Soil Building for Water Savings: Benefits & Practical Considerations

Agricultural Water Quality Alliance
8.13.14

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- Established in1978 by Allen, David & Steven Gill
- King City and Oxnard, CA, & Yuma, AZ
- About 17,000 acres, including double-cropping
- 20+ vegetables, including spinach, lettuce, romaine, celery, broccoli, cauliflower, onions, peppers, tomatoes, baby greens and more

Sustainable Farming Practices

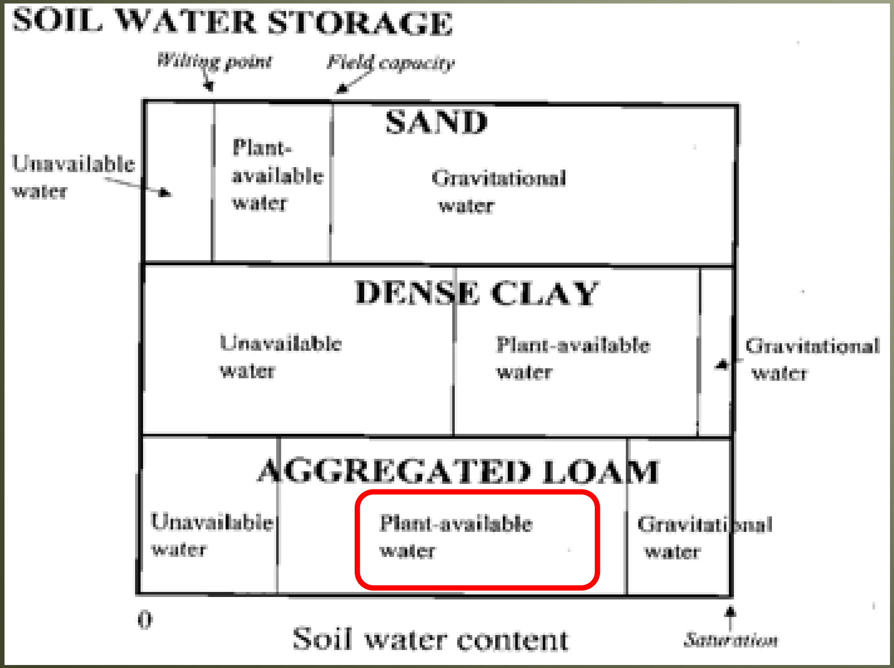
- Data analysis - baseline of resource use
- Tools - soil moisture sensors, water meters
- Science - Lab & field testing - soil, plant tissue and water
- Practices - Sprinkler & Drip Irrigation
- Waste - Drip tape re-use and recycling
- Energy – well pump efficiency tests, electrical conversion

Soil Building Practices

- Healthy soil = healthy food
- Basis of sustainable agriculture is maintaining fertility and productivity of land, year after year

Water Holding Capacity/ Infiltration

- Water in – Irrigation + Precipitation
- Water present - water content/tension of the soil
- Water movement through soil
  - Texture, structure, and size of soil pores
  - Soil layers
  - Root penetration/preferential flow
  - Evapotranspiration

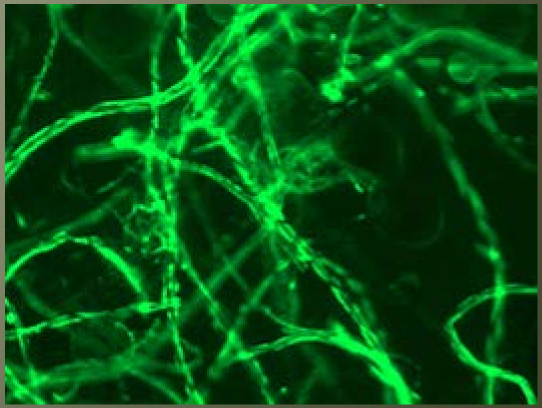


Texture	Field Capacity (in./ft)	Permanent Wilting Point (in./ft)	Available Water (in./ft)
Fine sand	1.4	0.4	1.1
Sandy loam	1.9	0.6	1.4
Fine sandy loam	2.5	0.8	1.8
Loam	3.1	1.2	1.95
Silt loam	3.4	1.4	2.03
Clay loam	3.7	1.8	1.95
Clay	3.9	2.5	1.4

FIGURE 7-7 Water retention of several soil textures. *(Adapted from Water: The Yearbook of Agriculture, USDA, 1955)*

Soil Organic Matter

- Source of nutrients
- Cation exchange capacity
- pH buffering
- Feeds & restores soil microbial populations
- Aggregate formation - “Soil glue”
    - Polysaccharides – sugars produced by microbes
    - Glomalin - protein on arbuscular mycorrhizal fungi hyphae
- Suppresses plant pathogens
- Erosion prevention & reduction
- Reduced surface crusting
- Reduced compaction
- Carbon sequestration
- Soil water-holding capacity



Glomalin image from: http://www.ars.usda.gov/is/AR/archive/jul08/glomalin0708.htm

Organic Matter & Water Retention

Table 1
Observed effect of organic matter content on soil water retention at two water potentials

Authors	– 33 kPa	– 1500 kPa
Bauer and Black (1981)	Yes	Yes
Bell and van Keulen (1995)	No	Yes
Beke and McCormick (1985)	No	Yes
Petersen et al. (1968)	No	Yes
Calhoun et al. (1973)	Yes	No
Lal (1979)	No	No
Danalatos et al. (1994)	No	No
De Jong (1983)	Yes	Yes
Jamison and Kroth (1958)	Yes	Yes
Riley (1979)	Yes	Yes
McBride and MacIntosh (1984)	ND	Yes
Salter and Haworth (1961)	No	No

5. Conclusion

(1) Relationship of soil water retention to organic carbon content is affected by proportions of textural components.

(2) Soil water retention at – 33 kPa is affected more strongly by the organic carbon than water retention at – 1500 kPa.

(3) Water retention of soils with coarse texture is substantially more sensitive to the amount of organic carbon as compared with fine-textured soils.

(4) The effect of changes in organic carbon content on soil water retention depends on the proportion of textural components and the amount of organic carbon present in the soil. At low carbon contents, an increase in carbon content leads to an increase in water retention in coarse soils and to decrease in water retention in fine-textured soils. At high carbon contents, an increase in carbon contents results in an increase in water retention of all textures.

(5) A comparable accuracy in estimating water retention has been achieved with regression trees and with polynomial neural networks of the group method of data handling.

(6) Test of the predictive ability of the GMDH equations resulted in the same accuracy of estimates for the independent data from soil quality studies as for the data set from the National Soil Characterization database.

(7) The developed equations can be used to evaluate effect of the soil carbon sequestration on soil hydraulic properties.

From Rawls et. Al. 2003, Effect of soil organic carbon on soil water retention. Geoderma 116 (2003) 61–76

Compost Program

- Since 2000, windrow composting on 7 acres of land
- 8,000 tons/year in 2000 → 20,000 tons/year in 2012
- 4-6 tons/acre applied
- Keith Day Company manages, 1-2 full time staff
- Waste reduction strategy – reduces pathogens, fuel, GHG emissions

Compost Ingredients

- Culled onions
- Spent mushroom substrate from Monterey Mushroom Co.
- Grape pomace from Courtside Cellars, San Miguel
- Green Waste from Johnson Canyon, Gonzales

Composting Considerations

- Regulated by California Integrated Waste Management Board (CIWMB) Regulations (Title CCR, Chapter 3.1), enforced by Monterey County
- Food Safety / LGMA
  - Testing - fecal coliforms, salmonella, E. coli.
  - Temperature & turning frequency
  - Distance to harvested fields
  - Cleaning of equipment
  - Documentation
  - Pre-harvest interval
  - Mushroom mulch sterilization
- Air Resources Board: Compost is a source of GHGs, VOCs / reactive organic gases (ROG), particulate matter, and ammonia (NH_3).

Composting Considerations

- Cost
  - Take valuable land out of production
  - Staff time
  - Equipment – turner, loader, water truck, spreader
  - Fuel to turn and spread on fields
- Application timing: slow-release of nutrients may not available when plants may need it
- Onion skins – mobile in windy conditions
- Odor management

Cover Crops

- Started in 2010 with 22 acres, 320 acres in 2013-14 winter
- Site selection
  - Sandy lots – goal to build SOM, reduce leaching
  - Hilly lots – goal to reduce soil erosion, reduce leaching
- Species used: triticale, Merced rye, wheat forage mix
- Drill seeded
- Disked under or harvested for cattle feed

Cover Cropping Benefits

- Protects water quality
  - reduces soil erosion & runoff
  - decreases leaching of nitrates
- “Banks” nitrogen until the spring
- Natural biofumigant - mustards
- Fixes atmospheric nitrogen – legumes
- Habitat for beneficial insects
- Potential revenue if crop is sold

Cover Crop Considerations – Environmental

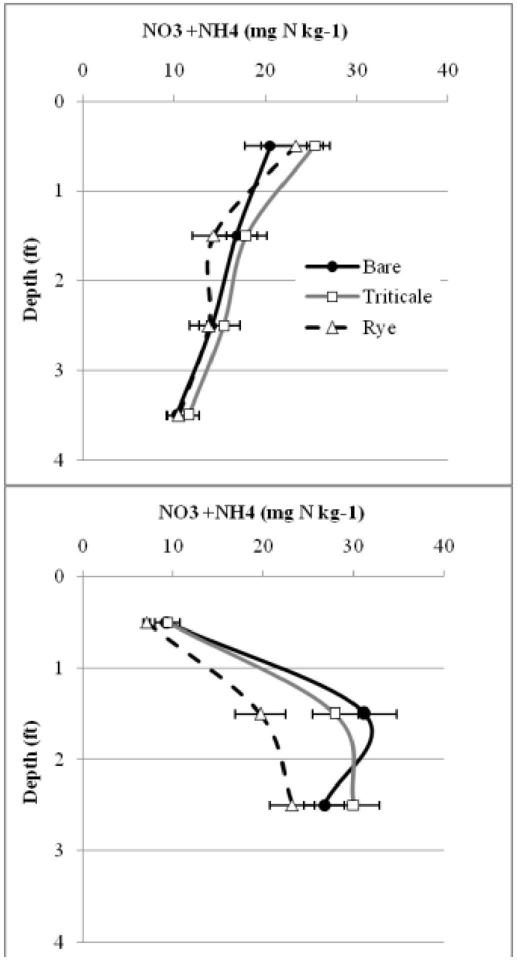
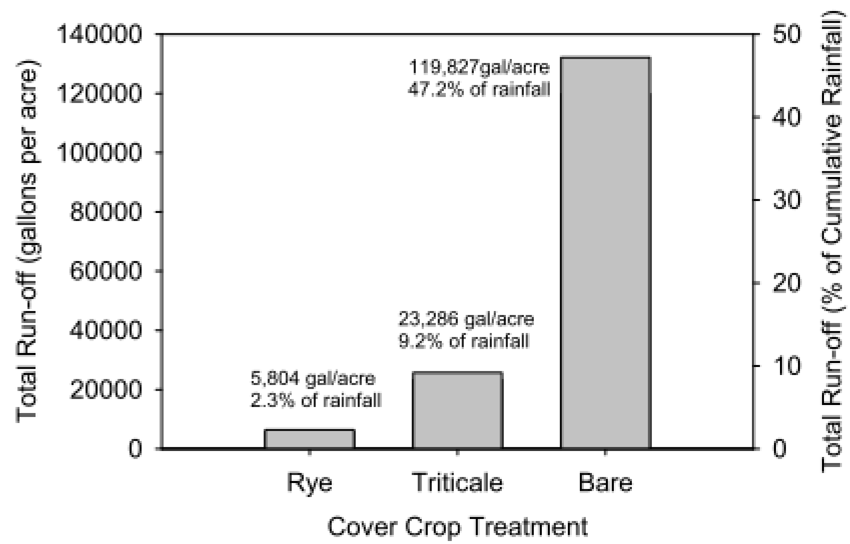


Figure 11. Nitrate and ammonium concentrations in the soil profile. Upper graph: November 23, 2009 prior to cover crop germination and lower graph: March 8, 2010 prior to tillage operations. Error bars represent the SE n=6.

Figure 6. Total runoff in the three cover crop treatments



From: Smith and Cahn 2011, Evaluation Low-residue Cover Crops to Reduce Nitrate Leaching, and Nitrogen and Phosphorous Losses from Winter Fallow Vegetable Production Fields in the Salinas Valley, 2011 Final Report. FREP/UCANR.

Cover Crop Considerations - Environmental

Agriculture, Ecosystems and Environment 155 (2012) 50–61

Contents lists available at SciVerse ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

The role of cover crops in irrigated systems: Water balance, nitrate leaching and soil mineral nitrogen accumulation

J.L. Gabriel[a], R. Muñoz-Carpena[b], M. Quemada[a,*]

Barley greatly reduced the NO_3^- leaching throughout the experimental period relative to fallow. The main effect appeared during the intercrop period and in the years when the drainage was abundant. Only in the unusually dry autumn of 2007/08, in which the precipitation from October to March was 101 mm, were the drainage and NO_3^- leaching similar (nonexistent) for all of the treatments. This large variability is characteristic of Mediterranean semiarid regions, in which soil N_{min} accumulates during the dry intercrop periods and is leached out of the soil profile when an unusually heavy rainy season occurs (Ruiz-Ramos et al., 2011). At the beginning of the experiment, the N_{min} content just before sowing the CC was high (~300 kg N ha^{-1}) and similar for all the treatments; therefore, the CC had an opportunity to show their ability to reduce NO_3^- leaching. Both the barley and vetch cut the NO_3^- leaching losses by more than half relative to fallow. At the same time, the barley greatly reduced the N_{min} content in the soil profile, as it captured most of the available N, whereas the N_{min} content in the vetch soil was midway between those of the fallow and the barley owing to atmospheric N_2 fixation. After the 2007 maize cropping, all of the treatments converged

Cover Crop Considerations - Timing

- species – timeframe to grow & provide desired benefit
- weather – field access
- decomposition time
- uptake of N in subsequent crop may not match N release
- prolonged wet, cold soils
- depletion of soil moisture

Cover Crop Considerations - Agronomic

Cover crop example	%N in cover crop	C:N ratio	Effect of N release
Cereal straw, cereal at heading	0.5 – 1.5%	> 25:1	Immobilization
Cereal at or before heading. Mustards at heading.	1.5 – 2.5%		May tie up N
Legumes, mustards, juvenile cereal	2.5 – 4%	10:1 to 15:1	Mineralization

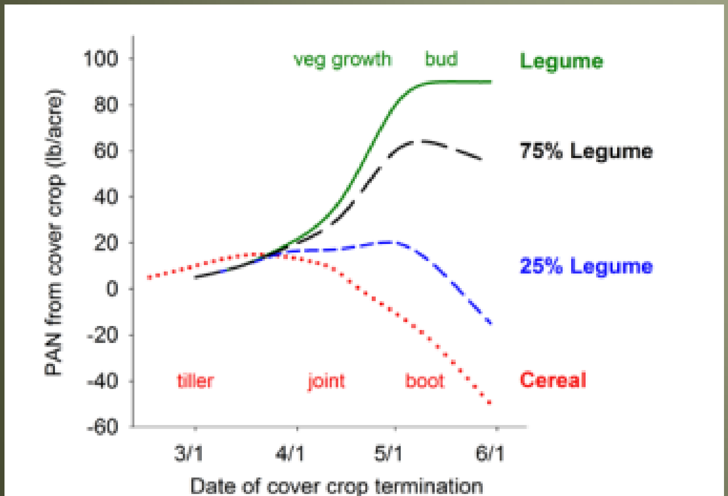


Figure 4.—Effect of kill date on typical plant-available N (PAN) release from cereal, legume, or mixed stands. Based on compilation of field data from Willamette Valley cover crop trials. Source: D. Sullivan.

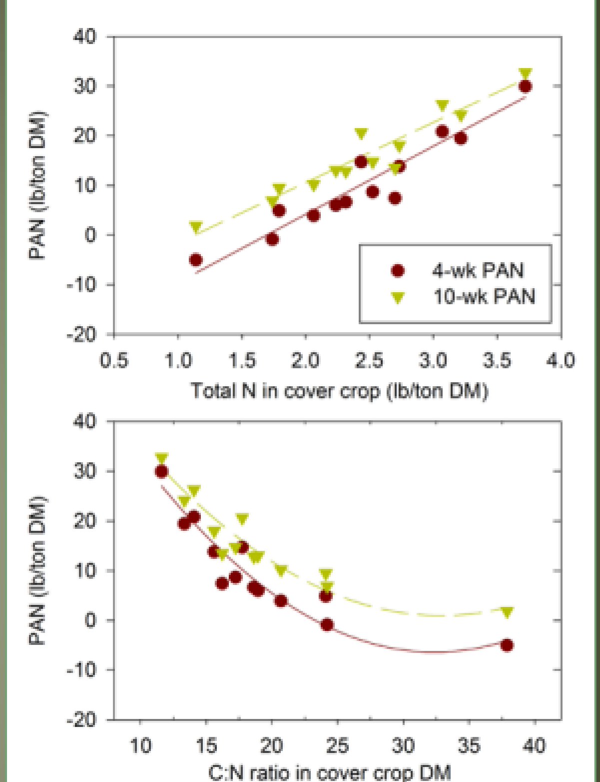


Figure 26.—PAN from cover crop residues (oat + vetch, rye + vetch, and oat + clover) as related to N percentage in cover crop DM (top) or C:N ratio (bottom).

Graphs from: Estimating Plant Available Nitrogen Release From Cover Crops, Pacific Northwest Extension Publication 636 (2012)

Cover Crop Considerations - Agronomic

Chart 4B **POTENTIAL DISADVANTAGES** Note change in symbols ○ = problem ● = not a problem

		Increase Pest Risks			Management Challenges					
	Species	weed potential	insects/ nematodes	crop disease	hinder crops	establish	till-kill	mow-kill	mature incorp.	**Comments Pro/Con**
NONLEGUMES	Annual ryegrass	○ [1]	◕	◕	◑	●	●	●	◑	If mowing, leave 3-4" to ensure regrowth.
NONLEGUMES	Barley	◔	◔	◔	◑	●	●	●	○	Can be harder than rye to incorporate when mature.
NONLEGUMES	Oats	●	◑	◕	◑	●	●	◔	◑	Cleaned, bin-run seed will suffice.
NONLEGUMES	Rye	◔	◑	◕	◔	◕	◕	●	○	Can become a weed if tilled at wrong stage.
NONLEGUMES	Wheat	◑	◔	◔	◑	●	●	◕	◑	Absorbs N and H_20 heavily during stem growth, so kill before then.
NONLEGUMES	Buckwheat	○	◕	●	●	●	●	●	●	Buckwheat sets seed quickly.
NONLEGUMES	Sorghum-sudangrass	◑	◕	●	◔	●	◕	◕	◔	Mature, frost-killed plants become quite woody.
BRASSICAS	Mustards	◔	◕	●	◑	●	●	◔	●	Great biofumigation potential; winterkills at 25° F.
BRASSICAS	Radish	◑	◕	●	●	●	●	●	●	Winter kills at 25° F; cultivars vary widely.
BRASSICAS	Rapeseed	◔	◔	●	◑	●	◑	◔	◕	Canola has less biotoxic activity than rape.

From: Managing Cover Crops Profitably, Western SARE 2012:
http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition

Cover Crop Considerations - Economic

- Harvest & sell vs. incorporate for full agronomic benefit
- Availability of labor in off-season
- Cost
  - seeds
  - labor
  - irrigation in dry years
  - weed control/herbicides
  - diesel/electricity for planting, irrigation
  - land rent
- Cover crops as weeds

Resources - Compost

CDFA - Compost Production and Utilization: A Grower's Guide
http://www.cdfa.ca.gov/is/ffldrs/frep/Nutrient_Mgmt_Tools.html

Leafy Greens Marketing Agreement - Food Safety Practices
http://www.lgma.ca.gov/food-safety-practices#downloads

Cal Recycle Composting Operations - Regulatory Requirements
http://www.calrecycle.ca.gov/laws/Regulations/Title14/ch31a5.htm

Cal Recycle - On Farm Composting
http://www.calrecycle.ca.gov/organics/farming/OnFarm.htm

Air Resources Board – Compost Emissions Work Group
http://www.calrecycle.ca.gov/organics/farming/OnFarm.htm

National Center For Appropriate Technology – Sustainable Agriculture Information Service
https://attra.ncat.org/publication.html

Resources – Cover Crops

Cover Cropping for Vegetable Production, UC-ANR Pub. 3517 (2011)

http://anrcatalog.ucdavis.edu/Items/3517.aspx

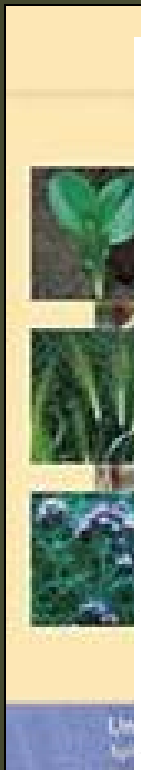


Table 2.1. Cover crop production and cultural information

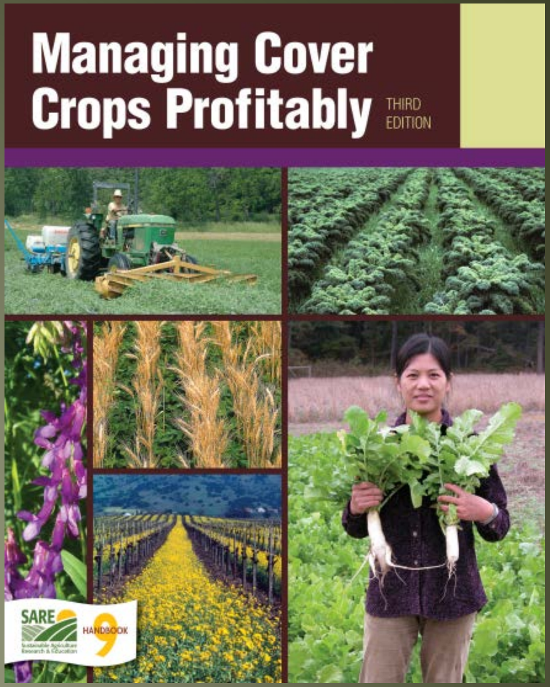
Scientific name	Common name	Common varieties	Growing season*	Seeds per pound	Typical seeding rate† (lb/ac)	Seeding depth (inches)	Rhizobium inoculant	Seedling vigor	Vigor of winter growth‡
GRASSES									
Avena sativa	oat								
Hordeum vulgare	barley								
Secale cereale	cereal rye								
Sorghum bicolor × *S. bicolor* ssp. *drummondii*	sorghum-sudangras								
Sorghum bicolor ssp. *drummondii*	sudangras								
Triticum aestivum	wheat								
× *Triticosecale rimpaui*	triticale								
LEGUMES									
Crotalaria juncea	sunn hem								
Pisum sativum	field pea								
Trifolium spp. and *Medicago* spp.	clovers an medics								
Vicia benghalensis	purple ve								
Vicia faba	bell bean								
Vicia sativa ssp. *sativa*	common vetch								
Vicia villosa ssp. *varia*	woollypo vetch								

Table 2.2. Characteristics of cover crops

Scientific name	Common name	Nitrogen fixation	Nitrogen scavenging	C:N ratio at maturity	Seeding hazard	Weed suppression	Comments
GRASSES							
Avena sativa	oat	—	excellent	high	low	moderate	Some varieties are the latest maturing of the cereals.
Hordeum vulgare	barley	—	excellent	high	high	good	Fast growing; many varieties are early maturing.
Secale cereale	cereal rye	—	excellent	high	moderate	excellent	At appropriate seeding rates, the variety Merced suppresses weeds well. AG 104 is resistant to rust.
Sorghum bicolor × *S. bicolor* ssp. *drummondii*	sorghum-sudangrass	—	excellent	high	moderate	good	Residues are allelopathic to tomatoes, lettuce, cole crops, and possibly other vegetables. Need to allow 6–8 weeks following incorporation of residue for allelochemicals to leach and/or break down.
Sorghum bicolor ssp. *drummondii*	sudangrass	—	excellent	high	moderate	good	Is tolerant of mowing and can produce large amounts of biomass.
Triticum aestivum	wheat	—	excellent	high	high	good	Its use as a cover crop is typically dependent upon seed price.
× *Triticosecale rimpaui*	triticale	—	excellent	high	moderate	good	Typically produces the most biomass of the cool-season grass cover crops. Resistant to rust.
LEGUMES							
Crotalaria juncea	crotalaria	excellent	poor	low	low	moderate	Upright growth to 6 feet tall.
Pisum sativum	field pea	excellent	poor	low	moderate	poor	Can be highly productive, but susceptible to root rot on heavy, wet soils.
Vicia benghalensis	purple vetch	excellent	poor	low	moderate	moderate	Tolerant of wet soils; a high nitrogen producer.
Vicia faba	bell bean	excellent	poor	low	moderate	poor	A reliably productive legume. Because of its upright growth it mixes well with grasses.

Resources – Cover Crops

Managing Cover Crops Profitably, Western SARE (2012)
http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition



Estimating Plant Available Nitrogen Release From Cover Crops, Pacific Northwest Extension Publication 636 (2012)

http://www.sare.org/Learning-Center/Project-Products/Western-SARE-Project-Products/Estimating-Plant-Available-Nitrogen-Release-from-Cover-Crops

PNW 636 • November 2012

ESTIMATING PLANT-AVAILABLE NITROGEN RELEASE FROM COVER CROPS

D.M. Sullivan and N.D. Andrews

HIGHLIGHTS

- Legume cover crops provide up to 100 lb PAN/a. To maximize PAN contribution from legumes, kill the cover crop at bud stage (early May).
- Cereal cover crops immobilize up to 50 lb PAN/a. To minimize PAN immobilization from cereals, kill the cover crop during the early stem elongation (jointing) growth stage (early April).
- Legume/cereal cover crop mixtures provide a wide range of PAN contributions, depending on legume content. When cover crop dry matter is 75 percent from cereals + 25 percent from legumes, PAN is usually near zero.
- A laboratory analysis for cover crop total N as a percentage in dry matter (DM) is a good predictor of a cover crop's capacity to release PAN for the summer crop.
  - When cover crops contain a low N percentage (less than 1.5 percent N in DM), they provide little or no PAN.
  - When cover crops contain a high N percentage (3.5 percent N in DM), they provide approximately 35 lb PAN/ton of dry matter.
  - PAN release increases linearly, as cover crop N percentage (in DM) increases from 1.5 to 3.5 percent.
- Cover crops decompose rapidly and release or immobilize PAN rapidly. Most PAN is released in 4 to 6 weeks after cover crop kill.
- PAN from legume cover crops is usually much less expensive than PAN from organic fertilizers.
- Values for cover crop PAN listed here are most applicable to winter cover crop/summer vegetable crop rotations in western Oregon and Washington.

Dan M. Sullivan, Extension soil scientist, and Nick D. Andrews, small farms Extension agent; both of Oregon State University

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Questions & Comments

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