BRASSICAS AND MUSTARDS

Type: Annual (usually winter or spring; summer use possible)

Roles: Prevent erosion, suppress weeds and soilborne pests, alleviate soil compaction and scavenge nutrients

Mix with: Other brassicas or mustards, small grains or crimson clover

Species: *Brassica napus, Brassica rapa, Brassica juncea, Brassica hirta, Raphanus sativus, Sinapsis alba*

See charts, pp. 66 to 72, for ranking and management summary.

Marianne Sarrantonio

RAPE or CANOLA (Brassica rapa)

Nomenclature Note: The cover crops described in this chapter all belong to the **family** BRASSICACEAE. Most but not all of the species belong to the **genus** *Brassica*. In common usage, the various species are sometimes lumped together as "brassicas" and sometimes distinguished as "brassicas" vs. "mustards." In this book, we will use brassicas as an umbrella term for all species; mustards will be used to distinguish that subgroup, which has some unique characteristics.

Adaptation Note: This chapter addresses management of eight different cover crop species with varying degrees of winterhardiness. Some can be managed as winter or spring annuals. Others are best planted in late summer for cover crop use but will winterkill. Consult the information on management, winterhardiness and winter vs. spring use (pp. 87-88) and the examples throughout the chapter, then check with local experts for specific adaptation information for your brassica cover crop of choice.

Brassica and mustard cover crops are known for their rapid fall growth, great biomass production and nutrient scavenging ability. However, they are attracting renewed interest primarily because of their pest management characteristics. Most *Brassica* species release chemical compounds that may be toxic to soil borne pathogens and pests, such as nematodes, fungi and some weeds. The mustards usually have higher concentrations of these chemicals.

Brassicas are increasingly used as winter or rotational cover crops in vegetable and specialty crop production, such as potatoes and tree fruits. There is also growing interest in their use in row crop production, primarily for nutrient capture, nematode trapping, and biotoxic or biofumigation activity. Some brassicas have a large taproot that can break through plow pans better than the fibrous roots of cereal cover crops or the mustards. Those brassicas that winterkill decompose very quickly and leave a seedbed that is mellow and easy to plant in.

With a number of different species to consider, you will likely find one or more that can fit your farming system. Don't expect brassicas to eliminate your pest problems, however. They are a good tool and an excellent rotation crop, but pest management results are inconsistent. More research is needed to further clarify the variables affecting the release and toxicity of the chemical compounds involved (see p. 82).

BENEFITS

Erosion control and nutrient scavenging. Brassicas can provide greater than 80% soil coverage when used as a winter cover crop (176). Depending on location, planting date and soil fertility, they produce up to 8,000 lb. biomass/A. Because of their fast fall growth, brassicas are well-suited to capture soil nitrogen (N) remaining after crop harvest. The amount of nitrogen captured is mainly related to biomass accumulation and the amount of N available in the soil profile.

Because they immobilize less nitrogen than some cereal cover crops, much of the N taken up can become available for uptake by main crops in early to late spring (see also *Building Soil Fertility and Tilth with Cover Crops*, pp. 16–24). Brassicas can root to depths of six feet or more, scavenging nutrients from below the rooting depth of most crops. To maximize biomass production and nutrient scavenging in the fall, brassicas must be planted earlier than winter cereal cover crops in most regions, making them more difficult to fit into grain production rotations.

Brassicas must be planted earlier than winter cereal cover crops in most regions.

Pest management. All brassicas have been shown to release bio-toxic compounds or metabolic by-products that exhibit broad activity against bacteria, fungi, insects, nematodes, and weeds. Brassica cover crops are often mowed and incorporated to maximize their natural fumigant potential. This is because the fumigant chemicals are produced only when individual plant cells are ruptured.

Pest suppression is believed to be the result of glucosinolate degradation into biologically active sulfur containing compounds call thiocyanates (152, 320). To maximize pest suppression, incorporation should occur during vulnerable life-stages of the pest (446).

The biotoxic activity of brassica and mustard cover crops is low compared to the activity of commercial fumigants (388). It varies depending on species, planting date, growth stage when killed, climate and tillage system. Be sure to consult local expertise for best results.

▼ **Precaution.** The use of brassicas for pest management is in its infancy. Results are inconsistent from year to year and in different geographic regions. Different species and varieties contain different amounts of bioactive chemicals. Be sure to consult local expertise and begin with small test plots on your farm.

Disease

In Washington, a SARE-funded study of brassica green manures in potato cropping systems compared winter rape (*Brassica napus*) and white mustard (*Sinapis alba*) to no green manure, with and without herbicides and fungicides. The winter rape system had a greater proportion of *Rhizoctonia*-free tubers (64%) than the white mustard (27%) and no green manure (28%) treatments in the non-fumigated plots. There was less *Verticillium* wilt incidence with winter rape incorporation (7%) than with white mustard (21%) or no green manure incorporation (22%) in non-fumigated plots (88).

In Maine, researchers have documented consistent reductions in *Rhizoctonia* (canker and black scurf) on potato following either rapeseed green manure or canola grown for grain (459, 460). They have also observed significant reductions in powdery scab (caused by *Spongospora subterranea*) and common scab (*Streptomyces scabiei*) following brassica green manures, especially an Indian mustard (*B. juncea*) green manure (458, 459).

Nematodes

In Washington state, a series of studies addressed the effect of various brassica and mustard cover crops on nematodes in potato systems (260, 266, 353, 283, 284, 285).

The Columbia root-knot nematode (*Meloidogyne chitwoodi*) is a major pest in the Pacific Northwest. It is usually treated with soil fumigants costing $20 million in Washington alone.

Rapeseed, arugula and mustard were studied as alternatives to fumigation. The brassica cover crops are usually planted in late summer (August) or early fall and incorporated in spring before planting mustard.

Results are promising, with nematodes reduced up to 80%, but—because of the very low damage threshold—*green manures alone cannot be recommended for adequate control of* Meloidogyne chitwoodi *in potatoes.* The current recommended alternative to fumigation is the use of rapeseed or mustard cover crop plus the application of MOCAP. This regimen costs about the same as fumigation (2006 prices).

Several brassicas are hosts for plant parasitic nematodes and can be used as trap crops followed by an application of a synthetic nematicide. Washington State University nematologist Ekaterini Riga has been planting arugula in the end of August and incorporating it in the end of October.

Nematicides are applied two weeks after incorporation, either at a reduced rate using Telone or the full rate of Mocap and Temik. Two years of field trials have shown that arugula in combination with synthetic nematicides reduced *M. chitwoodi* to economic thresholds.

Longer crop rotations that include mustards and non-host crops are also effective for nematode management. For example, a 3-year rotation of potatoes>corn>wheat provides nearly complete control of the northern root-knot nematode (*Meloidogyne hapla*) compared to methyl bromide and other broad-spectrum nematicides.

However, because the rotation crops are less profitable than potatoes, they are less commonly used. Not until growers better appreciate the less tangible long-term cover crop benefits of soil improvement, nutrient management and pest suppression will such practices be more widely adopted.

In Wyoming, oilseed radish (*Raphanus sativus*) and yellow mustard (*Sinapsis alba*) reduced the sugar beet cyst nematode populations by 19-75%, with greater suppression related to greater amount of cover crop biomass (231).

In Maryland, rapeseed, forage radish and a mustard blend did not significantly reduce incidence of soybean cyst nematode (which is closely related to the sugar beet cyst nematode). The same species, when grown with rye or clover, did reduce incidence of stubby root nematode (432).

Also in Maryland, in no-till corn on a sandy soil, winterkilled forage radish increased bacteria-eating nematodes, rye and rapeseed increased the proportion of fungal feeding nematodes, while nematode communities without cover crops were intermediate. The Enrichment Index, which indicates a greater abundance of opportunistic bacteria–eating nematodes, was 23% higher in soils that had brassica cover crops than the unweeded control plots.

These samples, taken in November, June (a month after spring cover crop kill), and August (under no-till corn), suggest that the cover crops, living or dead, increased bacterial activity and may have enhanced nitrogen cycling through the food web (432).

Weeds

Like most green manures, brassica cover crops suppress weeds in the fall with their rapid growth and canopy closure. In spring, brassica residues can inhibit small seeded annual weeds such as, pigweed, shepherds purse, green foxtail, kochia, hairy nightshade, puncturevine, longspine sandbur, and barnyardgrass (293), although pigweed was not inhibited by yellow mustard (178).

In most cases, early season weed suppression obtained with brassica cover crops must be supplemented with herbicides or cultivation to avoid crop yield losses from weed competition later in the season. As a component of integrated weed management, using brassica cover crops in vegetable rotations could improve weed control and reduce reliance on herbicides (39).

In Maine, the density of sixteen weed and crop species was reduced 23 to 34% following incorporation of brassica green manures, and weed establishment was delayed by 2 days, compared to a fallow treatment. However, other short-season green manure crops including oat, crimson clover and buckwheat similarly affected establishment (176).

In Maryland and Pennsylvania, forage radish is planted in late August and dies with the first hard frost (usually December). The living cover crop

and the decomposing residues suppress winter annual weeds until April and result in a mellow, weed-free seedbed into which corn can be no-tilled without any preplant herbicides. Preliminary data show summer suppression of horseweed but not lambsquarters, pigweed, or green foxtail (432).

Mustard cover crops have been extremely effective at suppressing winter weeds in tillage intensive, high value vegetable production systems in Salinas, California. Mustards work well in tillage intensive systems because they are relatively easy to incorporate into the soil prior to planting vegetables. However, the growth and biomass production by mustards in the winter is not usually as reliable as that of other cover crops such as cereal rye and legume/cereal mixtures (45).

Deep tillage. Some brassicas (forage radish, rapeseed, turnip) produce large taproots that can penetrate up to six feet to alleviate soil compaction (432). This so-called "biodrilling" is most effective when the plants are growing at a time of year when the soil is moist and easier to penetrate.

Their deep rooting also allows these crops to scavenge nutrients from deep in the soil profile. As the large tap roots decompose, they leave channels open to the surface that increase water infiltration and improve the subsequent growth and soil penetration of crop roots. Smaller roots decompose and leave channels through the plow plan and improve the soil penetration by the roots of subsequent crops (446).

Most mustards have a fibrous root system, and rooting effects are similar to small grain cover crops in that they do not root so deeply but develop a large root mass more confined to the soil surface profile.

SPECIES

Rapeseed (or Canola). Two *Brassica* species are commonly grown as rapeseed, *Brassica napus* and *Brassica rapa*. Rapeseed that has been bred to have low concentrations of both erucic acid and glucosinolates in the seed is called canola, which is a word derived from Canadian Oil.

Annual or spring type rapeseed belongs to the species *B. napus*, whereas winter-type or biennial rapeseed cultivars belong to the species *B. rapa*. Rapeseed is used as industrial oil while canola is used for a wider range of products including cooking oils and biodiesel.

Besides their use as an oil crop, these species are also used for forage. If pest suppression is an objective, rapeseed should be used rather than canola since the breakdown products of glucosinolates are thought to be a principal mechanism for pest control with these cover crops.

Rapeseed has been shown to have biological activity against plant parasitic nematodes as well as weeds (176, 365).

Due to its rapid fall growth, rapeseed captured as much as 120 lb. of residual nitrogen per acre in Maryland (6). In Oregon, aboveground biomass accumulation reached 6,000 lb./A and N accumulation was 80 lb./A.

Some winter-type cultivars are able to withstand quite low temperatures (10° F) (352). This makes rapeseed one of the most versatile cruciferous cover crops, because it can be used either as a spring- or summer-seeded cover crop or a fall-seeded winter cover crop. Rapeseed grows 3 to 5 feet tall.

Mustard. Mustard is a name that is applied to many different botanical species, including white or yellow mustard (*Sinapis alba*, sometimes referred to as *Brassica hirta*), brown or Indian mustard (*Brassica juncea*)—sometimes erroneously referred to as canola—and black mustard (*B. nigra* (L.) (231).

The glucosinolate content of most mustards is very high compared to the true *Brassicas*.

In the Salinas Valley, California, mustard biomass reached 8,500 lb./A. Nitrogen content on high residual N vegetable ground reached 328 lb. N/A (388, 422).

Because mustards are sensitive to freezing, winterkilling at about 25° F, they are used either as a spring/summer crop or they winter kill except in areas with little freeze danger. Brown and field mustard both can grow to 6 feet tall.

In Washington, a wheat/mustard-potato system shows promise for reducing or eliminating the soil fumigant metam sodium. White mustard and oriental mustard both suppressed potato early dying (*Verticillium dahliae*) and resulted in tuber

yields equivalent to fumigated soils, while also improving infiltration, all at a cost savings of about $66/acre (see www.plantmanagementnetwork.org/pub/cm/research/2003/mustard/).

Mustards have also been shown to suppress growth of weeds (See "Weeds" p. 99 and 39, 176, 365).

Radish. The true radish or forage radish (*Raphanus sativus*) does not exist in the wild and has only been known as a cultivated species since ancient times. Cultivars developed for high forage biomass or high oilseed yield are also useful for cover crop purposes. Common types include oilseed and forage radish.

Their rapid fall growth has the potential to capture nitrogen in large amounts and from deep in the soil profile (170 lb./acre in Maryland (234). Above ground dry biomass accumulation reached 8,000 lb./acre and N accumulation reached 140 lb./acre in Michigan (304). Below ground biomass of radishes can be as high as 3,700 lb./acre.

Oilseed radish is less affected by frost than forage radish, but may be killed by heavy frost below 25° F. Radish grows about 2–3 feet tall.

Radishes have been shown to alleviate soil compaction and suppress weeds (177, 446).

Turnips. Turnips (*B. rapa L. var. rapa (L.) Thell*) are used for human and animal food because of their edible root. Turnip has been shown to alleviate soil compaction. While they usually do not produce as much biomass as other brassicas, they provide many macrochannels that facilitate water infiltration (359). Similar to radish, turnip is unaffected by early frost but will likely be killed by temperatures below 25° F.

In an Alabama study of 50 cultivars belonging to the genera *Brassica, Raphanus*, and *Sinapis*, forage and oilseed radish cultivars produced the largest amount of biomass in central and south Alabama, whereas winter-type rapeseed cultivars had the highest production in North Alabama (425).

Some brassicas are also used as vegetables (greens). Cultivated varieties of *Brassica rapa* include bok choy (*chinensis group*), mizuna (*nipposinica group*), flowering cabbage (*parachinensis group*), chinese cabbage (*pekinensis group*) and turnip (*rapa group*). Varieties of *Brassica napus* include Canadian turnip, kale, rutabaga, rape, swede, swedish turnip and yellow turnip. Collard, another vegetable, is a cabbage, *B. oleracea* var. *acephala*, and *B. juncea* is consumed as mustard greens.

A grower in Maryland reported harvesting the larger roots of forage radish (cultivar DAIKON) cover crop to sell as a vegetable. In California, broccoli reduced the incidence of lettuce drop caused by *Sclerotinia* minor (175).

AGRONOMIC SYSTEMS

Brassicas must be planted earlier than small grain cover crops for maximum benefits, making it difficult to integrate them into cash grain rotations.

Broadcasting seeding (including aerial seeding) into standing crops of corn or soybean has been successful in some regions (235). See also *After 25 Years, Improvements Keep Coming*, (p. 52). Brassica growth does not normally interfere with soybean harvest, although could be a problem if soybean harvest is delayed. The shading by the crop canopy results in less cover crop biomass and especially less root growth, so this option is not recommended where the brassica cover crop is intended for compaction alleviation.

In a Maryland SARE-funded project, dairy farmers planted forage radish immediately after corn silage harvest. With a good stand of forage radish, which winterkills, corn can be planted in early spring without tillage or herbicides, resulting in considerable savings. The N released by the decomposed forage radish residues increased corn yield boost in most years. This practice is particularly useful when manure is fall-applied to corn silage fields. (For more information see SARE project report LNE03-192 http://www.sare.org/reporting/report_viewer.asp?pn=LNE03-192).

▼ **Precaution:** Brassica cover crops may be susceptible to carry-over from broadleaf herbicides applied to the previous grain crop.

Mustard Mix Manages Nematodes in Potato/Wheat System

Looking for a green manure crop to maintain soil quality in his intensive potato/wheat rotation, Dale Gies not only improved infiltration and irrigation efficiency, he also found biofumigation, a new concept in pest management.

Farming 750 irrigated acres with two sons and a son-in-law in the Columbia basin of Grant County, Wash., Gies started growing green manure crops in 1990 because he wanted to improve his soils for future generations. Since then, he has reduced his use of soil fumigants thanks to the biocidal properties of *Brassica* cover crops. In particular, Gies is most excited about results using a mixture of white or oriental mustard and arugula (*Eruca sativa*), also a brassica, to manage nematodes and potato early dying disease.

"We use the mustards to augment other good management practices," Gies cautions. "Don't expect a silver bullet that will solve your pest problems with one use."

Controlling nematodes is essential to quality potato production, both for the domestic and the international market. Farmers typically manage root knot nematodes (*Meloidogyne chitwoodi*) and fungal diseases with pesticides, such as Metam sodium, a fumigant used routinely to control early dying disease (*Verticillium dahliae*), that cost that up to $500 per acre. Farmers are especially vulnerable to early dying disease if their rotations contain fewer than three years between potato crops.

However, with potato prices dropping, potato farmers in Washington and elsewhere started looking for ways to reduce costs. Gies contacted Andy McGuire at Washington State University Extension for help documenting the results he was seeing with brassicas. With research funding from SARE, McGuire confirmed that the mustards improved infiltration. He also showed that white mustard was as effective as metam sodium in controlling potato early dying disease.

"The findings suggest that mustard green manures may be a viable alternative to the fumigant metam sodium in some potato cropping systems," says McGuire. "The practice can also improve water infiltration rates and provide substantial savings to farmers. Until more research is done, however, mustard cover crops should be used to *enhance*, not eliminate, chemical control of nematodes."

Researchers have found that mustards can also suppress common root rot (*Aphanomyces euteiches*) and the northern root-knot nematode (*Meloidogyne hapla*).

Vegetable Systems. Fall-planted brassica cover crops fit well into vegetable cropping systems following early harvested crops. White mustard and brown mustard have become popular fall-planted cover crops in the potato producing regions of the Columbia Basin of eastern Washington.

Planted in mid to late August, white mustard emerges quickly and produces a large amount of biomass before succumbing to freezing temperatures. As a component of integrated weed management, using brassica cover crops in vegetable rotations could improve weed control and reduce reliance on herbicides (39).

Winter-killed forage radish leaves a nearly weed- and residue-free seedbed, excellent for early spring "no-till" seeding of crops such as carrots, lettuce, peas and sweet corn. This approach can save several tillage passes or herbicide applications for weed control in early spring and can take advantage of the early nitrogen release by the forage radish. Soils warm up faster than under heavy residue, and because no seedbed preparation or weed control is needed, the cash crop can be seeded earlier than normal.

Two types of mustard commonly used in the Columbia Basin are white mustard (*Sinapis alba*, also called *Brassica hirta* or yellow mustard), and Oriental mustard (*Brassica juncea*, also called Indian or brown mustard). Blends of the two are often planted as green manures. Fall incorporation seems to be best to control nematodes and soil-borne diseases, and Oriental mustard may be better at it than white mustard.

Gies plants a mix of mustards and NEMAT, an arugula variety developed in Italy for nematode suppression. The arugula attracts nematodes but they cannot reproduce on its roots, so nematode populations reduce, according to Washington State University researcher Ekaterini Riga.

Riga's greenhouse studies showed that arugula reduced Columbia root knot nematode (*Meloidogyne chitwoodi*) populations compared to the control or other green manure treatments. Subsequent field trial in 2005 and 2006 showed that arugula in combination with half the recommended rate of Telone (another fumigant) or full rates of Mocap and Temik reduced root knot nematode populations from 700 nematodes per gram of soil to zero. The combination also improved potato yield and tuber quality and it is still affordable by the growers.

"Arugula acts both as a green manure and a nematode trap crop," says Riga.

"It contains chemicals with high biocidal activity that mimic synthetic fumigants. Since nematodes are attracted to the roots of Arugula, it can be managed as a trap crop."

What causes brassicas to have biocidal properties? Researchers are keying in on the presence of glucosinolates in mustards. When the crop is incorporated into the soil, the breakdown of glucosinolates produces other chemicals that act against pests. Those secondary chemicals behave like the active chemical in commercial fumigants like metam sodium.

More research is needed to better determine site- and species-specific brassica cover crop effects on pests. It seems to be working for Dale Gies, however, "whose short season fresh market potato system probably functions differently than processing potatoes" according to WSU's Andy McGuire. To stay updated on cover crop work in Washington State, see www.grant-adams.wsu.edu/agriculture/ covercrops/green_manures/.

For Gies, however, "Tying the whole system together makes it work economically, *and* it improves the soil."

—Andy Clark

MANAGEMENT

Establishment

Most *Brassica* species grow best on well drained soils with a pH range of 5.5–8.5. Brassicas do not grow well on poorly drained soils, especially during establishment. Winter cover crops should be established as early as possible. A good rule of thumb is to establish brassicas about 4 weeks prior to the average date of the first 28° F freeze. The minimum soil temperature for planting is 45° F; the maximum is 85° F.

Winter hardiness

Some brassicas and most mustards may winterkill, depending on climate and species. Forage radish normally winter kills when air temperatures drop below 23° F for several nights in a row. Winter hardiness is higher for most brassicas if plants reach a rosette stage between six to eight leaves before the first killing frost.

Some winter-type cultivars of rapeseed are able to withstand quite low temperatures (10° F) (352).

Late planting will likely result in stand failure and will certainly reduce biomass production and nutrient scavenging. Planting too early, however, may increase winterkill in northern zones (166).

In Washington (Zone 6), canola and rapeseed usually overwinter, mustards do not. Recent work with arugula (*Eruca sativa*) shows that it does overwinter and may provide similar benefits as the mustards (430).

In Michigan, mustards are planted in mid-August, and winterkill with the first hard frost, usually in October. When possible, plant another winter cover crop such as rye or leave strips of untilled brassica cover crop rather than leave the soil without growing cover over the winter (391).

In Maine, all brassica and mustards used as cover crops winterkill (166).

Winter vs. spring annual use

Brassica and mustard cover crops can be planted in spring or fall. Some species can be managed to winterkill, leaving a mellow seedbed requiring little or no seedbed preparation. For the maximum benefits offered by brassicas as cover crops, fall-planting is usually preferable because planting conditions (soil temperature and moisture) are more reliable and the cover crops produce more dry matter.

In Maryland, rapeseed and forage radish were more successful as winter- rather than spring-annual cover crops. The early spring planted brassicas achieved about half the quantities of biomass and did not root as deeply, before bolting in spring (432).

In Michigan, mustards can be planted in spring following corn or potatoes or in fall into wheat residue or after snap beans. Fall seedings need about 900 growing-degree-days to produce acceptable biomass, which is usually incorporated at first frost (usually October). Spring seeding is less reliable due to cool soil temperatures, and its use is limited mostly to late-planted vegetable crops (391).

In Maine, brassicas are either planted in late summer after the cash crop and winterkill, or they are spring-seeded for a summer cover crop (166).

Rapeseed planted in late spring to summer has been used with some success in the mid-Atlantic region to produce high biomass for incorporation to biofumigate soil for nematodes and diseases prior to planting strawberries and fruit trees.

Mixtures. Mix with small grains (oats, rye), other brassicas or legumes (e.g. clover). Brassicas are very competitive and can overwhelm the other species in the mixture. The seeding rate must be adjusted so ensure adequate growth of the companion species. Consult local expertise and start with small plots or experiment with several seeding rates.

Washington farmers use mixtures of white and brown mustard, usually with a greater proportion of brown mustard.

In Maryland and Pennsylvania, farmers and researchers seed the small grain and forage radish in separate drill rows rather than mixing the seed. This is done by taping closed alternate holes in the two seeding boxes of a grain drill with both small seed and large seed boxes. Two rows of oats between each row of forage radish has also proven successful (432). Rye (sown at 48 lb./A) can be grown successfully as a mixture with winter-killing forage radish (13 lb./A).

Killing

Brassica cover crops that do not winterkill can be terminated in spring by spraying with an appropriate herbicide, mowing, and/or incorporating above-ground biomass by tillage before the cover crop has reached full flower. Rolling may also be used to kill these covers if they are in flower.

Rapeseed has proved difficult to kill with glyphosate, requiring a higher than normal rate of application—at least 1 quart/acre of glyphosate—and possibly multiple applications. Radish, mustard, and turnip can be killed using a full rate of paraquat, multiple applications of glyphosate, or glyphosate plus 1pt/acre 2,4-D.

In Alabama and Georgia, brassica cover crops were reportedly harder to chemically kill than winter cereals. Timely management and multiple herbicide applications may be necessary for successful termination. If not completely killed, rapeseed volunteers can be a problem in the subsequent crop. Always check herbicide rotation restrictions before applying.

Another no-till method for terminating mature brassicas is flail mowing. Be sure to evenly distribute residue to facilitate planting operations and reduce allelopathic risk for cash crop. As mentioned above, many producers incorporate brassica residues using conventional tillage methods to enhance soil biotoxic activity especially in plasticulture systems.

Brassica pest suppression may be more effective if the cover crop is incorporated.

Seed and Planting

Because *Brassica* spp. seed may be scarce, it is best to call seed suppliers a few months prior to planting to check on availability. *Brassica* seeds in general are relatively small; a small volume of seed goes a long way.

- Rapeseed (Canola). Drill 5-10 lb./A no deeper than ¾ in. or broadcast 8–14 lb./A.
- Mustard. Drill 5-12 lb./A ¼–¾ in. deep or broadcast 10-15 lb./A.
- Radish. Drill 8 to 12 lb/A.¼–½ in. deep, or broadcast 12-20 lb./A. Plant in late summer or early fall after the daytime average temperature is below 80° F.
- Turnip. Drill 4-7 lb./A about ½ in. deep or broadcast 10-12 lb./A. Plant in the fall after the daytime average temperature is below 80° F.

Nutrient Management

Brassicas and mustards need adequate nitrogen and sulfur fertility. Brassica sulfur (S) nutrition needs and S uptake capacity exceed those of many other plant species, because S is required for oil and glucosinolate production. A 7:1 N/S ratio in soils is optimum for growing rape, while N/S ratios ranging from 4:1 to 8:1 work well for brassica species in general.

Ensuring sufficient N supply to brassicas during establishment will enhance their N uptake and early growth. Some brassicas, notably rape, can scavenge P by making insoluble P more available to them via the excretion of organic acids in their root zone (168).

Brassicas decompose quickly. Decomposition and nutrient turnover from roots (C:N ratios 20-30) is expected to be slower than that from shoots (C:N ratios 10-20), but overall faster than that of winter rye. A winter-killed radish cover crop releases plant available nitrogen especially early in spring, so it should be followed by an early planted nitrogen demanding crop to avoid leaching losses (432).

COMPARATIVE NOTES

Canola is more prone to insect problems than mustards, probably because of its lower concentration of glucosinolates.

In the Salinas Valley, which has much milder summer and winter temperatures than the Central Valley of California, brassica cover crops are generally less tolerant of suboptimal conditions (i.e. abnormally low winter temperatures, low soil nitrogen, and waterlogging), and hence are more likely to produce a nonuniform stand than other common cover crops (45).

▼ **Precautions.** The use of brassicas for pest management is in its infancy. Results are inconsistent from year to year and in different geographic regions. Be sure to consult local expertise and begin with small test plots on your farm.

Bio-toxic activity can stunt cash crop growth, thus avoid direct planting into just-killed green residue.

Brassica cover crops should NOT be planted in rotation with other brassica crops such as cabbage, broccoli, and radish because the latter are susceptible to similar diseases. Also, scattered volunteer brassica may appear in subsequent crops. Controlling brassica cover crop volunteers that come up in brassica cash crops would be challenging if not impossible.

Black mustard (*Brassica nigra*) is hardseeded and could cause weed problems in subsequent crops (39).

Rapeseed contains erucic acid and glucosinolates, naturally occurring internal toxicants. These compounds are anti-nutritional and are a concern when feeding to livestock. Human consumption of brassicas has been linked to reducing incidence of cancer. All canola cultivars have been improved through plant breeding to contain less than 2% erucic acid.

Winter rape is a host for root lesion nematode. In a SARE funded study in Washington, root lesion nematode populations were 3.8 times higher in the winter rape treatment than in the white mustard and no green manure treatments after green manure incorporation in unfumigated plots. However, populations in the unfumigated winter rape treatment were below the economic threshold both years of the study. For more information, go to www.sare.org/projects/ and search for SW95-021. See also SW02-037).

Rapeseed may provide overwintering sites for harlequin bug in Maryland (432).

Contributors: Guihua Chen, Andy Clark, Amy Kremen, Yvonne Lawley, Andrew Price, Lisa Stocking, Ray Weil

BUCKWHEAT

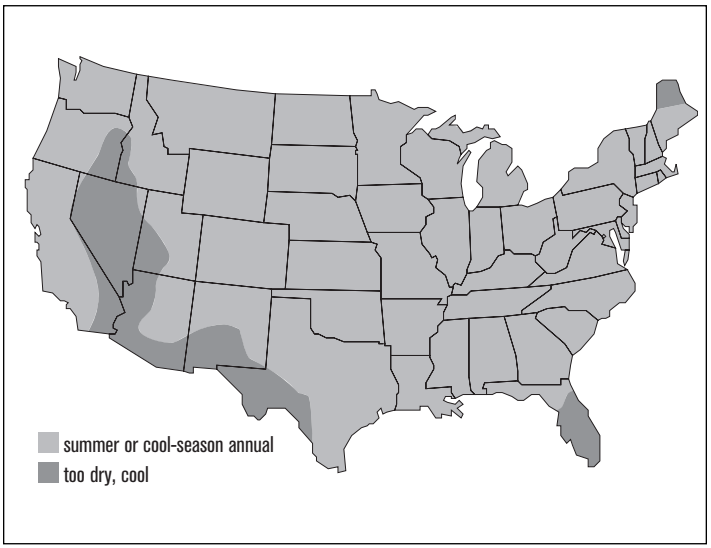
Fagopyrum esculentum

Type: summer or cool-season annual broadleaf grain

Roles: quick soil cover, weed suppressor, nectar for pollinators and beneficial insects, topsoil loosener, rejuvenator for low-fertility soils

Mix with: sorghum-sudangrass hybrids, sunn hemp

See charts, pp. 66 to 72, for ranking and management summary.



Buckwheat is the speedy short-season cover crop. It establishes, blooms and reaches maturity in just 70 to 90 days and its residue breaks down quickly. Buckwheat suppresses weeds and attracts beneficial insects and pollinators with its abundant blossoms. It is easy to kill, and reportedly extracts soil phosphorus from soil better than most grain-type cover crops.

Buckwheat thrives in cool, moist conditions but it is not frost tolerant. Even in the South, it is not grown as a winter annual. Buckwheat is not particularly drought tolerant, and readily wilts under hot, dry conditions. Its short growing season may allow it to avoid droughts, however.

BENEFITS

Quick cover. Few cover crops establish as rapidly and as easily as buckwheat. Its rounded pyramid-shaped seeds germinate in just three to five days. Leaves up to 3 inches wide can develop within two weeks to create a relatively dense, soil shading canopy. Buckwheat typically produces only 2 to 3 tons of dry matter per acre, but it does so quickly—in just six to eight weeks (257). Buckwheat residue also decomposes quickly, releasing nutrients to the next crop.

Weed suppressor. Buckwheat's strong weed-suppressing ability makes it ideal for smothering