# *Phacelia tanacetifolia*: What we know about its suitability as an insectary plant and cover crop in the mid-Atlantic region

Small Farm Success Project

Fact Sheet Number 2

## Introduction

*Phacelia tanacetifolia* Benth. is a versatile plant that is used extensively in Europe, both as a cover crop and as bee forage. It is also being increasingly used in California, especially in orchards and vineyards. Phacelia is quick to grow and flower and grows well in dry soil. It does a good job of limiting nitrate leaching when planted in the fall. In cooler areas, it can be used as a between cash crops cover crop in the summer and is also suitable as a winter-killed fall cover crop. Phacelia is listed as one of the top 20 honey-producing flowers for honeybees and is highly attractive to bumblebees and syrphid (hover) flies as well. Phacelia's habit of flowering abundantly and for a long period can increase beneficial insect numbers and diversity, because it's a good source of high quality nectar and pollen. Phacelia is also useful as a cut flower because of its unusual and attractive blooms, strong stems, and long vaselife.

Available research reports (primarily from California, Canada, and Europe) were reviewed to ascertain the potential benefits and problems with using phacelia as an insectary plant, cover crop, or intercrop in the mid-Atlantic region. In general, the research was conducted in areas with dissimilar climates to America's mid-Atlantic. However, since this plant is being used in a wide range of climatic regions, it does illustrate its adaptability to various climate and soil types. The fact that Europeans imported our U.S. native plant, use it extensively, and have bred it for specific characteristics indicate its value. However, there is conflicting information present in the research and little information available on phacelia's attributes in the mid-Atlantic. This paper will function as an introduction to a potentially useful cover crop and insectary plant for this region. It will hopefully lead to more experimentation and research in the mid-Atlantic on phacelia's utility.

## Information about the Plant

*Phacelia tanacetifolia* is a member of the Hydrophyllaceae family. This paper will refer to it as phacelia. Other English common names are: fiddleneck, tansy leaf, tansy phacelia, lacy phacelia, lacy scorpion-weed, valley verzenice, wild heliotrope, and bee's friend. Phacelia is an herbaceous, non-leguminous, flowering annual. Height has been reported to range from 6 to 47 inches (15 – 119 cm). The foliage is ferny in appearance (like tansy's) and the unusual flowers are in curling cymes (flat-topped, clustered flowers) in shades of blue, lavender, mauve, or white. Spring- and summer-planted phacelia flowers approximately 6 – 8 weeks after germination and flowering continues for at least 6 weeks. Phacelia is a long-day plant and requires at least 13 hours of daylight to initiate

flower development. The flower is lightly fragrant and is useful as a cutflower. It has a vaselife of 8 days in plain water.

Phacelia is native to Arizona, California, Nevada, and Mexico. It has naturalized elsewhere in temperate regions, but it is not listed on any federal or state noxious weed list. In its native habitat, phacelia is found at lower elevations on sandy or gravelly slopes in open areas. The natural blooming period is between March and May.

Phacelia seed is not yet widely available in the United States and it is usually available only as the straight species rather than a cultivated variety (cultivar). Europe has developed tetraploid cultivars ('Phaci' and 'Polifaci') and other cultivars specifically used for honey production ('Angelia' and 'Stala'). Other cultivars available in Europe are 'Gipha', 'Balo', 'Lisette', 'Bleu Clair', and 'Bienenfreund'. I was unable to document their specific attributes.

Phacelia is the primary component of two "bee forage" mixes available in Europe – Tübingen Mix (Germany) and Ascot Linde SN (the Netherlands). Research on these mixes has shown that phacelia was the component that was most attractive to insects (Carreck, 1997). A study in the United Kingdom showed that phacelia attracted 14 species of hymenoptera, 14 species of syrphid flies, and 6 species of lepidoptera (Carreck, 1997). Honeybees and bumblebees are the hymenoptera species most attracted to phacelia. Smaller and solitary bee species are less attracted.

## Germination and Seed Information

Research shows that phacelia is negatively aphotoblastic (needs dark for good germination) and thermodormant (germination is inhibited at high temperatures) (Chen & Thimann, 1966). Some researchers reported quick and even germination, others felt germination was uneven and capricious. Timeframes for germination ranged from 24 hours under optimum laboratory conditions to 20 days in the field. It was unclear from the research reports where the problems encountered with germination arose, but it was likely to have been caused by failure to bury the seed, an inappropriate soil temperature for germination or other inhibiting factor. Reports indicate very dry soil or low oxygen levels caused by wet or compacted soil reduces germination.

The small phacelia seed must be buried 1/8 – 1/4 inches (3 – 6 cm) to insure darkness for good germination. Soil temperature must be well below 86ºF (30ºC). This is the temperature that most researchers found to be completely inhibiting to germination (although seeds remain viable and can germinate if soil temperature subsequently decreases). The optimal range of soil temperatures for germination reported by most researchers falls between 50 – 68ºF (10 – 20ºC). Interestingly, Macchia et al. (2000) found in laboratory experiments that the optimum temperature for germination was 5°C [41°F] with 92% germination success. Excellent germination was also found at 3°C [37°F], 8°C [46°F], and 12°C [54°F]. Macchia et al. (2000) also found that the mean germination time lengthens as temperature was reduced (i.e. 11 days and 85% at 3°C but 2.8 days and 75% at 20°C). Sensitivity to light was not the same at all temperatures. At temperature's below 8°C, inhibition by light was sharply attenuated. These researchers recommended treating seed with $GA_3$ if soil temperatures were going to be high (20°C). Their research was aimed at the Italian seed industry to meet the increasing demand for seed. Duval's review of the literature (1992) states that seeds will remain viable for 3 - 4 years and up to six years if dry-stored.
Cool soil temperatures (37 – 68ºF / 3 – 20ºC) and darkness promote quick germination. However, germination will occur under less than optimum conditions. With warmer soil temperatures or

compacted soil, planting phacelia thickly or with an appropriate nurse crop such as buckwheat (*Fagopyrum esculentum*) that germinates reliably quickly may be one approach to counteract possible germination difficulties. Nurse crops protect the ground from erosion and shelter the second crop as it germinates more slowly. Suitable nurse crops when phacelia is used as an insectary planting would be quick-germinating insect-friendly herbs or flowers such as borage (*Borago officinalis*), cosmos (*Cosmos sulphureus*), or achillea (*Achillea millefolium*).

Phacelia has 234,960 seeds to the pound [517,993 per kg]. Suggested seeding rates vary widely from 3 lbs/ac (2.7 kg/ha) from the American Meadows seed catalog to 14 – 18 lbs/ac (12.5 – 16 kg/ha) from Brinton (1989). The majority of the research was done with a seeding rate of at least 10.7 lbs/ac (12 kg/ha). Of the research reports that stated the seeding rate, two stated the seed was broadcast, one stated the seed was drilled, and four did not state how the seed was sown. Seeding rates for providing insectary plants or cut flowers would reasonably be lower than seeding rates for a cover crop designed to come up thickly and choke out weeds.

## Value to Insects

Phacelia is highly attractive to honeybees, bumblebees, and syrphid flies and these insects are valuable pollinators. Syrphid fly larvae are voracious feeders on aphids and young caterpillars. Phacelia is also reputed to attract other beneficial insects, such as parasitic wasps and minute pirate bugs. It provides both pollen (for protein – needed for egg production) and high quality nectar (for carbohydrates – needed for energy) (Engels et al., 1994).

Phacelia's habit of quick growth and long flowering make it highly suited as an insectary plant. It can be succession sown so that flowers are present all season or it can be sown at a specific time to build up beneficial insect populations in anticipation of their need to control a crop pest. Phacelia will initiate flowering when daylengths are at least 13 hours, roughly mid-April to early September in the mid-Atlantic (depending on latitude). Once initiated by long days, flowering can continue into early October.

Altieri (1984) (University of California, Berkeley) reported on Soviet research in apple orchards. Phacelia was planted to enhance biological control of grubs, apple aphids, and San Jose scale by a variety of beneficial insects. Favorable results were presented. For instance, three successive planting of phacelia increased parasitization of San Jose scale from 5% in clean cultivated orchards to 75% when an understory of phacelia was blooming.

One caution – If you have a large area of phacelia planted, time the planting so that phacelia flowers are not blooming when you need a crop pollinated. Phacelia flowers are so attractive to pollinators that the flowers would compete successfully for pollinator services against most other flowering plants.

## Use as a Summer Cover Crop

If the soil temperature (for germination) is well under 86ºF (30ºC), phacelia can be an excellent summer cover crop because of its quick growth habit and ability to grow in hot, dry soil. No other crops are in the Hydrophyllaceae family which simplifies fitting phacelia into a rotation plan.

Brinton (1989) (Maine) gave phacelia an outstanding rating for production of above ground biomass. He relied on research done by Kohnlein-Vetter and O. Schmid in making his recommendations. However, he indicated the scientific name for his phacelia as "*Phacelia* spp." so it's not certain if the research was based on *Phacelia tanacetifolia*. I was unable to locate the research reports by Kohnlein-Vetter and Schmid to ascertain the species tested.

Phacelia is comparable to buckwheat in its use as a summer cover crop. See Table I below for primary differences between the two cover crops. Other attributes of these cover crops (i.e. rooting depth, attractiveness to beneficial insects, speed of growth, breakdown of dry matter, weed suppression, etc.) are similar.

| **Table I – Comparison of primary differences between phacelia and buckwheat** | **Phacelia** (*Phacelia tanacetifolia*) | **Buckwheat** (*Fagopyrum esculentum*) |
|---|---|---|
| **Biomass** | MORE – potential of 3300 – 6000 lbs/ac [3697 – 6722 kg/ha] (1) | LESS - potential of 2000 to 3000 lbs/ac [2241 – 3361 kg/ha] (1) |
| **Cold tolerance** | MORE – tolerant to 18° F [-8° C] (2) | LESS – very frost sensitive (1) |
| **Nutrient scavenging ability** | Good scavenger of N also absorbs Ca (4) | Poor scavenger of N, absorbs P and possibly Ca (1) |
| **Nitrogen content of biomass** | 4% (1) | 1.25% (1) |
| **Germination traits** | Seeds need dark; optimum soil temperature 37-68ºF [3-20ºC] (5) | Usually dependably quick and even |
| **Drought tolerance** | Grows well in dry soil (3) | Limited need for water (1) but less drought-tolerant than phacelia |

| | | |
|---|---|---|
| **Cost of seed** | Currently MORE expensive in the United States $60.55 – $155.70 per acre | LESS expensive $25.44 – $50.88 per acre |

References
(1) UC SAREP Cover Crop Database, accessed 2003.
(2) Hickman, 1996.
(3) Fielder and Peel, 1992.
(4) Peaceful Valley Farm Supply catalog, 2003.
(5) Chen and Thimann, 1966.

## Use as a Fall/Winter Cover Crop

Phacelia may be suitable as a winter-killed cover crop when a heavy crop residue is not needed in the spring. Research in other regions shows phacelia does a reasonably good job at catching nitrates before they leach into groundwater. Phacelia winter-kills at about 18ºF [-8ºC], and the residue breaks down readily. Various researchers have reported that winter-killed phacelia residue is not sufficient to control spring weeds. Duval (Quebec) reported that mature phacelia contained 20% lignin and 30-35% cellulose.

Dry Matter

Richards et al. (1996) (United Kingdom) tested six cover crops (volunteer crops of wheat or barley, forage rye (*Secale cereale* cv. Ammo), forage rape (*Brassica napus* cv. Barsica), mustard (*Sinapis alba*), Italian ryegrass (*Lolium multiflorum* cv. Bartissimo) and phacelia (*Phacelia tanacetifolia*) on nine commercial farms between 1991 and 1994. They found that overall, phacelia provided the greatest aboveground growth and gave the highest recorded dry matter yield (1140 DM lbs/ac [1280 kg DM/ha]).

Donald et al. (1995) (Nova Scotia) gave phacelia a favorable review. Their 1993, one year trial involved five cover crops (annual ryegrass var. Lemtal, oats var. Nova, alsike clover – common no. 1, phacelia var. Gipha, and oilseed radish – common seed). (Note – no crop was identified with a scientific name.) This research was conducted at two sites and with four planting dates. They reported that phacelia established quickly, gave good soil cover and excellent control of weeds. It also incorporated easily in the spring and did not tie up N with carbonaceous residues. They found that phacelia and oilseed radish were the best (of the five trialled) at carrying over N to the subsequent barley crop and they recommended phacelia if it could be planted before September 7$^{th}$ (their planting dates were July 20$^{th}$, August 20$^{th}$, September 20$^{th}$ and October 20$^{th}$).

Wyland et al. (1996) (California) compared phacelia cv. Phaci and Merced rye – *Secale cereale* cv. Merced on a commercial farm that produced spring and fall crops of lettuce and broccoli. The cover crops were planted on raised beds in double rows using a low seeding rate of 3.1 kg/ha [2.8 lbs/ac]. The researchers found no significant differences between the two cover crops in terms of biomass or N content. Phacelia produced 3241 lbs DM/ac [3640 kg DM/ha] and assimilated 94.4 lbs N/ac [106 kg N/ha] in the short winter there. Both cover crops had extensive, fibrous root systems that reached depths of 75 cm [29.5 in] although the majority of the root system was in the top 15 cm [5.9 in] of

the soil. The study also looked at potential disease and insect problems and found that neither cover crop introduced, enhanced, nor increased any insect or disease pathogens which threatened the following broccoli crop. Additionally, "The economic analysis indicated that the costs of cover cropping were minor compared with conventional winter management of fallowed fields and compared with the cost of producing broccoli." In California, the primary cost of the cover crop was for one irrigation used to stimulate germination of the seed.

Stivers-Young (1998) (New York) investigated phacelia's potential in western New York state. Eight cover crops were trialed at one site (Oats – *Avena sativa*, oilseed radish – *Raphanus sativus*, white senf mustard – *Brassica hirta*, kale – *Brassica oleracea*, canola – *Brassica napus*, turnip – *Brassica rapa*, yellow mustard – *Brassica hirta*, and phacelia). A planting on August 25th produced over 3000 DM kg/ha [2671 lbs/ac] of phacelia by mid-November. There was 100% cover in seven weeks using a seeding rate of 17 kg/ha [15.1 lbs/ac]. The researcher felt that phacelia performed well overall, but there was a big loss of biomass over the winter. From the first planting on 8/25, phacelia lost the most biomass over the winter (79%). Measured on 4/18, phacelia had 700 DM kg/ha remaining. Stivers-Young stated that phacelia needs to establish early. The 9/8 planting achieved less than half the DM yield of the 8/25 planting. Stivers (1998) found that phacelia accumulated more biomass and nitrogen than did oats which is the standard winter-killed cover crop used in the area. The range of optimum planting dates under these conditions is 25 Aug to 5 Sept. She also noted that although phacelia performed well, it was an impractical choice because of its limited availability and high price.

Nitrogen Accumulation

Jensen (1991) (Denmark) researched N accumulation by phacelia (*P. tanacetifolia* 'Anglia'), Italian ryegrass (*Lolium multiflorum* 'Prego'), perennial ryegrass (*Lolium perenne* 'Patora'), and white mustard (*Sinapis alba* 'Alba'). Aboveground dry matter (DM) accumulation for phacelia was 0.80 metric ton/ha [714 lbs/ac] following peas (*Pisum sativum* 'Solara') and 0.61 metric ton/ha [544 lbs/ac] following barley (*Hordeum vulgare* 'Golf'). Root DM was minimal at 0.04 metric ton/ha [3.5 lbs/ac] for both. Phacelia had a high percentage of nitrogen in the DM ranging from 4.59 – 5.10% in top DM and 2.96-3.50% belowground DM. The phacelia was sown after the pea and barley harvest (dates not given) and incorporated into the soil in early December. Note - Denmark has a history of keeping their fields bare over the winter (S. Ullrich – pers. comm. 6 May 2003). Because of the higher percent nitrogen incorporated, phacelia accumulated a comparable amount of nitrogen to higher DM yielding cover crops (that accumulated smaller percentages of nitrogen).

Richards et al. (1996) found that phacelia gave the greatest mean N yield at 166 kg N/ha [148 lbs/ac]. These researchers felt that the amount of nitrates recovered from the soil was low relative to the amount of nitrate present and seemed related to a less than optimum establishment of the cover crops due to relatively late sowings (dates ranged from August 27th to October 19th). They also felt that an increase in N supply to the subsequent crop should not necessarily be expected.

Rogasik (1992) (Germany) reported that with "early" fall sowing and adequate beginning levels of soil N, phacelia could take up 80-120 kg N/ha [71 – 107 lbs N/ac].

Donald et al. (1995) (Nova Scotia) found phacelia (cv. Gipha) gave little control of nitrate leaching.

The University of California found that Merced rye (*Secale cereale* cv. Merced) and phacelia both reduced nitrate leaching by 65-70%, compared to fields left fallow.

Bugg (1995) analyzed the data from research done by Jackson, Wyland, and Stivers in California. They evaluated six cover crops (including phacelia 'Phaci') for their ability to catch nitrates when planted as a winter cover crop before lettuce. They found that phacelia significantly depleted soil $NO_3$ – N compared to the bare ground control plots. Bugg stated that the phacelia assimilated 182 kg/ha [162 lbs/ac] of nitrates but it was unclear if this was the two-year average or the higher of the two years of research. This was a two-year trial on raised beds with subsurface drip irrigation. The lettuce was fertilized with ammonium sulfate at the rate of 85 kg N/ha (76 lbs. N/ac) the first year and 56 kg N/ha (50 lbs. N/ac) the second year.

Wyland et al. (1996) (California) found phacelia cv. Phaci assimilated 94.4 lbs N/ac [106 kg N/ha] following broccoli in the short California winter.

Crowley (1998) (Ireland) found that phacelia established quickly and evenly, producing full ground cover in two to three weeks at a low seeding rate of 7 kg/ha [6.2 lbs/ac]. He also found that phacelia wintered over in two years out of three and began to flower in mid-May. They allowed it to go to seed to evaluate its seed production (their information was that phacelia is a known poor seed producer). They found the seed difficult to harvest due to lodging and the maximum yield obtained was 1.0 metric ton/ha [892 lbs/ac].

In summary, phacelia may be useful as a fall cover crop. The seed needs to be planted by early fall to establish successfully. Phacelia is useful in reducing nitrate leaching and in providing potentially large amounts of biomass. Phacelia winterkills at about 18º F [-8º C], and the residue breaks down quickly after the crop is winterkilled. Phacelia is most useful for early spring crops where the farmer wants the soil to warm quickly, and where a weed-suppressing residue is not required.

## Management

Phacelia seed should be broadcast on a finely prepared seedbed. A cultipacker or rake can be used to bury the seed (1/4 inch [6 mm]). If possible, lightly irrigate. Phacelia is best planted when the soil temperature is between 37 – 68°F [3 – 20°C], and soil temperature closely follows air temperature. Broadcast seeding rates for phacelia used as a cover crop should be 11 – 18 lbs/ac [12.5 – 20 kg/ha]. Use 7 – 12 lbs/ac [8 – 13 kg/ha] if drilling. Use the higher seeding rate to increase phacelia's weed suppressing abilities. (Note - it's likely that with cool soil temperatures, well-aerated soil, good coverage of the seed, and irrigation after seeding, a much lower seeding rate is possible).

When used as a fall/winter catch crop, phacelia needs to be planted as early as possible in the fall. Phacelia winterkills at 18°F [-8°C] and the residue breaks down quickly. An early spring crop can be planted into the residue.

When used as an insectary planting, phacelia can be succession sown, or sown with other insectary plants such as borage (*Borago officinalis*), buckwheat (*Fagopyrum esculentum*), bachelor's button (*Centaurea cyanus*), and dill (*Anethum graveoleus*). Permanent insectary areas can be sown and allowed to reseed naturally from year to year. Use a seeding rate of 3 – 5 lbs/ac [3.5 – 5.5 kg/ha] when phacelia is planted alone; less if phacelia is sown in a mixture. Engels et al. (1994) use 40% phacelia in their bee forage (Tηbingen Mix).

## Mulch

Little research has been done on phacelia's suitability as a mulch (living or dead). No information was found relating to its shade tolerance.

Duval's summary of research (1992) reported that phacelia was intercropped with corn and sugar beets in a German study, and that it was able to tolerate tractor traffic even at full flower. He also reported that a study in Poland had found phacelia planted in apple orchards reduced winter mortality of young trees (no figures were reported).

Liptay (2002) (Ontario) found that tomatoes yielded 15% more with a dead mulch of phacelia. It gave good protection from sandblasting (damage to plants caused by wind-blown soil particles), but not good weed control.

Brinton (1989) (Maine) reported that phacelia was not well-suited as an undercrop for corn. It was competitive if planted early and didn't develop well if it was planted late. This appears to be derived from research by O. Schmid at the Institute for Biological Husbandry Research in 1979, but I was unable to locate the actual research report.

Bugg (1995) felt phacelia had potential as a living mulch in California orchards and vineyards because of its ability to assimilate N and increase beneficial insect populations.

## Problems

Several researchers question the wisdom of increasing insect diversity on the farm. Some insect pests also benefit from the high-quality pollen and nectar that phacelia provides. There is the possibility that growing phacelia could increase pest problems by aiding pest species more than beneficial species. This is a valid concern, and it needs to be addressed by additional research. [Phacelia may harbor lygus bugs (per the UC SAREP Cover Crop Database), accessed 2003.]

For now, the answer of whether additional insect diversity is right depends on the particular farm situation and the philosophy of the farmer.

Phacelia is a host of *Sclerotinia minor*. This disease is widespread with many host plants, the use of phacelia is unlikely to cause a problem in this region (E. Dutky, pers. comm. 11 April 2002). Phacelia is a host of *Phytophthora infestans* (late blight) (Turkensteen 1973), but these spores can blow many miles, and there are also many other host plants present in the mid-Atlantic. Phacelia is also a host of beet mild yellowing and beet yellows virus (Proeseler, et al., 1987).

## Conclusions

This plant has proven its usefulness as a food source for pollinators and other beneficial insects. It has also proven its value as a cover crop in other regions of the world. However, there are significant questions about its usefulness in the mid-Atlantic region. Specifically, we need to know how it performs in the field under our soil, temperature, and weather conditions. As a native to the

arid Southwest, the plant has likely evolved to germinate in response to a moisture surge within its specified temperature range. Does it need rain or an initial irrigation when it's planted in the mid-Atlantic? Is it shade tolerant? Can it be used successfully as an intercrop? How late can it be planted in the fall and still be effective at reducing nitrate leaching?

It appears that phacelia germinates best with temperatures between 37 and 68ºF (3 – 20ºC). The failure to germinate at higher soil temperatures may limit its usefulness. It's unclear how quickly the germination percentage drops off after 68°F [20°C] to zero percent germination at 86°F [30°C]. Phacelia also needs planted earlier in the fall than some fields are available. Still, it may be a good choice in some situations. These situations include: in the spring when there is a desire to attract beneficial insects and in the fall when it will be followed by a very early cash crop.

We also need information about phacelia's usefulness as forage. Several publications briefly mentioned forage as a use, and phacelia has a nitrogen content of 4%, but little else is known about its suitability as animal feed. We need more information about this potentially useful plant and on how it performs in this part of the world.

**Seed Sources**

Albright Seed Co.
(organic seed not available)
487 Dawson Dr., Bay 58
Camarillo, CA 93012
805-484-0551
www.albrightseed.com
2003 catalog price for phacelia 1 lb. $16

American Meadows
(organic seed not available)
223 Avenue D, Suite 30
Williston, VT 05495
802-951-5812
www.americanmeadows.com
2003 catalog price for phacelia 1 lb. $15.95

Peaceful Valley Farm Supply
(organic seed not available)
P.O. Box 2209
Grass Valley, Ca 95945
530-272-4769
www.groworganic.com
2003 catalog price for phacelia 10+ lbs 8.65/lb.

Seed Savers Exchange
(plans to have organic seed in the future)
3076 North Winn Road
Decorah, IA 52101-7776
563-382-5990
www.seedsavers.org
2003 catalog price for phacelia 1 lb. $40

Wildseed Farms
(organic seed not available)
425 Wildflower Hills
P.O. Box 3000
Fredericksburg, TX 78624
800-848-0078
www.wildseedfarms.com
2003 catalog price for phacelia 1 lb. $10

## Price Comparison with Other Cover Crops

Phacelia is not readily available and not cheap in this country. However, research reports from Europe repeatedly referred to it as an inexpensive cover crop seed. The problem is in its "newness" to this country – not to any inherent expense in producing it.

Additionally, the seeds are very small so far less is needed than for many other cover crops. Here is a comparison of cost (based on the seed cost from Peaceful Valley Farm Supply's 2003 catalog) for a few comparable cover crops. Seeding rates for crops other than phacelia were based on recommended rates in Managing Cover Crops Profitably and Northeast Cover Crops Handbook. Seeding rates vary depending on time of year, weather conditions, time of seeding, method of seeding, primary purpose of the cover crop, etc.

| Cover Crop | Rate of Seeding | Price/Lb. | Price per Acre |
|---|---|---|---|
| phacelia (*Phacelia tanacetifolia*) | 7 – 18 lbs/ac (8 – 20 kg/ha) | $8.65 | $60.55 – $155.70 |
| buckwheat (*Fagopyrum esculentum*) | 48 – 96 lbs/ac (54 – 108 kg/ha) | $0.53 | $25.44 – $50.88 |
| sudangrass (*Sorghum bicolor* var. *sudanense*) | 35 – 50 lbs/ac (39 – 56 kg/ha) | $0.60 | $21.00 – $30.00 |
| cereal rye (*Secale cereale)* | 60 – 160 lbs/ac (67 – 179 kg/ha) | $0.38 | $22.80 – $60.80 |
| mustard (*Brassica* and/or *Sinapis* spp.) | 5 – 12 lbs/ac (6 – 13 kg/ha) | $0.80 | $4.00 – $9.60 |
| crimson clover (*Trifolium incarnatum* ) | 8 – 12 lbs/ac (9 – 13 kg/ha) | $2.20 | $17.60 – $26.40 |

## Sources for Additional Information

University of California Sustainable Agriculture Resource and Education Program (UC SAREP) – Cover Crop Database http://www.sarep.ucdavis.edu/ccrop/

Engels, W., U. Schulz, & M. Rädle. 1994. Use of the Tübingen Mix for bee pasture in Germany, p. 57-65. In A. Matheson (ed.). Forage for Bees in an Agricultural Landscape. International Bee Research Association, Cardiff, UK.

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