grated light-flux density on leaf anatomy and photosynthesis. Amer. J. Bot. 66:940–945.
3. Choma, M.E., J.L. Garner, R.P. Marini, and J.A. Barden. 1982. Effects of fruiting on net photosynthesis and dark respiration of 'Hecker' strawberries. HortScience 17(2):212–213.
4. Darrow, G.M. 1932. Methods of measuring strawberry leaf area. Plant Physiol. 7:745–747.
5. Fordham, R. and M.E. Holgate. 1972. Estimation of leaf area of tea (*Camellia sinensis*, L.) from linear measurements. J. Hort. Sci. 47:131–135.
6. Hedge, D.M. 1979. Leaf area determinations in medicinal yam. Current Sci. 48:319–320.
7. Hughes, B.R. and J.T.A. Proctor. 1981. Estimation of leaflet, leaf, and total leaf area of *Panax quinquefolius* L. using linear measurements. J. Amer. Soc. Hort. Sci. 106(2):167–170.
8. Jahn, O.L. and M.N. Dana. 1966. Fruiting and growth of the strawberry plant. Proc. Amer. Soc. Hort. Sci. 188:352–359.
9. Jurik, T.W. 1980. Physiology, growth and life history characteristics of *Fragaria virginiana* Duchesne and *F. vesca* L. (Rosaceae). PhD Diss., Cornell Univ.
10. Jurik, T.W., J.F. Chabot, and B.F. Chabot. 1982. Effects of light and nutrients on leaf size, $CO_2$ exchange, and anatomy in wild strawberry (*Fragaria virginiana*). Plant Physiol. 70:1044–1048.
11. Manivel, L. and R.J. Weaver. 1974. Biometric correlations between leaf area and length measurements of 'Grenache' grape leaves. HortScience 9(1):27–28.
12. Sepaskhah, A.R. 1977. Estimation of individual and total leaf areas of safflowers. Agronomy J. 69:782–785.
13. Wiersma, J.V. and T.B. Bailey. 1975. Estimation of leaflet, trifoliolate, and total leaf areas of soybeans. Agronomy J. 67:26–30.

HortScience 20(6):1074–1075. 1985.

# Tolerance of Highbush and Rabbiteye Blueberry Cultivars to Hexazinone

**J.J. Baron[1], T.J. Monaco[2], and C.M. Mainland[2]**
*Department of Horticultural Science, North Carolina State University, Raleigh, NC 27695–7609*

*Additional index words.* *Vaccinium corymbosum*, *V. ashei*, soil organic matter, Velpar, soil type, herbicide

***Abstract.*** **Hexazinone was applied as a soil drench to 1-year-old rooted hardwood cuttings of highbush (*Vaccinium corymbosum* L.) and rabbiteye (*V. ashei* Reade) blueberries in a series of greenhouse experiments. No differences in susceptibility to hexazinone were detected among 10 highbush and 3 rabbiteye cultivars growing in a fine sand soil. Two highbush and 2 rabbiteye cultivars were assayed for hexazinone tolerance in low, medium, and high organic matter soil which contained 1.3%, 3.5%, and 49.5% organic matter, respectively. Hexazinone at 1 or 2 kg/ha had no inhibitory effect on blueberry growth in the high organic matter soil, inhibited growth slightly on the medium organic matter soil and caused severe injury in the low organic matter soil. At rates of 4 and 8 kg/ha, injury was severe on the medium and low organic matter soils but very slight on the high organic matter soil.**

Hexazinone [3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1*H*,3*H*)-dione] is a symmetrical triazine herbicide that controls many weeds not controlled by herbicides presently used in weed management programs for blueberries (1). Hexazinone has been reported to control weeds in lowbush blueberries better than simazine (6-chloro-*N*,*N*-diethyl-1,3,5-triazine-2,4-diamine), atrazine [6-chloro-*N*-ethyl-*N*-(1-methylethyl)-1,3,5-trazine-2,4 diamine], terbacil [5-chloro-3-(1,1-dimethylethyl)-6-methyl-2,4(1*H*,3*H*)pyrimidinedione], and diuron [N-(3,4-dichlorophenyl)-*N*,*N*-dimethylurea] (5).

Blueberries appear tolerant to soil applied hexazinone. James (3) in New Zealand, reported that applications of hexazinone at rates of 2 to 16 kg/ha on a peat soil had no adverse effect on highbush fruit production and caused a significant reduction in weed dry matter accumulation. However, greenhouse studies have shown that some highbush cultivars are sensitive to the soil applied hexazinone (4). Application of 1 to 3 kg/ha of hexazinone to the soil of dormant 3-year-old highbush 'Berkeley' caused interveinal chlorosis at the 1 kg/ha rate and severe foliar necrosis at the 2 and 3 kg/ha rate. Applications to 'Bluecrop' resulted in minor injury at 1 kg/ha, interveinal chlorosis at 2 kg/ha, and variable damage ranging from no effect to death at 3 kg/ha (4). In addition, applications of the herbicide directly to foliage of lowbush blueberries can cause considerable damage (2). Blueberry plants can tolerant hexazinone without yield reduction only if the herbicide is applied when the plants are dormant, or if application of the herbicide is directed to the base of the plant avoiding contact with foliage.

Two greenhouse experiments were conducted during 1983 at the North Carolina State Univ. Horticultural Science greenhouses to determine the influence of hexazinone rate and soil type on blueberry cultivar tolerance. Plant material consisted of 1-year-old rooted hardwood cuttings of highbush 'Angola', 'Bluechip', 'Bluecrop', 'Blueray', 'Croatan', 'Earliblue', 'Harrison', 'Jersey', 'Murphy', and 'Wolcott' and rabbiteye cultivars 'Powderblue', 'Premier', and 'Tifblue'. Plants were held in cold storage for 6 weeks at 1°C to satisfy chilling requirement before they were planted individually in 15 cm diameter pots containing a Lynn Haven fine sand soil with a pH of 4.1 and an organic matter content of 3.5%.

The dormant blueberry plants were placed in a 24°C day, 18° night greenhouse on 9 Mar. 1983. Immediately after leaf budbreak, 50 ml of hexazinone solutions, equivalent to rates of 0, 1, 2, 4, or 8 kg/ha were added as a soil drench. Plants were randomized in a complete block design with 4 replications and 1 plant per replication. Plants were watered as needed, and a commercial water soluble fertilizer (20.0 N–9.1P–16.6 K) was applied every 2 weeks. Seventy-five days after her-

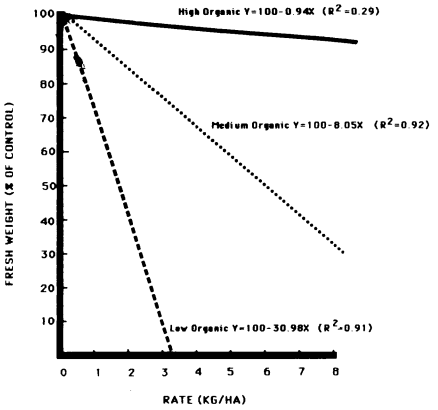


Fig. 1. Influence of soil organic matter content and hexazinone activity on fresh weight of blueberry (expressed as percentage of control).

Table 1. Correlation of several growth parameters of blueberry cuttings with fresh weight when plants were treated with 5 rates of hexazinone.

| Parameter | *r* |
|---|---|
| Shoot length (cm) | 0.97 |
| Leaf area ($cm^2$) | 0.97 |
| Leaf number | 0.99 |
| Dry weight (g) | 0.99 |

Received for publication 18 Mar. 1985. Paper No. 9781 of the J. Ser. of the N.C. Agr. Res. Serv., Raleigh, NC 27695-7601. The use of trade names in this publication does not imply endorsement by the N.C. Agri. Res. Serv. of the products named, nor criticism of similar ones not mentioned. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.
[1]Graduate Research Assistant.
[2]Professor.

Table 2. Properties of soils used in experiments.

| Classification | Property | | | | | |
|---|---|---|---|---|---|---|
| | pH | CEC[z] (me/100g) | OM[y] (%) | Sand (%) | Silt (%) | Clay (%) |
| Low organic[x] | 4.6 | 3.2 | 1.3 | 88.3 | 5.9 | 4.0 |
| Medium organic[w] | 4.1 | 5.8 | 3.5 | 84.9 | 4.8 | 6.8 |
| High organic[v] | 3.4 | 16.2 | 49.5 | 46.5 | 3.5 | 0.5 |

[z]Cation exchance capacity.
[y]Organic Matter (determined by chromic acid digestion method).
[x]Surface 10 cm of Leon sand from Bladen Co., N.C.
[w]Surface 10 cm of Lynn Haven fine sand from Bladen Co., N.C.
[v]Surface 10 cm of Pamlico muck from New Hanover Co., N.C.

bicides were applied, the plants were harvested and the leaf number, leaf area, new shoot length, fresh weight, and dry weight of each plant was measured and recorded. All measured growth parameters correlated well with fresh weights (Table 1); therefore only fresh weight measurements are presented in the results.

In the 2nd experiment, 1-year-old hardwood cuttings of highbush 'Jersey' and 'Croatan', and rabbiteye 'Tifblue' and 'Powderblue' were chilled and planted in each of 3 soils. The soils, ranging in organic matter content from 1.3% to 49.5%, were taken from commercial blueberry production sites (Table 2). Plants were treated and harvested by methods outlined in the first experiment.

Simple regression lines for the highbush and rabbiteye species were calculated based on fresh weight growth as percent of control at the various rates of application. No statistically significant differences in hexazinone tolerance were detected between the 2 blueberry species (data not shown). Both species had a significant rate response; as the rate of hexazinone increased, weight of the plants decreased. An $I_{50}$ value also was calculated for each of the 13 cultivars evaluated (Table 3). This value represents the rate of hexazinone that gave a 50% fresh weight reduction. Based on the $I_{50}$ values, no statistically significant differences exist in individual cultivar response to hexazinone. However, the highest $I_{50}$ was 81% higher than the lowest one. Because of the large differences in $I_{50}$ values, an analysis of co-variance was calculated on differences between regression lines for the individual cultivars. Again, there were no significant differences between cultivar response to hexazinone (data not shown).

Table 3. Rate of hexazinone required to give a 50% reduction of the fresh weight of 13 blueberry cultivars.

| Cultivar | $I_{50}$ Values (kg/ha) | Grouping[z] |
|---|---|---|
| Croatan | 9.50 | A |
| Bluecrop | 7.67 | A |
| Angola | 7.09 | A |
| Jersey | 6.66 | A |
| Murphy | 6.44 | A |
| Bluechip | 6.38 | A |
| Powderblue | 6.22 | A |
| Earliblue | 6.22 | A |
| Harrison | 5.98 | A |
| Premier | 5.83 | A |
| Blueray | 5.72 | A |
| Wolcott | 5.67 | A |
| Tifblue | 5.25 | A |

[z]Means separated by Tukey honest significant difference test, $P = 0.05$.

Injury to the blueberry plants developed slowly. Injury symptoms at the low rates (1–2 kg/ha) usually did not appear until more than 30 days after treatment and were characterized by tip burn and marginal necrosis. A few isolated plants exhibited complete leaf chlorosis. Injury at 4–8 kg/ha occurred within 14 days, was severe and characterized by complete leaf necrosis followed by defoliation. On some plants, leaf abscission occurred before the leaves became completely necrotic.

Because no statistically significant differences among species or cultivars were shown to exist, fresh weights from the 4 cultivars used in the assay for hexazinone tolerance in the 3 soil types were averaged within soil type. Simple regression lines for the rate response were drawn for the high, medium and low organic matter soils (Fig. 1) based on the percentage of fresh weight growth compared to the untreated control. The regression equations are as follows: high organic matter soil, $Y = 100 - 0.94x$ ($R^2 = 0.29$); medium organic matter soil, $Y = 100 - 8.05x$ ($R^2 = 0.92$); and low organic matter soil, $Y = 100 - 30.98x$ ($R^2 = 0.91$); where Y = fresh weight as percent of control and x = hexazinone rate in kg/ha. The regression lines on the low and medium organic matter soil were significant, indicating that fresh weight growth of these plants was significantly reduced with increased hexazinone rate. The high organic matter soil regression line was non-significant, indicating that there was no decrease in fresh weight when hexazinone rate was increased from 0 to 8 kg/ha. The regression line for the low organic matter soil had the largest negative slope, followed by the slopes for the medium and high organic matter soil. The more negative the slope, the lower the rate of hexazinone required for injury. In the low organic matter soil, most plants were killed by hexazinone at the 2 to 4 kg/ha rate, while very few injury symptoms were noted at 8 kg/ha on the high organic matter soil.

Soil type greatly influenced blueberry response to hexazinone. The soils consisted almost exclusively of sand and organic matter with almost no silt or clay (Table 2). The factors that varied most in these soils were organic matter content and cation exchange capacity. Tolerance of blueberries to hexazinone increased with an increase in organic matter content and cation exchange capacity. This same relationship has been shown with simazine, where the dose that reduced the fresh weight of oats by 50% was positively correlated with soil organic matter content and cation exchange capacity (6).

Severe injury symptoms and drastic reductions in fresh weight of blueberries that were observed in the low organic matter soil have rarely been observed in the field. Blueberry plants growing in the field are often older and larger than the 1-year-old rooted hardwood cuttings used in this study. In addition, plants in the greenhouse would be more susceptible to hexazinone due to the root system and applied herbicide being confined to the volume of the container.

Many highbush and rabbiteye blueberry cultivars seem to be tolerant to soil applied hexazinone under field and greenhouse conditions, but blueberries are not totally resistant to hexazinone. There are several factors that would be expected to reduce plant tolerance. Severe environmental conditions, such as heavy rains or drought can influence injury. Young plants or weak and diseased plants would be expected to be prone to injury. Soil type and properties influence susceptibility to the hexazinone.

The results of this study indicate that highbush and rabbiteye blueberries and the cultivars assayed are equally tolerant to hexazinone. Herbicidal activity of hexazinone is influenced by soil type, with organic matter content most likely having the greatest influence on herbicide activity in the soil.

## Literature Cited


1. Bonanno, A.R., J.J. Baron, T.J. Monaco, and C.M. Mainland. 1984. Blueberry cultivar response to hexazinone under varying soil conditions in North Carolina. Proc. 5th No. Amer. Blueberry Res. Workers Conf. 126–138.
2. Doohan, D.J. 1982. Hexazinone, a new herbicide for lowbush blueberries. Adaptive research report. Plant Industry Branch, New Brunswick Dept. Agr., Canada 43–44.
3. James, T.K. 1980. Control of weeds in blueberries. Proc. 33rd. New Zealand Weed and Pest Control Conf. 122–124.
4. Jensen, K.I.N. 1981. Hexazinone, a promising herbicide for highbush blueberries. HortScience 16(3):315–316.
5. Jensen, K.I.N., D.J. Doohan, and J. Thomson. 1981. Weed control in lowbush blueberries with hexazinone. Proc. Northeast Weed Sci. Soc. 35:47 (Abstr.).
6. Sheets, T.J., A.S. Crafts, and H.R. Drever. 1962. Soil effects on herbicides. Influence of soil properties on the phytotoxicities of the s-triazine herbicides. J. Agr. Food Chem. 10:458.