as follows: 10.0 = no apparent damage; 8.0 = very little apparent damage; 6.0 = many cupped or curled leaves but new growth not affected. Trees lacking complete coverage of foliage and having cupped and curled foliage on much of the remainder of the tree were rated by % of the tree covered with foliage, from 90% (4.5) to 10% (0.5).

'Bartlett' fruit yields were recorded by weight and 'd'Anjou' yields were estimated by fruit count and converted by kg on the basis of a random sample of weighed fruit. Trunk diameters were measured at the end of the growing season and compared to the previous season's measurements.

Damage was related to rootstock (Table 1). 'Bartlett' trees on French (from seed imported from France) rootstocks showed essentially no effect of 2,4-D. Only one tree on *Pyrus betulaefolia* Bunge. seedlings showed any effect. Trees on 'Bartlett' seedlings were affected to a greater degree, but all except 2 trees were rated 8 or above. Trees on 'Old Home' (clonal), 'Old Home × Farmingdale' (clonal) and 'Winter Nelis' (seedling) were given intermediate ratings. Most trees on *P. calleryana* seedlings were rather severely affected. Most trees on 'EM Quince A' and all trees on 'Provence' quince were rated 4.5 or lower.

On the average, 'd'Anjou' trees were damaged more than 'Bartlett'. The effect of rootstock on damage of 'd'Anjou' was similar to the effect on 'Bartlett'. Trees on quince and *P. calleryana* stocks were most affected and those on imported French seedlings were least affected with both scion cultivars.

Yield of 'Bartlett' trees corresponded very closely to the 2,4-D damage rating, but less with 'd'Anjou' (Table 1). Yield of 'Bartlett' in 1973 all decreased or remained about the same as for 1972 except for those on French stocks which increased slightly. Yield reductions in general corresponded to the damage rating. Yield of 'd'Anjou' was greater in 1973 than 1972 except for those on quince stocks. Some of this yield increase may be due to increased age and yield capability of the trees or 2,4-D may have stimulated fruit set directly or it may have indirectly affected fruit set through phloem damage. It should be noted, however, that the 'd'Anjou' yield increase in 1973 compared to 1972 tended to be less as damage increased, suggesting a negative effect of 2,4-D on yield rather than a positive effect.

The increases in trunk diameter did not consistently reflect the damage ratings becuase of the confounding effect of rootstock vigor, indicating that sizeable foliage reduction was necessary to overcome the vigor effect of rootstock. In general, trees with the highest ratings produced the greatest increases in trunk diameter.

No trees died during the first year after 2,4-D application. After the 1973-74 winter, 3 trees of 'd'Anjou'/'EM Quince A' and 2 trees of 'd'Anjou/'Provence' quince were dead. A few other badly weakened trees will probably die as a result of increased susceptibility to cold and other adverse conditions.

Apparently, the danger of 2,4-D damage in pear orchards can be decidedly influenced by rootstock. Pears on 'EM Quince A', 'Provence' quince and *P. calleryana* appeared to be much more prone to damage from soil applied 2,4-D than on the other rootstocks included in this test. Since most of the 2,4-D was probably in the upper 0.3 m to 0.4 m of soil (Benson, personal communication), the same zone as most feeder roots regardless of rootstock, rooting depth and areas of root concentration are not variables causing the observed differences. Perhaps rootstocks vary in permeability to 2,4-D or in their absorption or translocation capacity of 2,4-D or in their internal ability to modify this chemical.

Cover crop foliage will intercept and absorb 2,4-D. Therefore, it is assumed that the damage would have been reduced or possibly eliminated if the 2,4-D had been applied only on the grass cover between the rows and not on the bare strip of soil under the trees, in spite of the irrigation so close to the time of application.

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Glyphosate Toxicity to Apple Trees[1]

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Abstract. **Glyphosate at rates found adequate (3.36 kg/ha) for orchard weed control is phytotoxic and possibly fatal to young apple trees if it is intercepted by the tree's foliage in sufficient quantities. Its use appears safe, however, if precautions are used to avoid this contact. Following foliage absorption, the glyphosate is translocated to active growing points resulting in leaf attenuation and cupping and necrosis to leaves, terminals, and trunks.**

Glyphosate,N-phosphonomethylglycine, is a non-selective broad spectrum postemergence herbicide whose properties are described by Baird et al. (1). Jaworski (2) has reported on its mode of action. Directed applications have effectively controlled johnsongrass and bermudagrass (1, 3).

Abnormal growth from buds manifest by attenuated leaves with an upward curl was observed in the spring on two lower scaffolds of a young apple tree. It was surmised that these limbs had accidentally intercepted a glyphosate spray applied to tall johnsongrass in the orchard the previous Sept. This observation prompted these studies on glyphosate toxicity to apples.

In one study, glyphosate was applied on June 6 in a band under 2 adjacent rows of 5-year-old spur type 'Delicious' trees. One row had been pruned the previous week to remove growth originating on the lower 50 cm portion of the trunk. Glyphosate at 3.4 and 6.7 kg/ha (3 and 6 lb. ai/acre) was sprayed so that the lower 45 cm portion of the trunk in both rows was wetted. In the nonpruned row, low scaffold limbs near the point of origin, and their spur leaves were hit by the spray. The pruned row showed no phytotoxocity throughout the growing season whereas on the nonpruned trees, glyphosate translocation was evident 120 cm or more from the point of contamination within 14 days after treatment. This was manifest by phytotoxicity symptoms at the terminal growing points of the scaffolds wetted by the spray (Fig. 1). The new leaves were attenuated and cupped. Some scaffolds eventually died. The effect was strikingly similar to the advance of fire blight infection caused by *Erwinia amylovora* Burrill. In some instances necrosis extended into the trunk and spread downward and to a lesser extent, upward. Again, the damage resembled a fire blight canker.

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Table 1. Effect of foliar glyphosate applications on actively growing terminals of 'Starkspur Golden Delicious' trees, (1973).

Glyphosate rate (ppm)	Date applied	Terminal growth in 30 days (cm)			Phytotoxicity score at tip treated limb[z]			% terminals dead at 60 days		
		Basal 5[y]	Basal 10	Mid 5	Basal 5	Basal 10	Mid 5	Basal 5	Basal 10	Mid 5
5,000	July 19	96	66	51	1.2	2.0	1.0	20	0	20
10,000	July 19	61	33	43	3.8	5.0	1.0	60	100	20
Control			107			0.0			0	

[z]Phytotoxicity score avg of 5 replications: 0=none, 1=very light, 2=light, 3=mod., 4=severe, 5-leaves dead.
[y]Treatments as follows: Basal 5 leaves treated; Basal 10 leaves treated; Mid 5 leaves treated.

Table 2. Effect of glyphosate spray on trunks and lower scaffold limbs on newly planted 'Golden Delicious' and 'Delicious' apple trees, (1973).

Sprays applied	Glyphosate (kg/ha)	Growing points per tree[z]	% of all growing points/tree				% terminals actively growing Oct. 22
			Injured Sept. 27	Dead Sept. 27	Injured Oct. 22	Dead Oct. 22	
Bare trunk	1.7	10.0	0	0	0	0	40
	3.4	11.0	0	0	0	0	45
Painted trunk	1.7	6.3	0	0	0	0	57
	3.4	8.0	0	0	0	0	66
Bare trunk +	1.7	7.6	43	13	86	13	13
1 scaffold limbs	3.4	8.6	19	12	88	12	15
Bare trunk +	1.7	10.6	34	19	81	19	15
2 scaffold limbs	3.4	10.6	34	19	81	19	3

[z]At time treatment applied (avg of 3 replicates), Aug 14.

Symptoms occurred at both treatment rates.

In a second study, glyphosate at 5,000 or 10,000 ppm was applied to leaves of actively growing terminals of 'Starkspur Golden Delicious' trees. The herbicide was applied with a paint brush to the upper surface of either 5 basal leaves, 10 basal leaves, or the 5 midterminal leaves. The average fully expanded leaf number per terminal on the July 19 treatment date was 30. Treatments were replicated 5 times.

Although most treated leaves abscised with 10 days, translocation to the terminal growing point had already occurred. This produced phytotoxicity symptoms as previously described. Severity of phytotoxocity and % dead terminals after 60 days was related to glyphosate concn and leaf area treated, i.e. more injury resulted from treatment of 10 leaves (Table 1). Basal leaf treatment appeared more damaging than midterminal treatment. Later in the season, phytotoxicity was observed at growing points on limbs adjacent to some treated terminals. All glyphosate treatments reduced terminal growth.

In a further study, 'Golden Delicious' and 'Delicious' trees on M 106 rootstocks were set in the spring and given proper cultural care to stimulate growth. On August 14, glyphosate at 1.7 or 3.4 kg/ha (1.5 or 3 lb./acre in 35 gal/acre water) was applied from both sides of the tree row. The tree's exposure to the glyphosate spray was limited to the following conditions: a) bare trunk with no foliage exposed; b) trunk painted with Red Cap Seal paint[3], no foliage exposed; and c) bare trunks with 1 or 2 of the lowest scaffolds exposed. Wetting of foliage except for the specified scaffolds was prevented by covering with a paper bag during spraying. Treatments were replicated three times.

Fig. 1. Typical glyphosate phytoxicity symptom expression on 'Delicious' apple.

Fig. 2. Translocation of glyphosate from treated lower scaffold limb (a) to higher scaffold (b) of 'Golden Delicious' tree is indicated by phytoxicity symptom expression.

Glyphosate was virtually nontoxic to trees on which no foliage was wetted by the herbicide, i.e., bare or painted trunk (Table 2). When 1 or 2 scaffolds were sprayed (condition c) the treated limbs died within 40 days and furthermore symptoms appeared on some nontreated terminals (Fig. 2). Glyphosate rates appeared to have little influence on phytotoxicity. Necrosis was observed on trunks of some trees having dead scaffolds. Girdling caused by this necrosis may eventually result in tree loss.

Glyphosate absorbed by apple leaves is translocated throughout young apple trees but apparently preferentially to the nearest active growing point. It is also translocated to buds where symptom expression becomes manifest at bud break.

[3]Farwell Products Company, Wenachee, Washington.

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