PNW 498

Herbicide Drift and Carryover Injury in Potatoes

Recognizing the Symptoms

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Herbicides applied in crops grown in rotation with potatoes may drift onto potatoes growing in neighboring fields, persist in the soil for one or more years, or remain as residues in tanks of sprayers used later to treat potato fields.

Research at the University of Idaho and Colorado State University has shown that carryover, drift, and spray tank residues of some commonly used nonpotato herbicides may reduce potato yield, potato quality, or both (table 1). Furthermore, potato seed tuber quality may be reduced when mother plants are injured. This bulletin discusses factors affecting herbicide carryover, drift, and spray tank residues and describes foliar and tuber injury symptoms caused by nonpotato herbicides.

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.

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

Trade name	Common name	Source of injury
AAtrex	atrazine	Drift and carryover
Accent	nicosulfuron	Drift and carryover
Ally	metsulfuron	Drift and carryover
Arsenal	imazapyr	Drift and carryover
Assert	imazamethabenz	Drift and carryover
Banvel	dicamba	Drift and carryover
Beacon	primisulfuron	Drift and carryover
*Broadstrike	flumetsulam + others	Drift and carryover
Buctril	bromoxynil	Drift
Bronate	bromoxynil + MCPA	Drift
Curtail	clopyralid + 2,4-D	Drift and carryover
2,4-D	2,4-D	Drift
Exceed	prosulfuron + primisulfuron	Drift and carryover
Express	tribenuron	Drift
Glean	chlorsulfuron	Drift and carryover
Harmony Extra	thifensulfuron + tribenuron	Drift
Karmex	diuron	Drift and carryover
Oust	sulfometuron	Drift and carryover
Peak	prosulfuron	Drift and carryover
Permit	halosulfuron	Drift and carryover
Pursuit	imazethapyr	Drift and carryover
Roundup	glyphosate	Drift
Scorpion III	flumetsulam + clopyralid + 2,4-D	Drift and carryover
Stinger	clopyralid	Drift and carryover
Tordon	picloram	Drift and carryover
Velpar	hexazinone	Drift and carryover

** There are several Broadstrike products, including Broadstrike + Dual, Broadstrike + Treflan, Broadstrike Plus Corn PRE/PPI, and Broadstrike Post Corn. Each Broadstrike product contains flumetsulam plus a second herbicide that varies with the specific product.*

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. Some 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 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

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

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

***Figure 3. Banvel** drift. Malformed leaves.*

***Figure 4. Banvel** drift or carryover. Upwardly cupped leaves.*

***Figure 5. Banvel** drift or carryover. Fiddle-necked leaves.*

***Figure 6. Banvel** drift. Malformed tubers.*

 All photos are of Russet Burbank except where noted.

Figure 7. Banvel *drift. Cracks in bud end, elephant hide.*

Figure 8. Banvel *injury in plants grown from tubers of drift-damaged plants.*

Figure 9. Curtail or Stinger *drift or carryover. Initial symptom—curled new leaves.*

Figure 10. Curtail or Stinger *drift or carryover. Fiddlenecked leaves similar to those caused by Banvel and Tordon.*

Figure 11. Curtail or Stinger *carryover injury. Small tubers, malformed tubers.*

Figure 12. Curtail or Stinger *drift at tuber initiation. Malformed tubers.*

more sites for herbicide adsorption than silty soils, while silty 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. Because soils high in clay and organic matter adsorb more herbicide than silty or sandy soils low in organic matter, relatively less herbicide remains available in the soil solution for plant uptake in finer-textured soils than in low organic matter, sandy soils.

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, Amber, and Oust) not only persist longer at high than at low pH but are adsorbed less to soil particles. Therefore, these herbicides are more available for plant uptake in high pH soils, which may result in crop injury.

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 activities are reduced. Drought years may result in more herbicide persistence than usual and unanticipated injury to the following crop. Herbicides also are more likely to carry over when they are applied at higher rates or later in the season.

Cultural 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.

Supplemental fall irrigation can speed up herbicide degradation by increasing microbial populations, which are important for degrading many herbicides. Where carryover is a strong possibility, fall irrigation can minimize potential damage to potatoes the following growing season.

Record keeping

Complete field histories are key to avoiding herbicide carryover problems. Growers should maintain easily accessible files on crops grown, herbicides and other pesticides applied, irrigation and/or rainfall received, and tillage practices used in each field. Growers buying or leasing farmland for potato production should review a complete herbicide history for the land and carefully examine detailed crop management and herbicide application records before growing potatoes.

Herbicide drift

Herbicide drift is the unintended, uncontrolled 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 affecting the potential for herbicide drift include herbicide volatility, method of application, spray particle size, and environmental conditions such as air temperature, wind speed and direction, and thermal inversions (table 2).

Herbicide volatility

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 and some Banvel (dicamba) formulations are volatile and can produce vapor drift. 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. In contrast, nonvolatile herbicides such as Glean, Ally, Amber, Harmony Extra, Oust, Pursuit, Assert, and amine formulations of 2,4-D and MCPA cause drift damage only from droplet or dry particle movement away from the target site.

Environmental conditions

Low relative humidity and/or high temperature decrease spray droplet size by increasing droplet 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,

Table 2. Factors influencing herbicide drift.

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

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 drift from slight wind currents.

Method of application

Aerial application is generally more likely to result in spray drift than ground application 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.

Table 3. Potato plant injury symptoms caused by nonpotato herbicides.

Tuber damage	Leaf damage	Canopy damage
Cracks	Chlorosis (yellowing) in various patterns, depending on herbicide	Reduced canopy structure
Knobs	Puckered leaves	Lack of row closure
Folds	Blistered leaves	Light green cast to field
Popcorn-shaped tubers	Fiddlenecked leaves	Drought-stressed appearance
Lustrous tubers	Cupped leaves	Floral abortion
Pointed tubers	Curled leaves	
Kidney- or banana-shaped tubers	Elongated leaves	
Aerial tubers	Boat-shaped leaves	
Small tubers	Rolled leaves	
Excessive tuber number	Reddish or purple leaves	
Tuber chaining	Crinkled leaves	
Elephant hide	Spinach-leaf appearance	
	Lack of leaf expansion	

Figure 13. Accent *drift. Stunting, reduced leaf development, and yellowing of new growth; leaves roll upward.*

Figure 14. Harmony Extra *drift at emergence. Initial symptoms—yellowed new growth, stunted plants. Other sulfonylureas produce similar symptoms.*

Figure 15. Harmony Extra *drift at tuber initiation or tuber bulking. Rolled leaves and wilted, stunted, yellowed plants. Other sulfonylureas produce similar symptoms.*

Figure 18. Harmony Extra *drift at tuber initiation, Centennial Russet. Folded, creased tubers.*

Figure 16. Harmony Extra *drift at tuber initiation or tuber bulking. Yellowed plants; some reddish-purple leaves. Other sulfonylureas may produce similar symptoms.*

Figure 19. Harmony Extra *drift at tuber bulking. Multiple deep cracks in tubers.*

Figure 17. Harmony Extra *drift at emergence. Small tubers (U.S. No. 1 at left).*

 All photos are of Russet Burbank except where noted.

Figure 20. Accent *drift. Deeply cracked and/or folded tubers, often with small knobs.*

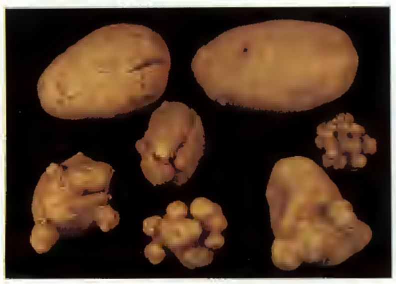

Figure 21. Oust *drift. Malformed tubers with deep cracks and/or multiple knobs.*

Figure 23. Accent *drift. Very large, malformed tubers may develop. Deep cracks, severe folding, multiple knobs, multiple secondary tubers growing on one common tuber.*

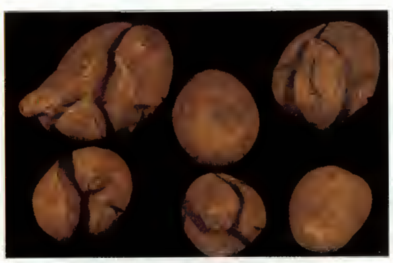

Figure 22. Oust *drift. Multiple deep cracks in tubers. Elephant hide.*

Figure 24. Oust *drift. Chains of small tubers along a stolon. Tuber chaining also may be caused by other sulfonylurea/imidazolinone herbicides and by heat stress.*

Figure 25. Oust *carryover. Proliferation of small, abnormal roots.*

Spray tank residues

Many nonpotato herbicides, such as Glean, Ally, Harmony Extra, Amber, Pursuit, Assert, Accent, Beacon, Peak, and Express are biologically active at very low rates, often less than 1 ounce of active ingredient per acre. This high level of biological activity can cause serious problems when sprayers used to apply these materials are then used to make pesticide applications to potatoes. This situation applies to ground application sprayers, airplane sprayers, and chemigation units. Some commercial applicators have invested in equipment dedicated solely to the application of highly active herbicides in order to eliminate the possibility of potato injury from herbicide residues in sprayers.

When sprayers serve the dual purposes of applying highly active nonpotato herbicides and applying potato pesticides, it is critically important to follow the sprayer clean-out procedures recommended by each herbicide manufacturer. Special attention should be paid to strainers, nozzle screens, nozzle tips, pumps, and old fiberglass tanks, which may retain residues on the frayed tank surface. Use of commercial cleaners, chlorine bleach, or ammonia solutions as recommended and rinses with clean water are very important for minimizing potential damage from spray tank residues.

Symptoms of herbicide carryover and drift

Potato injury symptoms pictured in this bulletin occurred in production fields, in greenhouse studies, or in herbicide injury field research trials. Symptoms may vary depending on the stage of potato growth and the growing conditions when the injury occurred. For example, herbicide injury at tuber initiation affects critical tuber growth events and may produce symptoms quite different from those occurring from herbicide injury during tuber bulking.

Symptoms may include changes in leaf or plant color, reductions in plant stand or plant architecture (height and degree of canopy closure), foliar damage, root damage, and a wide range of tuber malformations (table 3). Root damage frequently consists of pruned roots, but root proliferation also may occur. Occasionally, severe floral abortion may be observed.

Typically, the precise rate of nonpotato herbicide reaching the crop is not known, thereby complicating assessment of damage symptoms. Generally, the higher the herbicide rate, the more severe the injury symptoms will be. However, several herbicides may cause serious potato damage at levels below analytical detection. Some herbicides cause more damage than others, and damage may occur from a mixture of two or more nonpotato herbicides.

Some herbicides cause relatively few or minor foliar symptoms while causing serious tuber damage. Failure to look for tuber damage early in tuber development can result in considerable surprise when damaged tubers are dug at harvest time. For example, drift, carryover, or spray tank residues of some herbicides may malform 70 percent or more of the tubers produced.

Potato cultivars may vary in the type and severity of herbicide injury. In general, Russet Burbank is very sensitive to damage from a broad range of herbicides. Centennial Russet is relatively more tolerant of nonpotato herbicide injury, and varieties such as Sangre (a red potato) and Russet Norkotah are intermediate in their response to nonpotato herbicide injury.

Growth regulators

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 typical 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—Banvel is a benzoic acid herbicide absorbed by leaves, stems, and roots and translocated within the plant. Banvel may drift and cause potato injury or it 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 (figs. 3, 4). Higher doses may cause fiddlenecking (fig. 5) or give leaves a folded, hooded appearance. Petiole and leaf curling may accompany leaf wrinkling.

Banvel drift may cause malformed tubers (fig. 6), some with creases or cracks in the bud end, and may give the potato skin an appearance called "elephant hide" (fig 7). Occasionally, a bull's eye, or circle around the eye, appears. Russet Burbank tubers may be more rounded than is typical or may be malformed. Soil residues have not caused malformed tubers but have reduced tuber yield and grade in some studies.

Banvel also may carry over in tubers produced on drift-damaged plants and cause injury symptoms in plants grown from these tubers the following year (fig. 8).

Curtail and Stinger—These herbicides 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. 9). Higher doses often cause fiddlenecked leaves very similar to those caused by Banvel drift or carryover (fig. 10). In addition, the stems and leaves may thicken, and the leaves may look like broadened stems (strap-shaped leaves).

Some tubers are normal in shape, but small, while others may be malformed (figs. 11, 12). Circles may develop around the eyes, giving them a bull's-eye appearance. Total yield as well as yield of U.S. No. 1 tubers often is reduced by drift or carryover of Curtail or Stinger. Curtail and Stinger may carry over for more than one year.

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, fiddlenecking, and strap-shaped leaves.

Tordon may cause malformed tubers and small tubers that are more often irregularly shaped than smooth. Tordon is a long-residual herbicide and may carry over at levels that cause potato injury for many years.

ALS-inhibitors

Harmony Extra, Express, Accent, Amber, Ally, Glean, Oust, and others—These sulfonylurea herbicides interfere with the synthesis of certain amino acids essential to plant growth. When exposed to drift, the newest potato leaves turn yellow and plant growth is stunted (figs. 13, 14). Leaves may wilt and roll (figs. 13, 15). Leaves exposed to higher drift doses may become reddish purple, and stems may appear purplish (fig. 16).

Harmony Extra drift at emergence may result in small tubers (fig. 17). 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. 18, 19, 20, 21, 22, 23). High drift doses may cause popcorn-shaped tubers or chains of tubers along a stolon (fig. 24).

Ally, Glean, Amber, Oust, and several other sulfonylurea herbicides may carry over and delay potato emergence. Under carryover conditions, emerged plants may be grayish or bluish green and similar in appearance to severely drought-stressed plants, even though soil moisture may be optimal. Severe root pruning or a combination of root pruning and a proliferation of small, abnormal roots in some or all parts of the root system may appear (fig. 25). Tuber injury symptoms of carryover are similar to those of drift. Oust can damage some potato varieties at part-per-trillion levels in the soil, and may persist for more than one year.

Figure 26. Assert *drift or carryover. Yellowed new growth similar to that caused by the sulfonylureas; elongated, upwardly cupped leaves.*

Figure 27. Assert *drift, Centennial Russet. Note somewhat different leaf shape than injured Russet Burbank leaves in figure 26.*

Figure 28. Assert *drift or carryover at emergence. Curved tubers (U.S. No. 1 at left). Not pictured—bottlenecked tubers, dumbbells, knobby tubers.*

Figure 29. Assert *drift or carryover at tuber initiation. Curved tubers; deeply cracked tubers; folded, creased tubers (U.S. No. 1 at left).*

Figure 30. Assert *drift or carryover at tuber bulking. Deeply cracked or folded tubers (U.S. No. 1 at left).*

Figure 31. Assert *drift, Sangre. Malformed tubers with multiple, deep cracks.*

Figure 32. Assert *carryover (severe). Yellowed, stunted growth; strap-shaped or elongated leaves.*

Figure 33. Arsenal *drift at emergence. Yellowed new growth; elongated, cupped leaves similar to those caused by Assert; stunted plants.*

Figure 34. 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.*

Figure 35. Arsenal *drift at tuber bulking. Similar to symptoms of drift at tuber initiation at first, but plants eventually collapse and die.*

 All photos are of Russet Burbank except where noted.

Figure 36. Arsenal *drift at emergence. Malformed tubers (U.S. No. 1 at left).*

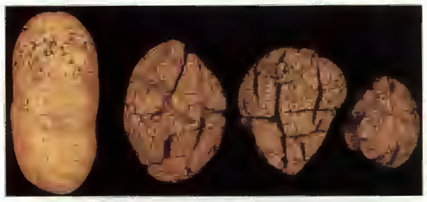

Figure 38. Arsenal *drift at tuber bulking. Malformed tubers with multiple deep cracks and elephant hide (U.S. No. 1 at left).*

Figure 39. Pursuit *drift at emergence. Malformed, crinkled leaves.*

Figure 37. Arsenal *drift at tuber initiation. Very small tubers with multiple knobs (U.S. No. 1 at left).*

Figure 40. 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.*

Figure 41. Pursuit *drift at emergence. Skinny and/or folded and creased tubers. Not shown—curved tubers. (U.S. No. 1 at left).*

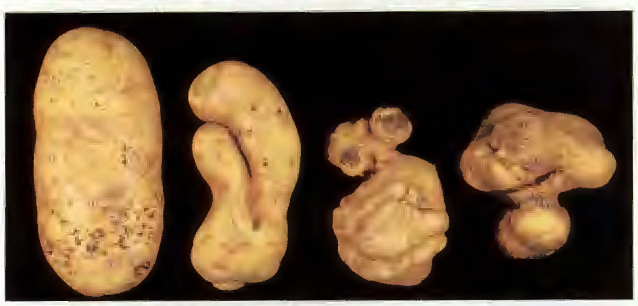

Figure 42. Pursuit *drift at tuber initiation. Malformed, folded, creased tubers; tubers with multiple knobs. (U.S. No. 1 at left).*

Figure 43. Pursuit *drift at tuber bulking. Malformed tubers with multiple deep cracks and elephant hide. (U.S. No. 1 at left).*

Figure 44. Pursuit *carryover, Russet Burbank. Plants are stunted and may appear yellow or dark, grayish-green. Leaves may be elongated, crinkled.*

Figure 45. Pursuit *carryover, Norqueen. Hooded or fiddlenecked leaves (Norse boat appearance).*

Figure 46. Pursuit *carryover, Norqueen. Wrinkled, spinach-leaf appearance.*

Figure 47. Pursuit *carryover, Russet Burbank. Elongated leaves with smooth, glossy appearance.*

Assert, Arsenal, and Pursuit—These are imidazolinone herbicides. They 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. Arsenal and Pursuit may persist in the soil for several years.

Assert drift initially causes stunting and yellowing of new growth, much like the sulfonylurea herbicides. As injury progresses, leaves elongate, develop a wrinkled appearance, and usually cup upward (fig. 26). The tips of the leaves often develop a characteristic boat shape, although specific symptoms may differ somewhat among varieties (fig. 27).

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. 28, 29, 30, 31). 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. 32). 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. 33). 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. 34). 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. 35). 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. 36). Drift at tuber initiation may produce severely malformed tubers, often with profuse knobs (popcorn-shaped tubers) (fig. 37). Drift at tuber bulking often results in tubers with multiple deep cracks and elephant hide (fig. 38).

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 a slight stunting of growth, mild yellowing of new growth, and crinkling of newer leaves (fig. 39). When drift occurs at tuber initiation or tuber bulking, the initial symptoms are similar to early symptoms of Arsenal injury (fig. 40). 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 a skinny shape (fig. 41). Symptoms of drift at tuber initiation include profuse knobs, folds, and creases (fig. 42). Symptoms of drift at tuber bulking include multiple deep cracks and elephant hide (fig. 43).

Soil residues of Pursuit may cause a number of different foliar symptoms depending on the dose to which the potato plant is exposed. Symptoms include yellowed new growth or dark green or grayish-green leaves (fig. 44). Leaves may be elongated, upwardly cupped, or fiddlenecked (fig. 45); strap-shaped and wrinkled (fig. 46); or smooth and glossy (fig. 47). The undersides of more severely injured leaves may be purplish. Symptoms also may vary somewhat with potato variety (e.g., figs. 44, 47 vs. figs. 45, 46). Stands may be reduced. Injured tubers may be knobby, skinny, curved, folded, creased, cracked, dumbbell-shaped, or pointed or may have a combination of these symptoms.

Amino acid synthesis inhibitors

Roundup—Roundup 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. 48). 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 (fig. 49). Roundup drift reportedly causes tuber breakdown in storage.

Photosynthetic inhibitors

Buctril—Buctril is a contact herbicide that interferes with photosynthesis. Buctril does not carry over in the soil. Depending on the amount of drift that occurs, leaves may first be spotted and then turn yellow to bronze or brown and appear burned (fig. 50). Leaf burn usually starts at the leaf margins. More serious injury kills leaves. Buctril drift does not cause malformed tubers but may result in small tubers and reduced yields.

AAtrex, Velpar, and Karmex—These three herbicides may cause carryover injury by interfering with photosynthesis. Typical foliar injury symptoms include yellowing of the older leaves followed by leaf death (fig. 51). Yellowing typically starts at the leaf margins. 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. With some herbicides, however, tuber damage can be moderate to severe even though foliar injury symptoms may be subtle. When foliar injury does occur, the crop should be followed carefully throughout the season. Many herbicides cause malformations (cracks, knobs, folds, curves) that are evident early in tuber development (fig. 52).

Potato seed quality may be reduced when mother plants are injured by drift or carryover of Assert, Arsenal, Pursuit, Curtail/Stinger, or Tordon. Drift of Banvel or Roundup also may reduce seed quality. Drift- or carryover-damaged seed may produce plants that emerge unevenly, have reduced vigor, produce a higher number of stems, or display foliar injury symptoms similar to those of the mother plant (e.g., fig. 8).

Further readings

Eberlein, C. V., and M. J. Guttieri. 1994. Potato (*Solanum tuberosum*) response to simulated drift of imidazolinone herbicides. Weed Science 42(1):70-75.

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For more information on potatoes

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***Figure 48. Roundup** drift. Yellowed new growth; stunted plants.*

***Figure 49. Roundup** drift. Malformed tubers, often with deep cracks, elephant hide.*

***Figure 50. Buctril** drift. Yellowed leaves; some leaf bronzing.*

***Figure 51. Atrazine** carryover. Yellowing of older leaves, beginning on leaf margins. Interveinal yellowing. (In Russet Burbank, metribuzin injury may cause similar symptoms initially, except that yellowing is veinal.)*

***Figure 52. Many nonpotato herbicides** can cause malformations (cracks, knobs, curved or folded shapes) early in tuber development.*

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All photos are of Russet Burbank except where noted.

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