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NO-TILL SPRING VEGETABLES AFTER FORAGE RADISH COVER CROP

Growing a forage radish (*Raphanus sativus* L.) cover crop can be an effective way to capture residual nutrients, prevent winter erosion, and facilitate no-till seeding of early vegetable crops. In addition to reducing soil disturbance, not having to till prior to spring planting reduces labor requirements at a critical point in the season and may allow earlier planting.

No-till seeding into a winterkilled forage radish cover crop in spring is effective in many soils for a number of crops including spinach, peas, and even root crops like potatoes, beets and carrots. Some soils with poor soil health, however, may require tillage to produce competitive yields.

Forage radish, which winterkills when temperatures drop to 17 -20°F, suppresses early spring weeds, allows soil to dry out and warm up, and provides an increased supply of nitrogen (N), sulfur (S), phosphorus (P) and other nutrients to crops in early spring. Because of the minimal amount of residue after forage radish, conventional planting equipment can effectively seed directly into the winterkilled cover crop without tillage. For early transplanted crops like onions, rows of radish can create holes into which transplants can be dropped.

To implement the radish-no-till system, considerable planning and care must go into establishing a productive forage radish stand. Seeding before the first week of September (in Maryland) is critical for spring weed suppression. Experiment station results in Maryland and farmer trials throughout the mid-Atlantic and northeast have shown that this system requires a closed cover crop canopy (no visible soil) in fall and may be ineffective in poorly structured, heavy soils.

How Forage Radish Affects the Spring Seedbed

The unique traits of forage radish make it an ideal cover crop before planting spring vegetables. In addition to weed suppression and nutrient release, radish taproots can penetrate compacted soil layers, a process called “biodrilling,” which can increase water infiltration and crop root growth. Because interest in forage radish is increasing, there are now several varieties on the market. The majority of research at the University of Maryland used Tillage® radish, but other brands of daikon-type forage radish have performed similarly. Oilseed radish (*Raphanus sativus* var. oleiferus) is related, but has a less well-formed and less aggressive fleshy taproot than forage radish varieties and goes to seed more quickly.

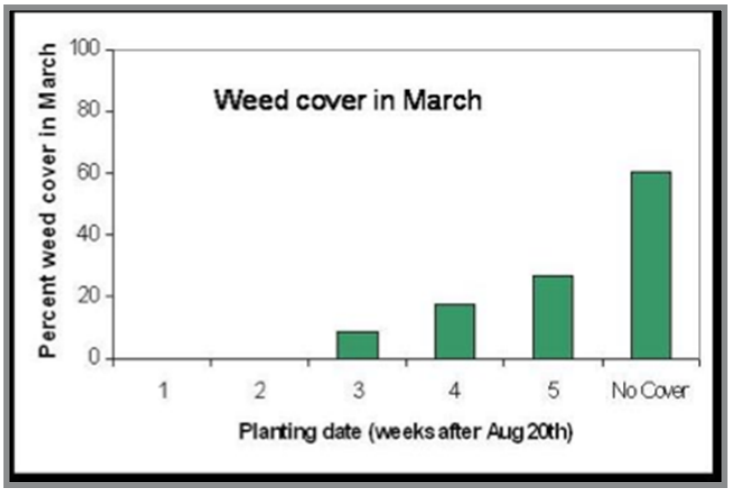
Weed suppression- Forage radish suppresses annual weeds via its canopy in the fall. Most weeds that appear in early spring initiate germination in fall. An early seeded forage radish cover crop with adequate water, planting density, and fertility creates a closed canopy with no visible soil 4-6 weeks after seeding. This canopy changes the nature of light that reaches the soil surface and prevents weed seeds from initiating germination.

Seeding date trials in Maryland revealed that the optimal seeding date for weed suppression is before the first week of September, after which weed suppression dramatically declines (Figure 1). If there are visible bare patches of soil among forage radish groundcover, it is unlikely there will be complete weed suppression in spring.

Although forage radish cover crops have been successfully established in tilled sod, there have also been reports of persistent perennial weeds when forage radish was established

in newly turned sod. The weed suppression mechanism of forage radish is generally effective for winter annual weeds, but perennial weeds can pose a challenge. In addition, the forage radish residue appears to favor germination of lambsquarter (*Chenopodium album*) seeds in April. Lambsquarter is related to spinach, which also appears to have increased emergence and growth following a forage radish cover crop.

Figure 1: There was complete weed suppression in March when a forage radish cover crop was seeded one and two weeks after August 20. Spring weed cover increased following later forage radish plantings. Although weed suppression is greater after a forage radish cover crop seeded five weeks after August 20 than after no cover crop, the weed suppression is not adequate for no-till spring seeding without herbicides. (Lawley and Weil, unpublished).



Soil moisture- In all but excessively well-drained sandy soils, soil conditions are often too wet for field work in early spring. Traffic and tillage when the soil is too wet can lead to soil compaction, destruction of aggregation, and increased susceptibility to erosion. Forage radish allows soils to dry out in spring, facilitating earlier field work without causing structural damage (Figures 2 and 3).

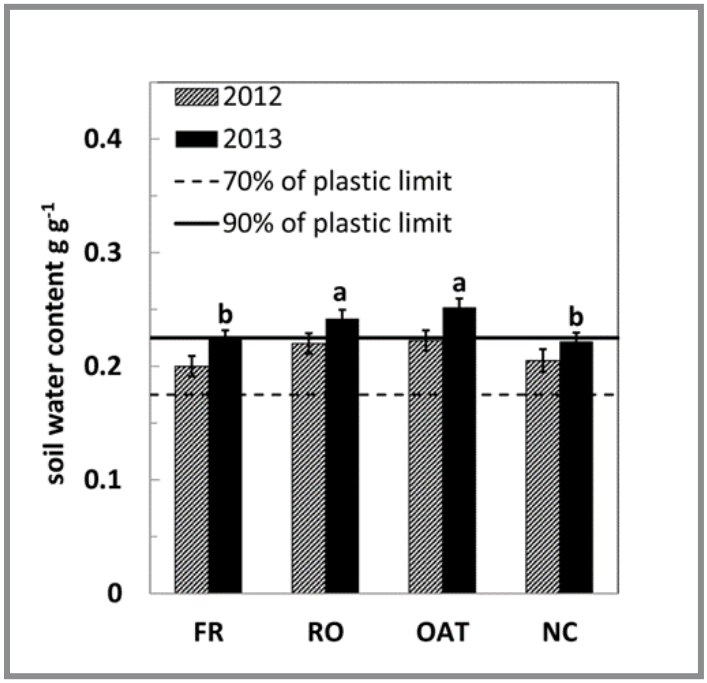


Figure 2: Soil gravimetric water content (0-8") in early April at Wye Research and Education Center, a moderately well drained silt loam. The 70-90% plastic limit is the water content at which the least amount of structural damage occurs from traffic and/or tillage. FR= forage radish, RO= radish/oat mix, OAT= oat, NC= no cover crop (tilled in November). Oat, a high-residue cover crop, increased the soil water content to the point at which traffic and tillage would likely cause damage. (Lounsbury and Weil, 2015).

Figure 3: Shovelful of soil in April in Massachussets after no cover crop (left) and forage radish (right). Photo: Julie Fine, University of Massachussetts.

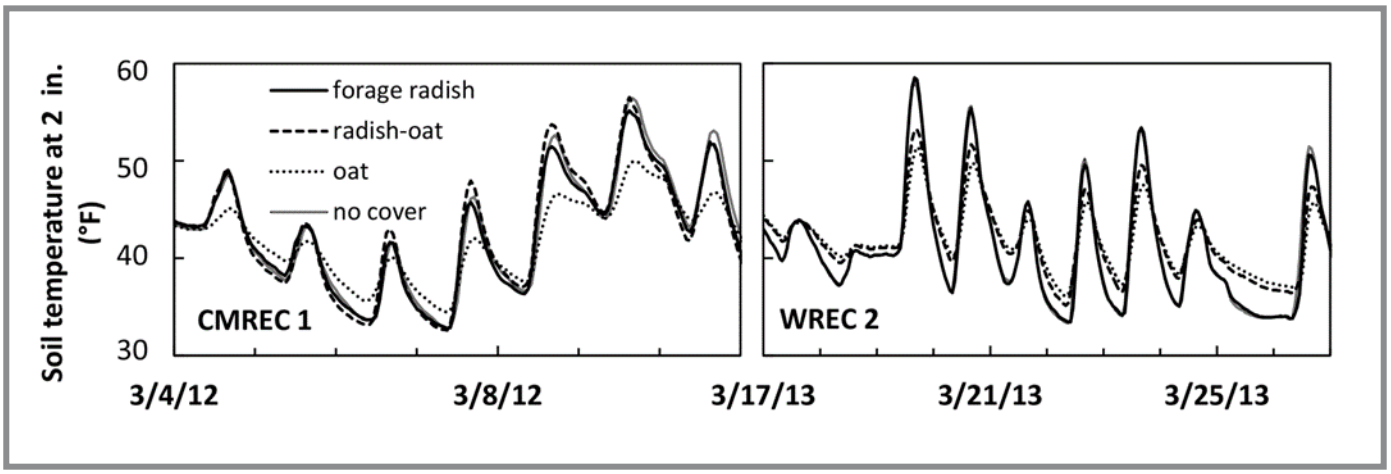


Figure 4: Soil temperature fluctuations for untilled soil in March at Central Maryland Research and Education Center, Clarksville (CMREC), and Wye Research and Education Center (WREC). Residue from oat moderates the daily high and low temperatures. The daily high temperature after radish is comparable to having no cover crop.

There is also evidence that the forage radish root channels facilitate greater infiltration after rain events. Thus, despite lower surface moisture content, the subsoil after forage radish may contain larger moisture reserves for subsequent crop use. Many early season vegetables like spinach are relatively shallow-rooted, but others, like carrots, have deep roots that extend well beyond the "plow zone" and can take advantage of these moisture reserves.

Soil temperature- One of the primary reasons for spring tillage is to increase soil temperatures for seed germination and crop growth. In some no-till systems that rely on high-residue cover crops for mulch, growers have reported delayed crop maturity. Because of the relatively residue-free soil surface after forage radish, the soil warms more rapidly than with a high-residue cover crop like oats (Figure 4).

Tillage further increases soil temperature, but evidence is inconclusive as to whether a temperature difference between tilled and untilled seedbeds after forage radish delays maturity in early-seeded spring crops. Some crops, such as lettuce and kohlrabi, have shown delayed maturity after no-till seeding, but others, including spinach and peas, have not. In related on-farm research in a sandy soil in Maine, carrots did not show delayed maturity, but farmers with heavier soils in Maryland have reported poor root growth with no-till seeded carrots.

Nutrient cycling- Because of its rapid growth and deep taproot (Figure 5), forage radish is able to scavenge nutrients from more than four feet deep in a soil profile. Forage radish tissue, both foliage and root, is unusually high in N, P, S, K (potassium), Ca (calcium), and B (boron), and other nutrients. Researchers measured increases in soluble N, S, and P in surface soil in spring after forage radish, indicating that fertilizer applications to subsequent crops can be reduced.

An early-seeded forage radish cover crop that achieves a closed canopy by early October will typically contain 150 lb N/acre or more before it winterkills. Tracking this N in spring is difficult, but it is clear that at least some becomes available in early spring. Increases of 35 lb nitrate-N/acre (0-12") as a direct result of forage radish have been observed in April in Maryland (Wang and Weil, 2018). The high S content in forage radish tissue is also available early in the season, with increases of 8-10 lb/acre sulfate-S (0-8") observed across multiple sites and years in March-May. Investigations into the P dynamics after a forage radish cover crop have shown that P is concentrated in the soil around the radish taproot holes (Figure 6).

Forage Radish Seed Germinates in Less than Two Days Under Optimal Conditions

Once a forage radish crop is established, it can grow rapidly (Figure 5). However, there are some conditions that limit crop growth and performance. Weed control of some sort, either herbicide or light tillage, is necessary prior to establishing the forage radish cover crop. If weed seeds are allowed to germinate before forage radish has established, it can hinder cover crop performance and weed suppression. As discussed, areas with perennial weed problems may not be well-suited to this system.

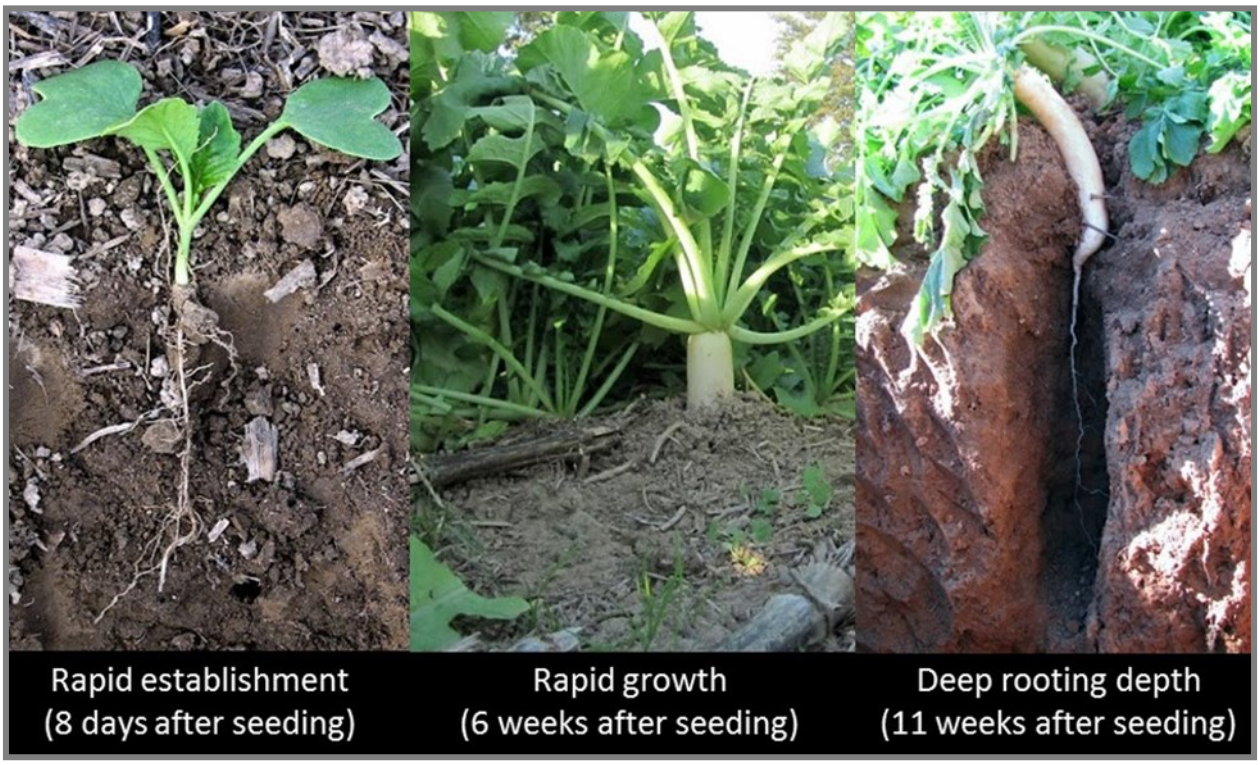


Figure 5: Forage radish establishes quickly in late summer/early fall if soil moisture is adequate. It then grows rapidly above and below ground if residual soil nutrients are present. Photos: Ray Weil and Natalie Lounsbury

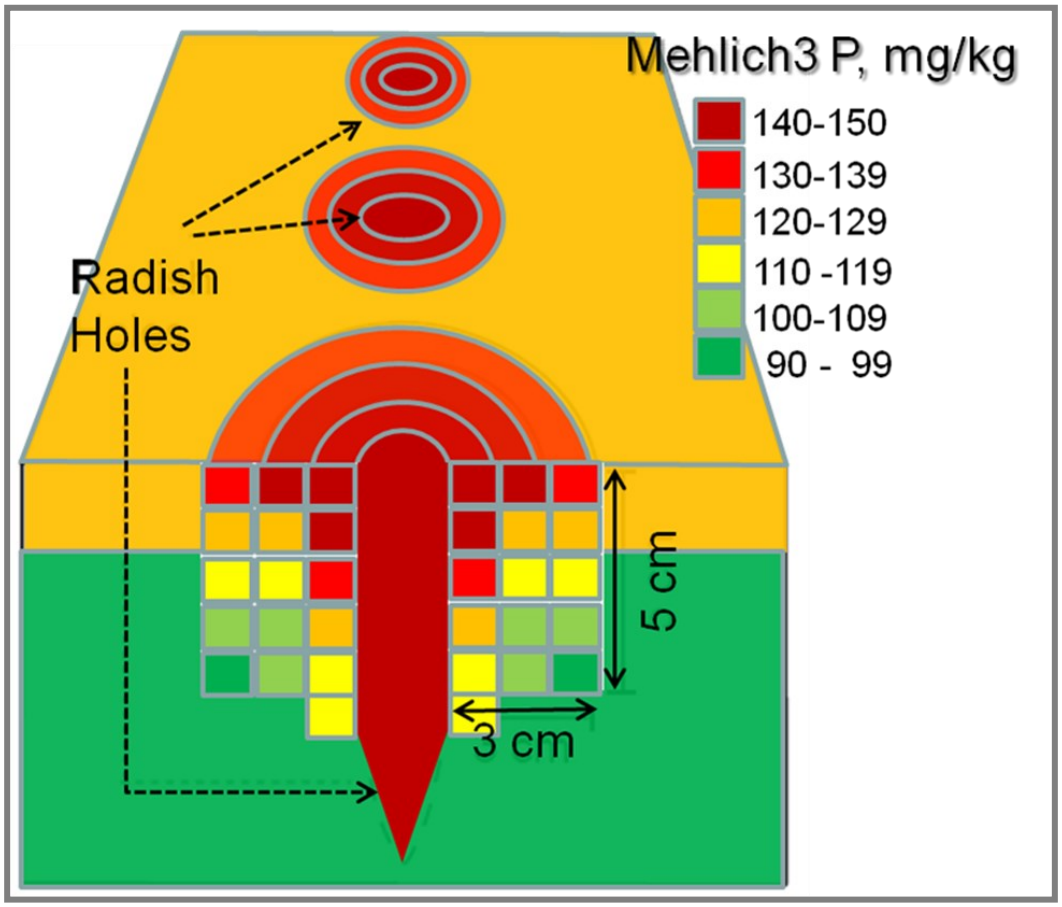


Figure 6: The concentration of Mehlich 3 extractable P is higher in the immediate region around the forage radish taproot hole (data from White and Weil, 2011). Image from Ray Weil.

Seeding- Early establishment and canopy closure are critical for weed suppression. Therefore, if no-till seeding without herbicides in spring is a goal of the cover cropping, forage radish should be seeded between the first and fourth week of August in Maryland. Seeds can be placed ¼"-1" deep (use the greater depth if soils are dry).

Recommended seeding rates for the popular Tillage Radish brand are 6 lbs/acre drilled, though research trials at the University of Maryland generally used a higher seeding rate of 8-9 lbs/acre. Broadcast rates are higher (9-12 lbs/acre), and germination from broadcast cover crop seed is greater when seed-soil contact is increased by cultipacking (crushing dirt clods, removing air pockets, and pressing down small stones to form a smooth, firm seedbed) or light incorporation. Other brands and varieties can have slightly different seed size and weight.

Calculate seeding rates to reach an optimal stand density of 4-6 plants per square foot. Lower seeding rates and stand density will result in larger radish roots, while higher densities can result in competition and poor overall performance (Figure 7). On most seed drills, the closest comparison is alfalfa, but settings for radish should be reduced by 10% or more from the recommended alfalfa settings. Small-scale push seeders like the Earthway and Planet Junior, can be effective in establishing small areas of cover crop.

Figure 7: Stands that are too dense can result in crowding and competition for nitrogen. The more vigorous growth evident where the drill skipped is because of less competition. The bare soil will allow weeds to grow, however.

Monitoring Fall Growth Ensures Optimal Results

Not all forage radish stands in fall will be adequate to facilitate no-till seeding of spring crops, especially in organic systems where weed suppression is paramount. A "good" forage radish stand will be apparent by late September or early October (Figure 8). Inadequate cover crop stands (Figures 9 and 10) are evident in fall, so spring plans can be made accordingly. Even though weed suppression may be insufficient for no-till in spring without herbicides, less unifom or high biomass cover crops can still provide benefits to the soil and subsequent crop.

Figure 8: Full canopy closure by late September (left) created a weed-free seedbed in March (right) in Clarksville, MD. Early canopy closure is essential to weed suppression.

Figure 9: Although this forage radish cover crop was seeded early, it endured a hurricane and very wet soil conditions in fall. Bare patches of soil in late September (top) are areas where weeds were present in March (bottom).

For No-till Seeding Vegetables in Spring, Pay Close Attention to Soil, Weeds, Crop Selection, and Equipment

Soil conditions and weed pressure should be monitored in spring prior to no-till seeding. In many soils, a forage radish cover crop adequately "prepares" the seedbed, and tillage is not necessary prior to planting spring crops. Some soils may not function well in this no-till system, however, and tillage may be necessary to achieve acceptable yields. Although a set of indicators has not been developed to determine which soils will support no-till and which will not, poorly aggregated soils with a history of intensive tillage and low organic matter may not provide adequate pore space for crop growth, microbial activity, and water movement within the soil. Long-term investment in improving soil health through cover crops and other organic matter additions along with reduced tillage may be necessary in these soils before no-till seeding can produce acceptable yields.

Usually very little forage radish leaf residue remains on the soil surface in early spring, but the large taproots can persist. Some farmers have called these radish "carcasses" (Figure 11). Heavy mechanical seeders, like Monosem®→ or Matermacc® →, with a double disk opener or coulter can slice through the radish carcasses with ease (Figure 12), even without residue cleaners. Less robust openers such as those on common Earthway® and Planet Junior® seeders can drag the carcasses and get clogged, and furrow closing with a chain or light wheel is ineffective. Some farmers have nonetheless reported success under optimal soil moisture conditions using an Earthway® seeder, provided care is taken to walk behind the seeder to ensure adequate seed-soil contact. Other farmers with higher clay content soils have reported that these push seeders skim the surface and are ineffective for no-till seeding.

One way to eliminate radish carcasses is to mow the living cover crop before it has winterkilled and chop up the above-ground portions. On a small-scale, some farmers have raked the radish carcasses off the beds prior to seeding with a push seeder.

Figure 10: Inadequate (and spotty) nutrient availability in fall will lead to poor radish growth. This was a sandy soil after a wheat crop with very low residual nutrient concentrations. A small amount of fertilizer for a forage radish cover crop may stimulate additional nutrient uptake that is greater than the nutrients applied.

Figure 11. Radish carcasses can get in the way of small seeders, but some farmers have still reported success using push seeders for direct seeding spring crops into winterkilled radish. Photo: Jack Gurley.

Figure 12. Heavy seeders with coulters and/or double disk openers have no trouble slicing through radish residue. Adjustments may be necessary for adequate furrow closing. Photo: Dave Liker.

Spring crops that have been grown successfully when no-till seeded after forage radish include spinach (Fig. 13), peas (Fig. 14), beets, carrots (Fig. 15), and lettuce, although reports on carrot performance have been mixed and lettuce has shown delayed maturity in no-till plantings (Figure 16). The differences in spinach response between two experiment stations (Table 1) exemplifies the differing crop responses to no-till seeding depending on soil type and soil health. Farmers have also reported successfully using the holes created by radish for onion transplants.

Figure 13. No-till spinach on April 30, 2013 in Clarksville, MD. Spinach was seeded into a winterkilled forage radish cover crop using a Monosem® seeder on March 11 without any herbicide application or pre-planting tillage. Photo: Natalie Lounsbury

Table 1. Fresh spinach yields as influenced by cover crop and tillage treatments at Central Maryland Research and Education Center, Clarksville (CMREC) and Wye Research and Education Center (WREC)

		CMREC		WREC	
Cover crop[1]	**Spring tillage treatment**	**2012**	**2013**[2]	**2012**[3]	**2013**
		----------*Mg ha*$^{-1}$----------			
Forage radish	No-till	19 ab	12 a	6.0 ab	2.8 b
Forage radish	Rototill	24 a	9.9 b	10 a	4.7 a
Radish-oat	No-till	5.3 b	10 b	—[4]	1.7 bc
Radish-oat	Rototill	3.7 b	9.1 b	8.2 ab	4.4 a
Oat	No-till	4.7 b	6.2 c	—[4]	0.8 c
Oat	Rototill	3.3 b	6.4 c	1.6 b	—[5]
No cover crop	No-till	1.8 b	4.2 d	—[4]	—[4]
No cover crop	Rototill	10 ab	7.3 c	—[4]	0.8 c

[a]Treatment means are presented (n=4). Within, but not between, site-years means followed by the same letter do not differ significantly (F-protected LSD p<0.05).
[1]Cover crops were planted in August of the year prior to spring spinach planting.
[2]Two successive harvests of mature leaves; all other site years, whole plants were harvested once. The third harvest is not accounted for in these data because it was only one block.
[3]n=3 for this year
[4]Crop failure
[5]Only one block planted because soil was too wet for tillage; yield data not included. (Lounsbury and Weil, 2015)

Figure 14. No-till sugarsnap peas on farm in Laurel, MD in 2013. Peas were seeded into winterkilled forage radish cover crop using a MaterMacc® seeder without any herbicide application. Photo: Dave Liker.

Figure 15. Carrots grown in a sandy soil in Maine. No-till after radish (left), tilled after radish (middle) and tilled after no cover crop (right). No-till carrots did not show delayed maturity and had higher marketability, though emergence was lower. Photo: Natalie Lounsbury.

Figure 16. With some crops like lettuce, delayed maturation has been observed after no-till seeding. In this case, the no-till seeded lettuce (left) caught up to the other lettuce in 10 days. Photo: Ray Weil.

Incorporating Forage Radish Cover Crops into a Diversified Farm

***Rotations*-** Many growers have concerns about growing a forage radish cover crop because they have many brassica cover crops in their rotations. Unfortunately, there has not been any research published on the effects of forage radish on brassica pests and diseases.

Farmers who have adopted this system have found that forage radish is easily seeded after garlic, onions, green beans, and myriad other crops are harvested in late July through early August. The opportunity cost of not growing another cash crop during this period must be weighed against the benefits provided by the cover crop. Forage radish is edible and can be marketed as "daikon" radish; harvesting a small portion of the crop to sell for this purpose in late fall will not significantly affect the overall performance. Both the greens and the roots are edible, though roots are more commonly found in Asian markets. The greens are more perishable than kale or collards.

Grazing livestock and wildlife- Grazing is a way of getting more value from cover crops, but there are food safety and regulatory concerns associated with grazing a cover crop prior to no-till seeding a vegetable crop for human consumption, especially a leafy green like spinach. Unwanted wildlife intrusions can pose similar concerns. To avoid this situation, it is recommended not to graze a forage radish cover crop before spring vegetable production. Likewise, keeping wildlife out of a cover crop area as much as possible is recommended.

Summing Up

Growing a forage radish cover crop can be an effective way to capture residual nutrients, prevent winter erosion, and facilitate no-till seeding of early vegetable crops. To implement this system, considerable planning and care must go into establishing a productive forage radish stand. Seeding before the first week of September (in Maryland) is critical for spring weed suppression. No-till seeding into a winterkilled forage radish cover crop in spring is effective in many soils for many crops including spinach, peas, and even root crops like beets in carrots under certain condition. Some soils with poor soil health, may require tillage to produce competitive yields. Even when spring tillage is required prior to cash crop production, forage radish provides a number of benefits, including increased nutrient availability in spring.

Table 2.

Month	To-do	What's happening
August	Seed radish in August (before first week of Sept)— 6-9 lb/acre drilled. In low-fertility soils, adding 20 lb N/acre can give the radish crop a boost so the roots can reach deeper soil layers where it can capture much more N.	In many cropping systems, there is residual N in the soil that has not been used by cash crops. An early seeded radish cover crop can capture this N as well as other nutrients. Throughout the fall growing season, radish roots can grow more than 4' deep and capture up to 300 lb N/acre, though more typical values are 150 lb N/acre.
September	Check radish stands for density and growth (optimal plant density is 4-6 plants per square foot). If there is inadequate fertility, it will be evident by late September.	Radish roots are rapidly elongating and capturing nutrients as radish foliage grows tremendously.
October	Check for any gaps in the radish canopy. If there is visible bare soil, no-tilling *without* herbicides in spring is not recommended.	Radish canopy is shading out light, preventing weed seeds from initiating germination. If the canopy is fully closed by early October, nearly 100% of annual weeds will be suppressed, leaving a weed-free seedbed in early spring. It is the light exclusion that suppresses weeds.
November	Harvest some radishes for markets or home consumption.	Harvesting a portion of the crop for consumption at this point will not substantially reduce the benefits of the cover crop and the radishes are highly desirable in certain markets (generally marketed as "daikon"). Grazing livestock is not recommended if spring vegetables are planned.

Month	To-do	What's happening
December		Frosts will knock back the radish, but it takes consecutive nights in the teens (°F) to kill the radish.
January	Radish can be mowed prior to winter-kill to avoid having "carcasses" in spring, but this is not necessary in most cases.	Radish generally dies in January in Maryland and will begin to decompose rapidly.
February	Check for complete winterkill. If the radish has not winterkilled yet, as was the case in 2012, killing via mechanical or chemical means may be necessary. See link on right for more info on killing radish.	*Managing Forage Radish Cover Crops that Fail to Winter-kill* (starts on P. 3) https://extension.umd.edu/sites/default/files/_docs/VegetableFruitHeadlines3-2.pdf
March	If canopy was closed in October and soil is well aggregated, no-till seed early spring cash crops like spinach, peas, and beets.	Very little cover crop residue remains on the soil surface, allowing the soil to dry out and warm up, and thus eliminating the need for tillage. Nitrogen and sulfur from the decomposing radish tissue become available in March-April, giving a boost to early crops.
April	Weed cash crops	Although the weed suppression from radish is nearly 100% in late March through early April, weed control may be necessary by mid-late April as it would be with most other systems.
May-June	Harvest cash crops	

For More Information

More information is available on our project website www.notillveggies.org.

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