Building Healthy Soils in Vegetable Gardens: Cover Crops Have Got It Covered

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Part I: Introduction to Cover Cropping

What are cover crops, anyway?

Cover crops are close-growing plants sown in rotation with food crops, or inter-seeded between food crops to cover bare ground. They are not harvested, but rather are planted to improve soil quality and provide other benefits for crop production and the environment. Before planting the next vegetable crop, most cover crops need to be cut down. The shoots can be chopped (or mowed) and left as mulch on the soil surface, or incorporated into the soil.

Figure 1. Rye and vetch cover crop in a community garden plot in May, just before it was cut down and mulched in preparation for planting vegetables. Photo credit: M. Gregory.

There is a large body of research supporting the use of cover crops on organic and sustainable farms.[1] However, vegetable gardeners can successfully plant and manage cover crops with hand tools, and reap the benefits of this practice for their soil and crops.[2]

Why should I plant a crop that I'm not going to harvest ?!?

Cover crops provide many benefits for future vegetable crop production, and for the garden agro-ecosystem system as a whole. Incorporating cover crops in vegetable rotations may:

- ***Increase soil organic matter levels, and therefore soil quality.*** As cover crop roots and shoots decompose, they build soil organic matter. This improves soil structure and water-holding capacity (Fig. 2), and increases slow-release nutrient reserves.[3] Fresh cover crop residues also nourish beneficial soil fauna (bacteria, fungi, worms, etc.) that improve soil tilth and aeration, recycle plant and animal wastes, and release nutrients for crops to use.

- ***Provide nitrogen for future food crops through legume nitrogen fixation***. Cover crops in the legume family (e.g., beans, peas, clovers, and vetches) add "new" nitrogen (**N**) to the soil. Legumes host N-fixing bacteria in bumps on their roots, also called nodules (Fig. 3). These bacteria take N from the air and convert it to a form the legume can use . When the plant decomposes, the fixed N also becomes part of the soil organic matter. Eventually, this N is released by microbes for crop uptake.[4]
- ***Improve nutrient retention and recycling.*** Over-wintering cover crops take up extra nutrients at the end of the growing season, which would otherwise be lost to leaching (when nutrients dissolve in rainwater and drain below the root zone, making the nutrients unavailable for plants). Over-wintering grasses like rye reduce N leaching by about 70% compared to bare soil.[5]
- ***Suppress weeds.*** Growing cover crops reduce weed growth through competition (e.g., for space, light, moisture, and nutrients) and allelopathy (releasing chemicals that inhibit other plants). After termination, cover crop mulch can prevent weed seedling emergence through the growing season.[6]
- ***Attract beneficial insects like bees & ladybugs.*** Cover crops often provide important resources (such as nectar and pollen and over-wintering habitat) for beneficial insects, including pollinator bees and natural enemies of insect pests.[1]
- ***Increase or maintain crop yields with less inputs.*** Well-managed cover crops can improve vegetable crop yields, or reduce the amount of fertilizer needed to obtain good yields.[7-10]

*Figure 2. Demonstration illustrating the effect of soil organic matter (**SOM**) on water-holding capacity:*

- *On the left is soil from an urban garden that received a rye/vetch cover crop for more than five years, and therefore has high SOM.*
- *On the right is soil from a garden that never received cover crops, and has lower SOM.*

This photo was taken 30 minutes after pouring equal amounts of water through the soils. The high-OM soil held most of the water, while much water drained through the low-OM soil. Since both soils were of similar texture, the difference in water-holding capacity can be attributed to the SOM. Photo credit: M. Gregory.

Figure 3. Nodules on the roots of legume cover crops: crimson clover (left) and hairy vetch (right). The nodules host nitrogen-fixing bacteria in the genus Rhizobia, which convert atmospheric nitrogen into plant-available forms. Photo credits: M. Gregory.

Vegetable gardeners have a number of cover crop options suited to different seasonal niches, management goals, and environmental conditions. To learn about the main groups of cover crops and how to select cover crops for your garden, see Part II (Types of Cover Crops) and Part III (Selecting Cover Crops).

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Part II: Types of Cover Crops – Nonlegumes, Legumes, and Mixtures (oh, my!)

Vegetable gardeners are turning to cover crops to improve soil quality, add nitrogen (**N**) to the soil through legume N fixation, suppress weeds, and attract beneficial insects in their gardens. In this article I'll introduce several groups of cover crops. Cover crop species can be broadly grouped into **non-legumes** (which do not fix N, but may take up and recycle nutrients left in the soil after vegetable crop harvest) and **legumes** (which fix N). **Mixtures** of non-legumes and legumes may offer the benefits of both types of cover crops.

Non-legume cover crops

Non-legume cover crops include species in several plant families:

- Grasses (Poaceae) include oats (Fig. 1a), winter rye (Fig. 1b), sorghum-sudangrass, and Japanese millet.
- Brassicas and mustards (Brassicaceae) include mustards, rapeseed, and tillage radishes.
- Buckwheat (Fig. 1c, Polygonaceae) is a popular summer cover crop.

Fig. 1. Examples of non-legume cover crops used in vegetable gardens *(Photo credits: M. Gregory)*

Fig. 1a. Oats *(*Avena sativa*) is a winter-kill cover crop in USDA Zones 7 and cooler. It is usually planted in late August, and dies with the first hard frosts.*

Fig. 1b. Winter rye *(*Secale cereale*) is a hardy over-wintering cover crop. It can be planted in September or October, and produces large amounts of biomass by May.*

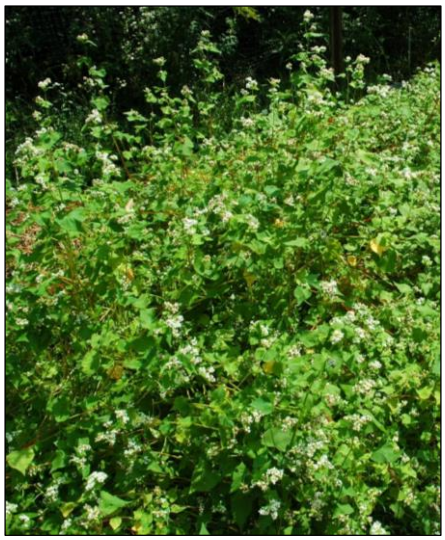

Fig. 1 c. *Buckwheat* (Fagopyrun esculentum) *is a fast-growing summer cover crop, suitable for planting between spring and fall vegetable crops.*

Benefits of non-legumes: [1, 11]

- *Prevent erosion* – Non-legumes establish and grow quickly, provide rapid soil cover, and have dense, fibrous root systems that hold soil in place.
- *Build soil organic matter* – Non-legumes produce high biomass, which contributes to soil organic matter.[3]
- *Retain and recycle nutrients* – Non-legumes take up nutrients left in the soil after vegetable harvest, which prevents them from being leached out of the garden during heavy spring rains.
- *Suppress weeds* – With their vigorous growth and high biomass, non-legumes can successfully compete with weeds, even in fertile soils. Some non-legumes (winter rye, sorghum-sudangrass, and Brassicas) also release chemicals that inhibit weed germination and growth. Residues of grass cover crops also provide a weed-suppressive mulch that lasts much of the growing season.
- *Disease management* -- Some Brassicaceae cover crops also release chemical compounds that may help control soil-borne pathogens and parasites (e.g., fungi, nematodes) upon incorporation. Winter rapeseed (*Brassica napus*) greatly reduced *Rhizoctonia* damage and *Verticillium* wilt in potato crops.[1, 11]

Drawbacks and constraints of non-legumes:

- *Slow nutrient supply and/or N immobilization* -- Non-legumes have lots of carbon (**C**) relative to N, which causes them to decompose slowly. As a result, nutrients in non-legume residues may not be available to vegetable crops quickly. If non-legume residues are incorporated into the soil, they may actually immobilize ("tie up") N for a few weeks as decomposer microbes take up soil N to balance the large amount of C in the plant residues they're breaking down.[1] For this reason, it's best to wait several weeks after incorporating a non-legume before planting vegetable crops.

Legume cover crops

Legume cover crops include field peas (Fig. 2a) crimson clover (Fig. 2b), hairy vetch (Fig. 2c), and cowpeas.

Fig. 2. Examples of legume cover crops used in vegetable gardens *(Photo credits: M. Gregory)*

Fig. 2a. Field peas *(*Pisum sativum*) can be planted as a winter-kill or early spring cover crop. It should only be planted in full sun, as this legume performs poorly in shaded areas.*[2]

Fig. 2b. Crimson clover *(*Trifolium incarnatum*) over-winters in Zones 7 and up, and can be used as a summer or winter-kill cover crop in cooler zones. Crimson clover is a high biomass producer and is quite shade-tolerant.*[2]

Fig. 2c. Hairy vetch *(*Vicia villosa*) is the hardiest legume, and will over-winter in even the northernmost parts of the US. It is an excellent legume for adding fixed N to the soil.*[2]

Benefits of legumes:

- *Nitrogen fixation* – Legume cover crops add 'new' nitrogen (**N**) to the soil through N fixation, which occurs when N-fixing bacteria in legume roots take N from the air and convert it to a form the plant can use. When legume residues break down, this N is added to the soil for food crops.[4]
- *Build soil organic matter and soil quality* – While legumes don't usually produce as much biomass as non-legumes, they also help build soil organic matter.[12, 13] Legumes are also excellent soil conditioners, because legume roots ooze sugars that stick soil particles together in larger crumbs, or aggregates.[14, 15] This helps the particles fit together loosely, making for a soft, porous soil.
- *Attract beneficial insects* – Many legume species provide resources for beneficial insects. Crimson clover provides pollen and nectar for native pollinator bees (Fig. 3), and both crimson clover and hairy vetch host predators such as lady beetles, which eat many pest insects.[1]

Figure 3. A bumblebee visits a crimson clover flower in a community garden. Photo credit: M. Gregory.

Drawbacks and constraints of legumes: [1, 3]

- *Slow growth, lower biomass* -- Legumes establish and grow more slowly than non-legumes, and usually produce lower biomass.
- *Less weed suppression* -- Legumes may not suppress weeds as effectively as non-legumes, particularly in soils with high N fertility. In Brooklyn gardens, legumes suppressed weeds in soils with low to moderate N fertility, but not in soils with high N fertility.[2] Legume residues break down quickly, so weed control by legume mulch may be short-lived.
- *Seed cost* -- Legume seeds are more costly than non-legumes.

Cover crop mixtures

Mixtures of non-legumes and legumes often combine the benefits of both types of cover crops.

Benefits of nonlegume/legume mixtures:

- *Produce large biomass and suppress weeds effectively* -- In many cases, cover crop mixtures provide more complete soil cover, greater biomass production, and more effective weed suppression than plantings of just one species.[1, 3] This is because mixtures of grasses and legumes use water, nutrients and sunlight very efficiently due to complementary root systems and growth habits. Grasses (like rye) also provide support for viny legumes (like hairy vetch), which allows the legume to access more light.
- *Increase N fixation* -- Planting legumes with grasses may enhance N fixation. Grasses out-compete legumes for soil N, forcing the legume to rely on N fixation. As long as the grass doesn't suppress legume biomass (see below), this can increase the total amount of N fixed. Promising grass/legume mixtures for N fixation include **rye/vetch** and **Japanese millet/cowpea**.[16]

- *Optimize nutrient cycling and nutrient supply to crops* -- Mixtures provide the benefits of N 'scavenging' by non-legumes *and* N additions by legumes.[1] At maturity, grass-legume mixtures often have an ideal C:N ratio of 25:1 – 30:1, which promotes a steady release of N for vegetable crop use as the cover crop plants decompose. N-rich legume residues prevent N tie-up that can occur when incorporating pure grass residues, while C-rich grass residues slow the breakdown of legume residues such that N is released at a rate that vegetable crops can use through the growing season.[11, 17]

Fig. 4. Examples of grass/legume mixtures used in vegetable gardens *(Photo credits: M. Gregory)*

***Fig. 4a. Oats/ Field peas** is a common winter-kill or early spring mixture. It should only be planted in full sun. Since oats may suppress field pea biomass and total N fixed,[2] try seeding the field peas at a higher rate.*

***Fig. 4b. Rye/ hairy vetch** is an excellent over-wintering mixture. The hairy vetch 'climbs' the rye, which allows the legume to access more light. In Brooklyn gardens, rye/vetch mixtures produced the highest biomass of any cover crop combination.[2]*

Drawbacks and constraints of nonlegume/legume mixtures:

- *Reduced N fixation if nonlegume out-competes the legume* – Mixing a non-legume with a legume may decrease the total amount of N fixed if the non-legume suppresses legume growth and biomass. This occurs in mixtures of: oats/field peas,[2, 18] rye/crimson clover,[2] and sorghum-sudangrass/cowpea.[16] Seeding the legume at a higher rate may result in a more even distribution of nonlegume and legume biomass – gardeners can experiment to find the relative seeding rate that works best in your soil.

Understanding the benefits and limitations of non-legumes, legumes, and mixtures is a great starting point for selecting cover crops to plant in your garden. For guidance on choosing specific cover crops based on your vegetable crop rotation, management goals, and soil and light conditions, see Part III: Selecting Cover Crops for Vegetable Gardens.

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Part III: Selecting Cover Crops for Vegetable Gardens

As I outlined in Part I and II of this series, cover crops can serve many purposes in small-scale vegetable gardens, including soil quality improvement, nitrogen (**N**) fixation, weed suppression, and habitat for beneficial insects. To achieve maximum benefits from cover crops, it's important to select appropriate species (or species mixtures) for each garden bed. In this article I'll highlight promising annual cover crop species for different seasonal niches, management goals, and environmental conditions. Much of this information is based on *preliminary* results from two seasons of cover crop research in Brooklyn, NY community gardens.[2]

Note: The cover crop seasonal niches and planting dates in this article are for USDA Plant Hardiness Zone 7 (average minimum winter temperature of 0-10°F). **To adapt this information for your local climate:**

1. Find your USDA Plant Hardiness Zone at: http://planthardiness.ars.usda.gov.
2. Consult your local Cooperative Extension and the book Managing Cover Crops Profitably to find ideal cover crop species and planting dates for your area. (Cover crop species profiles in this book all have maps indicating the most appropriate seasonal niche.)
3. A tip on adjusting planting dates: For **winter-kill and over-wintering cover crops** -- If you live in a *warmer climate* (Zone 8 and up), planting dates can be pushed *later* than those given in this article. If you live in a *colder climate* (Zones 6 and below), planting dates must be *earlier*. For **spring- and summer-planted cover crops**, the opposite is true.

Considerations when selecting cover crops

When choosing cover crops for a particular garden bed, there are three main considerations:[19]

- *Rotation planning:* What seasonal niche will the cover crop occupy? What vegetable crops will precede and follow the cover crop?
- *Management goals:* What do you want the cover crop to do? What cover crop function is most important -- adding organic matter to improve soil quality, contributing fixed N to the soil for food crops, suppressing weeds, providing habitat for beneficial insects, or suppressing a soil-borne disease?
- *Environmental conditions:* What species will grow well given your climate, soil, and light availability?

Seasonal niches

There are a number of seasonal niches when gardeners can fit cover crops into a vegetable rotation. **Winter-kill** and **over-wintering** cover crops are planted near the end of the growing season, and allow gardeners to take advantage of the warm summer months for vegetable production. **Summer** cover crops can be planted in the window after early spring crops (like lettuce) and before crops for a fall harvest (like broccoli or kale).

Winter-kill cover crops: Plant in late August, killed by frost

Winter-kill cover crops are planted in late August through early September, grow through the late summer and fall, and die with the first hard frosts (Fig. 1). It's best to plant winter-kill cover crops following a short-season vegetable (such as beans or beets) which can be harvested by mid- to late-August.

Plant a winter-kill cover crop in beds where you want to plant early spring crops in March and April (e.g., peas, spinach, broccoli).

Since these cover crops are killed by frost, they are **easy to manage**. The next season, you can plant cool-season crops (like peas, spinach, and broccoli) into the dead cover crop mulch as soon as the soil can be worked.

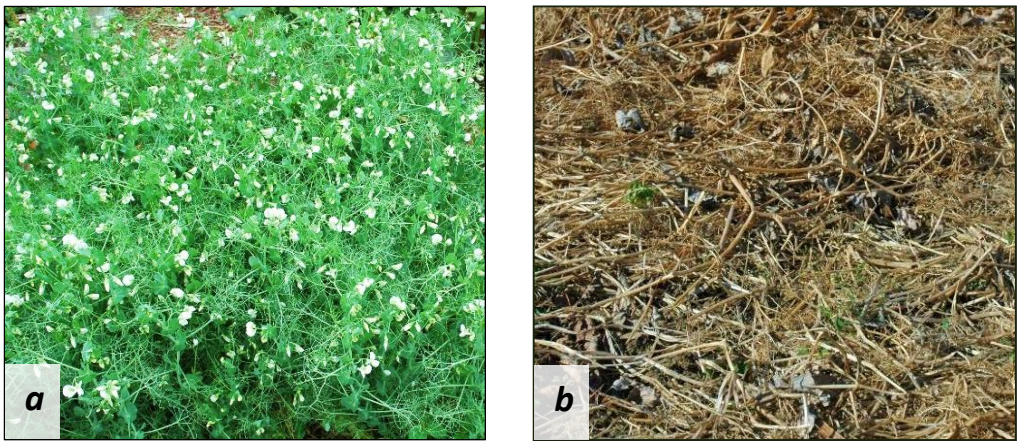

Figure 4. Field pea cover crop: a) growing in late fall and b) winter-killed mulch in early spring. Vegetable crops can be transplanted through the dead mulch as soon as the soil can be worked, in March or April. Photo credits: M. Gregory.

Due to their short growth period, however, winter-kill cover crops **produce much less biomass (plant material) and fix less N** to enrich the soil, compared to over-wintering cover crops (see below).[2] Since winter-kill cover crops decompose over the winter, they also **don't provide much spring weed suppression**.

In USDA Zone 7, winter-kill cover crops include **non-legumes** oats and brassicas and mustards, and a **legume**, field peas. (In Zones 5-6 and colder, crimson clover will also winter-kill.)

Over-wintering cover crops: Plant in September – October, Cut down at flowering in early May

Over-wintering cover crops are planted in September and October, survive the winter, and resume growth the following spring. These cover crops are a good choice where you have longer-season vegetable crops that produce into the fall, as the cover crop can be seeded beneath food crops finishing up for the season (Fig. 2a). The following spring, the cover crops should be cut down at flowering, usually in early May (Fig. 2b).

Plant an over-wintering cover crop to get the most benefit for soil quality, legume N fixation, and spring weed suppression.

When allowed to reach maturity (flowering), over-wintering cover crops **produce large amounts of biomass and fixed N**.[2] Since over-wintering cover crops are well-established in early spring, they also **provide excellent spring weed suppression**. In Brooklyn gardens, four over-wintering cover crop combinations reduced spring weed growth by 93-100%.[2]

The main disadvantage of winter-kill cover crops is that **gardeners must wait to plant vegetables until late May or early June the following spring**. To obtain the most biomass and legume N fixation (and to ensure that the cover crops do not re-sprout!), gardeners *must wait* until over-wintering cover crops flower before cutting them down. Since this occurs in May, it's *not* possible to plant early spring crops following an over-wintering cover crop. Instead, gardeners should choose warm-season, transplanted vegetables (e.g., tomatoes, peppers, eggplants, and Cucurbits), or short-season vegetables (e.g., beans) for planting after an over-wintering cover crop.

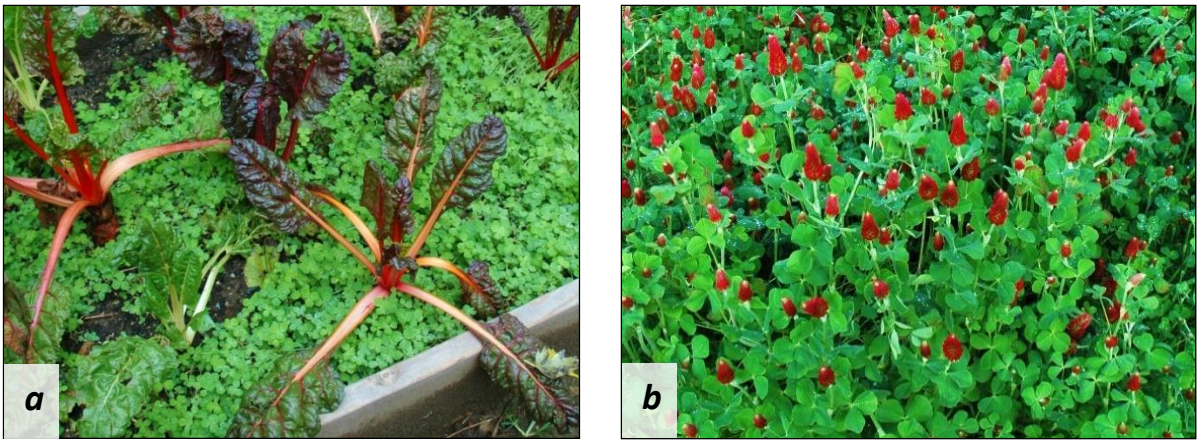

Figure 5. Crimson clover cover crop: a) under-seeded to Swiss chard in fall, and b) flowering the following spring. Photo credits: M. Gregory.

In USDA Zone 7, over-wintering cover crops include the **non-legumes** winter rye and winter wheat, and the **legumes** crimson clover and hairy vetch.

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Summer cover crops: Plant in June or July

Plant a summer cover crop to suppress weeds and add organic matter to your soil between early spring crops and crops transplanted for a fall harvest.

Summer cover crops can suppress weeds and add organic matter to the soil in the few months between early spring crops and late-season plantings for a fall harvest (June – mid-August). Some warm-season annuals can also be planted after a short-season vegetable in late July and allowed to grow into the fall for additional benefits to soil quality, weed suppression, and legume nitrogen fixation.

Summer non-legumes like buckwheat and Japanese millet are fast-growing and may provide excellent weed suppression. Be sure to cut down these cover crops about one week after they begin flowering in order to prevent seed set. For buckwheat, this will be just 35-40 days after sowing.[20] Japanese millet will take at least 45 days to mature.[21]

In USDA Zone 7, legumes that can be planted in the summer include cowpeas and crimson clover. To obtain the weed suppression benefits of non-legumes *and* the nitrogen fixation benefits of legumes, try planting a mixture. Finding an ideal combination – in which the non-legume does not suppress the legume – can be tricky, but there are a couple promising summer cover crop mixtures:

- **Japanese millet and cowpea:** The millet improves weed suppression over a cowpea monoculture, and also stimulates greater biomass production and nitrogen fixation by the cowpea.[16, 22]
- **Buckwheat and crimson clover:** Buckwheat's quick growth gets a jump start shading out weeds, but also suppresses the clover. To get the most out of this mixture, mow or clip the buckwheat when it begins flowering. This will allow light to reach the crimson clover, which can then grow and fix nitrogen into the fall.[23]

Management Goals

Most cover crops serve multiple purposes, but some will be better than others for different functions. Here are some tips on cover crop selection for common management goals.

Figure 6. Rye and hairy vetch is an excellent over-wintering cover crop combination that provides high biomass, N fixation by vetch, and weed suppression. (Photo credit: M. Gregory).

Increasing soil organic matter, Suppressing weeds
→ Over-wintering grass/legume mixtures

If your main goal is to build soil organic matter or suppress weeds, an **over-wintering grass-legume mixture** may be your best bet. Over-wintering mixtures produce high biomass (and therefore add lots of organic matter to the soil)[1, 3] and are well-established in spring to shade out weeds.

- In Brooklyn gardens, mixtures of **rye and hairy vetch** (Fig. 3) produced the most biomass of any cover crop combination and nearly eliminated spring weeds.[2]
- If a legume alone is desired (for example, to minimize the risk of N tie-up), **crimson clover** (Fig. 2) produced the highest biomass of all legumes in Brooklyn gardens. However, it had slightly lower weed suppression than other over-wintering cover crops.[2]

Nitrogen fixation → Legumes:

To add 'new' nitrogen to the soil for food crops, **legumes** must be planted – either by themselves, or in mixture with a non-legume. In our research with community gardeners, we studied three legume species.[2]

- **Hairy vetch fixed the most N** – on average, enough to completely supply the N needs of a heavy-feeding vegetable, like tomatoes or squash.
- **Crimson clover also fixed appreciable N** -- on average, enough to supply the N needs of a medium-feeding vegetable, like carrots.
- **Field peas fixed much less N** than the two over-wintering cover crops. Even light-feeding vegetables (like radishes) would require additional N inputs from compost or manure following a field pea cover crop.

Research on farms has shown that **summer annual legumes** like **cowpeas** (planted in mixture with Japanese millet)[16] and **crimson clover** planted during the summer niche[23] fix intermediate amounts of nitrogen – on average, enough to supply the N needs of light-feeding vegetables.

Mixtures with non-legumes can increase the percentage of N that legumes get from N fixation, and therefore the amount of 'new' N introduced to the garden (see Part II of this series). However, gardeners should experiment with mixtures to make sure the non-legume does not suppress legume growth. If the non-legume grows so vigorously that the legume doesn't have much space or light, the legume will grow very little and not fix much N. **Rye and hairy vetch** (Fig. 3) are usually a good mixture, since the hairy vetch is viny and can climb the rye.[16] That way, the hairy vetch can access more light and produce substantial biomass. In Brooklyn gardens, hairy vetch actually had equal biomass by itself and in mixture with rye -- even though the vetch was

seeded at just half the rate in the mixture![2] In other cases, it may be necessary to seed the legume at a higher rate than the grass to get good N fixation. In the cases of oats and field peas, or rye and crimson clover, the grass may suppress the legume and reduce N fixation.[2]

A few caveats: The comparisons of N fixed by various legumes with the needs of different vegetable crops provided above are rough 'ballpark' figures. However, the amount of N fixed by a legume varies tremendously between gardens due to differences in climate, light availability, soil, planting dates, and whether or not the legume was grown in mixture with a non-legume. Also, not all the N fixed by a legume cover crop becomes available during the first year after growing it. As the legume plant decomposes, some of its N will become part of soil organic matter, and can be released by microbes in future years for crops to use. Therefore, gardeners may need to grow legumes for several years -- to build up N reserves in soil organic matter -- before relying mostly on legumes to supply crop N needs.

Nutrient retention → Over-wintering grasses:

If you have very fertile soils and are concerned about retaining nutrients, **over-wintering grasses**, like winter rye (Fig. 4b), are the best choices. They are very efficient at taking up extra nutrients (especially N), have been shown to reduce N leaching by about 70% compared to bare soil.[5]

Nutrient retention may be important for many gardeners. Several studies have shown very high nutrient levels in home and community gardens, perhaps because of large compost applications over small areas.[24-27]

Environmental Conditions

In addition to seasonal niche and priority management goals, gardeners must also consider environmental conditions when choosing cover crops. Cover crops will perform the best when planted under conditions to which they are adapted, including appropriate climate (see the Note at the beginning of this article on selecting appropriate cover crops for your climate), soils, and light availability.

Soils

- **In light-textured (sandy) soils and soils with low to moderate fertility, legumes will perform well.**[28]
- **In very fertile soils (particularly those with high weed pressure), non-legumes or mixtures are a better choice.** Non-legume cover crops take up soil N more efficiently, and grow fast enough to compete with weeds. In Brooklyn gardens with very high N fertility, legumes did not grow fast enough to compete with weeds, but winter rye covered the soil and reduced weed growth in fertile soils (Fig. 4).[2]

Figure 7. Photos illustrating different weed suppression outcomes for legume and non-legume cover crops in very fertile soils. a) Crimson clover, a legume, provided poor weed suppression (note chickweed mixed in with the cover crop). b) Winter rye, a non-legume, grew quickly and provided good weed suppression. (Photo credits: M. Gregory.)

Light availability

All cover crops will benefit from full sun, but some are more tolerant of shade than others. In gardens in Brooklyn, we analyzed how light availability affected cover crop growth: [2]

- **In shaded areas, the cover crops with the greatest biomasses were: rye/legume mixtures, rye, and crimson clover**. Crimson clover was the most shade-tolerant legume, and produced similar biomass in shade and sun. Hairy vetch showed intermediate shade tolerance.
- **Winter-kill cover crops (field peas, oats, and oat/pea mixtures) all performed very poorly in shade.** As light availability increased, the field peas and oat/pea mixtures produced more biomass. Therefore, we only recommend these cover crops for use in full sun.

The table below summarizes planting dates and characteristics of several winter-kill and over-wintering cover crops for small-scale vegetable gardens. Once you've selected cover crops for each garden bed, check out Part IV of this series for tips on sourcing cover crop seed, and planting and managing cover crops in your vegetable garden.

Table 1. Promising cover crop options for gardeners in various seasonal niches, management goals each cover crop may help achieve, and appropriate environmental conditions for plantings. Legume cover crops are indicated by (**L**). DAS = Days after sowing.

Cover Crop Species	Plant date (Zone 7)	Termination date (Zone 7)	Management goals	Environmental conditions	Notes
WINTER-KILL COVER CROPS					
Field peas (L)	Late Aug	(Killed by frost)	Soil conditioner; Some N fixation	Full sun only	Avoid close rotations with legume vegetable crops (beans, peas)
Oats and Field peas (L)	Late Aug	(Killed by frost)	Soil conditioner; Some N fixation (but seed peas at higher rate); Fall weed suppression	Full sun only	Avoid close rotations with legume vegetable crops (beans, peas)
Brassicas	Late Aug	(Killed by frost)	N retention; Fall weed suppression; Disease management	High-fertility soils	Avoid close rotations with Brassica vegetable crops (bok choy, broccoli, cabbage, collards, etc.)
OVER-WINTERING COVER CROPS					
Crimson clover (L)	Early-mid Sept	Early May (at flowering)	Large biomass; High N fixation; Good spring weed suppression, except in high-fertility soils	Low- to moderate-fertility soils; Shade-tolerant	Winter-kills in Zones 5-6 and colder.
Hairy vetch (L)	Late Sept – Early Oct	Mid-May (at flowering)	Medium biomass; Very high N fixation; Excellent spring weed suppression	Low- to moderate-fertility soils; Somewhat shade-tolerant	
Rye	Mid-Sept – Late Oct	Early- to Mid-May (at flowering)	Very large biomass; Excellent N retention; Excellent spring weed suppression	High-fertility soils; Shade-tolerant	Allow ~2 weeks between cover crop termination and planting vegetables, to prevent N tie-up.
Rye and Hairy vetch (L)	Late Sept – Early Oct	Mid-May (at flowering)	Very large biomass; N fixation; N retention; Excellent spring weed suppression	Adapted to a range of soil fertility levels; Shade-tolerant	Allow ~2 weeks between cover crop termination and planting vegetables, to prevent N tie-up.
SUMMER COVER CROPS					
Buckwheat	June - August	1 week after flowering begins (35 – 45 DAS)	Very fast growth and soil cover; Soil conditioner; Excellent summer weed suppression	Light to medium, well-drained soils	Cut down 1 week after flowering begins to prevent seed set.
Buckwheat & Crimson clover (L)	July	Buckwheat – mow/trim at flowering; Crimson clover – allow growth into the fall	Soil cover, soil conditioning, & weed suppression from buckwheat; Moderate N fixation from crimson clover	Light to medium, well-drained soils	Mow or trim buckwheat at flowering to allow light to reach the crimson clover
Japanese millet and Cowpea (L)	July	Millet - 1 week after flowering begins (45+ DAS)	Summer weed suppression from Japanese millet; Moderate N fixation from cowpea	Medium to heavy soils (preferred by millet)	

Part IV: Planting and Managing Cover Crops in Vegetable Gardens

This article is part of a four-part series about cover cropping in vegetable gardens. To learn more, see:

- *Part I: Introduction to Cover Cropping*
- *Part II: Types of Cover Crops -- Non-Legumes, Legumes, and Mixtures (oh, my!)*
- *Part III: Selecting Cover Crops for Vegetable Gardens*

Once you've chosen cover crops that fit your vegetable rotation, management goals, and garden site (See Part III: Selecting Cover Crops for Vegetable Gardens), it's time to plant! This article contains tips on sourcing seed, and planting and managing cover crops using hand tools.

Sourcing Cover Crop Seed

- **Plan ahead!** Order your seed and legume inoculant (or confirm that local sources will stock what you need) in early spring, even for late summer or fall plantings. This will ensure that you find the varieties you want, and that you have the seed when it's time to plant. You can find a list of cover crop seed suppliers in the book Managing Cover Crops Profitably.
- **Try to source disease-resistant varieties** (e.g., Esker or Kame oats, Aroostock winter rye, etc.). Your local Cooperative Extension office can provide guidance on recommended varieties for your area.
- **Coordinate with other gardeners.** Cover crop seed may be less expensive (on a per-pound basis) when purchased in larger quantities. By purchasing larger bags of seed with a group of gardeners and distributing the seed, you may be able to save money.

Planting

Plant your cover crops on time (Table 1). Cover crops provide the most benefits when planted with ample time to grow during favorable weather. Delaying planting just two weeks past ideal dates can greatly reduce cover crop growth and weed suppression.[29, 30] Your local Cooperative Extension and the book Managing Cover Crops Profitably can provide guidance on ideal planting dates for different cover crops in your area.

Table 1. Planting dates for winter-kill and over-wintering cover crops, USDA Zone 7. Planting dates should be earlier in cooler zones (6 and below), and may be pushed later in warmer zones (8 and up).

Cover Crop	Planting dates
Winter-kill cover crops	
Oats, Field peas, Brassicas	Late Aug – early Sept
Over-wintering cover crops	
Crimson clover	Early - mid-Sept
Hairy vetch or Rye/ vetch	Mid-Sept - early Oct
Rye	Mid-Sept - late Oct

When planting legumes, use a legume inoculant. In order to fix nitrogen, each legume species requires that a particular type of *Rhizobia* bacteria be present in the soil to form nodules[31] (See Part II: Types of Cover Crops). Inoculation involves mixing a small amount of powder, containing appropriate *Rhizobia* bacteria, with legume seed at planting. To learn more about selecting the right inoculant and treating your legume seed with it, refer to the eOrganic publication Legume Inoculation for Organic Farming Systems.

- **To plant your cover crops:**
    - **Prepare your plot.** Remove weeds and crop residues, and -- if you are under-seeding cover crops to standing food crops -- stake and prune crops that are still producing. This creates space and light for your cover crops to grow.
    - **Rake the soil** to create a fine seedbed.
    - **Broadcast the seed evenly.** In garden settings, high seeding rates are recommended to achieve weed suppression.[32] In our work with gardeners in Brooklyn, we used ½ cup of seed for each 20 ft^2 area.[2] You can experiment to find a seeding density that provides good soil cover and healthy plant growth.
    - **Gently rake in the seed**, with small back-and-forth motions to bury the seed (Fig. 1).

Figure 8. Raking in cover crop seed in a community garden.

In urban areas, it may be necessary to **protect newly planted seeds with row cover**, to prevent birds from eating the seed (Fig. 2).[2] The row cover can be removed once plants are established.

Figure 9. a) Row cover over newly planted cover crop seed. b) Cover crops germinating under row cover. (Photo credits: M. Gregory)

Once planted, cover crops don't usually require much maintenance. If conditions are very dry, it may be beneficial to water the cover crop until it is well-established. This can be done with a sprinkler, or – in small areas – with a watering can.

Managing Cover Crops in Spring

Winter-kill cover crops are easy to manage, because they are killed by frost and usually don't leave a lot of residue by Spring. Vegetable crops can be transplanted through the mulch, or a shallow cultivation will prepare a fine seedbed for crops grown from seed.

Over-wintering cover crops require more work but are well worth the effort, as they provide much more organic matter, fixed N, and weed suppression than winter-kill cover crops.[2] Here's what to do with your thriving stand of crimson clover, hairy vetch, rye, or perhaps a mixture:

- **Wait for the cover crops to flower (Fig. 3) before terminating the stand.** Cover crops should be killed while in full bloom, but before they set seed. Here's why:
    - First, when cover crops flower, they are at their maximum biomass and (for legumes) nitrogen fixation. Just a couple weeks' growth in the spring can make a big difference for organic matter and nitrogen contributions to the soil.[1]
    - Second, cover crops are easier to kill at flowering – cutting the stems at ground level is enough to kill them. If you try to cut down the cover crops before flowering, they may re-sprout.

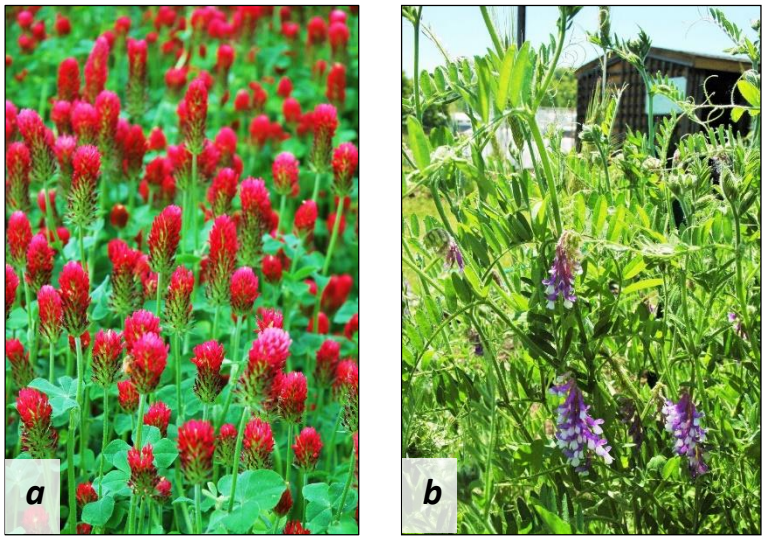

Figure 10. Flowers of over-wintering legume cover crops: a) crimson clover, and b) hairy vetch. To maximize cover crop contributions to soil organic matter and N fertility (and to prevent re-sprouting), gardeners should wait until the legumes are in full bloom before terminating the cover crop. Photo credits: M. Gregory.

- **Decide whether you will "cut-and-mulch" or incorporate your cover crop.**
    - **The "cut-and-mulch" technique** involves chopping the cover crop shoots and leaving them on the soil surface as a mulch, without burying the residues. This technique reduces soil disturbance and conserves more organic matter, leaves mulch for moisture conservation and weed suppression, and is less work. However, the cover crops *must* be in full flower, or they may re-sprout.
    - **Incorporating the cover crop** involves working the chopped cover crop shoots into the soil with a shovel. This will create a finer seedbed and promote more rapid release of N from legume residues. However, less organic matter will be conserved in the soil (since soil critters will break it down more quickly), and you must wait to plant vegetable crops until the clumps of plant material decompose.

- **If you cut-and-mulch your cover crop:**
    - Cut down the cover crop using a sharp pair of hedge shears or small sickle (Fig. 4). Begin at the top and work your way down to ground level, chopping the shoots into smaller pieces. Then, leave the chopped shoots as mulch on the soil surface. **DO NOT pull up the plants** – letting the roots decompose in place aerates the soil and preserves organic matter.
    - If you are transplanting vegetables (for example, tomatoes, peppers, or zucchini) you don't need to wait after mulching the cover crop. Simply push apart the mulch and dig holes to set your transplants.


Figure 11. Cutting down a crimson clover cover crop with hedge shears (left), leaving a thick mulch of chopped shoots to conserve soil moisture and suppress weeds (right). Photo credits M. Gregory.

- **If you incorporate your cover crop:**
    - Cut down the cover crop with hedge shears, as outlined above. Then, use a sharp shovel to further chop the shoots and work them into the top 3-5 inches of the soil.
    - Before planting seeds or setting transplants, wait at least 10 days, then check the seedbed. If there are clumps of plant material, wait a little longer. Grasses (e.g., wheat, rye) may take longer than legumes (e.g., clover, vetch).

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