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Diagnosing herbicide drift and carryover injury in potatoes

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Herbicides applied in crops grown in rotation with potatoes may drift onto potatoes or persist in the soil from the year of application to the following year. Research at the University of Idaho has shown that carryover or drift of some commonly used herbicides may reduce potato yield, quality, or both. This bulletin discusses factors affecting herbicide carryover and drift and describes foliar and tuber injury symptoms of herbicide carryover and drift.

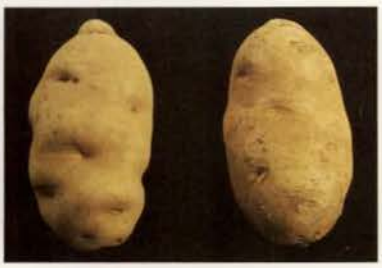
Herbicide carryover

Herbicide carryover, or persistence from one growing season to the next, is a potential problem with several herbicides used in crops grown before potatoes (Table 1). Certain herbicides are more likely than others to persist because of their chemical characteristics. Soil characteristics such as texture, organic matter, and pH also may affect carryover potential. In addition, environmental factors and cultural practices may affect the rate of herbicide breakdown in the soil and thus influence the potential for carryover.

Soil characteristics

Texture and organic matter — In general, carryover problems are more likely to occur in coarse-textured (sandy) soils and soils low in organic matter

1. 2,4-D drift. Malformed leaves.



2. 2,4-D drift. Deep eyes (untreated at right).

3. Banvel drift. Malformed leaves.

4. Banvel drift or carryover. Fiddlenecked leaves.

5. Banvel drift. Malformed tubers.

6. Banvel drift. Cracks in bud end.

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Table 1. Common herbicides that may injure potatoes from drift or carryover.

Herbicide	Source of injury
Ally	Drift and carryover
Arsenal	Drift and carryover
Assert	Drift and carryover
AAtrex (atrazine)	Drift and carryover
Banvel	Drift and carryover
Buctril	Drift
Curtail	Drift and carryover
2,4-D	Drift
Express	Drift
Glean	Drift and carryover
Harmony Extra	Drift
Karmex	Drift and carryover
Oust	Drift and carryover
Pursuit	Drift and carryover
Roundup	Drift
Stinger	Drift and carryover
Tordon	Drift and carryover
Velpar	Drift and carryover

than in clay soils and soils high in organic matter. The reason involves the amount of herbicide adsorbed by (adhering to) soil particles and the amount in the soil solution. Herbicide that is adsorbed to soil particles is not readily available for plant uptake. Herbicide in the soil solution, on the other hand, can be readily taken up and may injure susceptible plants.

The relative amounts of adsorbed herbicide and herbicide in the soil solution depend on several factors, including soil texture, organic matter, and pH. Soil texture is the relative proportion of sand, silt, and clay in the soil. Clay soils have a large total surface area and more sites for herbicide adsorption than silt soils, while silt soils have more herbicide adsorption sites than sandy soils. Organic matter particles also have a large total surface area and abundant sites for herbicide adsorption. Therefore, soils high in clay and organic matter adsorb more herbicide than silt or sandy soils low in organic matter, making the herbicide less available for plant uptake.

pH — Many herbicides tend to break down more slowly when the soil pH is alkaline (pH greater than 7) than when it is acidic (pH less than 7). Herbicides such as the sulfonylureas (for example, Glean, Ally, and Oust) not only persist longer at high than at low pH but are adsorbed less and therefore are more available for plant uptake.

Environmental factors

Herbicides usually are broken down to inactive compounds by chemical or microbial processes. These processes are generally most rapid in warm, moist soils. Herbicides persist longer in cool, dry soils because soil microbial and chemical activity is reduced. Herbicides are also more likely to carry over when they are applied at higher rates or later in the season.

Tillage practices

Certain tillage practices such as disking or chisel plowing concentrate herbicides near the soil surface. Moldboard plowing, on the other hand, dilutes herbicides by distributing them throughout the plow layer. Moldboard plowing a field containing a persistent herbicide will often decrease the potential for carryover problems.

Herbicide drift

Herbicide drift is the unintended movement of herbicide from a target to a nontarget area. A herbicide may move as a liquid, gas, or solid depending on its chemical characteristics and formulation. Spray drift is the movement of herbicide droplets to nontarget areas. Vapor drift is the movement of the gaseous form of a volatile herbicide to nontarget areas. Granules or dried particles of herbicide may drift from target areas in high winds but are generally not a significant source of herbicide drift.

Commonly used herbicides that may drift and injure potatoes are listed in Table 1. Factors that affect the potential for herbicide drift include herbicide volatility, environmental conditions, method of application, and spray particle size (Table 2).

Herbicide volatility

The volatility of a herbicide influences its potential for vapor drift. Volatile herbicides change from a solid or a liquid into a gas, and the vapors can drift longer and farther than spray droplets. For example, 2,4-D and MCPA esters are quite volatile and can produce vapor drift. But the amine forms of 2,4-D and MCPA are effectively nonvolatile and drift only as droplets or dry particles. Although environmental conditions may protect a neighboring crop from spray drift during application, changes in temperature and wind conditions after application may move vapors of a volatile herbicide into the crop.

Table 2. Factors influencing herbicide drift.

Factor	More drift	Less drift
Chemical volatility	Volatile	Nonvolatile
Weather	Windy	Calm
	Warm	Cool
	Low humidity	High humidity
	Inversion	Lapse
Application method	Aircraft	Ground
Spray particle size	Small	Large
Spray pressure	High	Low
Nozzle capacity	Small	Large
Spray angle	Wide	Narrow

Environmental conditions

Low relative humidity, high temperature, or both decrease spray droplet size by increasing evaporation. Smaller droplets travel farther in the wind and thus present a greater risk of drift. Wind speed and direction also influence the potential for drift damage. Application under windy conditions should be avoided, particularly when the prevailing winds would direct spray droplets onto susceptible crops.

Although calm, cool conditions are generally desirable for herbicide application, thermal inversions, which can be associated with calm conditions, increase the risk of herbicide drift. In an inversion, a layer of cool, still air is trapped beneath a blanket of warm air. Spray droplets tend to remain suspended in the layer of cool air longer than usual, increasing the concentration of droplets in the air and increasing the drift from slight wind currents.

Method of application

Aerial application is generally more likely than ground application to result in spray drift because of the greater boom height. Nozzle orientation, nozzle height, and aircraft speed all influence the possibility for drift.

Nozzles

Ground applicators often can reduce the potential for herbicide drift by modifying the spray system to produce larger droplets. Reducing nozzle pressure and increasing nozzle size both increase the size of spray droplets. Ordinary flat fan nozzles, which should be operated at 20 pounds per square inch or greater to maintain a uniform spray pattern, can sometimes be replaced by low pressure (LP) or extended range (XR) nozzles. These nozzles give a uniform pattern at 15 to 20 pounds per square inch.

Within most nozzle types, narrower spray angles and larger capacity nozzles produce larger droplets. For example, an 8002 flat fan nozzle produces larger droplets than an 8001 nozzle operated at the same pressure. In addition, special nozzles have been developed to reduce drift. The Raindrop nozzle, which has an attached secondary swirl chamber, is engineered to produce large droplets and very few small droplets.

Droplet size and herbicide effectiveness

Some herbicides can be applied with thickeners such as Lo-Drift or Nalco-Trol that increase droplet size and reduce drift by as much as 90 percent. Translocated (systemic) herbicides such as 2,4-D, MCPA, and Banvel generally do not lose their effectiveness when applied in larger droplets. However, contact herbicides such as Buctril need to be applied in a fine spray for optimal performance. Although Roundup is a translocated herbicide and should maintain its effectiveness in larger droplets, it may be partially inactivated by hard water or soil particles in the spray solution. Therefore, it is important to carefully follow the spray volume recommendations on the herbicide label.

Symptoms of herbicide carryover and drift

Potato injury symptoms pictured in this bulletin occurred in production fields or in herbicide injury research trials. Symptoms may vary depending on the stage of potato growth and growing conditions when the injury occurred.

2,4-D — 2,4-D is a phenoxy herbicide. Phenoxy herbicides are absorbed by leaves and translocated to growing points in roots and leaves. Foliar injury symptoms include wrinkled leaves (spinach leaf appearance), cupped leaves, leaves with parallel venation (long, narrow leaf appearance), and bent, twisted stems (epinasty) (fig. 1). The only tuber symptom is a deeper eye (fig. 2). 2,4-D does not carry over in the soil to injure potatoes grown the year after application.

Banvel — This is a benzoic acid herbicide absorbed by leaves, stems, and roots and translocated within the plant. Banvel may drift or may carry over when higher rates are used for perennial weed control the fall or spring before potato planting.

Foliar injury symptoms are similar for drift and carryover. Relatively low doses of Banvel cause leaf symptoms similar to those of 2,4-D including leaf wrinkling or crinkling, leaf cupping, parallel venation, and epinasty (fig. 3). Higher doses may cause fiddlenecking (fig. 4) or give leaves a folded, hooded appearance. Petiole and leaf curling may accompany leaf wrinkling.

Banvel drift may cause creases or cracks in the bud ends of tubers and may give the potato skin an appearance called ''elephant hide'' (figs. 5, 6). Occasionally, a bull's eye, or circle around the eye, appears. Russet Burbank tubers may be more rounded than is typical. Soil residues have not caused malformed tubers but have reduced tuber yield and grade in some studies.

Curtail, Curtail M, and Stinger — These all contain the active ingredient clopyralid, which is a picolinic acid herbicide. Injury symptoms of drift and carryover are similar. Low doses may cause the leaves of new growth to curl (fig. 7). Higher doses often cause a fiddlenecking of the leaves very similar to the symptoms of Banvel drift or carryover (fig. 8). In addition, the stems and leaves may thicken, and the leaves may look like broadened stems (strap-shaped leaves). Tubers usually are normal in shape, but small (fig. 9). Tubers may occasionally be irregularly shaped (Fig. 10), and cir-

7. Curtail or Stinger drift or carryover. Initial symptom — curled new leaves.

8. Curtail or Stinger drift or carryover. Fiddlenecked leaves similar to those caused by Banvel and Tordon.

9. Curtail or Stinger drift at emergence. Small tubers (U.S. No. 1 at left).

10. Curtail or Stinger drift at tuber initiation. Malformed tubers.

11. Harmony Extra drift at emergence. Initial symptoms — yellowed new growth, stunted plants. Other sulfonylureas produce similar symptoms.

12. Harmony Extra drift at tuber initiation or tuber bulking. Rolled leaves and wilted, stunted, yellowed plants. Other sulfonylureas produce similar symptoms.

15. Harmony Extra drift at tuber initiation. Folded, creased tubers.

13. Harmony Extra drift at tuber initiation or tuber bulking. Yellowed plants; some reddish-purple leaves.

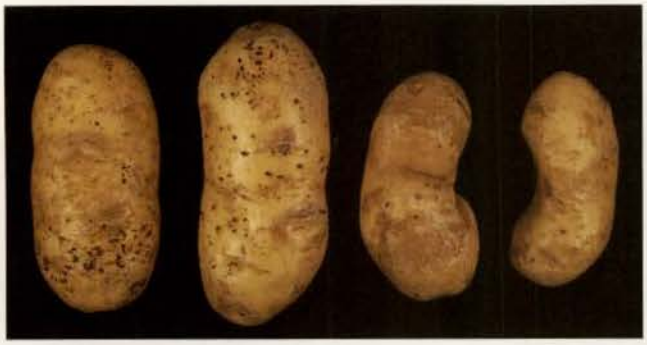
16. Harmony Extra drift at tuber bulking. Multiple deep cracks in tubers.

14. Harmony Extra drift at emergence. Small tubers (U.S. No. 1 at left).

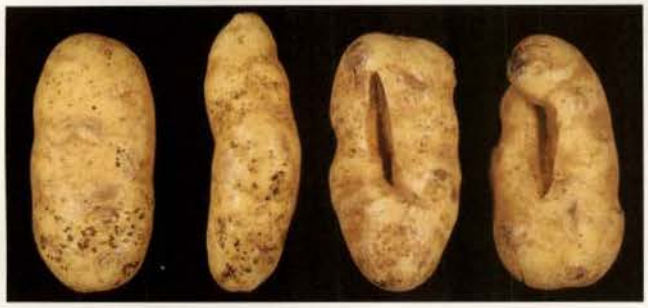
17. Oust drift. Malformed tubers with deep cracks and/or multiple knobs.

18. Oust drift. Multiple deep cracks in tubers.

19. Assert drift or carryover. Yellowed new growth similar to that caused by the sulfonylureas; elongated, upwardly cupped leaves.



20. Assert drift or carryover at emergence. Curved tubers (U.S. No. 1 at left). Not pictured — bottlenecks, dumbbells, knobby tubers.



21. Assert drift or carryover at tuber initiation. Curved tubers; deeply cracked tubers; folded, creased tubers (U.S. No. 1 at left).

22. Assert drift or carryover at tuber bulking. Deeply cracked or folded tubers (U.S. No. 1 at left).

23. Assert carryover (severe). Yellowed, stunted growth; strap-shaped or elongated leaves.

24. Arsenal drift at emergence. Yellowed new growth; elongated, cupped leaves similar to those caused by Assert; stunted plants.

25. Arsenal drift at tuber initiation. Rolled and wilted-looking leaves; stunted and yellowed plants. Similar to symptoms of Pursuit drift at tuber initiation or tuber bulking, though often more severe.

26. Arsenal drift at tuber bulking. Similar to symptoms of drift at tuber initiation at first, but plants eventually collapse and die.

27. Arsenal drift at emergence. Malformed tubers (U.S. No. 1 at left).

28. Arsenal drift at tuber initiation. Very small tubers with multiple knobs (U.S. No. 1 at left).

29. Arsenal drift at tuber bulking. Malformed tubers with multiple deep cracks and elephant hide (U.S. No. 1 at left).

MORE PHOTOS ON BACK PAGE

cles may develop around the eyes, giving them a bull's-eye appearance. Yield of U.S. No. 1 tubers is often reduced by drift or carryover of Curtail or Stinger.

Tordon — This is a picolinic acid herbicide closely related chemically to clopyralid (an ingredient in Curtail and Stinger). Injury symptoms of drift and carryover are very similar to those of Curtail and Stinger and include leaf curling and fiddlenecking and strap-shaped leaves. Tordon may cause malformed tubers and small tubers that are more often irregularly shaped than smooth.

Harmony Extra, Express, Ally, Glean, and Oust — These are sulfonylurea herbicides that interfere with the synthesis of certain amino acids essential to plant growth. They cause similar injury symptoms when they drift onto potatoes. Initially, the newest leaves turn yellow and plant growth is stunted (fig. 11). Leaves may wilt and roll (fig. 12). Leaves exposed to higher drift doses may become reddish purple, and stems may appear purplish (fig. 13).

Harmony Extra drift at emergence can cause small tubers (fig. 14). Tubers injured by the sulfonylureas may have any of the following symptoms: shallow to deep longitudinal cracks, knobs, and banana, pear, or folded shapes (figs. 15, 16, 17, 18). High drift doses may cause popcorn-shaped tubers or chains of tubers along a stolon.

Ally, Glean, and Oust may carry over. Soil residues of these herbicides may cause delayed emergence in addition to the symptoms described above. Tuber injury symptoms of carryover are similar to those of drift.

Assert, Arsenal, and Pursuit — These are imidazolinone herbicides. The imidazolinone herbicides interfere with the synthesis of certain essential amino acids at the same site of action as the sulfonylureas. Injury symptoms vary with herbicide, but all three may injure potatoes by drift or carryover.

Assert drift initially causes stunting and yellowing of new growth, much like the sulfonylurea herbicides. As injury progresses, leaves elongate, develop a wrinkled or spinach leaf appearance, and usually cup upward (fig. 19). The tips of the leaves often develop a characteristic boat-shaped appearance. Tuber symptoms are similar to some of those caused by the sulfonylureas and include knobs and shallow to deep longitudinal cracks in the tuber surface (figs. 20, 21, 22). Tubers may have dumbbell, banana, pear, or folded shapes.

Foliar injury from carryover may be similar to injury from drift or may be more severe. When the carryover dose is high, plant growth is extremely stunted and leaves are strap shaped (fig. 23). Tuber injury symptoms of carryover are similar to those of drift.

Arsenal drift injury symptoms vary with the potato growth stage at the time drift occurs. When drift occurs early in the season, before tuber initiation, Arsenal causes severe stunting of potato plants and an intense yellowing of the new growth (fig. 24). Leaves are elongated, wrinkled, and upwardly cupped. Higher drift doses cause severely reduced growth and strap-shaped leaves.

When drift occurs at tuber initiation or tuber bulking the initial symptom is leaf wilting (fig. 25). As injury progresses, leaves roll, plant growth stops, and plants begin to yellow. Plants do not recover, and plants injured by Arsenal drift at tuber bulking often die (fig. 26). Yield losses from early season Arsenal drift are moderate to severe, and losses from mid- to late-season drift are severe.

Tubers injured as a result of drift early in the season may be curved, creased, folded, knobby (sometimes profusely), or have a combination of these symptoms (fig. 27). Drift at tuber initiation may produce severely malformed tubers, often with profuse knobs (popcorn-shaped tubers) (fig. 28). Drift at tuber bulking often results in tubers with multiple deep cracks and elephant hide (fig. 29). Soil residues of Arsenal may result in foliar and tuber injury symptoms similar to those observed from early season Arsenal drift.

Pursuit drift also causes symptoms that vary with potato stage of growth at the time drift occurs. Pursuit drift early in the season may cause slight stunting of growth, mild yellowing of new growth, and crinkling of newer leaves (fig. 30). When drift occurs at tuber initiation or tuber bulking, the initial symptoms are similar to early symptoms of Arsenal injury (fig. 31). As injury progresses, leaves roll, plant growth stops, and plants begin to yellow. Plants remain stunted and malformed throughout the season. Yield losses from Pursuit drift at tuber initiation or bulking may be severe.

Tuber symptoms of early season drift include curves, folds, creases, and skinny shape (fig. 32). Tuber symptoms of drift at tuber initiation include profuse knobs, folds, and creases (fig. 33), and symptoms of drift at tuber bulking include multiple deep cracks and elephant hide (fig. 34).

Soil residues of Pursuit cause foliar symptoms similar to those of Assert, including yellowed new growth. Leaves may be elongated, upwardly cupped, and wrinkled, or they may be strap shaped. Stands may be reduced. Injured tubers may be knobby, skinny, curved, folded, creased, cracked, dumbbell shaped, pointed, or have a combination of these symptoms.

Roundup — This is a substituted amino acid herbicide that kills plants by interfering with the synthesis of certain essential amino acids. Roundup is absorbed by leaves and translocated throughout the plant. Roundup has no soil activity so it does not present a carryover problem. Typical symptoms of Roundup drift include

yellowing of new leaves and stunting of plant growth (fig. 35). At higher drift rates, leaves may lose color, turn brownish, and die. Roundup drift causes irregularly shaped tubers with creases, folds, cracks, and elephant hide skin (fig. 36).

Buctril — This is a contact herbicide that interferes with photosynthesis. Buctril does not carry over in the soil. Buctril drift usually injures leaves only. Depending on the amount of drift, leaves may turn yellow to bronze or brown and appear burned (fig. 37). Leaf burn usually starts at the leaf margins. Severe injury kills leaves. Buctril drift has caused no problems other than small tubers and reduced yields even when applied directly to potatoes.

AAtrex, Velpar, and Karmex — Three other herbicides that may cause carryover injury in Idaho are AAtrex (atrazine), Velpar, and Karmex. All three herbicides interfere with photosynthesis. Typical foliar injury symptoms include yellowing of the older leaves followed by leaf death. New leaves may be affected later if carryover doses are high. Reduced tuber size has been the main tuber injury symptom.

Potato yield and quality

Foliar injury symptoms from herbicide drift or carryover do not always mean that tuber yield or quality will be reduced. Potatoes can recover from low doses of some herbicides. However, when foliar injury does occur, the crop should be followed carefully throughout the season.

Potato seed quality may be reduced when mother plants are injured by drift or carryover of Assert, Arsenal, Pursuit, or Tordon. Drift of Banvel, Curtail/Stinger, or Roundup also may reduce seed quality. Drift- or carryover-damaged seed may produce plants that emerge unevenly, have reduced vigor, and display foliar injury symptoms similar to those of the mother plant.

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The potential for drift and carryover problems can be reduced by closely following all herbicide label directions. The label should provide information on susceptible crops and time restrictions before certain crops can be planted after herbicide application. Do not plant potatoes before the appropriate recropping interval has passed.

30. Pursuit drift at emergence. Malformed, crinkled leaves.

31. Pursuit drift at tuber initiation or tuber bulking. Rolled and wilted-looking leaves; yellowed, stunted plants. Symptoms similar to those of Arsenal drift at tuber initiation.

32. Pursuit drift at emergence. Skinny and/or folded and creased tubers (U.S. No. 1 at left). Not shown — curved tubers.

35. Roundup drift. Yellowed new growth; stunted plants.

33. Pursuit drift at tuber initiation. Malformed, folded, creased tubers; tubers with multiple knobs (U.S. No. 1 at left).

36. Roundup drift. Malformed tubers, often with deep cracks.

34. Pursuit drift at tuber bulking. Malformed tubers with multiple deep cracks and elephant hide (U.S. No. 1 at left).

37. Buctril drift. Yellowed leaves; some leaf bronzing.

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