Herbicide Damage Symptoms on Hemp

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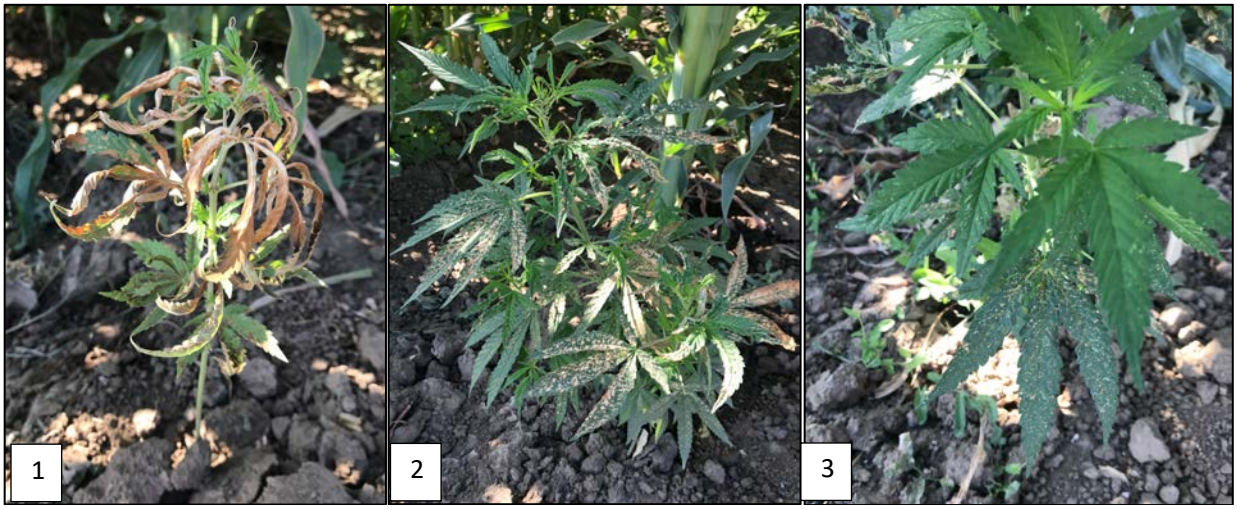
The introduction of a new crop into a landscape brings certain unknowns, including the risk of drift from neighboring crops. Hemp is a new, high-value commodity that is now being produced in many parts of California. Plants were sprayed with herbicides that are widely used during the hemp growing season. Materials were selected that are likely to be sprayed on commodities planted near, or adjacent to, a hemp field. The intention is to provide a brief description of herbicide injury expected from specific herbicides or similar modes of action.

Glyphosate is a postemergence herbicide that affects an enzyme important in the production of several essential amino acids in plants. Injury from drift of this type of herbicide typically is seen in the meristematic regions and youngest tissues first because these regions are rapidly growing and have the greatest need for amino acids. Glyphosate can translocate, or move within the plant, and moves from treated tissue to above and belowground meristems. Typical symptoms include chlorosis (yellowing) leading eventually to necrosis over the course of 5-10 days; some species can take on a purple coloration as well. In some cases, such as larger or woody plants, sublethal doses can lead to "witch's broom" due to shorter than normal internodes and "stacked" leaves as the plant begins to regrow. Because the herbicide is tightly bound to soil, crop injury from glyphosate is almost always associated with foliar exposure.

Paraquat is a postemergence herbicide that disrupts energy flow during photosynthesis. The herbicide can act very rapidly (hours), particularly under high-light conditions. Injury is due to membrane disruption by reactive oxygen and other free radicals; this results in leakage of cellular contents and rapid desiccation of affected tissues. Paraquat does not translocate well in plants, thus symptom severity is often a function of coverage and can range from specks from individual droplets to full necrosis from complete coverage. If the dose is insufficient to kill the plant, new growth will not be damaged. Paraquat is extremely tightly bound to soil and not likely to be taken up by plants via soil routes.

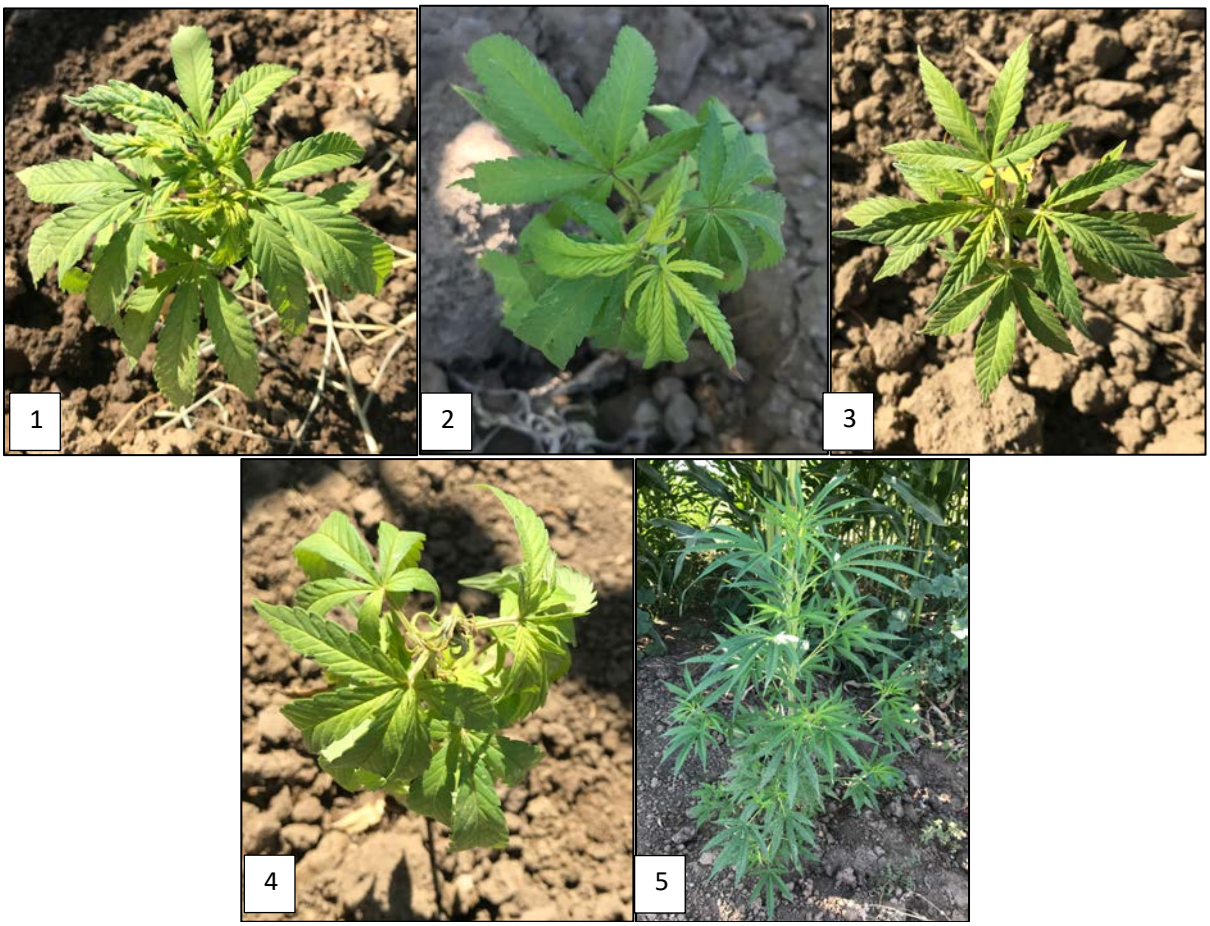
Glufosinate inhibits an enzyme important in amino acid synthesis and also leads to the accumulation of toxic levels of ammonia within the plant cells. Glufosinate movement in plants is fairly limited so injury severity is often a function of concentration and coverage. Typical symptoms initially occur with a few days beginning with wilting and chlorosis and progressing to necrotic tissue. Glufosinate injury is usually due to foliar exposure rather than soil routes.

PPO-inhibiting herbicides: (Saflufenacil (1), Carfentrazone (2), Oxyfluorfen (3)) inhibit an enzyme important in chlorophyll synthesis, among other things. These herbicides can quickly lead to the formation of free radicals within the cell which can damage lipids and proteins and cause disruption of membranes. Cells and tissues quickly desiccate and dry out. Some PPO herbicides are primarily used as foliar herbicides while others can have both foliar and soil activity. Transport within the plant is somewhat limited and occurs via the xylem (water conducting vessels). Because of this, symptom severity from PPO-inhibitor drift is a function of coverage; if the dose is sublethal, new tissues usually are not affected.



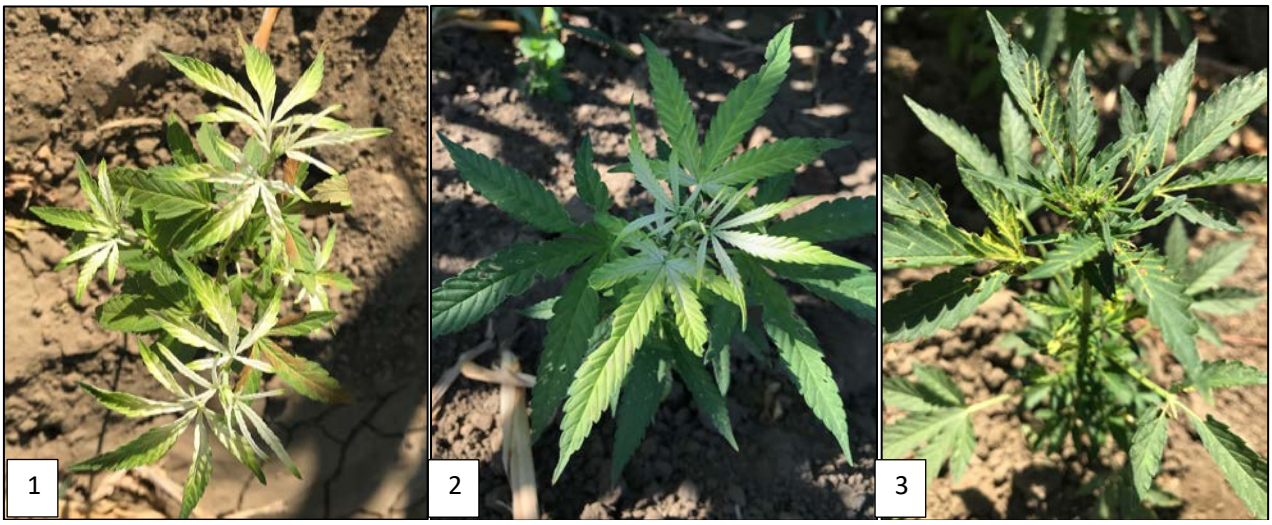
Propanil inhibits photosynthesis by blocking electron transport through photosystem II. Herbicides in this class typically are translocated via the xylem (water conducting tissues). Injury is usually first observed on the older, fully formed leaves because they are more actively photosynthesizing compared to younger, still-forming leaves. Injury often is initially noted at the leaf margins (chlorosis leading to necrosis) and then moving further into the interveinal areas of the leaf. If the plant survives foliar exposure, newly formed leaves may not be affected. Although propanil in this example is primarily used as a foliar herbicide, some other photosystem II inhibiting herbicides such as simazine, atrazine, or diuron are used as soil-applied materials.

ALS Inhibitors: (Bispyribac (1, 2), Imazapyr (3, 4), Rimsulfuron (5)) Several classes of herbicides inhibit the ALS enzyme, which is important in the synthesis of branched chain amino acids. Most of these herbicides have both foliar and soil activity. Like other amino acid synthesis inhibiting herbicides, symptoms from ALS inhibitors are usually first seen in the meristems and youngest tissues because they are rapidly growing and require large amounts of amino acids. At the whole plant level, symptoms are typically are characterized by general chlorosis leading to necrosis. Depending on the dose, sometimes an aboveground growing point may die and axial meristems released, which can result in an abnormal "branching" structure.

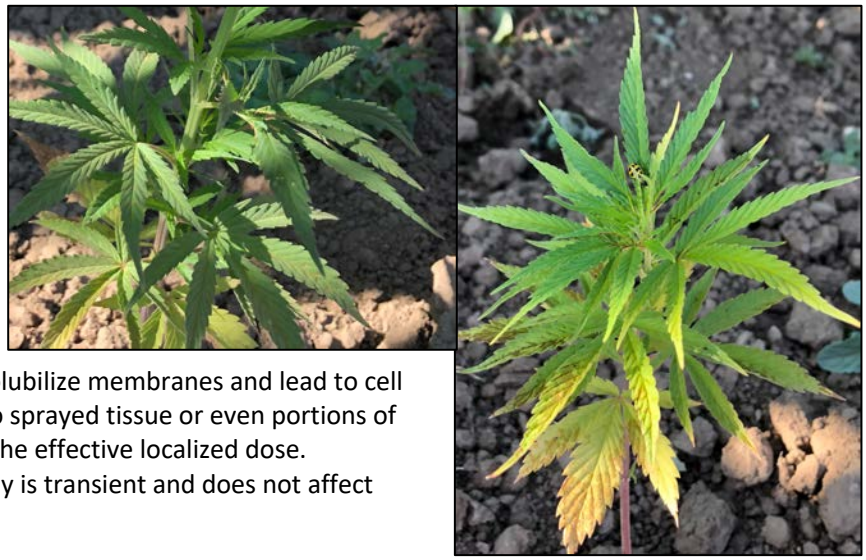


Synthetic Auxins: (Triclopyr (1), 2,4-D (2), Clopyralid-not pictured) There are several classes of herbicides that are known as synthetic auxins, plant growth regulator herbicides, or auxin-mimics. These herbicides affect primarily broadleaf plants, although there are some grasses affected by some herbicides. In general, as hormone mimics, synthetic auxin herbicides impact many cellular processes and lead to abnormal cell division and cell growth. At the whole plant level, this abnormal growth can take the form of leaf and stem twisting, cupping, bending, cracking and other epinastic growth. In some cases, leaf thickening, stem cracking, "strap" leaves, and other abnormal growth is observed. These symptoms can start relatively quickly after exposure and progress over days or weeks and eventually lead to necrotic tissues. Most synthetic auxin herbicide exposure is via foliar routes, however there are several herbicides in this class that can persist in soil and be taken up by that route.

HPPD-inhibiting herbicides (Mesotrione (1, 2) and *PDS-inhibiting herbicides* (Clomazone (3)) affect different steps in carotenoid biosynthesis. The carotenoids function to protect chlorophyll from damage from excess light energy. When carotenoid synthesis is inhibited, the most common symptoms is "bleaching" that can range from yellow in some plants to almost pure white leaf tissue in others. Usually, symptoms are first observed in the newly formed tissue that were never able to produce carotenoids but eventually can progress to older tissues as older carotenoids turn over and cannot be replaced. Bleaching can lead to tissue necrosis. Damage to established plants from drift of bleaching herbicides can be visual dramatic but rarely lethal. Damage to seedlings or young transplants from soil carryover may be more damaging.



Axxe (photo to left): Most organic herbicides such as Axxe have contact herbicidal activity by disrupting cell membranes which leads to cell and tissue desiccation. Like synthetic herbicides that disrupt membranes, these organic herbicides do not translocate well in plants and symptom severity is often a function of coverage and can range from specks from individual droplets to full necrosis from complete coverage. If dose and coverage is sublethal, new tissues usually are not affected.



Methylate Seed Oil (photos to right): Although methylate seed oil is not used alone for weed control, it was included in this demonstration because oil-based surfactants, or formulation emulsifiers in other pesticides, can sometimes cause "burning" similar to contact herbicides. Like contact herbicides, these types of oils can solubilize membranes and lead to cell and tissue necrosis. Often this injury is limited to sprayed tissue or even portions of leaves where droplets accumulate and increase the effective localized dose. Symptoms from this kind of phytotoxicity typically is transient and does not affect later-forming tissues directly.

ACCase inhibiting herbicides (Sethoxydim and Cyhalofop) inhibit a specific form of an enzyme common in grass plants but present in a slightly different form in broadleaf plants. Significant injury from ACCase herbicides is uncommon in broadleaf plants, although burn from the oil emulsifiers can occur. No symptoms were observed on hemp in this demonstration.

Active Ingredient	Example Trade Name	Common registered uses in California
glyphosate	Roundup (many products)	Many agricultural, industrial, and homeowner uses
paraquat	Gramoxone, Parazone	Preplant burndown in annual crops, orchard and vineyards
glufosinate	Rely, Lifeline, Finale	Preplant burndown in annual crops, orchard and vineyards, in-crop use in Liberty-Link cultivars
saflufenacil	Treevix, Sharpen	Orchards, alfalfa, corn, grasses
carfentrazone	Shark, QuickSilver	orchards and vineyards, cereal crops, some turf products.
oxyfluorfen	Goal, GoalTender, Galigan	Widely used in orchards, vegetable crops, fallow, roadsides, industrial sites.
propanil	Stam, SuperWham	Rice cropping systems
bipyribac-sodium	Regiment, Velocity	Rice cropping systems, some turf products
imazapyr	Polaris, Habitat	Industrial and roadsides, aquatic weeds, riparian and range restoration
rimsulfuron	Matrix, Grapple, Solida	Corn, orchards and vineyards, tomato, noncrop and industrial sites
triclopyr	Garlon, Grandstand, Turflon	Rice, brush and tree control, rights of way, aquatic weeds, turf products
2,4-D	2,4-D (many products)	broadleaf weed control in many grass and cereal crops
clopyralid	Transline, Confront	Rangeland, roadside, cereals and some tolerant crops
mesotrione	Broadworks, Callisto	orchards, corn, some legume crops
clomazone	Serano, Command	Rice systems, some vegetable and berry crops
ammonium nananoate	Axxe	many preplant or directed-spray applications. Organic certified.
methylated seed oil	MSO (many products)	Spray adjuvant used with many pesticides
sethoxydim	Fusilade	Grass weed control in many broadleaf crops and ornamentals, some homeowner products
cyhalofop	Clincher	Grass weed control in rice cropping systems.

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