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Sahara Mustard

Integrated Pest Management for Rangelands, Forests, and Natural Areas

Sahara mustard (*Brassica tournefortii*, aka African mustard, Asian mustard, Mostaza del Sahara) (Figure 1) is an invasive weed capable of spreading and invading a variety of habitats in California and southwestern North America. In several western states, Sahara mustard has been listed as a noxious weed or a species of concern. It grows especially well in disturbed areas but also grows well in natural sites. Sahara mustard is a short-lived winter annual that germinates from winter through spring completing its life cycle within a few months. Sahara mustard can invade a wide variety of habitats such as desert shrublands, desert dunes, ephemeral washes, grasslands, coastal sage scrub, coastal dunes, shrublands, roadsides, and abandoned or fallowed agricultural lands. It is generally found below 3,500 ft in elevation.

Sahara mustard is native to North Africa, the Middle East, and Southern Europe. It was likely accidentally introduced to California in the 1920s as a contaminate of date palms and was first recorded in the Coachella Valley. It has steadily spread since its introduction but was not widely recognized as a problem until populations became abundant in the 1990s and 2000s. Sahara mustard has spread into California, Nevada, Arizona, Utah, Texas, and Mexico in Baja California, Baja California Sur, Sonora, and Chihuahua. While it initially spread in the Sonoran Desert and expanded into the Mojave Desert, it has recently become more abundant along the coast and in the Central Valley of California, and the arid regions of central Nevada and southern Utah. The extent of its distribution, especially in a variety of habitats in California, is unknown.

Figure 1. Flowering Sahara mustard, *Brassica tournefortii*.

Figure 2. Sahara mustard cotyledons and first true leaves. Other mustards will look similar when they first germinate.

IDENTIFICATION AND BIOLOGY

Sahara mustard is a member of the mustard family, Brassicaceae. Mature plants can grow from 6 inches to almost 4 feet tall. The cotyledons are heart shaped and can sometimes have a purple tint on the underside (Figures 2 and 3). Plants are variable in size depending on growing conditions. Leaves can be from 3 to 12 inches long, occasionally up to 24 inches long in large plants, and from 0.5 to 4 inches wide with rounded ends. Leaves are deeply lobed and toothed with 4–10 lobe pairs on each leaf and basal leaves are covered in stiff white hairs that are prickly to the touch (Figure 4). Usually, a single flowering stem arises from the basal rosette and forms branches to produce a dense and wide inflorescence that

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includes from 6 to 20 flowers (Figure 5). Four-petaled yellow flowers are produced from the ends of the flowering stem and are generally 0.25 inch or smaller (Figure 6). Sahara mustard produces narrow fruits called siliques that are generally 1 to 3 inches long. Upon maturity, the siliques turn light tan-brown, and the seeds can easily be noticed between weak constrictions (Figure 7). The end of the fruit forms a one-seeded tapering beak, which can be up to 0.8 inch long. Sahara mustard fruits tend to grow at a distinct angle from the flowering stem, approximately 45 degrees, and the fruit and the pedicel (fruit stalk) grow straight. Seeds are 0.04 inch (1 mm) across and brown-red-purple. Seeds create a sticky mucilage when wet which aids in long distance dispersal by attaching to vehicles, equipment, tools, animals, or clothing. Plants tend to form a deep and thick tap root extending several feet below the surface in many types of soils. The root may extend especially deep in loose, sandy soils, allowing it to thrive in arid conditions.

Sahara mustard is a winter annual, first germinating during cool fall or winter rains and it can continue to germinate throughout the spring. Flowering can occur from early winter through the late spring and even in early summer in some locations if it's cool enough. Plants have a very fast growth cycle where seedlings can appear as quickly as 5 days after a significant rainfall. Flowering stems can appear in as little as 40 days, flowers appear 10 days later, and fruits can appear 60 days after germination. The entire life cycle can be completed in under 90 days. It is not unusual in areas with limited frost to observe plants flowering in December after germinating in October after rainfall or irrigation. Because Sahara mustard has a long germination window, a population in the middle of spring can consist of senesced mature plants, plants in flower, plants with large rosettes, and seedlings. In areas with a colder winter Sahara mustard may produce fewer cohorts and a more consistent population structure.

IMPACT

Sahara mustard can form large dense stands and can become the dominant herbaceous vegetation on a site in only a few years. Sahara mustard generally grows taller than most native winter annuals and seedlings of native perennials in California and outcompetes these plants for light, water, and resources, affecting the wildlife that depend on native winter annuals. When growing in dense patches Sahara mustard can reduce the visibility of spring wildflowers, thereby reducing recreation and tourism opportunities in these areas. The plant also has high oxalate content, so it may be toxic to wildlife if ingested.

A large single plant can produce thousands of seeds. While managers may focus on removing large individual plants, because of its

Figure 3. Underside of Sahara mustard cotyledon showing purple color. Not all Sahara mustard seedlings will show this purple color. Several other mustard species have purple on the underside of their cotyledons.

Figure 4. Basal rosette of Sahara mustard.

Figure 5. Large Sahara mustard rosette with inflorescence.

quick growth rate, even very small plants can produce dozens of seeds and grow at very high densities. Numerous small Sahara mustard plants also have the potential to reduce native plant populations. During a drought, Sahara mustard individuals can produce viable seed while native plant species need more water to reproduce. This seed production has been observed especially in washes, roadsides, or other areas where limited water may pool and temporarily collect in dry years. Seeds of Sahara mustard are easily dispersed long distances. The inflorescence can break free from the ground when dry and roll like a tumbleweed when winds are strong. Dry inflorescences have been observed floating across bodies of water and the seeds remain viable after being submerged for extended periods. When siliques are dry, they can shatter and send seeds flying several feet from the parent plant. The spherical seeds can roll along the soil surface during strong winds or move by surface flow during rain. Small animals can also carry and move seed. Occasionally, some siliques will not shatter when dry and old plants can hold seeds for over a year on dead skeletons.

MANAGEMENT

Once established, eradicating a Sahara mustard population takes consistent and repeated efforts. It is difficult to eliminate due to its rapid life cycle, long germination window, easily dispersed seeds, and moderately long-soil seed life. Successful management of Sahara mustard can be achieved after 3 to 4 years of consistent and timely control efforts. Sahara mustard can produce multiple cohorts of individuals each season and multiple control methods may be needed to reduce the population. Because Sahara mustard is an annual, populations will only be reduced if plants do not produce seeds every year. While most Sahara mustard seeds can survive 2 years in the soil, some can survive 3 years. It is unknown whether a minute fraction of seeds can persist for 4 or more years in the soil under field conditions. In storage in laboratory or indoor settings, seeds can persist for longer than 4 years, however longevity in the field is shorter.

Prevention

The most effective control of Sahara mustard is to prevent it from entering new sites. People, clothes, pets, vehicles including off-road vehicles, tools and equipment should be thoroughly cleaned before leaving an infested site and when entering a new clean area. Careful monitoring of areas, especially sites where soils are disturbed, along fence lines, roadsides, parking lots, embankments, trails, and recreational areas, will be crucial to detecting early infestations. Because Sahara mustard seeds easily disperse long distances, monitoring will be most successful when early detections are followed up with thorough scouting both near and away from infestations.

Cultural Control

Revegetation. Establishing or maintaining competitive vegetation can slow down a Sahara mustard infestation. Minimizing soil disturbances will also provide fewer optimal areas for Sahara mustard to flourish. Sahara mustard can also invade undisturbed and somewhat dense

Figure 6. Close up of Sahara mustard flower. The flowers of Sahara mustard tend to be paler yellow than other yellow-flowered mustard species in California.

Figure 7. Sahara mustard fruit with a tapering beak at end of fruit. The fruit size, length and angle of Sahara mustard is distinct from many other mustards in California.

stands of perennial plants, especially perennials that are dormant or small in the winter, thus while revegetation can slow an infestation, it will not be enough to stop an invasion by itself.

Physical Control

Hand Pulling/Hoeing. Sahara mustard is easily removed with a hoe or scuffle hoe early in the growing season when the rosette and the tap root are small. This method is effective on small populations, when individuals are scattered over a small area, or when labor is plentiful (such as during volunteer removal events). Sahara mustard can be pulled out of the ground by the inflorescence with gloved hands nearing the end of the season while the plant is bolting, but before fruits are produced. Gloves should be worn when working with this species because the stems and leaves have numerous prickly hairs that are painful, irritating, or both.

Hand pulling late in the season is often one removal method used with large volunteer groups who are eager to do weed work during spring wildflower blooms. If pulling events can be timed before Sahara mustard plants become large and before the plant is flowering and not in fruit, then pulled plants will not need to be bagged. In addition, the earlier Sahara mustard plants are pulled, the more time native wildflowers will have to grow and create vivid blooms without intense competition. Pulled plants should be bagged if fruits are present as some mature seeds may be present. Once plants become mature, they can become difficult to place in bags without fruits shattering and the seeds shooting out of the dry siliques. If Sahara mustard plants are being pulled when dry, a large tarp can be placed over the bagging area to catch the many seeds that shatter off the mature fruits.

Solarization. Solarization can be a successful method to reduce Sahara mustard seeds in the soil. Solarization tarps are laid out over infested patches after Sahara mustard plants have senesced during the late spring through the fall. Patches must be fully covered by the tarp and dead standing Sahara mustard plants cut down to prevent the stems from piercing the tarp. For more information on soil solarization see *Pest Notes: Soil Solarization for Gardens & Landscapes*.

Tent solarization is another potential control option and can be a highly successful method of killing seeds when plants are maturing. The treatment window for implementing this method is short since seeds begin dispersing soon after the plants desiccate.

Mowing. Mowing or clipping Sahara mustard can be minimally to moderately successful. When Sahara mustard plants are cut during the bolting stage a new stem will emerge, however this stem is often smaller than the original and produces fewer seeds. Repeated cuttings can reduce the number of seeds produced by individual plants, helping to achieve management goals. Numerous cuttings may be needed to stop seed production across an entire population. In thick infestations, mowing can reduce the amount of standing biomass enabling other control methods, like herbicides, to be more successful. A note of caution: since Sahara mustard seeds can easily stick to equipment, all equipment entering and leaving an infested site should be thoroughly cleaned.

Burning. Sahara mustard generally matures faster than most other vegetation. Because of this a selective prescribed fire where Sahara mustard is preferentially harmed compared to native species is difficult to implement. It is difficult to burn Sahara mustard before seeds mature without harming natives. The natives will be actively growing and be damaged by a fire, while some Sahara mustard may have already set seed. A thick stand of Sahara mustard can carry a fire when it has matured and dried, and the heat will kill seeds that have not dispersed. While these fires could reduce the number of Sahara mustard seeds, they will not harm the seeds in the soil and follow-up control methods will be required. Many areas where Sahara mustard grows, especially in the deserts, are highly sensitive to fire and native species are not adapted to fires. Even a single burn can harm native desert perennials for many years, even decades. Burning should be implemented only where desirable species are not present, such as where Sahara mustard is the dominant vegetation, in small areas, or in unusual places, such as a roadside berm without native plants. Flaming could control small actively growing Sahara mustard plants and would work over relatively small areas. Extreme caution should be taken to ensure a wildfire is not started with this technique and is best done in areas where risk of fire is very low.

Discing/Plowing. Discing or plowing can be effective at controlling one or a few cohorts of Sahara mustard. However, Sahara mustard grows well in disturbed soil and future efforts to reduce this species may be even more difficult due soil disturbance. Since Sahara mustard produces multiple cohorts each season, it could take several discing treatments to manage a population in a single year. Sahara mustard seeds become sticky when wet and can attach to discs or plows so equipment should be

thoroughly cleaned when leaving an infested site. If discing is conducted consider combining it with a competitive planting of desirable species, to help outcompete the Sahara mustard.

Biological Control

There are currently no approved biological agents for control of Sahara mustard. While some insects in the southwestern US have been found to feed on Sahara mustard, including the Bagrada bug (*Bagrada hilaris*), they do not adequately control Sahara mustard. Some pests of Sahara mustard have also been found to reduce the population of plants, including other mustards grown for food (such as broccoli and cabbage).

Chemical Control

Chemical control of Sahara mustard can be highly effective at several different times of the year. There are no herbicides that control Sahara mustard without harming non-target plants. Because Sahara mustard germinates rapidly, herbicides can be applied very early in the season shortly after a rainstorm when Sahara mustard seedlings have germinated but not all the natives have germinated. Mid- to late-season control can be highly successful when spot spraying plants. Using a small angle nozzle or a sprayer shield can minimize non-target plant impacts.

Several chemicals have been highly effective on Sahara mustard in the Southwestern U.S. The herbicide 2, 4-D controls broadleaved plants and has minimal soil activity. It can be applied postemergence to small Sahara mustard plants that have not yet flowered. Triclopyr is another broadleaf specific herbicide with minimal soil activity that can be applied postemergence to plants that have not yet flowered. It can be applied for spot treatments and for broadcast treatments. Glyphosate is a broad-spectrum herbicide with minimal soil activity that can be applied to postemergence plants for spot applications or broadcast sprayed.

Chlorsulfuron can be applied to Sahara mustard and provides good control. Since it is active in the soil, control continues for several weeks to months preventing germination of seeds. Chlorsulfuron can also be applied postemergence to seedlings through the rosette stage, but before the bolting stage. While some Australian researchers have noted poor control due to herbicide resistance with ALS inhibitors such as chlorsulfuron, this herbicide does successfully control Sahara mustard in California.

The herbicides pelargonic acid (which is currently produced as a synthetic herbicide), and the similar compound ammonium nonanoate (which some products are labeled for organic uses), are effective at controlling Sahara mustard. Higher rates are needed on small and medium sized plants, while lower rates may only provide control of very small plants. While pelargonic acid can provide control, glyphosate, triclopyr, and chlorsulfuron provide higher rates of control.

Preemergence herbicides can be used to control Sahara mustard before germination. These herbicides will control emerging seedlings and the herbicide needs to be incorporated into the soil by rainfall or irrigation before seeds germinate. Isoxaben can be applied to a wide variety of sites and has provided good control of other mustard species. Indaziflam also provides good control of other mustard species and shows promise for control of Sahara mustard. Sulfometuron could be applied preemergence or early postemergence and has been effective on other mustards. Other herbicides that could provide pre-emergence control of Sahara mustard would be imazapic and metsulfuron, although neither of these two herbicides are registered for use in California.

Broad-spectrum herbicides that are labelled for organic uses may be effective at controlling only small-sized Sahara mustard plants. These are contact herbicides and only kill the plant tissue they contact and are not translocated throughout the plant. They often require multiple treatments. These herbicides would be most effective early in the growing season. Medium- to large-sized plants are likely to re-sprout after being treated with contact herbicides, resulting in poor control.

A variety of other herbicides not listed here are effective at controlling other closely related mustard species, such as black mustard and London rocket (*Brassica nigra* and *Sisymbrium irio*, respectively), and these species may be listed on product labels and may provide similar levels of control on Sahara mustard. Caution should be warranted when trying an herbicide that does not list Sahara mustard on the label, while closely related Brassica species are listed. Apply these herbicides to a small patch of Sahara mustard plants and wait several days to weeks to determine the effectiveness of the herbicide. If successful, repeat the application to the rest of the population.

Herbicide Resistance. Because Sahara mustard has been found to be resistant to some herbicides in other parts of the world, including ALS-inhibitor herbicides like chlorsulfuron and sulfometuron, caution should be taken to ensure it does not develop resistance in North America. Combining multiple control methods or tank mixing herbicides with different modes of action are the best methods of preventing plants from developing herbicide resistance. A tank mixture of herbicides with multiple modes of action will be much more likely to prevent herbicide resistance than rotating herbicide modes of action throughout the season.

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WARNING ON THE USE OF CHEMICALS

Pesticides are poisonous. Some pesticides are more toxic than others and present higher risks to people, nontarget organisms, and the environment. A pesticide is any material (natural, organic, or synthetic) used to control, prevent, kill, suppress, or repel pests. "Pesticide" is a broad term that includes insecticides, herbicides (weed or plant killers), fungicides, rodenticides, miticides (mite control), molluscicides (for snails and slugs), and other materials like growth regulators or antimicrobial products such as bleach and sanitary wipes that kill bacteria.

Always read and carefully follow all precautions and directions provided on the container label. The label is the law and failure to follow label instructions is an illegal use of the pesticide. Store all chemicals in the original labeled containers in a locked cabinet or shed, away from food or feeds, and out of the reach of children, unauthorized persons, and animals. Never place pesticides in food or drink containers. Consult the pesticide label to determine active ingredients, correct locations for use, signal words, and personal protective equipment you should wear to protect yourself from exposure when applying the material.

Pesticides applied in your garden and landscape can move through water or with soil away from where they were applied, resulting in contamination of creeks, lakes, rivers, and the ocean. Confine pesticides to the property being treated and never allow them to get into drains or creeks. Avoid getting pesticide onto neighboring properties (called drift), especially onto gardens containing fruits or vegetables ready to be picked.

Do not place containers with pesticide in the trash or pour pesticides down the sink, toilet, or outside drains. Either use all the pesticide according to the label until the container is empty or take unwanted pesticides to your local Household Hazardous Waste Collection site. Contact your county agricultural commissioner for additional information on safe container disposal and for the location of the Hazardous Waste Collection site nearest you. Follow label directions for disposal of empty containers. Never reuse or burn the containers or dispose of them in such a manner that they may contaminate water supplies or natural waterways.

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