Weed Management in Potatoes with Spartan Herbicide

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Spartan is a new herbicide for weed management in potatoes (table 1). Applied preemergence to weeds and potatoes, it controls many broadleaf weeds, including redroot pigweed, common lambsquarters, kochia, hairy nightshade, and black nightshade. Depending on rate, it suppresses some grasses such as barnyardgrass, crabgrasses, and foxtails. Spartan may be tank-mixed with Eptam, Prowl, Dual Magnum/Dual II Magnum, Matrix, Outlook, Stalwart, or Sencor for broad-spectrum weed control. Spartan has a different mode of action from other potato herbicides making it a valuable tool for herbicide-resistant weed management.

Table 1. Effectiveness of preemergence Spartan and Spartan tank mixtures on weeds in potatoes.

	Spartan	Spartan + Dual II Magnum	Spartan + Eptam	Spartan + Matrix	Spartan + Outlook	Spartan +Prowl	Spartan + Sencor
Broadleaves							
Amaranth, Palmer	C	C	C	C	C	C	C
Chickweed, common	C	C	C	C	C	C	C
Cocklebur, common	PC	PC	PC	PC	PC	PC	PC-C
Flixweed	C	C	C	C	C	C	C
Knotweed, prostrate	S	PC	C	C	C	C	C
Kochia	C	C	C	C	C	C	C
Lambsquarters, common	C	C	C	C	C	C	C
Mallow, common	C	C	C	C	C	C	C
Mustard, tansy	PC	PC-C	PC	C	PC-C	PC-C	C
Mustard, tumble	C	C	C	C	C	C	C
Mustard, wild	PC-C	PC-C	PC-C	C	PC-C	PC-C	C
Nightshade[a]							
black	C	C	C	C	C	C	C
eastern black	C	C	C	C	C	C	C
cutleaf	C	C	C	C	C	C	C
hairy	C	C	C	C	C	C	C
Pigweed							
prostrate	C	C	C	C	C	C	C
redroot	C	C	C	C	C	C	C
smooth	C	C	C	C	C	C	C
Purslane, common	C	C	C	C	C	C	C
Shepherd's-purse	C	C	C	C	C	C	C
Smartweed, Pennsylvania	C	C	C	C	C	C	C
Thistle, Russian	C	C	C	C	C	C	C
Velvetleaf[b]	PC-C	PC-C	PC-C	PC-C	PC-C	PC-C	C
Waterhemp, tall	C	C	C	C	C	C	C
Grasses and sedges							
Barley, volunteer	S	S	C	C	S	S	S
Barnyardgrass[c]	S	C	C	C	C	C	PC-C
Crabgrass, large	S	C	C	PC	C	C	PC-C
Foxtail, green or yellow	S	C	C	C	C	C	PC-C
Nutsedge, yellow[c]	PC	PC-C	PC	PC	PC	PC	PC
Oat, volunteer	S	S-PC	C	PC-C	S-PC	S-PC	PC-C
Oat, wild	S	S-PC	C	PC-C	S-PC	S-PC	PC-C
Wheat, volunteer	S	PC	PC-C	C	S-PC	S-PC	S-PC
Witchgrass	S	C	C	S-PC	C	C	PC

NOTE: C = control ≥85%; PC = partial control, 71 to 84%; S = suppression, 50 to 70%; all according to PNW university and USDA/ARS test results. Use rates in coarse- to medium-textured soils with ≤3% O.M.: Spartan 75 DF, 2 to 4 oz/A; Spartan 4F, 3 to 6 fl oz/A; Dual II Magnum, 1 to 2 pt/A; Eptam 3.5 to 7 pt/A; Matrix, 1 to 1.5 oz/A; Outlook, 14 to 18 fl oz/A; Prowl 3.3 EC, 1.2 to 2.4 pt/A; Prowl H_2O, 1.5 to 2.0 pt/A; Sencor 75 DF, ⅓ to 1 ⅓ lb/A; Sencor 4, ½ to 2 pt/A.

[a] The EPA-approved FMC Corp. Spartan herbicide use label and supplemental use labels list hairy nightshade as only partially controlled (71-84%) and do not list cutleaf nightshade as controlled or partially controlled.

[b] The EPA-approved FMC Corp. Spartan herbicide use label and supplemental use labels list velvetleaf as only partially controlled (71-84%).

[c] The EPA-approved FMC Corp. Spartan use label and supplemental use labels list barnyardgrass and yellow nutsedge as controlled (85% +).

Mode of action and potato tolerance

Sulfentrazone, the active ingredient in Spartan, inhibits chlorophyll production by inhibiting protoporphyrinogen oxidase (protox). Spartan applied to soil is absorbed by the roots of emerging plants. Chlorophyll production inhibition causes a chain of events within the plant that includes a buildup of toxic intermediate compounds, cell membrane disruption, and lipid peroxidation. Foliar contact by Spartan with susceptible plants results in rapid desiccation and necrosis of exposed plant tissues. Spartan injury has occurred in the absence of light, leading weed scientist to speculate that Spartan may have an additional or secondary mode of action separate from protox inhibition.

Most potato varieties tested are tolerant to Spartan applied according to the label *before potato emergence*. Differential absorption and translocation of Spartan's active ingredient, sulfentrazone, in potatoes compared with susceptible plants is believed responsible for the differential tolerance. Root absorption in susceptible plants can be two to three times greater than in potato plants. Furthermore, movement of the herbicide from the roots to the shoots, where protox is located, can be twice as great in susceptible plants as in potatoes. Because Spartan apparently is not metabolized any faster in potatoes than in susceptible plants, some foliage response/injury can be expected in potato plants that have emerged prior to Spartan application.

Effects of soils and the environment on weed control and potato tolerance

Weed control and crop tolerance are affected by herbicide movement and availability in soil and herbicide uptake and translocation in plants. The following soil and environmental factors can affect Spartan in soil and plants and, therefore, affect weed control and crop tolerance with Spartan: soil texture, soil organic matter (O.M.) content, soil pH, heavy rainfall after application, heat-induced crop stress, and cool/moist conditions.

Table 2. Spartan 75 DF preemergence application rates, ounces per acre.

	Soil texture[a]		
Organic matter (%)	Coarse	Medium	Fine
<1	2.0-3.0	2.0-3.0	2.5-3.5
1 to 3	2.0-3.0	2.5-4.0	3.0-4.0
>3	3.0-4.0	3.5-4.5	4.0-5.3

Note: Within the rate ranges, use lower rates for soils with pH >7.0 and higher rates for soils with pH <7.0.

[a]**Coarse**—sand, loamy sand, sandy loam; **medium**—sandy clay loam, sandy clay, loam, silt loam, silt; **fine**—silty clay loam, silty clay, clay loam, clay.

Weed control

Although Spartan can be adsorbed by soil O.M. it is soluble and possibly more available for plant uptake in soils with a pH greater than 6.6. Infiltration and movement of this herbicide in soil water can be greater in soils with coarser textures (high sand content) than in finer-textured soils (high clay content). Coarse-textured soils often have lower organic matter contents and higher soil pH, both of which can increase Spartan activity, and, in turn, affect weed control and potato tolerance. In the Pacific Northwest, the effective Spartan rate in coarse- to medium-textured soils with up to 3% O.M. is 2 to 4 oz/A (75 DF). However, in medium-textured soils with more than 3% O.M., Spartan may be applied at 4.5 oz/A (75 DF) if soil pH is less than 7.0. Please refer to table 2 for Spartan rates as functions of soil texture, pH, and percentage O.M.

Potato tolerance

The University of Idaho, Oregon State University, and USDA/ARS in Washington have conducted potato variety tolerance trials with Spartan (table 3). Potato injury, consisting of slight plant height reduction/stunting, transient black discoloration on foliage, and/or chlorosis on foliage, sometimes occurred in these trials. In an Oregon State University trial, Russet Burbank recovered from slight, early injury with no tuber yield or quality reduction.

Injury in Idaho trials usually occurred earlier in the season (approximately 2 weeks prior to row closure) than in similar trials conducted in Washington. Potato injury in the Washington trials was usually observed just prior to row closure and sometimes persisted after row closure. Although % O.M. was higher in the Idaho soil, soil pH also was higher than in Washington, resulting in early herbicide movement to the potato root uptake zone as irrigation water was applied. In Washington, under lower soil pH, the herbicide was less soluble and most likely took longer to move to the potato root uptake zone in amounts sufficient to cause injury.

As in Oregon, where only Russet Burbank was tested for tolerance, in Idaho and Washington, reductions in tuber quality or yield usually did not occur in any variety tested even though crop injury was observed. However, reductions in quality and yield did occur during one of the three years the variety tolerance trials were conducted. That year, unusually high temperatures before row closure in Idaho and

in Washington led to more frequent and more total early season irrigation compared with other test years. The increased irrigation likely moved higher concentrations of Spartan to the potato root zone earlier in the season than in other test years. These higher concentrations in the root zone most likely resulted in more herbicide being taken up by the potato plants when they were smaller and not as capable of metabolizing the herbicide as quickly as older, larger plants. Reduced plant vigor and a possible reduction in herbicide metabolism caused by the unusually early heat stress, combined with early herbicide injury, reduced potato tuber quality and yield.

All six varieties tested in Idaho during the year when heat stress occurred early—Russet Burbank, Ranger Russet, Russet Norkotah, Shepody, Alturas, and Bannock Russet—had reduced quality and yield. Of the four varieties tested that year in Washington—Russet Burbank, Ranger Russet, Russet Norkotah, and Shepody—Ranger Russet and Shepody had reduced total tuber yields and Ranger Russet had reduced U.S. No. 1 tuber yields compared with the same varieties grown in untreated, weed-free control plots. Quality and yield of these varieties were not affected by Spartan applied preemergence at the same rates during other test years at the same locations.

Because Spartan can be mobile in coarse-textured soils with high pH, rainfall events occurring soon after application to these soils may move the herbicide into the potato root zone earlier than movement with typical, scheduled irrigations. As in the Idaho and Washington tolerance trials when increased early irrigation probably moved Spartan into the potato root uptake zone early, rainfall events soon after application could cause early movement of Spartan at near-application concentrations, resulting in early season injury, and, possibly, potato tuber quality and yield reductions.

Table 3. Potato varieties tolerant to Spartan applied preemergence in research trials conducted in the Pacific Northwest and other potato growing areas.

Location/researchers Soil characteristics Spartan rates tested	**Tolerant potato varieties**
Eastern Idaho/University of Idaho	
loam, pH 8.0, 1 to 1.5% O.M. 2 or 4 oz/A (75 DF)	Russet Burbank, Ranger Russet, Russet Norkotah, Shepody, Alturas, Bannock Russet[a]
Eastern Washington/USDA-ARS	
sand, pH 7.0, 0.5% O.M. 2, 4, or 5.3 oz/A (75 DF)	Russet Burbank, Ranger Russet[b], Russet Norkotah, Shepody[c]
Eastern Oregon/Oregon State University	
silt loam, pH 7.0, 1.5% O.M. 2, 2.6, or 4 oz/A (75 DF)	Russet Burbank
Colorado/Colorado State University	
loamy sand, pH 7.5, 0.8% O.M. 2.6, 4, or 5.3 oz/A (75 DF)	Russet Norkotah, Russet Nugget, Chipeta, Sangre
Southern Texas/Texas A&M	
fine sand, pH 6.8, 0.5% O.M.	Atlantic[d]
loamy sand, pH 7.6, 0.6% O.M.	Atlantic
fine sand, pH 7.0, 0.6% O.M.	Atlantic
2, 2.6, 4, or 5.3 oz/A (75 DF)	
Virginia/Virginia Tech	
sandy loam soil, pH 6.2, <1% O.M. 2, 2.6, 4, or 5.3 oz/A (75 DF)	Superior

[a] Spartan treatments in Idaho resulted in U.S. No. 1 and total tuber yield reduction in all six varieties tested compared with untreated, weed-free controls during a year when unusual early heat stress occurred before row closure.
[b] Spartan treatments in Washington resulted in U.S. No. 1 and total tuber yield reduction in Ranger Russet compared with the untreated, weed-free control during a year when unusual early heat stress occurred before row closure.
[c] Spartan treatments in Washington resulted in total tuber yield reduction in Shepody compared with the untreated, weed-free control during a year when unusual early heat stress occurred before row closure.
[d] Spartan treatments in the Texas trial with fine sand soil, pH 6.8, and 0.5% O.M. resulted in total tuber yield reduction of Atlantic compared with an untreated, weed-free control. Irrigation was applied 48 h after application at this trial location and was not applied after applications at the other Texas locations.

See table 3 for varieties tested for Spartan tolerance in Pacific Northwest and other potato production area research trials.

Spartan application

Spartan may be applied by ground, air, or chemigation after potato planting and before weeds or potatoes emerge. Whichever method is used, avoid overlaps during application, continuously agitate during mixing and application, and shut off spray booms while turning, slowing, or stopping or over-application may result.

Do not exceed spray pressures of 40 psi unless specified by the manufacturer of drift-reducing spray tips and nozzles.

Avoid storing Spartan spray mixtures overnight as settling of product may occur.

Application methods

Chemigation. Chemigation application only can be made with center pivot, lateral move, end tow, solid set, or hand move irrigation systems. Apply Spartan in 0.25 to 0.5 inch water per acre prior to potato emergence. Do not exceed 0.5 inch water or the herbicide may move below the effective weed control zone. Avoid runoff of irrigation water. Spartan may be applied with other products labeled for chemigation use in potatoes.

Ground application. Apply Spartan in a minimum of 10 gallons water per acre.

Aerial application. Apply Spartan in a minimum of 5 gallons water per acre.

Incorporation of Spartan applications

Although Spartan can be applied to the soil surface without risk of photodecomposition or volatilization, ground or aerial applications should be sprinkler incorporated with 0.5 to 1.0 inch of water to insure activation and proper placement. *Mechanical incorporation is not recommended.* Do not exceed 1.0 inch sprinkler water for incorporation after ground or aerial applications or the herbicide may move below the effective weed control zone.

If adequate rainfall occurs after Spartan application, sprinkler incorporation may not be necessary. Optimal performance can be achieved if either rainfall or overhead irrigation is received within 7 days following ground or aerial application.

In general, coarse soil types with high pH and/or low % O.M. require less chemigation or sprinkler incorporation amounts than finer-textured soils with lower pH and/or higher % O.M.

Caution: Use of highly alkaline (high pH) irrigation water following application may increase the amount of herbicide available in the soil solution for uptake by the potato crop. *Irrigation with water having pH greater than 7.5 could result in adverse crop response.*

Weed control prior to Spartan application

Best weed control will occur if a hilling operation to control any emerged weeds is performed at, or just prior to potato emergence, and Spartan is applied as soon after hilling as possible but before potato plants emerge.

When a hilling or drag-off type of tillage is not performed to mechanically control emerged weeds prior to Spartan application, tank-mixing Spartan with a burn-down herbicide labeled for use prior to potato emergence (e.g., glyphosate or paraquat—see EPA-approved labels for specific rates, adjuvant, and application information) is recommended.

Applying Spartan in tank mixtures

Read and follow the applicable restrictions and limitations and directions for use on all product labels in a tank mixture. The most restrictive labeling applies to use of tank mixtures.

Spartan may be tank-mixed with other soil-applied herbicides labeled for preemergence use in potatoes for improved weed control (figures 1-3).

Tank-mixing Spartan with a herbicide that controls grasses is recommended.

Resistant weed management

Spartan has a different mode of action from all other herbicides currently labeled for use in potatoes. Therefore, weed populations resistant to those other herbicides may be controlled by Spartan. For example, some potato production areas in the Pacific Northwest have kochia or Russian thistle biotypes resistant to acetolactate synthase (ALS) inhibitor herbicides, or pigweed or common lambsquarters biotypes resistant to triazine herbicides. Since Spartan has a different mode of action from these herbicides, it may be used to control the resistant weeds.

To slow the onset of resistant weed population development and to help control herbicide-resistant weeds, use tank mixtures of herbicides with different modes of action and overlapping weed control spectrums in a given year as well as different herbicide modes of action from year to year in the potato cropping system rotation. Using a particular herbicide or herbicide mode of action repeatedly in a cropping system rotation will increase the risk of developing

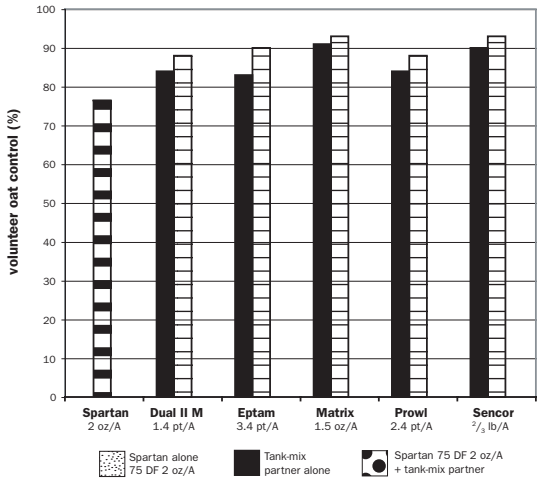

Figure 1. Season-long volunteer oat control with Spartan and other potato herbicides applied preemergence, alone and in combination, University of Idaho trials, 2001-03.

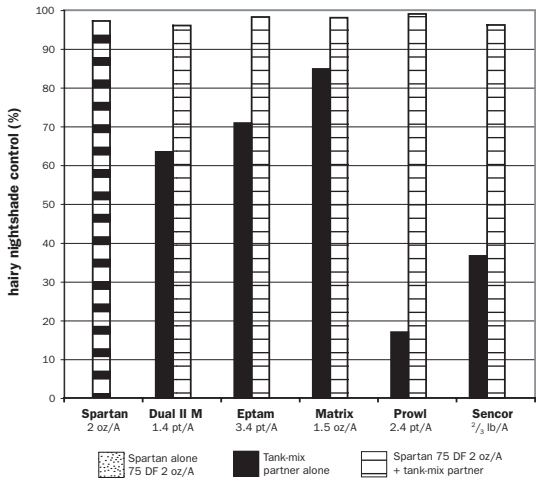

Figure 2. Season-long hairy nightshade control with Spartan and other potato herbicides applied preemergence, alone and in combination, University of Idaho trials, 2001-03.

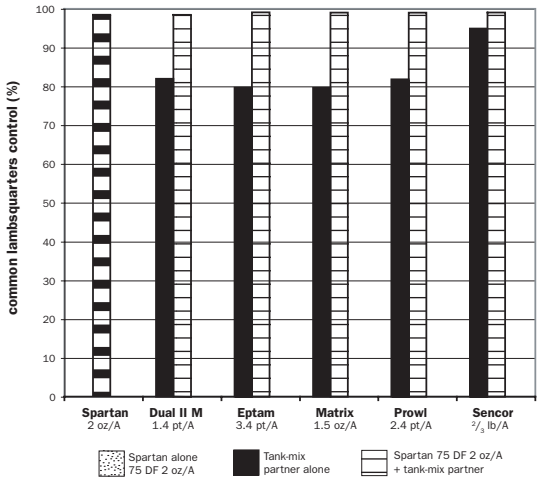

Figure 3. Season-long common lambsquarters control with Spartan and other potato herbicides applied preemergence, alone and in combination, University of Idaho trials, 2001-03.

Precautions and restrictions

Signal word: **CAUTION**

Personal protective equipment (PPE): Applicators and other handlers must wear long-sleeved shirt and long pants, waterproof gloves, and shoes plus socks.

Re-entry interval (REI): 12 hours.

Do not apply more than 5.3 oz/A Spartan per 12-month period. The 12-month period begins upon the initial Spartan application date.

Note: Before using Spartan herbicide as permitted according to the label, read and follow all applicable directions, restrictions, and precautions on the label or attached to the herbicide product container. Supplemental labels permitting use of Spartan herbicide contain revised use instructions and/or restrictions that may differ from those on the container label.

resistant weed populations. For more information on herbicide-resistant weeds present in the Pacific Northwest and on herbicide-resistant weed management, please refer to *Herbicide-Resistant Weeds and Their Management*, Pacific Northwest Extension Bulletin 437.

Spartan degradation, recropping, and rotational crop restrictions

The primary method of soil dissipation of sulfentrazone, the active ingredient of Spartan, is microbial degradation. Sulfentrazone half-life (time for half of the herbicide in the soil to degrade) has been stated as 110 to 280 days depending on soil and environmental conditions.

Sulfentrazone degradation is generally faster under warm, moist conditions than under cool, dry conditions. Optimal microbial degradation occurs when the soil pH and water content allow for high herbicide solubility and low soil adsorption. In these environments, the herbicide is usually available to the microbes for degradation. Conditions promoting microbial activity—adequate soil moisture and appropriate temperatures and soil pH for microbial activity rather than dormancy or death—must also be present.

If typical Pacific Northwest potato production irrigation practices are not implemented during the herbicide application year, or if drought conditions occur during the fall and winter after herbicide

application, the half-life of this herbicide may be closer to the high end of the half-life range than to the low end.

Recropping after crop failure. If Spartan is applied to a labeled crop and crop failure occurs, only crops labeled for Spartan, or any tank mix partner used, whichever is most restrictive, may be planted.

Rotational crop restrictions. Crops planted after potato harvest in fields treated with Spartan can be affected by Spartan that may remain in the soil. See table 4 for rotational crop guidelines.

Table 4. Rotational crop restrictions after Spartan application.

Crop	Interval (months)
Alfalfa	12
Barley	4
Cabbage	Anytime
Canola	24
Cereal grains: buckwheat, oats, pearl millet, proso millet, teosinte, wild rice	12
Corn, field	10
Corn, pop	18
Corn, sweet	18
Dry shell pea and beans	Anytime
Horseradish	Anytime
Limas	Anytime
Mint	Anytime
Potatoes	Anytime
Rye	4
Sorghum	10
Soybeans	Anytime
Sunflowers	Anytime
Sugarbeets	36
Sweet potatoes	12
Triticale	4
Wheat	4

Note: For crops not listed, the rotation interval is a minimum of 12 months (except peanuts or tobacco—anytime; rice—4 months, cotton—18 months).

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Always read the label!

Always refer to the EPA-approved labels for specific herbicide rates, timing, tank-mix partners, and application methods and requirements.

Trade Names—To simplify information, trade names have been used. No endorsement of named products is intended nor is criticism implied of similar products not mentioned.

Pesticide Residues—Any recommendations for use are based on currently available labels for each pesticide listed. If followed carefully, residues should not exceed the established tolerances. To avoid excessive residues, follow label directions carefully with respect to rate, number of applications, and minimum interval between application and reentry or harvest.

Groundwater—To protect groundwater, when there is a choice of pesticides, the applicator should use the product least likely to leach.

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