvier (1948)
Malus floribunda	F	S	S	30	28	This Study
Prunus persica	F	S	L	8	8	Kingsbury (1964)
Prunus serrulata	F	S	L	1	1	This Study
Prunus triloba	F	S	L	5	5	Rosenthaler (1929)
Sorbus aucuparia	F	S	L	5	5	Seigler (1976)
Saxifragaceae						
Hydrangea arborescens	—	—	L	150	0	—
Taxaceae						
Taxus cuspidata	F	M/S	L	30	9	Hegnauer (1959)
Taxodiaceae						
Metasequoia glypostroboides	S	W/M	L	3	2	van Dijk, *et al.* (1974)
Tiliaceae						
Tilia americana	S	W/S	L	171	7	This Study
Tilia cordata	S	W/S	L	23	4	This Study
Tilia euchlora	S	W	L	3	1	This Study
Tilia tomentosa	S	M	L	3	1	This Study

[1] The speed of the reaction was considered fast (F) if less than two hours were required to give a strong test, and slow (S) is more than two hours were required.

[2] The strength of the reaction was weak (W) if the Feigl Anger paper turned a light blue, moderate (M) if it turned a medium blue, and strong (S) if it turned a deep blue.

[3] Plant part tested: L = young leaves; S = seeds; F = flowers; P = petals.

amined, the speed and strength of the cyanide test, the part of the plant examined, the number of individuals of each species examined, and the number of individuals of each species that tested positive for cyanogenesis.

Aceraceae: No member of this family has been reported previously as being cyanogenic (Tjon Sie Fat, 1979; Gibbs, 1974). During the present study, the tests of vegetative material were always negative, but the flowers of *Acer platanoides* L. (Norway maple) and *A. rubrum* L. (red maple) occasionally gave a weak to moderate positive cyanide test. Of the fourteen trees of Norway maple examined, flowers from eleven tested positive, as did flowers from one of the nine trees of red maple.

Apocynaceae: At least six members of this family have been reported to be cyanogenic (Gibbs, 1974; Seigler, 1976; Tjon Sie Fat, 1979). In addition, during the present study, of the 45 individuals of *Vinca minor* L. (small periwinkle) examined, the young leaves of one individual gave a weak positive test for cyanide.

Buxaceae: No reports of cyanogenesis have been found for this family (Gibbs, 1974; Tjon Sie Fat, 1979). Of the ten plants of *Buxus microphylla* Sieb. & Zucc. (Korean box) examined, seven gave a weak to moderate reaction within 24 hours when young leaves were tested.

Calycanthaceae: Some members of this family have been reported to be cyanogenic (Hegnauer, 1958; van Valen, 1978). During the present study, of the five individuals of *Calycanthus floridus* L. (Carolina allspice) examined, the young leaves of one gave a moderate positive test within 24 hours.

Celastraceae: Except for a single report (Tjon Sie Fat, 1979), no positive cyanide tests have been reported from members of this family. During the present study, weak to strong reactions were obtained for young leaves from 14 of the 25 cultivated specimens of *Euonymus alatus* (Thunb.) Sieb. (winged wahoo) examined. In a naturalized population of this species, found in a wooded ravine one mile east of Charleston, Coles County, Illinois, 30 individuals tested negative for cyanogenesis.

Magnoliaceae: Three species in this family have been reported as cyanogenic (Tjon Sie Fat, 1979). During the present study it was found that immature leaves of *Liriodendron tulipifera* L. (tulip tree) are cyanogenic with 119 of 120 individuals testing strongly positive, usually within one hour. Also, the petals of one individual of *Magnolia acuminata* L. (cucumber magnolia) gave a strongly positive test for cyanide, the petals of three individuals of *M. soulangeana* Soul. (flowering magnolia) gave a moderately positive test; while the petals of one individual of *M. stellata* (Sieb. & Zucc.) Maxim. (starry magnolia) gave a weakly positive test. In all three of these species, the vegetative and other floral parts gave a negative test. Also, it was not uncommon for petals from different flowers on the same plant to test negative while others gave a positive reaction. Of the seven specimens of *M. virginiana* L. (sweet bay magnolia) studied, all plant parts tested negative for cyanide.

Oleaceae: Tjon Siet Fat (1979) and Seigler (1976) list no members of this family have been reported to be cyanogenic. During the present study, flowers of *Syringa vulgaris* L. (common lilac) were found to occasionally release cyanide. Of the twelve white flowering individuals examined, five gave a weak to strong positive reaction.

Platanaceae: Five species of the genus *Platanus* are known to be cyanogenic (Fikenscher and Ruijgrok, 1977). During the present study it was found that the immature leaves of *Platanus occidentalis* L. (American sycamore) are usually strongly cyanogenic with 130 of 158 individuals testing positive. Of the 23 individuals of *P. acerifolia* (Ait.) Willd. (London plane tree) tested, all were strongly cyanogenic. Commonly, mature leaves and leaves from herbarium specimens of these two species test negative for cyanide production.

Rosaceae: More than 160 species in this family have been reported to be cyanogenic (Gibbs, 1974; Tjon Sie Fat, 1979). In many species, only the leaves are cyanogenic but sometimes flowers, fruits, or seeds are known to release hydrogen cyanide. Most members tested during the present study were strongly cyanogenic (Table 1). All species of *Amelanchier* (juneberry), *Cotoneaster* (Cotoneaster), and *Prunus* (peach and cherry) tested were strongly cyanogenic, as were *Chaenomeles japonica* (Thunb.) Lindl. (Japanese quince), *Exochorda racemosa* (Lindl.) Rehd. (pearl-bush), *Sorbus aucuparia* L. (European mountain ash), and the seeds of *Malus floribunda* Sieb. (showy crab-apple).

Saxifragaceae: Cyanogenesis is fairly common in this family, many species of currants and gooseberries (Ribes) and hydrangea (*Hydrangea*) have been reported to produce cyanide (Tjon Sie Fat, 1979). Of the 150 individuals of *Hydrangea arborescens* L. (wild hydrangea) tested, none were cyanogenic.

Taxaceae: *Taxus cuspidata* Sieb. & Zucc. (Japanese yew) has been reported cyanogenic by Hegnauer (1959) and Towers, McInnes and Neish (1964). In the present study, of the 30 individuals examined, nine gave a moderate to strong positive reaction in less than two hours.

Taxodiaceae: *Metasequoia glypostroboides* Hu & Cheng (dawn redwood) has been reported previously to be cyanogenic (van Dijk, *et al.*, 1974). In the present study two of the individuals tested gave a weak to moderate reaction.

Tiliaceae: Gibbs (1974) reported that seven species in this family are known to be cyanogenic. In the present study four species of basswoods (*Tilia*) were found to occasionally liberate cyanide. In all four of these species cyanogenesis is sporadic and the majority of the individuals examined tested negative. In *Tilia americana* L. (American linden) only 7 of 171 individuals tested positive, in *T. cordata* Mill. (small-leaved linden) only 4 of 23 individuals were positive, while in *T. euchlora* K. Koch. (Crimean linden) and *T. tomentosa* Moench. (white linden) one of three individuals tested positive for each species.

The present study indicates that cyanogenesis is relatively common in many families of plants. Most of the taxa examined are from families in which cyanogenesis is considered to be fairly common (Gibbs, 1974; Tjon Sie Fat, 1979). Included in this group are the Apocynaceae, Calycanthaceae, Magnoliaceae, Platanaceae, Rosaceae, Taxaceae, and Tiliaceae. As more taxa of these families are examined it is very possible that cyanogenesis will be found in many of the species, particularly if numerous specimens are examined. In contrast, some of the taxa found to be cyanogenic in the present study are from families in which no previous reports of cyanide production could be found (Aceraceae, Buxaceae, and Oleaceae). It is possible that cyanogenesis is rare in these families, or equally possible that few members of these families have been tested.

The data also suggests that cyanogenesis is relatively common in ornamental woody plants. In many species, however, the extent of cyanogenesis is highly variable, as not all individuals of a taxon gave positive results (Table 1). In some taxa, particularly *Acer platanoides, Buxus microphylla, Liriodendron tulipifera, Platanus* spp., and many members of the Rosaceae, the large majority of the individuals examined tested positive for cyanide production. In other species, however, the number of cyanogenic individuals was relatively low, particularly when many specimens were available for testing.

A lethal dose of cyanide for humans is generally considered to be in the range of 0.5-3.5 mg/kg of body weight. Many of the plants tested during the present study produce high concentrations of HCN, as indicated by the deep blue color of the Feigl Anger paper. According to Dickenmann (1982) the deep blue reaction indicates that more than 50 mg of HCN are produced per kg of fresh weight. Therefore, of the taxa studied, all that gave a fast, strong reaction (Table 1) produced enough HCN to kill a human if ingested in sufficient quantities.

Literature Cited

Bailey, L. H. 1964. Manual of cultivated plants. New York, The MacMillan Co.

Dickenmann, R. 1982. Cyanogenesis of *Ranunculus montanus s.l.* from the Swiss Alps. Ber. Geobot. Inst. ETH, Stiftung Rubel. 49:56-75.

Feigl, F. and V. Anger. 1966. Replacement of benzidine by copper ethylacetoacetate and tetra base as spot-test reagent for hydrogen cyanide and cyanogen. Analyst 91:282-284.

Fikenscher, L. H. and H. W. L. Ruijgrok. 1977. Cyanogenese bei den Cormophyten. 13. Mitteilung. Die cyanogenen glucoside von *Platanus*-Sippen. Planta Medica 31:290-293.

Gibbs, R. D. 1974. Chemotaxonomy of flowering plants. McGill-Queen's University Press, Montreal. 4 vols.

Greshoff, M. 1909. Phytochemical investigations at Kew. Kew Bull. Misc. Inform. 10:397-418.

Hegnauer, R. 1958. Over de verspreiding van blauwzuur bij vaatplanten. Pharm. Weekblad 93:801-819.

Hegnauer, R. 1959. Die verbreiting der blausäure bei den Cormophyten. 2. Mitteilung. Die cyanophytenese in genus *Taxus*. Pharm. Weekblad 94:241-248.

Hegnauer, R. 1971. Probleme der Chemotaxonomie, erlautert am Beispiel der cyanogenen Pflanzenstoffe. Pharm. Acta Helv. 46:585-601.

Kingsbury, J. M. 1964. Poisonous plants of the United States and Canada. Prentice-Hall, Inc., Englewood Cliffs, New Jersey. xii + 626 pp.

Plouvier, V. 1948. Sur l-acide cyanhydrique de quelques Rosacees-Spirées. Comp. Rend. Acad. Sci. Paris 227:1260-1262.

Rosenthaler, L. 1926. Beitrage zur blausäurefrage. 18. Neue blausäure-pflanzen. Pharm. Acta Helv. 1:167-168.

Rosenthaler, L. 1929. Beitrage zur blausäurefrage. 26. Neue blausäure-vorkommen. Pharm. Acta Helv. 4:196-199.

Seigler, D. S. 1976. Plants of the Northeastern United States that produce cyanogenic compounds. Econ. Bot. 30:395-407.

Seigler, D. S. 1977. The naturally occurring cyanogenic glycosides. Progress in Phytochemistry. 4:83-120. eds. L. Reinhold, J. B. Harborne, and T. Swain. Pergamon Press, Oxford.

Seigler, D. S. 1981. Recent developments in the chemistry and biology of cyanogenic glycoides and lipids. Revista Latinaméricana de Química. 12:39-48.

Tantisewie, B., H. W. L. Ruijgrok, and R. Hegnauer, 1969. Die verbreitung der blausäure bei den Cormophyten. 5. Mitteilung: Über cyanogene verbindungen bei den Parietales und bei einegen weiteren Sippen. Pharm. Weekblad 104:1341-1355.

Tidwell, R. H., J. L. Beal, D. G. Patel, A. Tye, and P. N. Patil. 1970. A study of the cyanogenic content and toxicity of the fruit of selected species of *Cotoneaster*. Econ. Bot. 24:47-50.

Tjon Sie Fat, L. A. 1979. Contribution to the knowledge of cyanogenesis in Angiosperms. Ph. D. Dissertation. Rijksuniversiteit te Leiden. 52pp.

Towers, G. H. N., A. G. McInnes, and A. C. Neish. 1964. The absolute configurations of the phenolic cyanogenic glycosides taxiphyllin and dhurrin. Tetrahedron 20:71-77.

van Dijk, B. B., A. C. van der Plas-de Wijs, and H. W. L. Ruijgok. 1974. Cyanogenese bei den Gymnospermem. Phytochemistry 13:159-160.

van Valen, F. 1978. Contribution to the knowledge of cyanogenesis in Angiosperms. 6. Communication. Cyanogenesis in some Magnoliidae. Proc. Koninkl. Nederl. Akad. Wetensch. 81C:355-361.