TECHNICAL NOTES

NATURAL RESOURCES CONSERVATION SERVICE – WYOMING

AGRONOMY NO. 29 **July 29, 2009**

SUBJECT: Cover Crops

Cover crops provide many benefits. Some common goals for cover crops are to:

Reduce soil erosion
Provide or utilize nitrogen
Add organic matter
Provide weed control
Provide habitat for beneficial organisms and wildlife
Trap snow

In Wyoming, the most common reason for implementing cover crops is to protect against erosion due to wind and rain during the critical erosion periods.

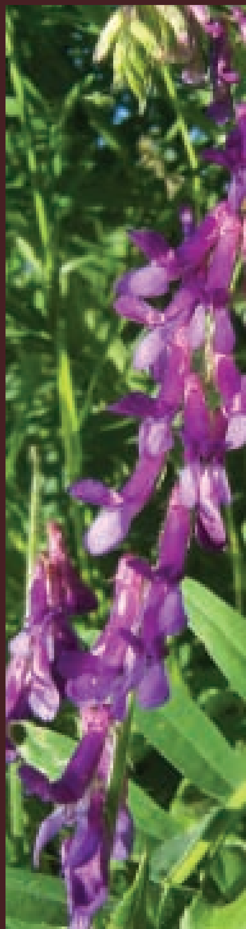
Long-term use of cover crops increases water infiltration and reduces evaporation. They trap surface water and add organic matter by slowing erosion and runoff. Cover crops reduce nonpoint source pollution caused by the run-off of sediments, nutrients and pesticides. Nutrients may be managed when nitrogen-fixing (legumes) cover crops produce nitrogen for the next crop or the cover crop utilizes excess nutrients in the soil profile. Cover crops may also trap snow if heights are left around ten inches going into winter. This ground cover will be also benfit wildlife.

Identify the best time and place for a cover crop in the crop rotation. To find a suitable cover crop one must find crops that will work best with a minimum of risk and expense. Document the dates when crops are seeded and harvested and add rainfall, frost-free periods and times of heavy labor or equipment demand. Look for open periods in each field that correspond to good conditions for cover crop establishment, under-utilized acres, and opportunities in the season work schedule. Test a few options on a small scale.

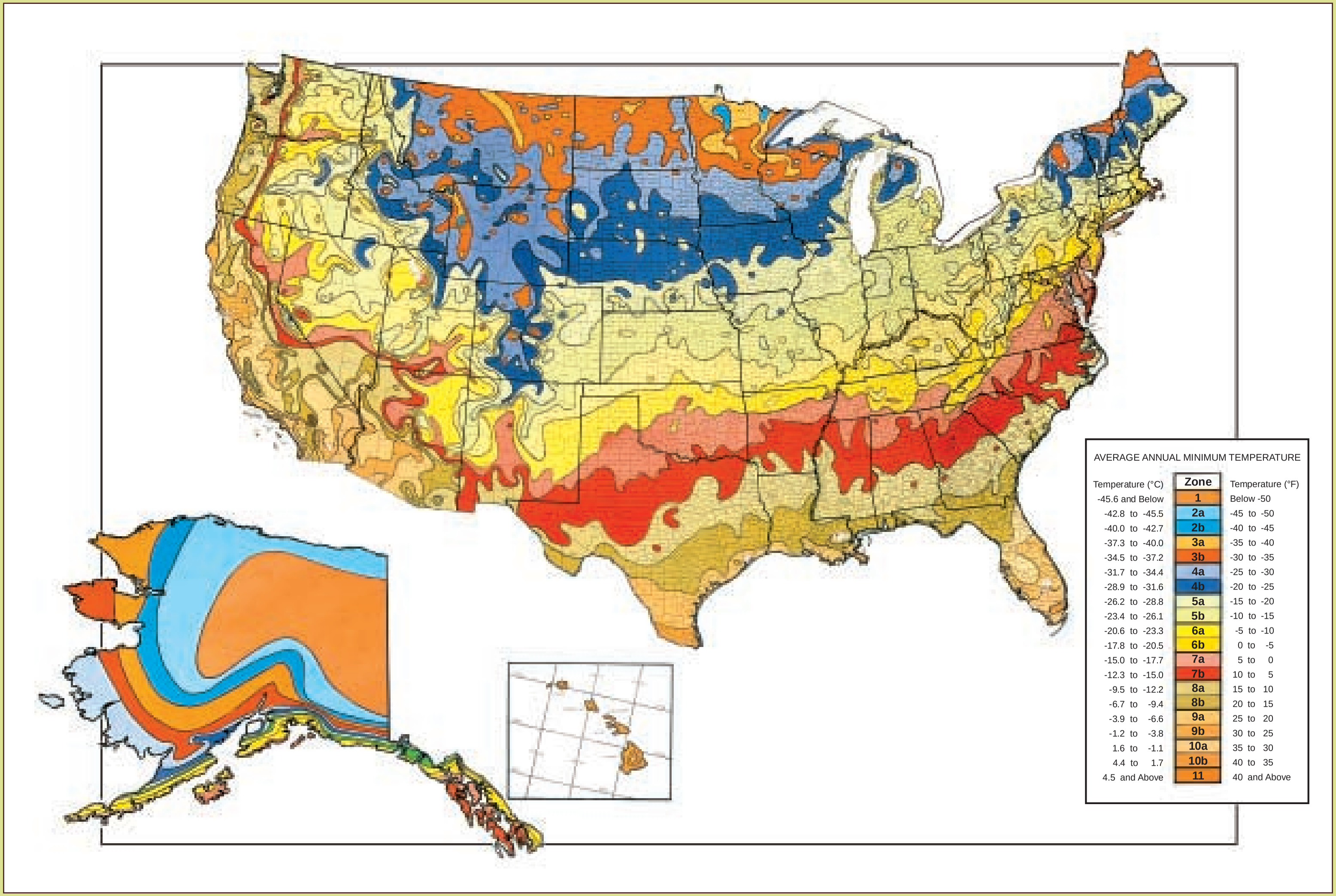
Credit goes to an abbeviated version of the Sustainable Agriculture Network publication "Managing Cover Crops Profitably", 3rd edition, and The Rodale Institute charts of cover crops in providing information on most cover crops adapted to Wyoming. This is not an exclusive list. The Lingle Sustainable Agriculture Research and Education Center (SAREC) continues to experiment and trial crops suitable for Wyoming climates.

Managing Cover Crops Profitably

THIRD EDITION



USDA Plant Hardiness Zone Map



Agricultural Research Service USDA

Chart 1 **TOP REGIONAL COVER CROP SPECIES**[1]

Bioregion	N Source	Soil Builder	Erosion Fighter	Subsoil Loosener	Weed Fighter	Pest Fighter
Northeast	red cl, hairy v, berseem, swt cl	ryegrs, swt cl, sorghyb, rye	rye, ryegrs, sub cl, oats	sorghyb, swt cl, forad	sorghyb, ryegrs, rye, buckwheat	rye, sorghyb, rape
Mid-Atlantic	hairy v, red cl, berseem, crim cl	ryegrs, rye, swt cl, sorghyb	sub cl, cowpeas, rye, ryegrs	sorghyb, swt cl, forad	rye, ryegrs, oats, buckwheat	rye, sorghyb, rape
Mid-South	hairy v, sub cl, berseem, crim cl	ryegrs, rye, sub cl, sorghyb	sub cl, cowpeas, rye, ryegrs	sorghyb, swt cl	buckwheat, ryegrs, sub cl, rye	rye, sorghyb
Southeast Uplands	hairy v, red cl, berseem, crim cl	ryegrs, rye, sorghyb, swt cl	sub cl, cowpeas, rye, ryegrs	sorghyb, swt cl	buckwheat, ryegrs, sub cl, rye	rye, sorghyb
Southeast Lowlands	winter peas, sub cl, hairy v, berseem, crim cl	ryegrs, rye, sorghyb, sub cl	sub cl, cowpeas, rye, ryegrs, sorghyb	sorghyb	berseem, rye, wheat, cowpeas, oats, ryegrs	rye, sorghyb
Great Lakes	hairy v, red cl, berseem, crim cl	ryegrs, rye, sorghyb, ryegrs, swt cl	oats, rye, ryegrs	sorghyb, swt cl, forad	berseem, ryegrs, rye, buckwht, oats	rye, sorghyb, rape
Midwest Corn Belt	hairy v, red cl, berseem, crim cl	rye, barley, sorghyb, swt cl	wht cl, rye, ryegrs, barley	sorghyb, swt cl, forad	rye, ryegrs, wheat, buckwht, oats	rye, sorghyb
Northern Plains	hairy v, swt cl, medics	rye, barley, medic, swt cl	rye, barley	sorghyb, swt cl	medic, rye, barley	rye, sorghyb
Southern Plains	winter peas, medic, hairy v	rye, barley, medic	rye, barley	sorghyb, swt cl	rye, barley	rye, sorghyb
Inland Northwest	winter peas, hairy v	medic, swt cl, rye, barley	rye, barley	sorghyb, swt cl	rye, wheat, barley	rye, mustards, sorghyb
Northwest Maritime	berseem, sub cl, lana v, crim cl	ryegrs, rye, sorghyb, lana v	wht cl, rye, ryegrs, barley	sorghyb, swt cl	ryegrs, lana v, oats, wht cl	rye, mustards
Coastal California	berseem, sub cl, lana v, medic	ryegrs, rye, sorghyb, lana v	wht cl, cowpeas, rye, ryegrs	sorghyb, swt cl	rye, ryegrs, berseem, wht cl	sorghyb, crim cl, rye
Calif. Central Valley	winter peas, lana v, sub cl, medic	medic, sub cl	wht cl, barley, rye, ryegrs	sorghyb, swt cl	ryegrs, wht cl, rye, lana v	sorghyb, crim cl, rye
Southwest	medic, sub cl	sub cl, medic, barley	barley, sorghyb		medic, barley	

[1]ryegrs=annual ryegrass. buckwht=buckwheat. forad=forage radish. rape=rapeseed. sorghyb=sorghum-sudangrass hybrid. berseem=berseem clover. winter peas=Austrian winter pea. crim cl=crimson clover. hairy v=hairy vetch. red cl=red clover. sub cl=subterranean clover. swt cl=sweetclover. wht cl=white clover. lana v=LANA woollypod vetch.

Chart 2 **PERFORMANCE AND ROLES**

Group	Species	Legume N Source	Total N (lb./A)[1]	Dry Matter (lb./A/yr.)	N Scavenger[2]	Soil Builder[3]	Erosion Fighter[4]	Weed Fighter	Good Grazing[5]	Quick Growth
NONLEGUMES	Annual ryegrass *p. 74*			2,000–9,000	Very Good	Very Good	Very Good	Very Good	Very Good	Very Good
NONLEGUMES	Barley *p. 77*			2,000–10,000	Very Good	Very Good	Excellent	Very Good	Very Good	Very Good
NONLEGUMES	Oats *p. 93*			2,000–10,000	Very Good	Good	Very Good	Excellent	Good	Excellent
NONLEGUMES	Rye *p. 98*			3,000–10,000	Excellent	Excellent	Excellent	Excellent	Good	Excellent
NONLEGUMES	Wheat *p. 111*			3,000–8,000	Very Good	Very Good	Very Good	Very Good	Very Good	Very Good
NONLEGUMES	Buckwheat *p. 90*			2,000–4,000	Poor	Good	Fair	Excellent	Poor	Excellent
NONLEGUMES	Sorghum-sudan. *p. 106*			8,000–10,000	Excellent	Excellent	Excellent	Very Good	Very Good	Excellent
BRASSICAS	Mustards *p.81*		30–120	3,000–9,000	Good	Very Good	Very Good	Very Good	Good	Very Good
BRASSICAS	Radish *p. 81*		50–200	4,000–7,000	Excellent	Very Good	Very Good	Excellent	Good	Very Good
BRASSICAS	Rapeseed *p. 81*		40–160	2,000–5,000	Very Good	Good	Very Good	Very Good	Good	Very Good
LEGUMES	Berseem clover *p. 118*	Excellent	75–220	6,000–10,000	Very Good	Very Good	Very Good	Excellent	Excellent	Excellent
LEGUMES	Cowpeas *p. 125*	Excellent	100–150	2,500–4,500	Fair	Good	Excellent	Excellent	Good	Very Good
LEGUMES	Crimson clover *p. 130*	Very Good	70–130	3,500–5,500	Good	Very Good	Very Good	Very Good	Excellent	Good
LEGUMES	Field peas *p. 135*	Excellent	90–150	4,000–5,000	Fair	Good	Very Good	Good	Very Good	Very Good
LEGUMES	Hairy vetch *p. 142*	Excellent	90–200	2,300–5,000	Fair	Very Good	Good	Good	Good	Fair
LEGUMES	Medics *p. 152*	Good	50–120	1,500–4,000	Fair	Good	Good	Very Good	Very Good	Excellent
LEGUMES	Red clover *p. 159*	Very Good	70–150	2,000–5,000	Good	Very Good	Good	Very Good	Excellent	Fair
LEGUMES	Subterranean clovers *p.164*	Excellent	75–200	3,000–8,500	Fair	Very Good	Very Good	Excellent	Very Good	Good
LEGUMES	Sweetclovers *p. 171*	Excellent	90–170	3,000–5,000	Fair	Excellent	Very Good	Very Good	Very Good	Good
LEGUMES	White clover *p. 179*	Excellent	80–200	2,000–6,000	Fair	Good	Very Good	Very Good	Excellent	Fair
LEGUMES	Woollypod vetch *p. 185*	Excellent	100–250	4,000–8,000	Good	Excellent	Good	Excellent	Good	Very Good

[1]**Total N**—Total N from all plant. Grasses not considered N source. [2]**N Scavenger**—Ability to take up/store excess nitrogen.
[3]**Soil Builder**—Organic matter yield and soil structure improvement. [4]**Erosion Fighter**—Soil-holding ability of roots and total plant.
[5]**Good Grazing**—Production, nutritional quality and palatability. Feeding pure legumes can cause bloat.

○=Poor; ◔=Fair; ◑=Good; ◕=Very Good; ●=Excellent

Chart 2 **PERFORMANCE AND ROLES** continued

Group	Species	Lasting Residue[1]	Duration[2]	Harvest Value[3] F*	Harvest Value[3] S*	Cash Crop Interseed[4]	Comments
NONLEGUMES	Annual ryegrass	◕	◕	◑	◔	●	Heavy N and $H_2$0 user; cutting boosts dry matter significantly.
NONLEGUMES	Barley	●	◑	◕	◑	◕	Tolerates moderately alkaline conditions but does poorly in acid soil < pH 6.0.
NONLEGUMES	Oats	◑	◔	◑	◑	●	Prone to lodging in N-rich soil.
NONLEGUMES	Rye	●	◕	◔	◔	◕	Tolerates triazine herbicides.
NONLEGUMES	Wheat	◕	◕	◑	◕	◔	Heavy N and $H_2$0 user in spring.
NONLEGUMES	Buckwheat	○	◔	○	◔	◕	Summer smother crop; breaks down quickly.
NONLEGUMES	Sorghum-sudangrass	◕	●	●	○	○	Mid-season cutting increases yield & root penetration.
BRASSICAS	Mustards	◔	◑	○	◔	○	Suppresses nematodes and weeds.
BRASSICAS	Radish	◔	◑	◕	◔	◔	Good N scavenging and weed control; N released rapidly.
BRASSICAS	Rapeseed	◑	◕	◔	●	○	Suppresses *Rhizoctonia.*
LEGUMES	Berseem clover	◑	●	●	◕	◑	Very flexible cover crop, green manure, forage.
LEGUMES	Cowpeas	◔	●	◑	◑	◑	Season length, habit vary by cultivar.
LEGUMES	Crimson clover	◑	◔	●	◕	●	Established easily, grows quickly if planted early in fall; matures early in spring.
LEGUMES	Field peas	◔	◑	●	◕	●	Biomass breaks down quickly.
LEGUMES	Hairy vetch	◔	◕	◔	◕	◑	Bi-culture with small grain expands seasonal adaptability.
LEGUMES	Medics	◑	◕	◑	◑	◑	Use annual medics for interseeding.
LEGUMES	Red clover	◔	◑	●	◕	●	Excellent forage, easily established; widely adapted.
LEGUMES	Subterranean clover	◕	◕	◕	○	●	Strong seedlings, quick to nodulate.
LEGUMES	Sweetclovers	◕	◕	◕	◑	◑	Tall stalks, deep roots in second year.
LEGUMES	White clover	◔	●	◕	◑	◕	Persistent after first year.
LEGUMES	Woollypod vetch	◔	◕	◔	◕	◑	Reseeds poorly if mowed within 2 months of seeddrop; overgrazing can be toxic.

[1]**Lasting Residue**—Rates how long the killed residue remains on the surface. [2]**Duration**—Length of vegetative stage. [3]**Harvest Value**—Economic value as a forage (F) or as seed (S) or grain. [4]**Cash Crop Interseed**—Rates how well the cover crop will perform with an appropriate companion crop.

○ =Poor; ◔ =Fair; ◑ =Good; ◕ =Very Good; ● =Excellent

Chart 3A **CULTURAL TRAITS**

Group	Species	Aliases	Type[1]	Hardy through Zone[2]	Tolerances: heat	drought	shade	flood	low fert	Habit[3]	pH (Pref.)	Best Established[4]	Min. Germin. Temp.
NONLEGUMES	Annual ryegrass *p. 74*	Italian ryegrass	WA	6	Fair	Fair	Very Good	Very Good	Fair	U	6.0–7.0	ESp, LSu, EF, F	40F
NONLEGUMES	Barley *p. 77*		WA	7	Very Good	Very Good	Good	Fair	Very Good	U	6.0–8.5	F, W, Sp	38F
NONLEGUMES	Oats *p. 93*	spring oats	CSA	8	Fair	Fair	Fair	Good	Good	U	4.5–7.5	LSu, ESp W in 8+	38F
NONLEGUMES	Rye *p. 98*	winter, cereal, or grain rye	CSA	3	Good	Very Good	Very Good	Good	Excellent	U	5.0–7.0	LSu, F	34F
NONLEGUMES	Wheat *p. 111*		WA	4	Good	Good	Good	Poor	Good	U	6.0–7.5	LSu, F	38F
NONLEGUMES	Buckwheat *p. 90*		SA	NFT	Good	Poor	Fair	Fair	Fair	U/SU SU	5.0–7.0	Sp to LSu	50F
NONLEGUMES	Sorghum-sudan. *p. 106*	Sudax	SA	NFT	Excellent	Excellent	Good	Good	Good	U	6.0–7.0	LSp, ES	65F
BRASSICAS	Mustards *p.81*	brown, oriental white, yellow	WA, CSA	7	Good	Very Good	Good	Fair	Fair	U	5.5–7.5	Sp, LSu	40F
BRASSICAS	Radish *p. 81*	oilseed, Daikon, forage radish	CSA	6	Good	Fair	Good	Fair	Fair	U	6.0–7.5	Sp, LSu, EF	45F
BRASSICAS	Rapeseed *p. 81*	rape, canola	WA	7	Fair	Good	Good	Fair	Fair	U	5.5–8	F, Sp	41F
LEGUMES	Berseem clover *p. 118*	BIGBEE, multicut	SA, WA	7	Very Good	Good	Very Good	Good	Good	U/SU SU	6.2–7.0	ESp, EF	42F
LEGUMES	Cowpeas *p. 125*	crowder peas, southern peas	SA	NFT	Excellent	Very Good	Good	Fair	Excellent	SU/C	5.5–6.5	ESu	58F
LEGUMES	Crimson clover *p. 130*		WA, SA	7	Good	Fair	Very Good	Fair	Good	U/SU	5.5–7.0	LSu/ESu	
LEGUMES	Field peas *p. 135*	winter peas, black peas	WA	7	Fair	Good	Fair	Fair	Fair	C	6.0–7.0	F, ESp	41F
LEGUMES	Hairy vetch *p. 142*	winter vetch	WA,CSA	4	Fair	Good	Good	Fair	Fair	C	5.5–7.5	EF, ESp	60F
LEGUMES	Medics *p. 152*		SP, SA	4/7	Excellent	Very Good	Very Good	Fair	Good	P/Su	6.0–7.0	EF, ESp, ES	45F
LEGUMES	Red clover *p. 159*		SP, B	4	Fair	Fair	Very Good	Good	Fair	U	6.2–7.0	LSu; ESp	41F
LEGUMES	Subterranean cl. *p. 164*	subclover	CSA	7	Good	Very Good	Very Good	Good	Excellent	P/SP	5.5–7.0	LSu, EF	38F
LEGUMES	Sweetclovers *p. 171*		B, SA	4	Very Good	Excellent	Fair	Fair	Excellent	U	6.5–7.5	Sp/S	42F
LEGUMES	White clover *p. 179*	white dutch ladino	LP, WA	4	Good	Good	Very Good	Very Good	Good	P/SU	6.0–7.0	LW, E to LSp, EF	40F
LEGUMES	Woollypod vetch *p. 185*	Lana	CSA	7	Very Good	Very Good	Good	Good	Very Good	SP/C	6.0–8.0	F	

[1]B=Biennial; CSA=Cool season annual; LP=Long-lived perennial; SA=Summer annual; SP=Short-lived perennial; WA=Winter annual
[2]See USDA Hardiness Zone Map, inside front cover. NFT=Not frost tolerant. [3]C=Climbing; U=Upright; P=Prostrate; SP=Semi-prostrate; SU=Semi-upright. [4]E=Early; M=Mid; L=Late; F=Fall; Sp=Spring; Su=Summer; W=Winter

○ =Poor; ◔ =Fair; ◑ =Good; ◕ =Very Good; ● =Excellent

Chart 3B **PLANTING**

	Species	Depth	Seeding Rate					Cost ($/lb.)[1]	Cost/A (median)[2]		Inoc. Type	Reseeds[3]
			Drilled		Broadcast							
			lb./A	bu/A	lb./A	bu/A	oz./100 ft^2		drilled	broadcast		
NONLEGUMES	Annual ryegrass	0–1/2	10–20	.4–.8	20–30	.8–1.25	1	.70–1.30	12	24		U
	Barley	3/4–2	50–100	1–2	80–125	1.6–2.5	3-5	.17–.37	20	27		S
	Oats	1/2–1 1/2	80–110	2.5–3.5	110–140	3.5–4.5	4–6	.13–.37	25	33		S
	Rye	3/4–2	60–120	1-2	90–160	1.5–3.0	4–6	.18–.50	25	35		S
	Wheat	1/2–1 1/2	60–120	1–2	60–150	1–2.5	3–6	.10–.30	18	22		S
	Buckwheat	1/2–1 1/2	48–70	1–1.4	50–90	1.2–1.5	3–4	.30–.75	32	38		R
	Sorghum-sudangrass	1/2–1 1/2	35	1	40–50	1–1.25	2	.40–1.00	26	34		S
BRASSICAS	Mustards	1/4–3/4	5–12		10–15		1	1.50–3.00	16	24		U
	Radish	1/4–1/2	8–13		10–20		1	1.50–2.50	22	32		S
	Rapeseed	1/4–3/4	5–10		8–14		1	1.00–2.00	11	16		S
LEGUMES	Berseem clover	1/4–1/2	8–12		15–20		2	1.70–2.50	22	39	crimson, berseem	N
	Cowpeas	1–1 1/2	30–90		70–120		5	.85–1.50	71	113	cowpeas, lespedeza	S
	Crimson clover	1/4–1/2	15-20		22–30		2–3	1.25–2.00	27	40	crimson, berseem	U
	Field peas	1 1/2–3	50–80		90–100		4	.61–1.20	50	75	pea, vetch	S
	Hairy vetch	1/2-1 1/2	15–20		25–40		2	1.70–2.50	35	65	pea, vetch	S
	Medics	1/4–1/2	8–22		12–26		2/3	2.50–4.00	58	75	annual medics	R
	Red clover	1/4–1/2	8–10		10–12		3	1.40–3.30	23	28	red cl, wht cl	S
	Subterranean clover	1/4–1/2	10–20		20–30		3	2.50–3.50	45	75	clovers, sub, rose	U
	Sweetclovers	1/4–1.0	6–10		10–20		1.5	1.00–3.00	16	32	alfalfa, swt cl	U
	White clover	1/4–1/2	3–9		5–14		1.5	1.10–4.00	19	30	red cl, wht cl	R
	Woollypod vetch	1/2–1	10–30		30–60		2-3	1.25–1.60	30	65	pea, vetch	S

[1]Per pound in 50-lb. bags as of summer/fall 2006; To locate places to buy seed, see *Seed Suppliers* (p. 166).
[2]Mid-point price at mid-point rate, seed cost only. [3]**R**=Reliably; **U**=Usually; **S**=Sometimes; **N**=Never (reseeds).

Chart 4A **POTENTIAL ADVANTAGES**

		Soil Impact			Soil Ecology				Other		
	Species	subsoiler	free P&K	loosen topsoil	nematodes	disease	allelopathic	choke weeds	attract beneficials	bears traffic	short windows
NONLEGUMES	Annual ryegrass *p. 74*	Good	Good	Excellent	Good	Good	Good	Excellent	Fair	Excellent	Excellent
NONLEGUMES	Barley *p. 77*	Good	Good	Very Good	Fair	Good	Very Good	Very Good	Good	Good	Excellent
NONLEGUMES	Oats *p. 93*	Poor	Fair	Very Good	Poor	Good	Very Good	Excellent	Poor	Good	Excellent
NONLEGUMES	Rye *p. 98*	Fair	Very Good	Excellent	Good	Very Good	Excellent	Excellent	Fair	Very Good	Excellent
NONLEGUMES	Wheat *p. 111*	Good	Very Good	Very Good	Fair	Fair	Fair	Very Good	Fair	Good	Good
NONLEGUMES	Buckwheat *p. 90*	Poor	Excellent	Very Good	Fair	Poor	Very Good	Excellent	Excellent	Poor	Excellent
NONLEGUMES	Sorghum-sudangrass *p. 106*	Excellent	Good	Good	Very Good	Very Good	Excellent	Excellent	Good	Good	Excellent
BRASSICAS	Mustards *p.81*	Fair	Good	Very Good	Very Good	Very Good	Very Good	Very Good	Good	Good	Very Good
BRASSICAS	Radish *p. 81*	Excellent	Very Good	Good	Very Good	Good	Very Good	Excellent	Fair	Fair	Very Good
BRASSICAS	Rapeseed *p. 81*	Good	Fair	Good	Very Good	Good	Very Good	Good	Good	Fair	Good
LEGUMES	Berseem clover *p. 118*	Fair	Very Good	Very Good	Poor	Poor	Fair	Very Good	Good	Fair	Very Good
LEGUMES	Cowpeas *p. 125*	Good	Good	Very Good	Poor	Poor	Poor	Excellent	Very Good	Poor	Excellent
LEGUMES	Crimson clover *p. 130*	Fair	Good	Good	Fair	Good	Fair	Good	Very Good	Fair	Good
LEGUMES	Field peas *p. 135*	Fair	Fair	Very Good	Good	Very Good	Fair	Very Good	Very Good	Fair	Very Good
LEGUMES	Hairy vetch *p. 142*	Good	Good	Very Good	Fair	Good	Good	Very Good	Excellent	Poor	Poor
LEGUMES	Medics *p. 152*	Good	Fair	Fair	Good	Good	Fair	Very Good	Fair	Fair	Excellent
LEGUMES	Red clover *p. 159*	Very Good	Very Good	Good	Fair	Fair	Good	Good	Very Good	Good	Good
LEGUMES	Subterranean clover *p. 164*	Poor	Fair	Good	Fair	Fair	Very Good	Excellent	Very Good	Very Good	Very Good
LEGUMES	Sweetclovers *p. 171*	Excellent	Excellent	Excellent	Fair	Fair	Fair	Good	Very Good	Good	Poor
LEGUMES	White clover *p. 179*	Fair	Fair	Very Good	Poor	Poor	Good	Very Good	Good	Excellent	Good
LEGUMES	Woollypod vetch *p. 185*	Very Good	Good	Very Good	Fair	Fair	Good	Excellent	Very Good	Fair	Good

○=Poor; ◔=Fair; ◑=Good; ◕=Very Good; ●=Excellent

Chart 4B **POTENTIAL DISADVANTAGES**

Note change in symbols ○ = problem ● = not a problem

Group	Species	Increase Pest Risks: weed potential	Increase Pest Risks: insects/ nematodes	Increase Pest Risks: crop disease	Management Challenges: hinder crops	Management Challenges: establish	Management Challenges: till-kill	Management Challenges: mow-kill	Management Challenges: mature incorp.	Comments Pro/Con
NONLEGUMES	Annual ryegrass	○ [1]	◕	◕	◑	●	●	●	◑	If mowing, leave 3-4" to ensure regrowth.
	Barley	◔	◔	◔	◑	●	●	●	○	Can be harder than rye to incorporate when mature.
	Oats	●	◑	◕	◑	●	●	◔	◑	Cleaned, bin-run seed will suffice.
	Rye	◔	◑	◕	◔	◕	◕	●	○	Can become a weed if tilled at wrong stage.
	Wheat	◑	◔	◔	◑	●	●	◕	◑	Absorbs N and H_2O heavily during stem growth, so kill before then.
	Buckwheat	○	◕	●	●	●	●	●	●	Buckwheat sets seed quickly.
	Sorghum-sudangrass	◑	◕	●	◔	●	◕	◕	◔	Mature, frost-killed plants become quite woody.
BRASSICAS	Mustards	◔	◕	●	◑	●	●	◔	●	Great biofumigation potential; winterkills at 25° F.
	Radish	◑	◕	●	●	●	●	●	●	Winter kills at 25° F; cultivars vary widely.
	Rapeseed	◔	◔	●	◑	●	◑	◔	◕	Canola has less biotoxic activity than rape.
LEGUMES	Berseem clover	●	◑	◕	●	●	◔	◔	◕	Multiple cuttings needed to achieve maximum N.
	Cowpeas	●	◑	◕	●	●	●	●	●	Some cultivars, nematode resistant.
	Crimson clover	◑	○	◕	●	◕	◕	◕	◕	Good for underseeding, easy to kill by tillage or mowing.
	Field peas	●	◑	◔	●	●	●	●	◕	Susceptible to *sclerotinia* in East.
	Hairy vetch	◑	◑	●	●	◑	◔	●	◑	Tolerates low fertility, wide pH range, cold or fluctuating winters.
	Medics	◑	◔	●	◕	◕	◔	◕	◕	Perennials easily become weedy.
	Red clover	◑	◔	◕	●	◕	◑	◔	◕	Grows best where corn grows well.
	Subterranean clover	◑	○	◑	◑	●	◔	○	◕	Cultivars vary greatly.
	Sweetclovers	◔	◔	●	◑	●	◑	◕	◔	Hard seed possible problem; does not tolerate seeding year mowing
	White clover	◑	◑	◕	◔	◕	○	◑	◕	Can be invasive; survives tillage.
	Woollypod vetch	◑	◑	◔	◑	◑	◕	●	◔	Hard seed can be problematic; resident vegetation eventually displaces.

[1]Note change in symbols, this page only: ○ = problem. ◔ = Could be a moderate problem. ◑ = Could be a minor problem. ◕ = Occasionally a minor problem. ● = not a problem

grass cover crop also to serve as a pasture. Some varieties tolerate heat fairly well and can persist for several years under sound grazing practices that allow the grass to reseed. As a hay option, annual ryegrass can provide 2,000 to 6,000 pounds of dry forage per acre, depending on moisture and fertility levels (422). For highest quality hay, cut no later than the early bloom stage and consider growing it with a legume. When using ryegrass for grass waterways and conservation strips on highly erodible slopes, applying 3,000 to 4,000 pounds of straw per acre after seeding at medium to high rates can help keep soil and seed in place until the stand establishes (422).

Management Cautions

Ryegrass is a heavy user of moisture and N. It performs poorly during drought or long periods of high or low temperature, and in low-fertility soils. It can compete heavily for soil moisture when used as living mulch. It also can become a weed problem (361).

COMPARATIVE NOTES

- Establishes faster than perennial ryegrass but is less cold-hardy
- Less persistent but easier to incorporate than perennial ryegrass
- About half as expensive as perennial ryegrass
- In Southern USA, annual is more adapted and produces much greater biomass

Cultivars. Many varieties are widely available. Improved cultivars should be considered if growing for forage. There are diploid (2n = 14 chromosomes) and tetraploid (4n = 28 chromosomes) cultivars. Tetraploids produce larger plants with wider leaves and mature later.

Seed sources. See *Seed Suppliers* (p. 195).

BARLEY

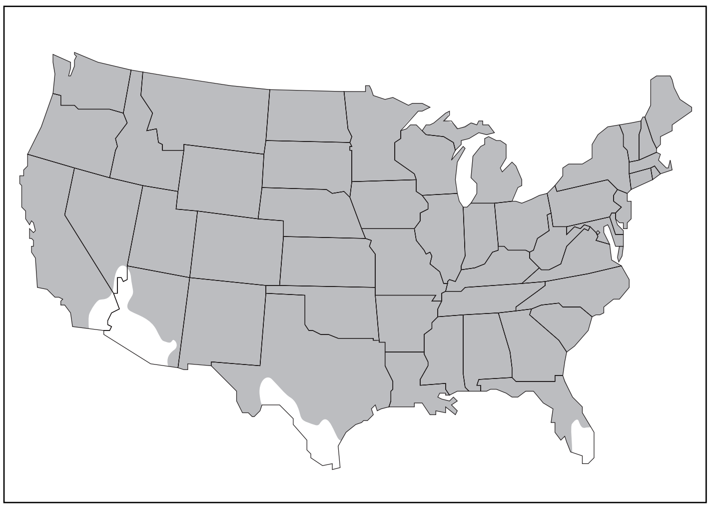
Hordeum vulgare

Type: cool season annual cereal grain

Roles: prevent erosion, suppress weeds, scavenge excess nutrients, add organic matter

Mix with: annual legumes, ryegrass or other small grains

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



Inexpensive and easy to grow, barley provides exceptional erosion control and weed suppression in semi-arid regions and in light soils. It also can fill short rotation niches or serve as a topsoil-protecting crop during droughty conditions in any region. It is more salt tolerant than other small grains and can sop up excess subsoil moisture to help prevent saline seep formation (136).

It's a fine choice for reclaiming overworked, weedy or eroded fields, or as part of a cover crop mix for improving soil tilth and nutrient cycling in perennial cropping systems in Hardiness Zone 8 or warmer.

Barley prefers cool, dry growing areas. As a spring cover crop, it can be grown farther north than any other cereal grain, largely because of its short growing period. It also can produce more biomass in a shorter time than any other cereal crop (273).

BENEFITS

Erosion control. Use barley as an overwintering cover crop for erosion control in Zone 8 and warmer, including much of California, western Oregon and western Washington. It's well-suited for vineyards and orchards, or as part of a mixed seeding.

A fast-growing barley can be grown farther north and produce more biomass in a shorter time than any other cereal grain.

As a winter annual, barley develops a deep, fibrous root system. The roots can reach as deep as 6.5 feet. As a spring crop, barley has a comparatively shallow root system but holds soil strongly to minimize erosion during droughty conditions (71).

Nutrient recycler. Barley can scavenge significant amounts of nitrogen. It captured 32 lb. N/A as a winter cover crop following a stand of fava beans (*Vicia faba*) in a California study, compared with 20 lb./A for annual ryegrass. A barley cover crop reduced soil N an average of 64 percent at eight sites throughout North America that had received an average of 107 lb. N/A (265). Intercropping barley with field peas (*Pisum sativum*) can increase the amount of N absorbed by barley and returned to the soil in barley residue, other studies show (215, 218). Barley improves P and K cycling if the residue isn't removed.

Weed suppressor. Quick to establish, barley outcompetes weeds largely by absorbing soil moisture during its early growing stages. It also shades out weeds and releases allelopathic chemicals that help suppress them.

Tilth-improving organic matter. Barley is a quick source of abundant biomass that, along with its thick root system, can improve soil structure and water infiltration (273, 445). In California cropping systems, cultivars such as UC476 or COSINA can produce as much as 12,900 lb. biomass/A.

Nurse crop. Barley has an upright posture and relatively open canopy that makes it a fine nurse crop for establishing a forage or legume stand. Less competitive than other small grains, barley also uses less water than other covers crops. In weedy fields, wait to broadcast the forage or legume until after you've mechanically weeded barley at the four- or five-leaf stage to reduce weed competition.

As an inexpensive, easy-to-kill companion crop, barley can protect sugarbeet seedlings during their first two months while also serving as a soil protectant during droughty periods (details below).

Pest suppression. Barley can reduce incidence of leafhoppers, aphids, armyworms, root-knot nematodes and other pests, a number of studies suggest.

MANAGEMENT

Establishment & Fieldwork

Barley establishes readily in prepared seedbeds, and can also be successfully no-tilled. It prefers adequate but not excessive moisture and does poorly in waterlogged soils. It grows best in well-drained, fertile loams or light, clay soils in areas having cool, dry, mild winters. It also does well on light, droughty soils and tolerates somewhat alkaline soils better than other cereal crops.

With many varieties of barley to choose from, be sure to select a regionally adapted one. Many are well-adapted to high altitudes and cold, short growing seasons.

Spring annual use. Drill at 50 to 100 lb./A (1 to 2 bushels) from 3/4 to 2 inches deep into a prepared seedbed, or no-till using the same seeding rate.

If broadcasting, prepare the seedbed with at least a light field cultivation. Sow 80 to 125 lb./A (1.5 to 2.5 bushels) and harrow, cultipack or disk lightly to cover. Use a lower rate (25 to 50 pounds) if overseeding as a companion crop or a higher rate (140 pounds) for very weedy fields. When broadcasting, consider seeding half in one direction, then the rest in a perpendicular direction for better coverage (71).

Winter annual use. Barley can be used as a winter annual cover crop wherever it is grown as a winter grain crop. It is less winter-hardy than rye. In Zone 8 or warmer, it grows throughout the winter if planted from September through February. Plantings before November 1 generally fare best, largely due to warmer soil conditions.

Expect mixed results if trying to use barley as a self-reseeding cover crop.

Mixed seedings. Barley works well in mixtures with other grasses or legumes. In low-fertility soils or where you're trying to minimize tie-up of soil nitrogen, growing barley with one or more legumes can be helpful. Your seeding cost per pound will increase, but the reduced seeding rate can offset some of this. A short-season Canadian field pea would be a good companion, or try an oat/barley/pea mix, suggests organic farmer Jack Lazor, Westfield, Vt.

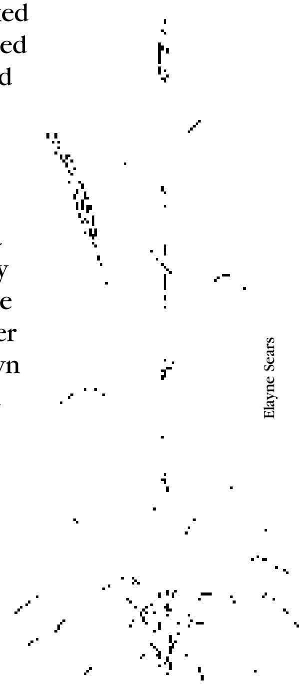
In northern California, Phil LaRocca (LaRocca Vineyards, Forest Ranch, Calif.) lightly disks his upper vineyard's soil before broadcasting a mix of barley, fescue, brome, LANA vetch, and crimson, red and subterranean clovers, usually during October. He seeds at 30 to 35 lb./A, with 10 to 20 percent being barley. "I've always added more barley to the seeding rate than recommended. More is better, especially with barley, if you want biomass and weed suppression," he says.

After broadcasting, LaRocca covers erosion-prone areas with 2 tons of rice straw per acre, which is "cheaper than oat straw here and has fewer weed seeds," he notes. "The straw decomposes quickly and holds seed and soil well." Besides contributing to soil humus (as the cover crop also does), the straw helps keep the seedbed warm and moist. That can be very helpful in LaRocca's upper vineyard, where it sometimes snows in winter.

In his other, less-erodible vineyard, LaRocca disks up the cover vegetation, then runs a harrow quickly on top of the disked alleyways to set a seedbed before broadcasting and cultipacking a similar mix of cover crops.

Field Management

Although barley absorbs a lot of water in its early stages, it uses moisture more efficiently than other cereals and can be grown without irrigation in some situations. About half of the commercial barley acreage in dryland areas is irrigated, however. California cropping systems that include barley tend to be irrigated as well. Low seeding rates won't necessarily conserve moisture, as vegetative growth often increases.



Elayne Sears

BARLEY (Hordeum vulgare)

LaRocca hasn't had any moisture problems or grape-yield concerns from growing barley or other cover crops, even in the 40 percent of his upper vineyard that isn't furrow-irrigated. "Once your vines are established, their root system is deeper and much more competitive than a typical cover crop's root system," he observes.

Mowing can postpone and prolong barley flowering, as with other cereal grains. As a spring cover, barley puts on biomass quickly, so you can kill it in plenty of time for seeding a following crop. If you want barley to reseed, don't mow until most of the stand has headed and seed is about to fall off.

To encourage reseeding of his cover mix, Phil LaRocca allows every other row in his upper vineyard to go to seed, then disks it down. That lets him skip reseeding some blocks.

If you're concerned about barley reseeding or crop competition when intercropped, however, plant a lighter stand, suggests Alan Brutlag, Wendell, Minn. During droughty conditions, he broadcasts

25 to 30 pounds of barley per acre as a soil-protective companion crop for sugarbeet seedlings. The low-density stand is easy to stunt or kill a month later with the combination of herbicides and crop oil that he uses for weed control in his sugarbeets. Another control option is a single application of an herbicide labeled for grass control.

Killing

Kill barley with a grass herbicide in late spring, or by rolling disking or mowing at the mid- to late-bloom stage but before it starts setting seed.

If plant-parasitic nematodes have been a problem, incorporate overwintered barley early in spring, before warm temperatures encourage nematode populations.

Pest Management

Annual weeds and lodging can occur when growing barley in high-fertility soils, although these wouldn't pose problems in a barley cover crop. Despite their less dense canopy, six-rowed varieties tend to be taller and more competitive against weeds than two-rowed varieties. If you're considering a grain option, harrowing or hoeing just before barley emergence could reduce weeds that already have sprouted.

Barley produces alkaloids that have been shown to inhibit germination and growth of white mustard (247). These exudates also protect barley plants from fungus, armyworm larvae, bacteria and aphids (248, 455).

Barley seems to reduce the incidence of grape leafhoppers in vineyards and increase levels of beneficial spiders, one California grower observed (211). Growing high-biomass cover crops such as barley or rye increased populations of centipedes, predator mites and other important predators, independent of tillage system used, a study in the Pacific Northwest found (444).

Cutworms and other small grain pests can be occasional problems. Some perennial crop growers in California report increased incidence of gophers when growing cover crop mixes and try to minimize this by encouraging owl populations.

Avoid seeding in cold, damp soils, which makes barley more prone to fungus and disease. Assuming adequate soil moisture, shallow seeding can hasten emergence and lessen incidence of root rot disease, if this has been a problem in your area (397). Varieties resistant to leaf diseases are available. Two-rowed varieties are more resistant to leaf rust and mildew. Also avoid planting barley after wheat.

If nematodes are likely to be a problem, plant late in fall or during winter to avoid warm-season growth and incorporate early in spring in Zone 8 and warmer. Barley can be a host for a nematode species (*Meloidogyne javanica*) that adversely affects Thompson seedless grapes.

Barley drastically reduced root-knot nematode (*Meloidogyne hapla* M. Chitwood) populations and increased marketable carrot yields by at least seventeen-fold in a Quebec study comparing three-year rotations (242).

Other Options

Barley can be grazed lightly in winter or spring or cut for hay/haylage (191). It has greater forage nutritive value than oats, wheat or triticale. It also can be grown as a specialty grain for malting, soups, bread and other uses. As a feed grain (in a hog ration, for example), it can replace some costlier corn.

COMPARATIVE NOTES

- Barley tillers more than oats and also is more drought-tolerant, but oats generally perform better as a companion crop or winterkilled nurse crop because they are less competitive than barley (397).
- Barley tolerates alkaline soils better than any other cereal.
- Winter cultivars are less winterhardy than winter wheat, triticale or cereal rye.

Cultivars. Many commercial varieties are available. Look for low-cost, regionally adapted cultivars with at least 95-percent germination.

Six-rowed cultivars are better for overseeding, and are more heat- and drought-tolerant. Two-rowed types have more symmetrical kernels and are more disease-resistant (e.g. leaf rust and mildew) than six-rowed types, in which two-thirds of the lateral rows of the spike are smaller and twisted.

Seed sources. See *Seed Suppliers* (p. 195).

BRASSICAS AND MUSTARDS

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

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

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

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

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

RAPE or CANOLA (Brassica rapa)

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

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

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

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

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

BENEFITS

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

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

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

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

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

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

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

Disease

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

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

Nematodes

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

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

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

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

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

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

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

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

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

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

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

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

Weeds

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

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

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

In Maryland and Pennsylvania, forage radish is planted in late August and dies with the first hard frost (usually December). The living cover crop and the decomposing residues suppress winter annual weeds until April and result in a mellow, weed-free seedbed into which corn can be no-tilled without any preplant herbicides. Preliminary data show summer suppression of horseweed but not lambsquarters, pigweed, or green foxtail (432).

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

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

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

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

SPECIES

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

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

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

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

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

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

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

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

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

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

In Washington, a wheat/mustard-potato system shows promise for reducing or eliminating the soil fumigant metam sodium. White mustard and oriental mustard both suppressed potato early dying (*Verticillium dahliae*) and resulted in tuber yields equivalent to fumigated soils, while also improving infiltration, all at a cost savings of about $66/acre (see www.plantmanagementnet work.org/pub/cm/research/2003/mustard/).

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

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

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

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

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

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

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

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

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

AGRONOMIC SYSTEMS

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

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

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

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

Mustard Mix Manages Nematodes in Potato/Wheat System

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

—Andy Clark

MANAGEMENT

Establishment

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

Winter hardiness

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

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

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

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

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

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

Winter vs. spring annual use

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

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

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

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

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

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

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

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

Killing

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

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

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

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

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

Seed and Planting

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

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

Nutrient Management

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

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

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

COMPARATIVE NOTES

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

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

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

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

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

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

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

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

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

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

BUCKWHEAT

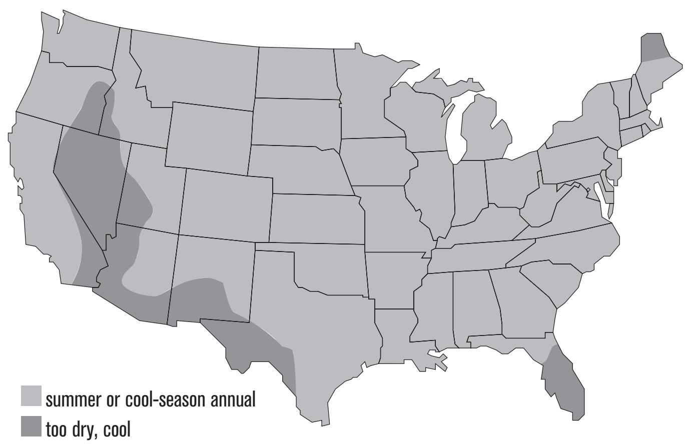
Fagopyrum esculentum

Type: summer or cool-season annual broadleaf grain

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

Mix with: sorghum-sudangrass hybrids, sunn hemp

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



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

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

BENEFITS

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

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

COMPARATIVE NOTES

- Buckwheat has only about half the root mass as a percent of total biomass as small grains (355). Its succulent stems break down quickly, leaving soils loose and vulnerable to erosion, particularly after tillage. Plant a soil-holding crop as soon as possible.
- Buckwheat is nearly three times as effective as barley in extracting phosphorus, and more than 10 times more effective than rye—the poorest P scavenger of the cereal grains (355).
- As a cash crop, buckwheat uses only half as much soil moisture as soybeans (299).

Seed sources. See *Seed Suppliers* (p. 195).

OATS

Avena sativa

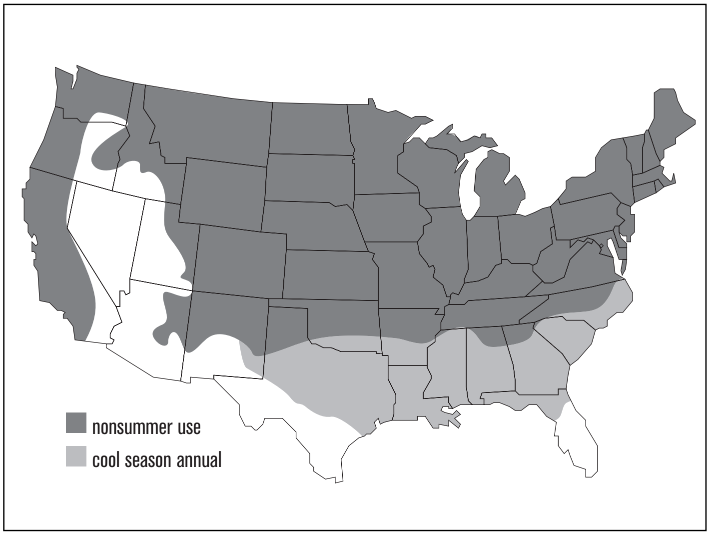
Also called: spring oats

Type: cool season annual cereal

Roles: suppress weeds, prevent erosion, scavenge excess nutrients, add biomass, nurse crop

Mix with: clover, pea, vetch, other legumes or other small grains

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



If you need a low-cost, reliable fall cover that winterkills in Hardiness Zone 6 and colder and much of Zone 7, look no further. Oats provide quick, weed-suppressing biomass, take up excess soil nutrients and can improve the productivity of legumes when planted in mixtures. The cover's fibrous root system also holds soil during cool-weather gaps in rotations, and the ground cover provides a mellow mulch before low-till or no-till crops.

An upright, annual grass, oats thrive under cool, moist conditions on well-drained soil. Plants can reach heights in excess of 4 feet. Stands generally fare poorly in hot, dry weather.

BENEFITS

You can depend on oats as a versatile, quick-growing cover for many benefits:

Affordable biomass. With good growing conditions and sound management (including timely planting), expect 2,000 to 4,000 pounds of dry matter per acre from late-summer/early fall-seeded oats and up to 8,000 pounds per acre from spring stands.

Nutrient catch crop. Oats take up excess N and small amounts of P and K when planted early enough. Late-summer plantings can absorb as much as 77 lb. N/A in an eight- to ten-week period, studies in the Northeast and Midwest have shown (313, 329).

Where the plant winterkills, some farmers use oats as a nitrogen catch crop after summer legume plowdowns, to hold some N over winter without needing to kill the cover in spring. Some of the N in the winterkilled oats may still be lost by spring, either through denitrification into the atmosphere or by leaching from the soil profile. Consider mixing oats with an overwintering legume if your objective is to maximize N contribution to the next crop.

Oats are a reliable, low-cost cover that winterkill in Zone 6 and much of Zone 7.

Smother crop. Quick to germinate, oats are a great smother crop that outcompetes weeds and also provides allelopathic residue that can hinder germination of many weeds—and some crops (see below)—for a few weeks. Reduce crop suppression concerns by waiting two- to three weeks after killing oats before planting a subsequent crop.

Fall legume nurse crop. Oats have few equals as a legume nurse crop or companion crop. They can increase the fertilizer replacement value of legumes. Adding about 35 to 75 lb. oats/A to the seeding mix helps slow-establishing legumes such as hairy vetch, clovers or winter peas, while increasing biomass. It also helps reduce fall weeds. The oats will winterkill in many areas while improving the legume's winter survival.

Spring green manure or companion crop. Spring-seeded with a legume, oats can provide hay or grain and excellent straw in the Northern U.S., while the legume remains as a summer—or even later—cover. There's also a haylage option with a fast-growing legume if you harvest when oats are in the dough stage. The oats will increase the dry matter yield and boost the total protein, but, because of its relatively high nitrogen content, could pose a nitrate-poisoning threat to livestock, especially if you delay harvesting until oats are nearing the flowering stage.

The climbing growth habit of some viny legumes such as vetch can contribute to lodging and make oat grain harvest difficult. If you're growing the legume for seed, the oats can serve as a natural trellis that eases combining.

MANAGEMENT

Establishment & Fieldwork

Time seeding to allow at least six to 10 weeks of cool-season growth. Moderately fertile soil gives the best stands.

Late-summer/early-fall planting. For a winterkilled cover, spring oats usually are seeded in late summer or early fall in Zone 7 or colder. Broadcasting or overseeding will give the best results for the least cost, unless seeding into heavy residue. Cleaned, bin-run seed will suffice.

If broadcasting and you want a thick winterkilled mulch, seed at the highest locally recommended rate (probably 3 to 4 bushels per acre) at least 40 to 60 days before your area's first killing frost. Assuming adequate moisture for quick germination, the stand should provide some soil-protecting, weed-suppressing mulch.

Disk lightly to incorporate. In many regions, you'll have the option of letting it winterkill or sending in cattle for some fall grazing.

If seeding oats as a fall nurse crop for a legume, a low rate (1 to 2 bushels per acre) works well.

If drilling oats, seed at 2 to 3 bushels per acre $1/2$ to 1 inch deep, or $1\,1/2$ inches when growing grain you plan to harrow for weed control.

Shallow seeding in moist soil provides rapid emergence and reduces incidence of root rot disease.

Timing is critical when you want plenty of biomass or a thick ground cover. As a winter cover following soybeans in the Northeast or Midwest, overseeding spring oats at the leaf-yellowing or early leaf-drop stage (and with little residue present) can give a combined ground cover as high as 80 percent through early winter (200). If you wait until closer to or after soybean harvest, however, you'll obtain much less oat biomass to help retain bean residue, Iowa and Pennsylvania studies have shown.

Delaying planting by as little as two weeks in late summer also can reduce the cover's effectiveness as a spring weed fighter, a study in upstate New York showed. By spring, oat plots that had been planted on August 25 had 39 percent fewer weed plants and one-seventh the weed biomass of control plots with no oat cover, while oats planted two weeks later had just 10 percent fewer weed plants in spring and 81 percent of the weed biomass of control plots (329, 330).

No-hassle fieldwork. As a winterkilled cover, just light disking in spring will break up the brittle oat residue. That exposes enough soil for warming and timely planting. Or, no-till directly into the mulch, as the residue will decompose readily early in the season.

Winter planting. As a fall or winter cover crop in Zone 8 or warmer, seed oats at low to medium rates. You can kill winter-planted oats with spring plowing, or with herbicides in reduced-tillage systems.

Spring planting. Seeding rate depends on your intended use: medium to high rates for a spring green manure and weed suppressor, low rates for mixtures or as a legume companion crop. Higher rates may be needed for wet soils or thicker ground cover. Excessive fertility can encourage lodging, but if you're growing oats just for its cover value, that can be an added benefit for weed suppression and moisture conservation.

Easy to kill. Oats will winterkill in most of zone 7 or colder. Otherwise, kill by mowing or spraying soon after the vegetative stage, such as the milk or soft dough stage. In no-till systems, rolling/crimping will also work (best at dough stage or later). See *Cover Crop Roller Design Holds Promise For No-Tillers,* p. 146. If speed of spring soil-warming is not an issue, you can spray or mow the oats and leave on the soil surface for mulch.

OATS (Avena sativa)

If you want to incorporate the stand, allow at least two to three weeks before planting the next crop.

Killing too early reduces the biomass potential and you could see some regrowth if killing mechanically. But waiting too long could make tillage of the heavier growth more difficult in a conventional tillage system and could deplete soil moisture needed for the next crop. Timely killing also is important because mature oat stands can tie up nitrogen.

Pest Management

Allelopathic (naturally occurring herbicidal) compounds in oat roots and residue can hinder weed growth for a few weeks. These compounds also can slow germination or root growth of some subsequent crops, such as lettuce, cress, timothy, rice, wheat and peas. Minimize this effect by waiting three weeks after oat killing before seeding a susceptible crop, or by following with an alternate crop. Rotary hoeing or other pre-emerge mechanical weeding of solo-seeded oats can improve annual broadleaf control.

Oats are **less prone to insect problems** than wheat or barley. If you're growing oats for grain or forage, armyworms, various grain aphids and mites, wireworms, cutworms, thrips, leafhoppers, grubs and billbugs could present occasional problems.

Oats, Rye Feed Soil in Corn/Bean Rotation

Bryan and Donna Davis like what cover crops have done for their corn/soybean rotation. They use less grass herbicide, have applied insecticides only once in the last six years, and they have seen organic matter content almost double from less than 2% to almost 4%.

Rye and oats are the cover crop mainstays on the nearly 1,000 acres they farm near Grinnell, Iowa. Bryan and Donna purchased the farm—in the family since 1929—in 1987 and almost immediately put most of the operation under 100% no-till, a system they had experimented with over the years. They now till some acres and are also in the process of transitioning 300 acres to organic.

Moving 1/3 of their acreage toward organic seems the logical culmination of the Davis' makeover of their farm that started with a desire to "get away from the chemicals." That was what motivated them to start using cover crops to feed the soil and help manage pests.

"We were trying to get away from the idea that every bug and weed must be exterminated. Rather, we need to 'manage' the system and tolerate some weed and insect pressure. It should be more of a balance," says Bryan.

Bryan and Donna are practitioners and proponents of "biological farming," a systems approach based on such principles as feeding the soil to keep it biologically active, reducing chemical inputs and paying attention to trace elements or micronutrients in order to maintain balance in the system. Cover crops play an integral role in this system.

They seed oats at 2-3 bu/A in spring or fall, depending on time and labor availability. Donna does most of the combining and planting, but even with a lot of acres for two people to manage, cover crops are a high priority on their schedule. Fall-seeded oats are planted after soybean harvest and "need rain on them soon after planting to get them started." They'll put on about a foot of growth before winterkilling, usually in December in their south-central Iowa conditions.

Spring oats are broadcast in mid or late March with a fertilizer cart and then rotary harrowed. If going back to corn, they seed at a heavier, 3.5 bu rate, expecting only about 5 or 6 weeks of growth before they work down the cover crop with a soil finisher and plant corn in early May. For soybeans, they either kill chemically and no-till the beans, or work down and seed conventionally.

They have managed rye in different ways over the years depending on its place in the rotation, but prefer to seed into killed or tilled rye rather than a living cover crop. They figure that they get about 35 lb. N from oats and up to 60 lb. from rye.

On their organic transition acres they are applying chicken manure (2 tons/A), and cover crops are crucial to sopping up excess nutrients and crowding out the weeds that crop up in response to the extra nutrients. They feel that their efforts to balance nutrients are also helping with weed control, because weeds feed on nutrient imbalances.

In addition to the increase in soil organic matter, attributed to cover crops and no-tillage, they've also seen improvements in soil moisture and infiltration. Fields that used to pond after heavy rains no longer do. Soybeans are weathering drought better, and corn stays green longer during a "more natural" drying down process.

"Our system takes more time and is more labor intensive, but if you look at the whole budget, we are doing much better now. We have cut our chemical costs dramatically, and have reduced fertility costs—in some fields—by ⅓ to ½," says Bryan. "With energy costs these days, you can't afford not to do this."

Davis is careful to note that this is not just about adding one component such as cover crops. "You need to address the whole system, not just one piece of the pie. To be able to have a sustaining system, you must work with the living system. Feed the soil and give it a roof over its head." Cover crops play a crucial role in that system.

—Andy Clark

Resistant oat varieties can minimize rusts, smuts and blights if they are a concern in your area or for your cropping system. Cover crops such as oats help reduce root-knot nematodes and vegetable crop diseases caused by *Rhizoctonia*, results of a producer study in South Carolina show (448), although brassicas are better. To reduce harmful nematodes that oats could encourage, avoid planting oats two years in a row or after nematode-susceptible small grains such as wheat, rye or triticale (71).

Other Options

There are many low-cost, regionally adapted and widely available oat varieties, so you have **hay, straw, forage or grain options**. Select for cultural and local considerations that best fit your intended uses. Day-length, stalk height, resistance to disease, dry matter yield, grain test weight and other traits may be important considerations. In the Deep South, fast-growing black oats (*Avena strigosa*) look promising as a weed-suppressive cover for soybeans. See *Up-and-Coming Cover Crops* (p. 191).

Aside from their value as a cover crop, oats are a great feed supplement, says grain and hog farmer Carmen Fernholz, Madison, Minn. A niche market for organic oats also could exist in your area, he observes.

Oats are more palatable than rye and easily overgrazed. If using controlled grazing in oat stands, watch for high protein levels, which can vary from 12 to 25 percent (434). The potassium level of oat hay also is sometimes very high and could cause metabolic problems in milking cows if it's the primary forage. Underseeding a legume enhances the forage option for oats by increasing the biomass (compared with solo-cropped oats) and providing nitrogen for a subsequent crop.

COMPARATIVE NOTES

- Fall brassicas grow faster, accumulate more N and may suppress weeds, nematodes and disease better than oats.
- Rye grows more in fall and early spring, absorbs more N and matures faster, but is harder to establish, to kill and to till than oats.
- As a legume companion/nurse crop, oats outperform most varieties of other cereal grains.
- Oats are more tolerant of wet soil than is barley, but require more moisture.

Seed sources. See *Seed Suppliers* (p. 195).

SORGHUM-SUDANGRASS HYBRIDS

Sorghum bicolor **x** *S. bicolor var. sudanese*

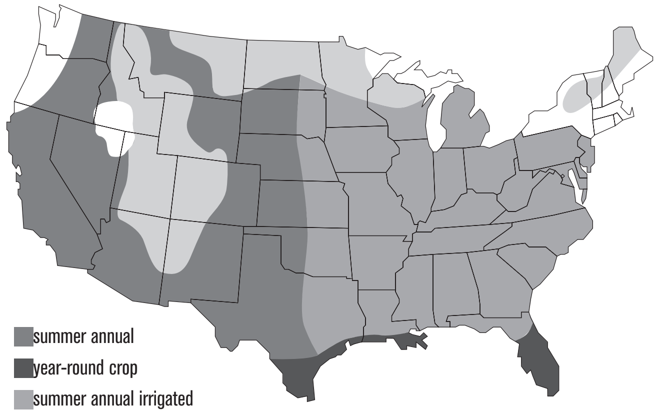
Also called: Sudex, Sudax

Type: summer annual grass

Roles: soil builder, weed and nematode suppressor, subsoil loosener

Mix with: buckwheat, sesbania, sunnhemp, forage soybeans or cowpeas

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



Sorghum-sudangrass hybrids are unrivaled for adding organic matter to worn-out soils. These tall, fast-growing, heat-loving summer annual grasses can smother weeds, suppress some nematode species and penetrate compacted subsoil if mowed once. Seed cost is modest. Followed by a legume cover crop, sorghum-sudangrass hybrids are a top choice for renovating overfarmed or compacted fields.

The hybrids are crosses between forage-type sorghums and sundangrass. Compared with corn, they have less leaf area, more secondary roots and a waxier leaf surface, traits that help them withstand drought (361). Like corn, they require good fertility—and usually supplemental nitrogen—for best growth. Compared with sudangrass, these hybrids are taller, coarser and more productive.

Forage-type sorghum plants are larger, leafier and mature later than *grain* sorghum plants. Compared with sorghum-sudangrass hybrids, they are shorter, less drought tolerant, and don't regrow as well. Still, forage sorghums as well as most forms of sudangrass can be used in the same cover-cropping roles as sorghum-sudangrass hybrids. All sorghum- and sudangrass-related species produce compounds that inhibit certain plants and nematodes. They are not frost tolerant, and should be planted after the soil warms in spring or in summer at least six weeks before first frost.

BENEFITS

Biomass producer. Sorghum-sudangrass grows 5 to 12 feet tall with long, slender leaves, stalks up to one-half inch in diameter and aggressive root systems. These features combine to produce ample biomass, usually about 4,000 to 5,000 lb. DM/A. Up to 18,000 lb. DM/A has been measured with multiple cuttings on fertile soils with adequate moisture.

Subsoil aerator. Mowing whenever stalks reach 3 to 4 feet tall increases root mass five to eight times compared with unmowed stalks, and forces the roots to penetrate deeper.

In addition, tops grow back green and vegetative until frost and tillering creates up to six new, thicker stalks per plant. A single mowing on New York muck soils caused roots to burrow 10 to 16 inches deep compared to 6 to 8 inches deep for unmowed plants. The roots of mowed plants fractured subsoil compaction with wormhole-like openings that improved surface drainage. However, four mowings at shorter heights caused plants to behave more like a grass and significantly decreased the mass, depth and diameter of roots (277, 450, 451).

Weed suppressor. When sown at higher rates than normally used for forage crops, sorghum-sudangrass hybrids make an effective smother crop. Their seedlings, shoots, leaves and roots secrete allelopathic compounds that suppress many weeds. The main root exudate, **sorgoleone**, is strongly active at extremely low concentrations, comparable to those of some synthetic herbicides (370). As early as five days after germination, roots begin secreting this allelochemical, which persists for weeks and has visible effects on lettuce seedlings even at 10 parts per million (440).

Sorghum-sudangrass hybrids suppress such annual weeds as velvetleaf, large crabgrass, barnyardgrass (126, 305), green foxtail, smooth pigweed (190), common ragweed, redroot pigweed and purslane (316). They also suppressed pine (214) and redbud tree seedlings in nursery tests (154). The residual weed-killing effects of these allelochemicals increased when sorghum-sudangrass hybrids were treated with the herbicides sethoxydim, glyphosate or paraquat, in descending order of magnitude (144).

Nematode and disease fighter. Planting sorghum-sudangrass hybrids instead of a host crop is a great way to disrupt the life cycles of many diseases, nematodes and other pests. For example, when sorghum-sudangrass or sorghum alone were no-tilled into endophyte-infected fescue pastures in Missouri that had received two herbicide applications, the disease was controlled nearly 100 percent. No-till reseeding with endophyte-free fescue completed this cost-effective renovation that significantly improved the rate of gain of yearling steers (16).

Renews farmed-out soils. The combination of abundant biomass production, subsoiling root sys-

Marianne Sarrantonio

SORGHUM-SUDANGRASS (Sorghum bicolor X S. bicolor var. sudanese

tems, and weed and nematode suppression can produce dramatic results.

On a low-producing muck field in New York where onion yields had fallen to less than a third of the local average, a single year of a dense planting of sorghum-sudangrass hybrid restored the soil to a condition close to that of newly cleared land (217).

Widely adapted. Sorghum-sudangrass hybrids can be grown throughout the U.S. wherever rainfall is adequate and soil temperature reaches 65° F to 70° F at least two months before frost. Once established, they can withstand drought by going nearly dormant. Sorghum-sudangrass hybrids tolerate pH as high as 9.0, and are often used in rotation with barley to reclaim alkaline soil (421). They tolerate pH as low as 5.0.

Quick forage. Sorghum-sudangrass is prized as summer forage. It can provide quick cover to prevent weeds or erosion where legume forages have been winterkilled or flooded out. Use care because these hybrids and other sorghums can produce prussic acid poisoning in livestock. Grazing poses the most risk to livestock when plants are young (up to 24 inches tall), drought stressed or killed by frost. Toxicity danger varies between cultivars.

MANAGEMENT

Establishment

Plant sorghum-sudangrass when soils are warm and moist, usually at least two weeks after the prime corn-planting date for your area. It will tolerate low-fertility, moderate acidity and high alkalinity, but prefers good fertility and near-neutral pH (361). Standard biomass production usually requires 75 to 100 lb. N/A .

With sufficient surface moisture, broadcast 40 to 50 lb./A, or drill 35 to 40 lb./A as deep as 2 inches to reach moist soil. These rates provide a quicker canopy to smother weeds than lower rates used for forage production, but they require mowing or grazing to prevent lodging. Herbicide treatment or a pass with a mechanical weeder may be necessary if germination is spotty or perennial weeds are a problem. New York on-farm tests show that a stale seedbed method—tilling, then retilling to kill the first flush of weeds just before planting—provides effective weed control.

These heat-loving plants are unrivaled for adding organic matter to soils.

Warm season mixtures. Plant sorghum-sudangrass in cover crop mixtures with buckwheat or with the legumes sesbania (*Sesbania exaltata*), sunnhemp (*Crotolaria juncea*), forage soybeans (*Glycine max*) or cowpeas (*Vigna unguiculata*). Broadcast these large-seeded cover crops with the sorghum-sudangrass, then incorporate about 1 inch deep. Fast-germinating buckwheat helps suppress early weeds. Sorghum-sudangrass supports the sprawling sesbania, forage soybeans and cowpeas. Sunnhemp has an upright habit, but could compete well for light if matched with a sorghum-sudangrass cultivar of a similar height.

Field Management

Plants grow very tall (up to 12 feet), produce tons of dry matter and become woody as they mature. This can result in an unmanageable amount of tough residue that interferes with early planting the following spring (277).

Mowing or grazing when stalks are 3 to 4 feet tall encourages tillering and deeper root growth, and keeps regrowth vegetative and less fibrous until frost. For mid-summer cuttings, leave at least 6 inches of stubble to ensure good regrowth and continued weed suppression. Delayed planting within seven weeks of frost makes mowing unnecessary and still allows for good growth before winterkilling (277, 361).

Disking while plants are still vegetative will speed decomposition. Make several passes with a heavy disk or combination tillage tool to handle the dense root masses (277). Sicklebar mowing or flail chopping before tillage will reduce the number of field operations required to incorporate the crop and speed decomposition. Sicklebar mowers cut more cleanly but leave the stalks whole. Using a front-mounted flail chopper avoids the problem of skips where tractor tires flatten the plants, putting them out of reach of a rear-mounted chopper.

Any operations that decrease the residue size shortens the period during which the decomposing residue will tie up soil nitrogen and hinder early planted crops in spring. Even when mowed, residue will become tough and slower to break down if left on the surface.

Flail chopping after frost or killing the cover crop with herbicide will create a suitable mulch for no-till planting, preserving soil life and soil structure in non-compacted fields.

Pest Management

Weeds. Use sorghum-sudangrass to help control nutsedge infestations, suggests Cornell Extension IPM vegetable specialist John Mishanec. Allow the nutsedge to grow until it's about 4 to 5 inches tall but before nutlets form, about mid-June in New York. Kill the nutsedge with herbicide, then plant the weed-smothering hybrid.

To extend weed suppressive effects into the second season, select a cultivar known for weed suppression and leave roots undisturbed when the stalks are mowed or grazed (440).

Beneficial habitat. Some related sorghum cultivars harbor beneficial insects such as seven-spotted lady beetles (*Coccinella septempunctata*) and lacewings (*Chrysopa carnea*) (421).

Nematodes. Sorghum-sudangrass hybrids and other sorghum-related crops and cultivars suppress some species of nematodes. Specific cultivars vary in their effectiveness on different races of nematodes. These high-biomass-producing crops have a general suppressive effect due to their organic matter contributions. But they also produce natural nematicidal compounds that chemically suppress some nematodes, many studies show.

Timing of cutting and tillage is very important to the effectiveness of nematode suppression. The cover crop needs to be tilled before frost while it is still green. Otherwise, the nematicidal effect is lost. For maximum suppression of soilborne diseases, cut or chopped sudangrass must be well incorporated immediately (308).

For suppressing root-knot nematodes in Idaho potato fields, rapeseed has proven slightly more effective and more dependable than sorghum-sudangrass hybrids (394).

In an Oregon potato trial, TRUDAN 8 sudangrass controlled Columbia root-knot nematodes (*Meloidogoyne Chitwoodi*), a serious pest of many vegetable crops. Control extended throughout the zone of residue incorporation. The cover crop's effect prevented upward migration of the nematodes into the zone for six weeks, working as well as the nematicide ethoprop. Both treatments allowed infection later in the season (285).

In the study, TRUDAN 8 sudangrass and the sorghum-sudangrass hybrid cultivars SORDAN 79 and SS-222 all reduced populations of root-knot nematodes. These cultivars are poor nematode hosts and their leaves—not roots—have a nematicidal effect. TRUDAN 8 should be used if the crop will be grazed due to its lower potential for prussic acid poisoning. The sorghum-sudangrass cultivars are useful if the cover crop is intended for anti-nematicidal effects only (285). In other Oregon and Washington trials, the cover crop suppression required supplemental chemical nematicide to produce profitable levels of U.S. No. 1 potatoes (285). These same sudangrass and sorghum-sudangrass hybrid cultivars failed to show any significant nematicidal effects in a later experiment in Wisconsin potato fields (249).

When faced with infestations of the nematodes *Meloidogoyne incognita* and *M. arenaria*, Oswego, N.Y., onion grower Dan Dunsmoor found that a well-incorporated sorghum-sudangrass cover crop was more effective than fumigation. Further, the nematicidal effect continued into the next season, while the conditions a year after fumigation seemed worse than before the application. He reports that the sorghum-sudangrass cover crop also controls onion maggot, thrips and Botrytis leaf blight (217).

These plants produce chemicals that inhibit certain weeds and nematodes.

Insect pests. Chinch bug (*Blissus leucopterus*), sorghum midge (*Contarinia sorghicola*), corn leaf aphid (*Rhopalosiphum maidis*), corn earworm (*Heliothis zea*), greenbugs (*Schizaphis graminum*) and sorghum webworm (*Celama sorghiella*) sometimes attack sorghum-sudangrass hybrids. Early planting helps control the first two pests, and may reduce damage from webworms. Some cultivars and hybrids are resistant to chinch bugs and some biotypes of greenbugs (361). In Georgia, some hybrids hosted corn leaf aphid, greenbug, southern green stinkbugs (*Nezara viridula*) and leaffooted bug (*Leptoglossus phyllopus*).

Crop Systems

There are several strategies for reducing nitrogen tie-up from residue:

- Interplant a legume with the sorghum-sudangrass hybrid.
- Plant a legume cover crop *after* the sorghum-sudangrass hybrid, in either late summer or the following spring.
- Apply nitrogen fertilizer or some other N source at incorporation and leave the land fallow for a few months when soil is not frozen to allow decomposition of the residue.

Summer Covers Relieve Compaction

A summer planting of sudangrass was the best single-season cover crop for relieving soil compaction in vegetable fields, a team of Cornell researchers found. Yellow mustard, HUBAM annual white sweetclover and perennial ryegrass also were effective to some extent in the multi-year study. "But sudangrass has proven the most promising so far," says project coordinator David Wolfe. "It has shown the fastest root growth."

"Sudangrass is best managed with one mowing during the season," Wolfe adds. Mowing promotes tillering and a deep, penetrating root system. Mowing also makes it easier to incorporate the large amount of biomass produced by this crop. With its high C:N ratio, it adds to soil organic matter.

Farmers and researchers have long known that alfalfa's deep root system is a great compaction-buster. But alfalfa does not establish easily on wet compacted fields, and most vegetable growers can't afford to remove land from production for two to three years to grow it, notes Wolfe. Many also lack the equipment to subsoil their fields, which is often only a temporary solution, at best. That's why Wolfe geared his study to identify cover crops that can produce results in a single season. In the case of heat-loving sudangrass, it also may be possible to squeeze a spring or fall cash crop into the rotation while still growing the cover during summer.

Heavy equipment, frequent tillage and lack of organic matter contribute to compaction problems for vegetable growers in the Northeast, where frequent rains often force growers into the fields when soils are wet. Compacted soils slow root development, hinder nutrient uptake, stunt plants, delay maturity and can worsen pest and disease problems (451). For example, the Cornell researchers found that slow-growing cabbages direct-seeded into compacted soils were vulnerable to flea beetle infestations (450).

Brassica cover crops such as yellow mustard were solid challengers to sudangrass as a compaction reliever, but it was sometimes difficult to establish these crops in the test. "We still have a lot to learn about how best to grow brassicas and fit them into rotations with vegetables," Wolfe says.

Wolfe and his team assessed the cover crops' effectiveness by measuring yields of subsequent crops and conducting a host of soil quality measurements, including infiltration rates, water-holding capacity, aggregate stability and organic matter levels.

For more information, contact David Wolfe, 607-255-7888; dww5@cornell.edu.

Updated in 2007 by Andy Clark

If you kill the cover crop early enough in fall, the residue will partially break down before cold temperatures slow biological action (361). Where possible, use sorghum-sudangrass ahead of later-planted crops to allow more time in spring for residue to decompose.

Planting sorghum-sudangrass every third year on New York potato and onion farms will rejuvenate soil, suppress weeds and may suppress soil pathogens and nematodes. Working a legume into the rotation will further build soil health and add nitrogen. Sorghum-sudangrass hybrids can provide needed soil structure benefits wherever intensive systems cause compaction and loss of soil organic matter reserves. See *Summer Covers Relieve Compaction*, above.

Grown as a summer cover crop that is cut once and then suppressed or killed, sorghum-sudangrass can reduce weeds in fall-planted alfalfa. Sorghum-sudangrass suppressed alfalfa root growth significantly in a Virginia greenhouse study (144), but no effect was observed on alfalfa germination when alfalfa was no-till planted into killed or living sorghum-sudangrass (145).

In Colorado, sorghum-sudangrass increased irrigated potato tuber quality and total marketable yield compared. It also increased nutrient uptake efficiency on the sandy, high pH soils. In this system, the sorghum-sudangrass is grown with limited irrigation, but with enough water so that the biomass could be harvested for hay or incorporated as green manure (112, 113).

In California, some table grape growers use sorghum-sudangrass to add organic matter and to reduce the reflection of light and heat from the soil, reducing sunburn to the grapes.

COMPARATIVE NOTES

Sorghum-sudangrass hybrids can produce more organic matter per acre, and at a lower seed cost, than any major cover crop grown in the U.S.

Incorporated sorghum-sudangrass residue reduces N availability to young crops more than oat residue but less than wheat residue (389).

Cultivars. When comparing sorghum-sudangrass cultivars, consider traits such as biomass yield potential, tillering and regrowth ability, disease resistance, insect resistance (especially if greenbugs are a problem) and tolerance to iron deficiency chlorosis.

If you plan to graze the cover crop, select sorghum-sudangrass hybrids and related crops with lower levels of dhurrin, the compound responsible for prussic acid poisoning. For maximum weed control, choose types high in sorgoleone, the root exudate that suppresses weeds. Sterile cultivars are best where escapes could be a problem, especially where crossing with johnsongrass (*Sorghum halpense*) is possible.

Seed sources. See *Seed Suppliers* (p. 195).

WINTER WHEAT

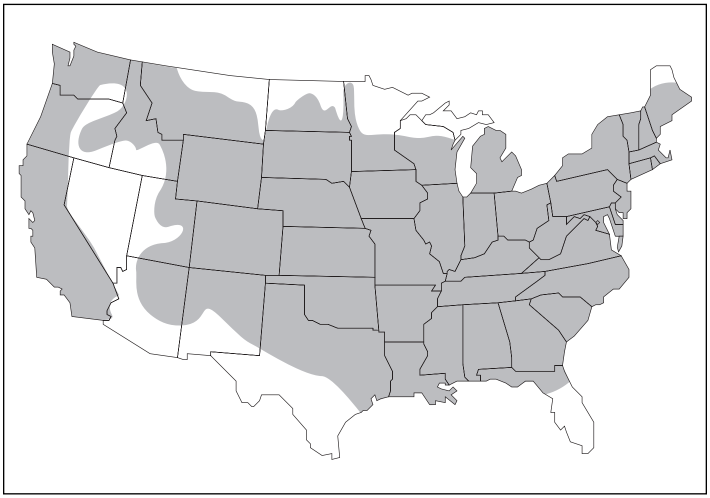
Triticum aestivum

Type: winter annual cereal grain; can be spring-planted

Roles: prevent erosion, suppress weeds, scavenge excess nutrients, add organic matter

Mix with: annual legumes, ryegrass or other small grains

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



Although typically grown as a cash grain, winter wheat can provide most of the cover crop benefits of other cereal crops, as well as a grazing option prior to spring tiller elongation. It's less likely than barley or rye to become a weed and is easier to kill. Wheat also is slower to mature than some cereals, so there is no rush to kill it early in spring and risk compacting soil in wet conditions. It is increasingly grown instead of rye because it is cheaper and easier to manage in spring.

Whether grown as a cover crop or for grain, winter wheat adds rotation options for underseeding a legume (such as red clover or sweet-clover) for forage or nitrogen. It works well in no-till or reduced-tillage systems, and for weed control in potatoes grown with irrigation in semi-arid regions.

BENEFITS

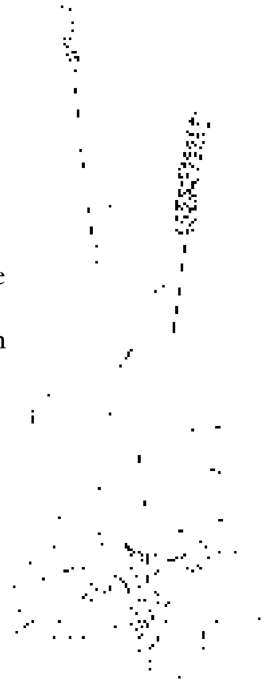
Erosion control. Winter wheat can serve as an overwintering cover crop for erosion control in most of the continental U.S.

Nutrient catch crop. Wheat enhances cycling of N, P and K. A heavy N feeder in spring, wheat takes up N relatively slowly in autumn. It adds up, however. A September-seeded stand absorbed 40 lb. N/A by December, a Maryland study showed (46). As an overwintering cover rather than a grain crop, wheat wouldn't need fall or spring fertilizer.

A 50 bushel wheat crop can take up 20 to 25 lb. P_2O_5 and 60 lb. K_2O per acre by boot stage. About 80 percent of the K is recycled if the stems and leaves aren't removed from the field at harvest. All the nutrients are recycled when wheat is managed as a cover crop, giving it a role in scavenging excess nitrogen.

"Cash and Cover" crop. Winter wheat can be grown as a cash crop or a cover crop, although you should manage each differently. It provides a cash-grain option while also opening a spot for a winter annual legume in a corn>soybean or similar rotation. For example:

- In the Cotton Belt, wheat and crimson clover would be a good mix.
- In Hardiness Zone 6 and parts of Zone 7, plant hairy vetch after wheat harvest, giving the legume plenty of time to establish in fall. Vetch growth in spring may provide most of the N necessary for heavy feeders such as corn, or all of the N for sorghum, in areas northward to southern Illinois, where early spring warm-up allows time for development.
- In much of Zone 7, cowpeas would be a good choice after wheat harvest in early July or before planting winter wheat in fall.
- In the Corn Belt and northern U.S., undersow red clover or frostseed sweetclover into a wheat nurse crop if you want the option of a year of hay before going back to corn. With or without underseeding a legume or legume-grass mix, winter wheat provides great grazing and nutritional value and can extend the grazing season.
- In Colorado vegetable systems, wheat reduced wind erosion and scavenged N from 5 feet deep in the profile (111, 114).
- In parts of Zone 6 and warmer, you also have a dependable double-crop option. See *Wheat Boosts Income and Soil Protection* (p. 113).


Elayne Sears

WINTER WHEAT (Triticum aestivum)

Weed suppressor. As a fall-sown cereal, wheat competes well with most weeds once it is established (71). Its rapid spring growth also helps choke weeds, especially with an underseeded legume competing for light and surface nutrients.

Soil builder and organic matter source. Wheat is a plentiful source of straw and stubble. Wheat's fine root system also improves topsoil tilth. Although it generally produces less than rye or barley, the residue can be easier to manage and incorporate.

When selecting a locally adapted variety for use as a cover crop, you might not need premium seed. A Maryland study of 25 wheat cultivars showed no major differences in overall biomass production at maturity (92). Also in Maryland, wheat produced up to 12,500 lb. biomass/A following high rates of broiler litter (87).

In Colorado, wheat planted in August after early vegetables produced more than 4,000 lb. biomass/A, but if planted in October, yielded only one-tenth as much biomass and consequently scavenged less N (114).

Wheat Boosts Income *and* Soil Protection

Wheat is an ideal fall cover crop that you can later decide to harvest as a cash crop, cotton farmer Max Carter has found. "It's easier to manage than rye, still leaves plenty of residue to keep topsoil from washing away—and is an excellent double crop," says Carter.

The southeastern Georgia farmer no-till drills winter wheat at 2 bushels per acre right after cotton harvest, without any seedbed preparation. "It gives a good, thick stand," he says.

"We usually get wheat in by Thanksgiving, but as long as it's planted by Christmas, I know it'll do fine," he adds. After drilling wheat, Carter goes back and mows the cotton stalks to leave some field residue until the wheat establishes.

Disease or pests rarely have been a problem, he notes.

"It's a very easy system, with wheat always serving as a fall cover crop for us. It builds soil and encourages helpful soil microorganisms. It can be grazed, or we can burn some down in March for planting early corn or peanuts anytime from March to June," he says.

For a double crop before 2-bale-an-acre cotton, Carter irrigates the stand once in spring with a center pivot and harvests 45- to 60-bushel wheat by the end of May. "The chopper on the rear of the combine puts the straw right back on the soil as an even blanket and we're back planting cotton on June 1."

"It sure beats idling land and losing topsoil."

If weed control is important in your system, look for a regional cultivar that can produce early spring growth. To scavenge N, select a variety with good fall growth before winter dormancy.

MANAGEMENT

Establishment & Fieldwork

Wheat prefers well-drained soils of medium texture and moderate fertility. It tolerates poorly drained, heavier soils better than barley or oats, but flooding can easily drown a wheat stand. Rye may be a better choice for some poor soils.

Biomass production and N uptake are fairly slow in autumn. Tillering resumes in late winter/early spring and N uptake increases quickly during stem extension.

Adequate but not excessive N is important during wheat's early growth stages (prior to stem growth) to ensure adequate tillering and root growth prior to winter dormancy. In low-fertility or light-textured soils, consider a mixed seeding with a legume (80). See *Wheat Offers High Value Weed Control, Too* (p. 114).

A firm seedbed helps reduce winterkill of wheat. Minimize tillage in semiarid regions to avoid pulverizing topsoil (358) and depleting soil moisture.

Winter annual use. Seed from late summer to early fall in Zone 3 to 7—a few weeks earlier than a rye or wheat grain crop—and from fall to early winter in Zone 8 and warmer. If you are considering harvesting as a grain crop, you should wait until the Hessian fly-free date, however. If cover crop planting is delayed, consider sowing rye instead.

Drill 60 to 120 lb./A (1 to 2 bushels) into a firm seedbed at a 1/2- to 1 1/2-inch depth or broadcast 60 to 160 lb./A (1 to 2.5 bushels) and disk lightly or cultipack to cover. Plant at a high rate if seeding late, when overseeding into soybeans at the leaf-yellowing stage, when planting into a dry seedbed or when you require a thick, weed-suppressing stand. Seed at a low to medium rate when soil moisture is plentiful (71).

After cotton harvest in Zone 8 and warmer, no-till drill 2 bushels of wheat per acre without any seedbed preparation. In the Southern Plains, 1 bushel is sufficient if drilling in a timely fashion (302).

With irrigation or in humid regions, you could harvest 45- to 60-bushel wheat, then double crop

Wheat Offers High-Value Weed Control

Pairing a winter wheat cover crop with a reduced herbicide program in the inland Pacific Northwest could provide excellent weed control in potatoes grown on light soils in irrigated, semiarid regions. A SARE-funded study showed that winter wheat provided effective competition against annual weeds that infest irrigated potato fields in Washington, Oregon and Idaho.

Banding herbicide over the row when planting potatoes improved the system's effectiveness, subsequent research shows, says project coordinator Dr. Charlotte Eberlein at the University of Idaho's Aberdeen Research and Extension Center. "In our initial study, we were effectively no-tilling potatoes into the Roundup-killed wheat," says Eberlein. "In this study we killed the cover crop and planted potatoes with a regular potato planter, which rips the wheat out of the potato row." A grower then can band a herbicide mixture over the row and depend on the wheat mulch to control between-row weeds.

"If you have sandy soil to start with and can kill winter wheat early enough to reduce water-management concerns for the potatoes, the system works well," says Eberlein.

"Winter rye would be a slightly better cover crop for suppressing weeds in a system like this," she notes. "Volunteer rye, however, is a serious problem in wheat grown in the West, and wheat is a common rotation crop for potato growers in the Pacific Northwest."

She recommends drilling winter wheat at 90 lb./A into a good seedbed, generally in mid-September in Idaho. "In our area, growers can deep rip in fall, disk and build the beds (hills), then drill wheat directly into the beds," she says. Some starter N (50 to 60 lb./A) can help the wheat establish. If indicated by soil testing, P or K also would be fall-applied for the following potato crop.

The wheat usually does well and shows good winter survival. Amount of spring rainfall and soil moisture and the wheat growth rate determine the optimal dates for killing wheat and planting potatoes.

Some years, you might plant into the wheat and broadcast Roundup about a week later. Other years, if a wet spring delays potato planting, you could kill wheat before it gets out of hand (before the boot stage), then wait for better potato-planting conditions.

Moisture management is important, especially during dry springs, she says. "We usually kill the wheat from early to mid May—a week or two after planting potatoes. That's soon enough to maintain adequate moisture in the hills for potatoes to sprout."

An irrigation option ensures adequate soil moisture—for the wheat stand in fall or the potato crop in spring, she adds. "You want a good, competitive wheat stand and a vigorous potato crop if you're depending on a banded herbicide mix and wheat mulch for weed control," says Eberlein. That combination gives competitive yields, she observes, based on research station trials.

with soybeans, cotton or another summer crop. See *Wheat Boosts Income and Soil Protection* (p. 113). You also could overseed winter wheat prior to cotton defoliation and harvesting.

Another possibility for Zone 7 and cooler: Plant full-season soybeans into wheat cover crop residue, and plant a wheat cover crop after bean harvest.

Mixed seeding or nurse crop. Winter wheat works well in mixtures with other small grains or with legumes such as hairy vetch. It is an excellent nurse crop for frostseeding red clover or sweetclover, if rainfall is sufficient. In the Corn Belt, the legume is usually sown in winter, before wheat's vegetative growth resumes. If frostseeding, use the full seeding rates for both species, according to recent work in Iowa (34). If you sow sweetclover in fall with winter wheat, it could outgrow the wheat. If you want a grain option, that could make harvest difficult.

Spring annual use. Although it's not a common practice, winter wheat can be planted in the spring as a weed-suppressing companion crop or early forage. You sacrifice fall nutrient scavenging, however. Reasons for spring planting include winter kill or spotty overwintering, or when you just didn't have time to fall-seed it. It won't have a chance to vernalize (be exposed to extended cold after germination), so it will not head out and usually dies on its own within a few months, without setting seed. This eliminates the possibility of it becoming a weed problem in subsequent crops. By sowing when field conditions permit in early spring, within a couple months you could have a 6- to 10-inch tall cover crop into which you can no-till your cash crop. You might not need a burndown herbicide, either.

Early spring planting of *spring* wheat, with or without a legume companion, is an option, especially if you have a longer rotation niche available.

Field Management

You needn't spring fertilize a winter wheat stand being grown as a cover crop rather than a grain crop. That would defeat the primary purpose (N-scavenging) of growing a small grain cover crop. As with any overwintering small grain crop, however, you will want to ensure the wheat stand doesn't adversely affect soil moisture or nutrient availability for the following crop.

Killing

Kill wheat with a roller crimper at soft-dough stage or later, with a grass herbicide, or by plowing, disking or mowing before seed matures. As with other small grain cover crops, it is safest to kill about 2-3 weeks before planting your cash crop, although this will depend on local conditions and your killing and tillage system.

Because of its slower spring growth, there is less need to rush to kill wheat in spring as is sometimes required for rye. That's one reason vegetable grower Will Stevens of Shoreham, Vt., prefers wheat to rye as a winter cover on his heavy, clay-loam soils. The wheat goes to seed slower and can provide more biomass than an earlier killing of rye would, he's found. With rye, he has to disk two to three weeks earlier in spring to incorporate the biomass, which can be a problem in wet conditions. "I only chisel plow wheat if it's really rank," he notes.

Wheat is less likely than barley or rye to become a weed, and is easier to kill.

Pest Management

Wheat is less likely than rye or barley to become a weed problem in a rotation, but is a little more susceptible than rye or oats to insects and disease. Managed as a cover crop, wheat rarely poses an insect or disease risk. Diseases can be more of a problem the earlier wheat is planted in fall, especially if you farm in a humid area.

Growing winter wheat could influence the buildup of pathogens and affect future small-grain cash crops, however. Use of resistant varieties and other IPM practices can avoid many pest problems in wheat grown for grain. If wheat diseases or pests are a major concern in your area, rye or barley might be a better choice as an overwintering cover crop that provides a grain option, despite their lower grain yield.

Other Options

Choosing wheat as a small-grain cover crop offers the flexibility in late spring or early summer to harvest a grain crop. Spring management such as removing grazing livestock prior to heading and topdressing with N is essential for the grain crop option.

Seed sources. See *Seed Suppliers* (p. 195).

OVERVIEW OF LEGUME COVER CROPS

Commonly used legume cover crops include:

- Winter annuals, such as crimson clover, hairy vetch, field peas, subterranean clover and many others
- Perennials like red clover, white clover and some medics
- Biennials such as sweetclover
- Summer annuals (in colder climates, the winter annuals are often grown in the summer)

Legume cover crops are used to:

- Fix atmospheric nitrogen (N) for use by subsequent crops
- Reduce or prevent erosion
- Produce biomass and add organic matter to the soil
- Attract beneficial insects

Legumes vary widely in their ability to prevent erosion, suppress weeds and add organic matter to the soil. In general, legume cover crops do not scavenge N as well as grasses. If you need a cover crop to take up excess nutrients after manure or fertilizer applications, a grass, a brassica or a mixture is usually a better choice.

Winter-annual legumes, while established in the fall, usually produce most of their biomass and N in spring. Winter-annual legumes must be planted earlier than cereal crops in order to survive the winter in many regions. Depending on your climate, spring management of legumes will often involve balancing early planting of the cash crop with waiting to allow more biomass and N production by the legume.

Perennial or biennial legumes can fit many different niches, as described in greater detail in the individual sections for those cover crops. Sometimes grown for a short period between cash crops, these forage crops also can be used for more than one year and often are harvested for feed during this time. They can be established along with—or overseeded into—other crops such as wheat or oats, then be left to grow after cash crop harvest and used as a forage. Here they are functioning more as a rotation crop than a cover crop, but as such provide many benefits including erosion and weed control, organic matter and N production. They also can break weed, disease and insect cycles.

Summer-annual use of legume crops includes, in colder climates, the use of the winter-annual crops listed above, as well as warm-season legumes such as cowpeas. Grown as summer annuals, these crops produce N and provide ground cover for weed and erosion control, as well as other benefits of growing cover crops. Establishment and management varies widely depending on climate, cropping system and the legume itself. These topics will be covered in the individual sections for each legume.

Legumes are generally lower in carbon and higher in nitrogen than grasses. This lower C:N ratio results in faster breakdown of legume residues. Therefore, the N and other nutrients contained in legume residues are usually released faster than from grasses. Weed control by legume residues may not last as long as for an equivalent amount of grass residue. Legumes do not increase soil organic matter as much as grasses.

Mixtures of legume and grass cover crops combine the benefits of both, including biomass production, N scavenging and additions to the system, as well as weed and erosion control. Some cover crop mixtures are described in the individual cover crop sections.

COVER CROP MIXTURES EXPAND POSSIBILITIES

Mixtures of two or more cover crops are often more effective than planting a single species. Cover crop mixtures offer the best of both worlds, combining the benefits of grasses and legumes, or using the different growth characteristics of several species to fit your needs.

You can use cover crop mixtures to improve:

- Winter survival
- Ground cover
- Use of solar energy
- Biomass and N production
- Weed control
- Duration of active growing period
- Range of beneficial insects attracted
- Tolerance of adverse conditions
- Forage options
- Response to variable soil traits

Disadvantages of cover crop mixtures may include:

- Higher seed cost
- Too much residue
- More complicated management
- Difficult to seed

Crop mixtures can reduce risk in cropping systems because each crop in the mix may respond differently to soil, pest and weather conditions. In forage or grazing systems, for example, a mix of rye, wheat and barley is more nutritious, can be grazed over a longer period of time and is less likely to be devastated by a single disease.

Using drought-tolerant plants in a perennial mix builds in persistence for dry years. Using a number of cover crops with "hard seed" that takes many months to germinate also improves coverage over a broader range of conditions.

Mixing cultivars of a single species with varied maturity dates and growth habits maintains optimum benefits for a longer time. Orchardists in California mix subclovers to keep weeds at bay all season. One cultivar comes on early, then dies back as two later cultivars—one tall and one short—come on strong. Because they reseed themselves, the cooperative trio persists year after year.

Sometimes you don't know how much N may be left after cash crop harvest. Do you need a grass to scavenge leftover N, or a legume to provide fixed N? A grass/legume cover crop mixture adjusts to the amount of available soil N: If there is a lot of N, the grass dominates; if there is not much available soil N, the legume will tend to dominate a mixture. In either case, you get the combined benefit of N scavenging by the grass cover crop and N additions from the legume cover crop.

Mixing low-growing and taller crops, or fast-starting grasses and slow-developing legumes, usually provides better erosion control because more of the ground is covered. The vegetation intercepts more raindrops before they can dislodge soil particles. Sunlight is used more efficiently because light that passes through the tall crop is captured by the low-growing crop.

Adding grasses to a fall-seeded legume improves soil coverage over winter and increases the root mass to stabilize topsoil. A viny crop like vetch will climb a grass, so it can get more light and fix more N, or so it can be harvested more easily for seed. A faster-growing crop serves as a nurse crop for a slow-growing crop, while covering the ground quickly for erosion control. The possibilities are endless!

Mixtures can complicate management, however. For example:

- They may cost more to seed. Seeding rates for each component of the mix are usually lower than for sole-crop plantings, but the total seed cost may still be more.
- The best time to kill one crop may not be the best for another crop, so a compromise date may be used.
- If you use herbicides, your choices may be limited when you plant a mixture of legumes and nonlegumes.
- Sometimes you can end up with more residue than your equipment can handle.

FIELD PEAS

Pisum sativum subsp. arvense

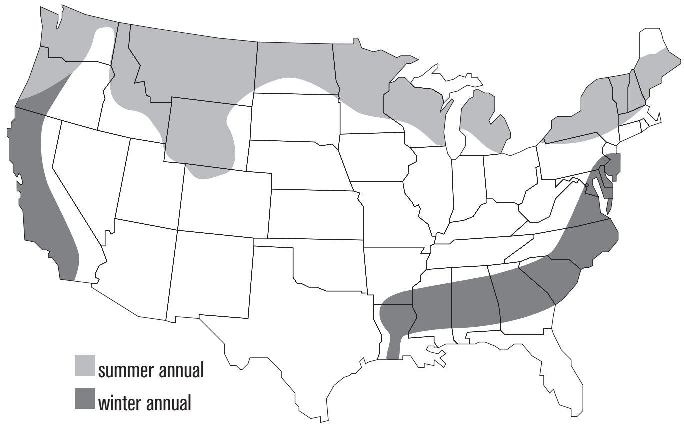
Also called: Austrian winter peas (black peas), Canadian field peas (spring peas)

Type: summer annual and winter annual legume

Roles: plow-down N source, weed suppressor, forage

Mix with: strong-stemmed wheat, rye, triticale or barley for vertical support

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



High N-fixers, field peas produce abundant vining forage and contribute to short-term soil conditioning. Succulent stems break down easily and are a quick source of available N (361). Field peas grow rapidly in the cool, moist weather they encounter as winter annuals in the South and in parts of Idaho, and as early-sown summer annuals in the Northeast, North Central and Northern Plains areas. Harvest options as high-quality forage and seed increase their value.

Winter-hardy types of field peas, especially **Austrian winter peas**, can withstand temperatures as low as 10° F with only minor injury, but they don't overwinter consistently in areas colder than moderate Hardiness Zone 6. They are sensitive to heat, particularly in combination with humidity. They tend to languish in mid-summer even in the cool Northeast (361), where average summers have fewer than 30 days exceeding 86° F. Temperatures greater than 90° F cause flowers to blast and reduce seed yield. On humus-rich black soils, field peas will produce abundant viny growth with few seed pods.

Use in the East and Southeast is limited by field peas' susceptibility to *Sclerotinia* crown rot, which can destroy whole fields during winter in the mid-Atlantic area. Risk of infection increases if pea crops are grown on the same land in close rotation.

Canadian field peas are a related strain of vining pea. These annual "spring peas" can outgrow *spring*-planted *winter* peas. They often are seeded with triticale or another small grain. Spring peas have larger seeds, so there are fewer seeds per pound and seeding rates are higher, about 100 to 160 lb./A. However, spring pea seed is a bit less expensive than Austrian winter pea seed. TRAPPER is the most common Canadian field pea cultivar.

This section focuses on the widely grown Austrian winter pea. "Field peas" refers to both the winter and spring types.

BENEFITS

Bountiful biomass. Under a long, cool, moist season during their vegetative stages, Austrian winter peas produce more than 5,000 lb. dry matter/A, even when planted in spring in colder climates. Idaho farmers regularly produce 6,000 to 8,000 lb. DM/A from fall-planted Austrian winter peas. Because the residue breaks down quickly, only peas in the high-production areas build up much long-term organic matter. Peas do not make a good organic mulch for weed control (361).

Nitrogen source. Austrian winter peas are top N producers, yielding from 90 to 150 lb. N/A, and at times up to 300 lb. N/A.

Plowed down as green manure, fall-planted legume crops of Austrian winter pea, alfalfa and hairy vetch each produced enough N for the production of high-quality muskmelons under plastic mulch and drip irrigation in a Kansas study. Melon yields produced with the legumes were similar to those receiving synthetic fertilizer at 63 and 90 lb. N/A. The winter peas in the experiment produced 96 lb. N/A the first year and 207 lb. N/A the second (387).

Austrian winter peas harvested as hay then applied as mulch mineralized N at more than double the rate of alfalfa hay. The N contribution was measured the summer after a fall plowdown of the residue. The estimated N recovery of Austrian winter pea material 10 months after incorporation was 77 percent—58 percent through spring wheat and 19 percent in the soil (254).

Austrian winter pea green manure provided the highest spring wheat yield the following year in a Montana trial comparing 10 types of medics, seven clovers, yellow biennial sweet clover and three grains. Crops that produced higher tonnage of green manure usually had a negative effect on the subsequent wheat crop due to moisture deficiency that continued over the winter between the crops (381). Field peas can leave 80 lb. N/A if terminated at mid-season in lieu of summer fallow in dryland areas, or leave more than 30 lb. N/A after pea harvest at season's end (74).

A winter pea green manure consistently resulted in higher malting barley protein content than that following other legumes or fallow in a Montana trial. Annual legumes harvested for seed left less soil N than did plots in fallow. Also tested were fava bean, lentil, chickpea, spring pea, winter pea hay and dry bean (262).

Rotational effects. Pulse crops (grain legumes such as field peas, fava beans and lentils) improved sustainability of dryland crop rotations by providing disease suppression, better tilth and other enhancements to soil quality in a Saskatchewan study. Even at rates of 180 lb. N/A, fertilizer alone was unable to bring yields of barley planted into barley residue to the maximum achieved from these pulse residues (163).

Water thrifty. In a comparison of water use alongside INDIANHEAD lentils and GEORGE black medic, Austrian winter pea was the most moisture-efficient crop in producing biomass. Each crop had used 4 inches of water when Austrian winter pea vines were 16 inches long, the lentils were 6 to 8 inches tall and the black medic central tillers were 4 inches tall (383).

Austrian winter peas grown in a controlled setting at 50° F recorded more than 75 percent of its N_2 fixed per unit of water used by the 63rd day of growth. White clover, crimson clover and hairy vetch reached the same level of water efficiency, but it took 105 days (334).

Quick growing. Rapid spring growth helps peas out compete weeds and make an N contribution in time for summer cash crops in some areas.

Forage booster. Field peas grown with barley, oat, triticale or wheat provide excellent livestock forage. Peas slightly improve forage yield, but significantly boost protein and relative feed value of small grain hay.

Seed crop. Seed production in Montana is about 2,000 lb./A and about 1,500 lb./A in the Pacific Northwest. Demand is growing for field peas as food and livestock feed (74).

Long-term bloomer. The purple and white blossoms of field peas are an early and extended source of nectar for honeybees.

Chill tolerant. Austrian winter pea plants may lose some of their topgrowth during freezes, but can continue growing after temperatures fall as low as 10° F. Their shallow roots and succulent stems limit their overwintering ability, however. Sustained cold below 18° F without snow cover usually kills Austrian winter pea (202). To maximize winter survival:

- Select the most winter-hardy cultivars available—GRANGER, MELROSE and COMMON WINTER.
- Seed early enough so that plants are 6 to 8 inches tall before soil freezes, because peas are shallow rooted and susceptible to heaving. Try to plant from mid-August to mid-September in Zone 5.
- Plant into grain stubble or a rough seedbed, or interseed into a winter grain. These environments protect young pea roots by suppressing soil heaving during freezing and thawing. Trapped snow insulates plants, as well.


Marianne Sarrantonio

FIELD PEAS (Pisum sativum subsp. *arvense)*

MANAGEMENT

Establishment & Fieldwork

Peas prefer well-limed, well-drained clay or heavy loam soils, near-neutral pH or above and moderate fertility. They also do well on loamy sands in North Carolina. Field peas usually are drilled 1 to 3 inches deep to ensure contact with moist soil and good anchoring for plants.

If you broadcast peas, incorporation will greatly improve stands, as seed left exposed on the surface generally does not germinate well. Long-vined plants that are shallow-seeded at low seeding rates tend to fall over (lodge), lay against the soil and rot. Combat this tendency by planting with a small grain nurse crop such as oats, wheat, barley, rye or triticale. Reduce the pea seeding rate by about one quarter—and grain by about one third—when planting a pea/grain mix.

Planted at 60 to 80 lb./A in Minnesota, Austrian winter peas make a good nurse crop for alfalfa.

Field pea seed has a short shelf life compared with other crops. Run a germination test if seed is more than two years old and adjust seeding rate accordingly. If you haven't grown peas in the seeded area for several years, inoculate immediately before seeding.

West. In mild winter areas of California and Idaho, fall-plant for maximum yield. In those areas, you can expect *spring-planted* winter peas to produce about half the biomass as those that are fall-planted. Seed by September 15 in Zone 5 of the Inter-Mountain region in protected valleys where you'd expect mild winter weather and good, long-term snow cover. October-planted Austrian winter pea in the Zone 9 Sacramento Valley of California thrive on cool, moist conditions and can contribute 150 lb. N/A by early April.

The general rule for other parts of the semi-arid West where snow cover is dependable is to plant peas in the fall after grain harvest. In these dry regions of Montana and Idaho, overseed peas at 90 to 100 lb./A by "frostseeding" any time soils have become too cold for pea germination. Be sure residue cover is not too dense to allow seed to work into the soil through freeze/thaw cycles as the soil warms (383).

In the low-rainfall Northern Plains, broadcast clear stands of peas in early spring at a similar rate for the "Flexible Green Manure" cropping system (below). Seeding at about 100 lb./A compensates somewhat for the lack of incorporation and provides strong early competition with weeds (383). Plant as soon as soil in the top inch reaches 40° F to make the most of spring moisture (74).

A mixture of Austrian winter peas and a small grain is suitable for dryland forage production because it traps snow and uses spring moisture to produce high yields earlier than spring-seeded annual forages (74). With sufficient moisture, spring peas typically produce higher forage yields than Austrian winter peas.

East. Planted as a companion crop in early spring in the Northeast, Austrian winter peas may provide appreciable N for summer crops by Memorial Day (361). In the mid-Atlantic, Austrian winter peas and hairy vetch planted October 1 and killed May 1 produced about the same total N and corn yields (108).

Southeast. Seed by October 1 in the inland Zone 8 areas of the South so that root crowns can become established to resist heaving. Peas produce more biomass in the cooler areas of the South than where temperatures rise quickly in spring (74, 361). Peas planted in late October in South Carolina's Zone 8 and terminated in mid- to late April produce 2,700 to 4,000 lb. dry matter/A (23).

Killing

Peas are easily killed any time with herbicides, or by disking or mowing after full bloom, the stage of maturity that provides the optimum N contribution. Disk lightly to preserve the tender residue for some short-term erosion control.

Winter pea residue breaks down and releases N quickly.

The downside to the quick breakdown of pea vines is their slimy condition in spring if they winterkill, especially in dense, pure stands. Planting with a winter grain provides some protection from winterkill and reduces matting of dead pea vegetation.

Pest Management

Winter peas break crop disease cycles, Ben Burkett of Petal, Miss., has found. *Septoria* leaf spot problems on his cash crops are reduced when he plants Austrian winter pea in fall after snap beans and ahead of collards and mustard greens the next summer. Between October 15 and November 15, Burkett broadcasts just 50 lb./A then incorporates the seed with a shallow pass of his field cultivator. They grow 3 to 6 inches tall before going dormant in late December in his Zone 8 location about 75 miles north of the Gulf of Mexico. Quick regrowth starts about the third week in January. He kills them in mid-April by disking, then shallow plows to incorporate the heavy residue (202).

Farmers and researchers note several IPM cautions, because Austrian winter peas:
- Host some races of nematodes
- Are susceptible to winter *Sclerotinia* crown rot, *Fusarium* root rot as well as seed rot and blights of the stem, leaf or pod
- Are variably susceptible to the *Ascochyta* blight (MELROSE cultivar has some resistance)
- Host the pathogen *Sclerotinia* minor. There was a higher incidence of leaf drop in California lettuce planted after Austrian winter peas in one year of a two-year test (232).

Austrian winter peas were heavily damaged by *Sclerotinia trifoliorum* Eriks in several years of a four-year study in Maryland, but the crop still produced from 2,600 to 5,000 lb. dry matter/A per year in four out of five years. One year DM production was only 730 lb./A. Mean N contribution despite the disease was 134 lb. N/A. Overall, Austrian winter peas were rated as being more suited for Maryland Coastal Plain use than in the Piedmont, due to harsher winters in the latter location (204).

To combat disease, rotate cover crops to avoid growing peas in the same field in successive years. To minimize disease risk, waiting several years is best. To minimize risk of losing cover crop benefits to *Sclerotinia* disease in any given season, mix with another cover crop such as cereal rye.

Crop Systems

Northern Plains. Austrian winter peas (and other grain legumes) are increasingly used instead of fallow in dryland cereal rotations. The legumes help prevent saline seeps by using excess soil moisture between cereal crops. They also add N to the system. The legume>cereal sequence starts with a spring- or fall-planted grain legume (instead of fallow), followed by a small grain.

Peas work well in this system because they are shallow-rooted and therefore do not extract deep soil moisture. The pea crop is managed according to soil moisture conditions. Depending on growing season precipitation, the peas can be grazed, terminated or grown to grain harvest. Growers terminate the crop when about 4 inches of plant-available water remains in the soil, as follows:

- **Below-normal rainfall**—terminate the grain legume early.
- **Adequate rainfall**—terminate the grain legume when about 4 inches of soil water remains. Residue is maintained for green manure, moisture retention and erosion prevention.
- **Above-average rainfall**—grow the crop to maturity for grain harvest.

In conventional fallow systems, fields are left unplanted to accumulate soil moisture for the cash crop. Weeds are controlled using tillage or herbicides.

Grain legumes provide a soil-protecting alternative to fallow that can be managed to ensure adequate moisture for the cereal crop. Legumes provide long-term benefits by producing N for the subsequent crop, disrupting disease, insect and weed cycles and building soil.

Austrian winter peas work in these rotations where there is at least 18 inches of rain per year. INDIANHEAD lentils (*Lens culinaris* Medik), a specialty lentil for cover crop use, are also widely used in this system.

Montana research shows that when soil moisture is replenished by winter precipitation, annual legumes can substitute for fallow without significantly reducing the yield of the next barley crop. Montana rainfall averages 12-16 inches, so peas are planted but can only be taken to grain harvest in above-normal rainfall years. The legume can generate income from harvest of its hay or grain or through fertilizer N savings from the legume's contribution to the small grain crop (136).

In Idaho, fall-seeded Austrian winter peas harvested for seed provided income, residual N from the pea straw and soil disease suppression in a study of efficient uses of the legume cover. A crop rotation of Austrian winter pea (for grain)>winter wheat>spring barley produced similar wheat yields as did using the peas as green manure or leaving the field fallow in the first year. While neither Austrian winter pea green manure nor fallow produced income, the green manure improved soil organic matter and added more N for wheat than did summer fallow. Fallow caused a net soil capacity loss by "mining" finite soil organic matter reserves (253).

In a northern Alberta comparison of conventional (tilled), chemical (herbicide) and green (field pea) fallow systems, spring-planted field peas provided 72 lb. N/A, significantly more than the other systems. The field pea system was also more profitable when all inputs were considered, providing higher yield for two subsequent cash crops, higher income and improvement of soil quality (12).

In the Northeast, spring-planted peas can be incorporated by Memorial Day.

Southeast. Fall-seeded Austrian winter peas outproduced hairy vetch by about 18 percent in both dry matter and N production in a three-year test in the Coastal Plain of North Carolina. When legumes were grown with rye, wheat or spring oats, Austrian winter pea mixtures also had the highest dry matter yields. Over the three years, Austrian winter peas ranked the highest (dry-matter and N) in the legume-only trials and as the legume component of the legume/grain mixtures. In descending order after the peas were hairy vetch, common vetch and crimson clover. The peas were sown at 54 lb./A in the pure seedings and 41 lb./A in mixtures (344).

In the year of greatest N fixation, soil N in the Austrian winter pea mixture treatments was 50 percent greater than the average of all other treatments. Researchers noted that the bottom leaves of pea vines were more decomposed than other legumes, giving the crop an earlier start in N contribution. Further, soil N in the upper 6 inches of soil under the Austrian winter peas held 30 to 50 percent of the total soil inorganic N in the winter pea treatments, compared with levels of less than

Peas Do Double Duty for Kansas Farmer

PARTRIDGE, Kan.—Jim French figures Austrian winter peas provide free grazing, free nitrogen, or both. The vining legume produces just as much N for the following grain sorghum crop even if he lets his registered Gelbvieh herd eat all they want of the winter annual's spring growth.

French farms on flat, well-drained sandy loam soil near Partridge, Kan. He manages about 640 acres each of cash crops (winter wheat and grain sorghum) and forages (alfalfa, sudangrass, winter peas and cowpeas, and an equal area in grass pasture). Peas follow wheat in the three-year crop rotation on his south-central Kansas farm. He chisel plows the wheat stubble twice about 7 inches deep, disks once to seal the surface, then controls weeds as necessary with a light field cultivator.

Between mid-September and mid-October he inoculates about 30 lb./A of the peas and drills them with an old John Deere double-run disk drill in 8-inch rows. Establishment is usually good, with his only anxiety coming during freeze-thaw cycles in spring. "Each time the peas break dormancy, start to grow, then get zapped with cold again they lose some of their root reserves and don't have quite the resistance to freezing they did. They'll sprout back even if there's vegetative freeze damage as long as their food reserves hold out," French reports.

Ironically, this spring freezing is less of a problem further north where fields stay frozen longer before a slower thaw. This works as long as snow cover protects the peas from the colder early and mid-winter temperatures. In most years, he sets up temporary fence and turns his cattle into the peas about April 1 at the stocking rate of two animal units per acre. During the best years of mild weather and adequate moisture, "the cattle have a hard time keeping up," says French. Depending on his need for forage or organic matter, he leaves the cattle in until he incorporates the pea stubble, or gives it time to regrow.

One reason he gets about the same 90 to 120 lb. N/A contribution with or without grazing is that the winter pea plants apparently continue N fixation and root growth while being grazed. Soil tests show that 25 to 30 lb. N/A are available in the nitrate form at incorporation in late spring, with the balance in an organic form that mineralizes over the summer. Grazing the peas helps to contain cheatgrass, which tends to tie up N if it's incorporated just ahead of his sorghum crop.

French is sold on winter peas ahead of his grain sorghum because it provides N while reducing weed pressure from cheatgrass and pigweed and decreasing lodging from charcoal root rot. The option to use the peas as forage—while still achieving adequate sorghum yield—lets him buy less processed feed, improves livestock health and accelerates conversion of the peas' organic material into available soil nutrients.

"Winter peas work best where you integrate crops and livestock," says French. "They give you so many benefits."

30 percent in the top soil layer for all other treatments. In situations where the early-summer N release from peas could be excessive, mixing Austrian winter peas with a grain can moderate the N contribution and slow down its release into the soil (344).

The carbon to nitrogen (C:N) ratio of plant matter is an indication of how rapidly vegetation will break down. Mixtures of small grains with Austrian winter peas and the vetches had C:N values from 13 to 34, but were generally under 25 to 30, the accepted threshold for avoiding net immobilization of N (344).

Austrian winter peas and crimson clover can provide adequate N for conventionally planted cotton in South Carolina. In a three-year trial, fertilizer rates of up to 150 lb. N/A made no improvement to cotton yield on the pea plots. The evaluation showed that soil nitrate under Austrian winter peas peaked about nine weeks after incorporation (22).

Austrian winter peas achieved 50 to 60 percent groundcover when they were overseeded at about 75 lb./A into soybeans at leaf yellowing in southeastern Pennsylvania, where they can survive some winters. The peas produced nearly 2 tons of dry matter and 130 lb. N/A by May 20 in this test (191). Overseeding peas into corn at last cultivation is not recommended due to poor shade tolerance.

Austrian winter peas, like other hollow-stemmed succulent covers such as vetch and fava beans, do not respond well to mowing or cutting after they begin to bloom. In their earlier stages, Austrian winter peas will regrow even when grazed several times. See *Peas Do Double Duty for Kansas Farmer* (p. 140).

After three years of moisture testing, Kansas farmer Jim French can explain why he sees more soil moisture after spring grazing than when the peas are left to grow undisturbed. "There's decreasing overall transpiration because there's less leaf area to move moisture out of the soil into the air. Yet the root mass is about the same." Ungrazed peas pump more water as they keep growing.

Other Options.

Harvest field peas for hay when most of the pods are well formed. Use a mower with lifting guards and a windrow attachment to handle the sprawling vines.

COMPARATIVE NOTES

Field peas won't tolerate field traffic due to succulent stems (191). When selecting types, remember that long-vined varieties are better for weed control than short-vined types.

Cultivars. MELROSE, known for its winter-hardiness, is a cultivar of the Austrian winter pea type. Planted the first week of September in Idaho, MELROSE peas yielded 300 lb. N/A and 6 tons of dry matter the next June. Planted in mid-April, the cultivar yielded "just" 175 lb. N/A and 3.5 T dry matter/A (202).

In dryland systems, winter peas produce abundant biomass with limited moisture.

GRANGER is an improved winter pea that has fewer leaves and more tendrils, which are stiffer than standard cultivars. It is more upright and its pods dry more quickly than other winter pea types. MAGNUS field peas have out-produced Austrian winter peas in California and bloom up to 60 days earlier.

Seed sources. See *Seed Suppliers* (p. 195).

HAIRY VETCH

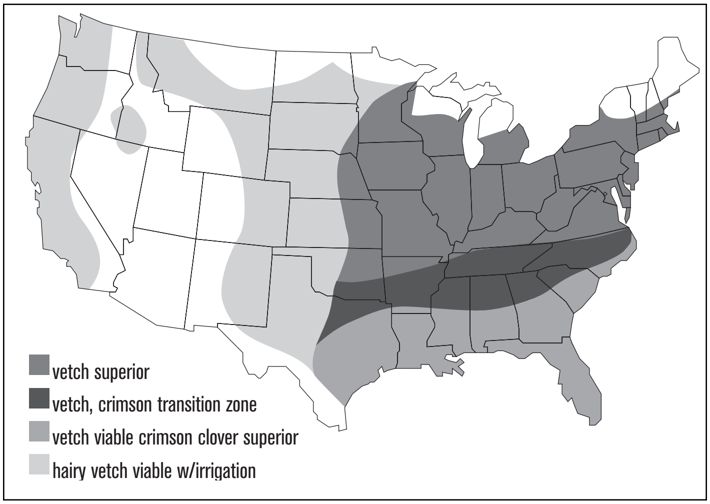
Vicia villosa

Type: winter annual or summer annual legume

Roles: N source, weed suppressor, topsoil conditioner, reduce erosion

Mix with: small grains, field peas, bell beans, crimson clover, buckwheat

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



Few legumes match hairy vetch for spring residue production or nitrogen contribution. Widely adapted and winter hardy through Hardiness Zone 4 and into Zone 3 (with snow cover), hairy vetch is a top N provider in temperate and subtropical regions.

The cover grows slowly in fall, but root development continues over winter. Growth quickens in spring, when hairy vetch becomes a sprawling vine up to 12 feet long. Field height rarely exceeds 3 feet unless the vetch is supported by another crop. Its abundant, viney biomass can be a benefit and a challenge. The stand smothers spring weeds, however, and can help you replace all or most N fertilizer needs for late-planted crops.

BENEFITS

Nitrogen source. Hairy vetch delivers heavy contributions of mineralized N (readily available to the following cash crop). It can provide sufficient N for many vegetable crops, partially replace N fertilizer for corn or cotton and increase cash crop N efficiency for higher yield.

In some parts of California and the East in Zone 6, hairy vetch provides its maximum N by safe corn planting dates. In Zone 7 areas of the Southeast, the fit is not quite as good, but substantial N from vetch is often available before corn planting.

Corn planting date comparison trials with cover crops in Maryland show that planting *as late* as May 15 (the very end of the month-long local planting period) optimizes corn yield and profit from the system. Spring soil moisture was higher under the vetch or a vetch-rye mixture than under cereal rye or no cover crop. Killed vetch left on the surface conserved summer moisture for improved corn production (80, 82, 84, 85, 173, 243).

Even without crediting its soil-improving benefits, hairy vetch increases N response and produces enough N to pay its way in many systems. Hairy vetch without fertilizer was the preferred option for "risk-averse" no-till corn farmers in Georgia, according to calculations comparing costs, production and markets during the study. The economic risk comparison included crimson clover, wheat and winter fallow. Profit was higher, but less predictable, if 50 pounds of N were added to the vetch system (310).

Hairy vetch ahead of no-till corn was also the preferred option for risk averse farmers in a three-

Note: To roughly estimate hairy vetch N contribution in pounds per acre, cut and weigh fresh vetch top growth from a 4-foot by 4-foot area. Multiply pounds of fresh vetch by 12 to gauge available N, by 24 to find total N (377). For a more accurate estimate, see *How Much N?* (p. 22).

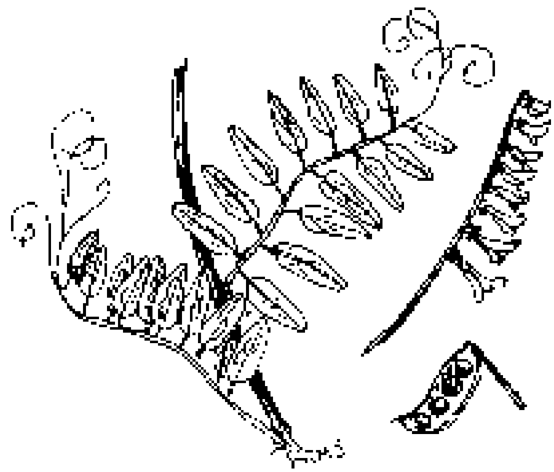
year Maryland study that also included fallow and winter wheat ahead of the corn. The vetch-corn system maintained its economic advantage when the cost of vetch was projected at maximum historic levels, fertilizer N price was decreased, and the herbicide cost to control future volunteer vetch was factored in (173). In a related study on the Maryland Coastal Plain, hairy vetch proved to be the most profitable fall-planted, spring desiccated legume ahead of no-till corn, compared with Austrian winter peas and crimson clover (243).

In Wisconsin's shorter growing season, hairy vetch planted after oat harvest provided a gross margin of $153/A in an oat/legume/corn rotation (1995 data). Profit was similar to using 160 lb. N/A in continuous corn, but with savings on fertilizer and corn rootworm insecticide (400).

Hairy vetch provides yield improvements beyond those attributable to N alone. These may be due to mulching effects, soil structure improvements leading to better moisture retention and crop root development, soil biological activity and/or enhanced insect populations just below and just above the soil surface.

Soil conditioner. Hairy vetch can improve root zone water recharge over winter by reducing runoff and allowing more water to penetrate the soil profile through macropores created by the crop residue (143). Adding grasses that take up a lot of water can reduce the amount of infiltration and reduce the risk of leaching in soils with excess nutrients. Hairy vetch, especially an oats/hairy vetch mix, decreased surface ponding and soil crusting in loam and sandy loam soils. Researchers attribute this to dual cover crop benefits: their ability to enhance the stability of soil aggregates (particles), and to decrease the likelihood that the aggregates will disintegrate in water (143).

Hairy vetch improves topsoil tilth, creating a loose and friable soil structure. Vetch doesn't build up long-term soil organic matter due to its tendency to break down completely. Vetch is a succulent crop, with a relatively "low" carbon to nitrogen ratio. Its C:N ratio ranges from 8:1 to 15:1, expressed as parts of C for each part of N. Rye C:N ratios range from 25:1 to 55:1, showing why it persists much longer under similar conditions than does vetch. Residue with a C:N ratio of 25:1 or more tends to immobilize N. For more information, see *How Much N?* (p. 22), and the rest of that section, *Building Soil Fertility and Tilth with Cover Crops* (p. 16).



HAIRY VETCH (Vicia villosa)

Early weed suppression. The vigorous spring growth of fall-seeded hairy vetch out-competes weeds, filling in where germination may be a bit spotty. Residue from killed hairy vetch has a weak allelopathic effect, but it smothers early weeds mostly by shading the soil. Its effectiveness wanes as it decomposes, falling off significantly after about three or four weeks. For optimal weed control with a hairy vetch mulch, select crops that form a quick canopy to compensate for the thinning mulch or use high-residue cultivators made to handle it.

Mixing rye and crimson clover with hairy vetch (seeding rates of 30, 10, and 20 lb./A, respectively) extends weed control to five or six weeks, about the same as an all-rye mulch. Even better, the mix provides a legume N boost, protects soil in fall and winter better than legumes, yet avoids the potential crop-suppressing effect of a pure rye mulch on some vegetables.

Good with grains. For greater control of winter annual weeds and longer-lasting residue, mix hairy vetch with winter cereal grains such as rye, wheat or oats.

Growing grain in a mixture with a legume not only lowers the overall C:N ratio of the combined residue compared with that of the grain, it may actually lower the C:N ratio of the small grain residue as well. This internal change causes the grain residue to break down faster, while accumulating the same levels of N as it did in a monoculture (344).

Moisture-thrifty. Hairy vetch is more drought-tolerant than other vetches. It needs a bit of moisture to establish in fall and to resume vegetative growth in spring, but relatively little over winter when above-ground growth is minimal.

Phosphorus scavenger. Hairy vetch showed higher plant phosphorus (P) concentrations than crimson clover, red clover or a crimson/ryegrass mixture in a Texas trial. Soil under hairy vetch also had the lowest level of P remaining after growers applied high amounts of poultry litter prior to vegetable crops (121).

Fits many systems. Hairy vetch is ideal ahead of early-summer planted or transplanted crops, providing N and an organic mulch. Some Zone 5 Midwestern farmers with access to low-cost seed plant vetch after winter grain harvest in mid-summer to produce whatever N it can until it winterkills or survives to regrow in spring.

Widely adapted. Its high N production, vigorous growth, tolerance of diverse soil conditions, low fertility need and winter hardiness make hairy vetch the most widely used of winter annual legumes.

MANAGEMENT

Establishment & Fieldwork

Hairy vetch can be no-tilled, drilled into a prepared seedbed or broadcast. Dry conditions often reduce germination of hairy vetch. Drill seed at 15 to 20 lb./A, broadcast 25 to 30 lb./A. Select a higher rate if you are seeding in spring, late in the fall, or into a weedy or sloped field. Irrigation will help germination, particularly if broadcast seeded.

Plant vetch 30 to 45 days before killing frost for winter annual management; in early spring for summer growth; or in July if you want to kill or incorporate it in fall or for a winter-killed mulch.

Hairy vetch has a relatively high P and K requirement and, like all legumes, needs sufficient sulfur and prefers a pH between 6.0 and 7.0. However, it can survive through a broad pH range of 5.0 to 7.5 (120).

An Illinois farmer successfully no-tills hairy vetch in late August at 22 lb./A into closely mowed stands of fescue on former Conservation Reserve Program land (417). Using a herbicide to kill the fescue is cheaper than mowing, but it must be done about a month later when the grass is actively growing for the chemical to be effective. Vetch also can be no-tilled into soybean or corn stubble (50, 80).

In Minnesota, vetch can be interseeded into sunflower or corn at last cultivation. Sunflower should have at least 4 expanded leaves or yield will be reduced (221, 222).

Farmers in the Northeast's warmer areas plant vetch by mid-September to net 100 lb. available N/A by mid-May. Sown mid-August, an oats/hairy vetch mix can provide heavy residue (180).

Rye/hairy vetch mixtures mingle and moderate the effects of each crop. The result is a "hybrid" cover crop that takes up and holds excess soil nitrate, fixes N, stops erosion, smothers weeds in spring and on into summer if not incorporated, contributes a moderate amount of N over a longer period than vetch alone, and offsets the N limiting effects of rye (81, 83, 84, 86, 377).

Seed vetch/rye mixtures, at 15-25 lb. hairy vetch with 40-70 lb. rye/A (81, 361).

Overseeding (40 lb./A) at leaf-yellowing into soybeans can work if adequate rainfall and soil moisture are available prior to the onset of freezing weather. Overseeding into ripening corn (40 lb./A) or seeding at layby has not worked as consistently. Late overseeding into vegetables is possible, but remember that hairy vetch will not stand heavy traffic (361).

Killing

Your mode of killing hairy vetch and managing residue will depend on which of its benefits are most important to you. Incorporation of hairy vetch vegetation favors first-year N contribution, but takes significant energy and labor. Keeping vetch residue on the surface favors weed suppression, moisture retention, and insect habitat, but may reduce N contribution. However, even in no-till systems, hairy vetch consistently provides very large N input (replacing up to 100 lb. N/A).

In spring, hairy vetch continues to add N through its "seed set" stage after blooming. Biomass and N increase until maturity, giving either greater benefit or a dilemma, depending on your ability to deal with vines that become more sprawling and matted as they mature.

Mulch-retaining options include strip-tilling or strip chemical desiccation (leaving vetch untreated between the strips), mechanical killing (rotary mowing, flailing, cutting, sub-soil shearing with an undercutter, or chopping/flattening with a roller/crimper) or broadcast herbicide application.

No-till corn into killed vetch. The best time for no-till corn planting into hairy vetch varies with local rainfall patterns, soil type, desired N contribution, season length and vetch maturity.

In **southern Illinois**, hairy vetch no-tilled into fescue provided 40 to 180 lb. N/A per year over 15 years for one researcher/farmer. He used herbicide to kill the vetch about two weeks before the area's traditional mid-May corn planting date. The 14-day interval was critical to rid the field of prairie voles, present due to the field's thick fescue thatch.

He kills the vetch when it is in its pre-bloom or bloom stage, nearing its peak N-accumulation capacity. Further delay would risk loss of soil moisture in the dry period customary there in early June. When the no-tilled vetch was left to grow one season until seed set, it produced 6 tons of dry matter and contributed a potentially polluting 385 lb. N/A (417). This high dose of N must be managed carefully during the next year to prevent leaching or surface runoff of nitrates.

A series of trials in **Maryland** showed a different mix of conditions. Corn planting in late-April is common there, but early killing of vetch to plant corn then had the surprising effect of *decreasing* soil moisture and corn yield, as well as predictably lowering N contribution. The earlier-planted corn had less moisture-conserving residue. Late April or early May kill dates, with corn no-tilled 10 days later, consistently resulted in higher corn yields than earlier kill dates (82, 83, 84, 85). With hairy vetch and a vetch/rye mixture, summer soil water conservation by the cover crop residue had a greater impact than spring moisture depletion by the growing cover crop in determining corn yield (84, 85).

Results in the other trials, which also included a pure rye cover, demonstrated the management flexibility of a legume/grain mix. Early killed rye protects the soil as it conserves water and N, while vetch killed late can meet a large part of the N requirement for corn. The vetch/rye mixture can conserve N and soil moisture while fixing N for the subsequent crop. The vetch and vetch/rye mixture accumulated N at 130 to 180 lb./A. The mixture contained as much N or more than vetch alone (85, 86).

In an **Ohio** trial, corn no-tilled into hairy vetch at mid-bloom in May received better early season weed control from vetch mulch than corn seeded into vetch killed earlier. The late planting date decreased yield, however (189), requiring calculation to determine if lower costs for tillage, weed control, and N outweigh the yield loss.

Once vetch reaches about 50% bloom, it is easily killed by any mechanical treatment. To mow-kill for mulch, rye grown with hairy vetch improves cutting by holding the vetch off the ground to allow more complete severing of stems from roots. Rye also increases the density of residue covering the vetch stubble to prevent regrowth.

Much quicker and more energy-efficient than mowing is use of a modified Buffalo rolling stalk chopper, an implement designed to shatter standing corn stubble. The chopper's rolling blades break over, crimp and cut crop stems at ground level, and handle thick residue of hairy vetch at 8 to 10 mph (169).

Cover Crop Roller Design Holds Promise For No-Tillers

However, timing of control and planting in a single pass could limit adoption; hope lies in breeding cover crops that flower in time for traditional planting window.

THE POSSIBILITY of using rollers to reduce herbicide use isn't new, but advances are being made to improve the machines in ways that could make them practical for controlling no-till cover crops.

Cover crop rolling is gaining visibility and credibility in tests by eight university/farmer research teams across the country. The test rollers were designed and contributed by The Rodale Institute (TRI), a Pennsylvania-based organization focused on organic agricultural research and education. The control achieved with the roller is comparable to a roller combined with a glyphosate application, according to TRI.

The Rodale crop rollers were delivered to state and federal cooperative research teams in Virginia, Michigan, Mississippi, North Dakota, Pennsylvania, Georgia, California and Iowa in Spring, 2005. Funding for the program comes from grants and contributions from the Natural Resources Conservation Service and private donors. I&J Manufacturing in Gap, Pa., fabricated the models distributed to the research teams.

"The requirement is that each research leader partners with a farmer cooperator to adapt the rollers to local conditions and cover cropping systems," explains Jeff Moyer, TRI's farm manager. "Our goal is to gain more knowledge about the soil building and weed management effects of cover crops while reducing the need for herbicides," he says.

Farmer Built. Moyer designed and built the first front-mounted TRI roller prototype in 2002 in conjunction with Pennsylvania farmer John Brubaker, whose land abuts the TRI property. The original 10-foot, 6-inch roller width is equal to 4 rows on 30-inch spacing, with a 3-inch overlap on each end. The original design has already been modified to include a 15-foot, 6-inch model suitable for use with a 6-row planter on 30-inch rows. It can be adapted to fit a 4-row planter on 38-inch rows, and a 5-foot version for 2-row vegetable planters.

"We realize that 6-row equipment is small by today's standards, and work is under way on a system that mounts one section of the roller in front of the tractor with the remainder mounted on the planter ahead of the row units. This design will allow as wide a roller system as a farmer needs," Moyer says.

Chevron Pattern. The chevron pattern on the face of the roller came about after the designers realized that mounting the roller blades in a straight line would cause excessive bouncing, while just curving the blades in a screw pattern would act like an auger and create a pulling effect. "If you were driving up a hill that might be fine, but we don't need help pulling our tractors down the steep slopes we farm. The chevron pattern neutralizes any forces that might pull the tractor in either direction," Moyer explains. It overcomes both the bounce of straight-line blades and the auguring effect of corkscrew blades.

"In addition, with the twisted blade design, only a very small portion of the blade touches the ground at any one time as it turns, so the full pressure of the roller is applied 1 inch at a time. This roller design works better than anything we've ever used," he adds.

Prior to settling on the TRI prototype, Moyer and Brubaker studied stalk choppers with nine rolling drums arranged in two parallel rows. This design required 18 bearings and provided lots of places for green plant material to bunch up. The TRI ground-driven roller has a single cylinder and two offset bearings inset 3 inches on either side and fronted with a shield. The blades are welded onto the 16-inch-diameter drum, but replacement blades can be purchased from the manufacturer and bolted on as needed. The 10-foot, 6-inch roller weighs 1,200 pounds empty and 2,000 pounds if filled with water.

Front Mount Benefits. The biggest advantage of the front-mounted roller is that the operator can roll the cover crop and no-till the cash crop in a single field pass, Moyer explains. In TRI trials, simultaneous rolling and no-till planting eliminated seven of the eight field passes usually necessary with conventional organic corn production, including plowing, discing, packing, planting, two rotary hoe passes and two cultivations.

Rolling the field and no-tilling in one pass also eliminates the problem of creating a thick green cover crop mat that makes it difficult to see a row marker line on a second pass for planting.

Also, planting in a second pass in the opposite direction from which the cover crop was rolled makes getting uniform seeding depth and spacing more difficult because the planter tends to stand the plant material back up. "Think of it as combing the hair on your dog backwards," Moyer says.

"Another disadvantage of rear-mounted machines like stalk choppers is that the tractor tire is the first thing touching the cover crop. If the soil is even a little spongy, the cover crop will be pushed into the tire tracks and because the roller is running flat, it can't crimp the depressed plant material. A week later the plants missed by the roller will be back up and growing again."

Crop Versatility. The TRI roller concept has been tested in a wide range of winter annual cover crops, including cereal rye, hairy vetch, wheat, triticale, oats, buckwheat, clover, winter peas and other species. Timing is the key to success, Moyer emphasizes, and a lot of farmers don't have the patience to make it work right.

"The bottom line is that winter annuals want to die anyway, but if you time it wrong, they're hard to kill," he says. "If you try to roll a winter annual before it has flowered—before it has physiologically reproduced—the plant will try to stand up again and complete the job of reproduction, the most important stage of its life cycle. But, if you roll it after it has flowered, it will dry up and die."

At least a 50 percent, and preferably a 75 to 100 percent bloom, is recommended before rolling. Moyer hopes to see plant breeders recognize the need to develop cover crop varieties with blooming characteristics that coincide with preferred crop planting windows.

"We really like to use hairy vetch on our farm, for example, because it's a great source of nitrogen and is a very suitable crop to plant corn into. The roller crimps the stem of the hairy vetch every 7 inches, closing the plant's vascular system and ensuring its demise.

"The problem is we would like it to flower a couple weeks earlier to fit our growing season. It's hard for farmers to understand when it's planting time and we're telling them to wait a couple more weeks for their cover crop to flower," he says.

"We need to identify the characteristics we want in cover crops and encourage plant breeders to focus on some of those. It should be a relatively easy task to get an annual crop to mature a couple weeks earlier, compared to some of the breakthrough plant breeding we've seen recently," Moyer says.

continued on page 148

For More Information. Updates on roller research, more farmer stories and plans for the TRI no-till cover crop roller can be accessed at www.newfarm.org/depts/notill. To ask questions of The Rodale Institute, e-mail to info@rodaleinst.org.

See also "Where can I find information about the mechanical roller-crimper used in no-till production?" http://attra.ncat.org/calendar/question.php/2006/05/08/p2221.

To contact the manufacturer of commercially available cover crop rollers, visit www.croproller.com.

Editor's Note: PURPLE BOUNTY, a new, earlier variety of hairy vetch, was released in 2006 by the USDA-Agricultural Research Service, Beltsville, MD in collaboration with the Rodale Institute, Pennsylvania State University and Cornell University.
—Ron Ross. Adapted with permission from www.no-tillfarmer.com

No-till vegetable transplanting. Vetch that is suppressed or killed without disturbing the soil maintains moisture well for transplanted vegetables. No-till innovator Steve Groff of Lancaster County, Pa., uses the rolling stalk chopper to create a killed organic mulch. His favorite mix is 25 lb. hairy vetch, 30 lb. rye and 10 lb. crimson clover/A.

Winter hardy through the warmer parts of Zone 4, few legumes can rival hairy vetch's N contributions.

No-till, delayed kill. Farmers and researchers are increasingly using a roller/crimper to kill hairy vetch and other cover crops (11). Jeff Moyer and others at the Rodale Institute in Kutztown, Pa., roll hairy vetch and other cover crops in late May or early June (at about 50% flower). The modified roller is front-mounted, and corn is no-tilled on the same pass (303). See *Cover Crop Roller Design Holds Promise For No-Tillers*, p. 146.

Also useful in killing hairy vetch on raised beds for vegetables and cotton is the improved prototype of an undercutter that leaves severed residue virtually undisturbed on the surface (96). The undercutter tool includes a flat roller attachment, which, by itself, usually provides only partial suppression unless used after flowering.

Herbicides will kill vetch in three to 30 days, depending on the material used, rate, growth stage and weather conditions.

Vetch incorporation. As a rule, to gauge the optimum hairy vetch kill date, credit vetch with adding two to three pounds of N per acre per sunny day after full spring growth begins. Usually, N contribution will be maximized by early bloom (10-25 percent) stage.

Cutting hairy vetch close to the ground at full bloom stage usually will kill it. However, waiting this long means it will have maximum top growth, and the tangled mass of mature vetch can overwhelm many smaller mowers or disks. Flail mowing before tillage helps, but that is a time and horsepower intensive process. Sickle-bar mowers should only be used when the vetch is well supported by a cereal companion crop and the material is dry (422).

Management Cautions

About 10 to 20 percent of vetch seed is "hard" seed that lays ungerminated in the soil for one or more seasons. This can cause a weed problem, especially in winter grains. In wheat, a variety of herbicides are available, depending on crop growth stage. After a corn crop that can utilize the vetch-produced N, you could establish a hay or pasture crop for several years.

Don't plant hairy vetch with a winter grain if you want to harvest grain for feed or sale.

Production is difficult because vetch vines will pull down all but the strongest stalks. Grain contamination also is likely if the vetch goes to seed before grain harvest. Vetch seed is about the same size as wheat and barley kernels, making it hard and expensive to separate during seed cleaning (361). Grain price can be markedly reduced by only a few vetch seeds per bushel.

A severe freeze with temperatures less than 5° F may kill hairy vetch if there is no snow cover, reducing or eliminating the stand and most of its N value. If winterkill is possible in your area, planting vetch with a hardy grain such as rye ensures spring soil protection.

Pest Management

In legume comparison trials, hairy vetch usually hosts numerous small insects and soil organisms (206). Many are beneficial to crop production, (see below) but others are pests. Soybean cyst nematode (*Heterodera glycines*) and root-knot nematode (*Meliodogyne* spp.) sometimes increase under hairy vetch. If you suspect that a field has nematodes, carefully sample the soil after hairy vetch. If the pests reach an economic threshold, plant nematode-resistant crops and consider using another cover crop.

Other pests include cutworms (361) and southern corn rootworm (67), which can be problems in no-till corn, tarnished plant bug, noted in coastal Massachusetts (56), which readily disperses to other crops, and two-spotted spider mites in Oregon pear orchards (142). Leaving unmowed remnant strips can lessen movement of disruptive pests while still allowing you to kill most of the cover crop (56).

Prominent among beneficial predators associated with hairy vetch are lady beetles, seven-spotted ladybeetles (56) and bigeyed bugs (*Geocaris* spp.). Vetch harbors pea aphids (*Acyrthosiphon pisum*) and blue alfalfa aphids (*Acyrthosiphon kondoi*) that do not attack pecans but provide a food source for aphid-eating insects that can disperse into pecans (58). Similarly, hairy vetch blossoms harbor flower thrips (*Frankliniella* spp.), which in turn attract important thrip predators such as insidious flower bugs (*Orius insidiosus*) and minute pirate bugs (*Orius tristicolor*).

Two insects may reduce hairy vetch seed yield in heavy infestations: the vetch weevil or vetch bruchid. Rotate crops to alleviate buildup of these pests (361).

CROP SYSTEMS

In no-till systems, killed hairy vetch creates a short-term but effective spring/summer mulch, especially for transplants. The mulch retains moisture, allowing plants to use mineralized nutrients better than unmulched fields. The management challenge is that the mulch also lowers soil temperature, which may delay early season growth (361). One option is to capitalize on high quality, low-cost tomatoes that capture the late-season market premiums. See *Vetch Beats Plastic* (p. 150).

Mix hairy vetch with cereal grains to reduce the risk of N leaching.

How you kill hairy vetch influences its ability to suppress weeds. Durability and effectiveness as a light-blocking mulch are greatest where the stalks are left whole. Hairy vetch severed at the roots or sickle-bar mowed lasts longer and blocks more light than flailed vetch, preventing more weed seeds from germinating (96, 411).

Southern farmers can use an overwintering hairy vetch crop in continuous no-till cotton. Vetch mixed with rye has provided similar or even increased yields compared with systems that include conventional tillage, winter fallow weed cover and up to 60 pounds of N fertilizer per acre. Typically, the cover crops are no-till drilled after shredding cotton stalks in late October. Covers are spray killed in mid-April ahead of cotton planting in May. With the relatively late fall planting, hairy vetch delivers only part

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Note: An unmowed rye/hairy vetch mix sustained a population of aphid-eating predators that was six times that of the unmowed volunteer weeds and 87 times that of mown grass and weeds (57).

Vetch Beats Plastic

BELTSVILLE, Md.—Killed cover crop mulches can deliver multiple benefits for no-till vegetable crops (1, 2, 3, 4). The system can provide its own N, quell erosion and leaching, and displace herbicides. It's also more profitable than conventional commercial production using black plastic mulch. A budget analysis showed it also should be the first choice of "risk averse" farmers, who prefer certain although more modest profit over higher average profit that is less certain (224).

The key to the economic certainty of a successful hairy vetch planting is its low cost compared with the black plastic purchase, installation and removal.

From refining his own research and on-farm tests in the mid-Atlantic region for several years, Aref Abdul-Baki, formerly of the USDA's Beltsville (Md.) Agricultural Research Center, outlines his approach:

- Prepare beds—just as you would for planting tomatoes—at your prime time to seed hairy vetch.
- Drill hairy vetch at 40 lb./A, and expect about 4 inches of top growth before dormancy, which stretches from mid-December to mid-March in Maryland.
- After two months' spring growth, flail mow or use other mechanical means to suppress the hairy vetch. Be ready to remow or use herbicides to clean up trouble spots where hairy vetch regrows or weeds appear.
- Transplant seedlings using a minimum tillage planter able to cut through the mulch and firm soil around the plants.

The hairy vetch mulch suppresses early season weeds. It improves tomato health by preventing soil splashing onto the plants, and keeps tomatoes from soil contact, improving quality. Hairy vetch-mulched plants may need more water. Their growth is more vigorous and may yield up to 20 percent more than those on plastic. Completing harvest by mid-September allows the field to be immediately reseeded to hairy vetch. Waiting for vetch to bloom in spring before killing it and the tight fall turnaround may make this system less useful in areas with a shorter growing season than this Zone 7, mid-Atlantic site.

Abdul-Baki rotates season-long cash crops of tomatoes, peppers and cantaloupe through the same plot between fall hairy vetch seedings. He shallow plows the third year after cantaloupe harvest and seeds hairy vetch for flat-field crops of sweet corn or snap beans the following summer.

He suggests seeding rye (40 lb./A) with the vetch for greater biomass and longer-lasting mulch. Adding 10-12 lb./A of crimson clover will aid in weed suppression and N value. Rolling the covers before planting provides longer-lasting residue than does mowing them. Some weeds, particularly perennial or winter annual weeds, can still escape this mixture, and may require additional management (4).

of its potential N in this system. It adds cost, but supplies erosion control and long-term soil improvement (35).

Cotton yields following incorporated hairy vetch were perennial winners for 35 years at a northwestern Louisiana USDA site. Soil organic matter improvement and erosion control were additional benefits (276).

Other Options

Spring sowing is possible, but less desirable than fall establishment because it yields significantly less biomass than overwintering stands. Hot weather causes plants to languish.

Hairy vetch makes only fair grazing—livestock do not relish it.

Harvesting seed. Plant hairy vetch with grains if you intend to harvest the vetch for seed. Use a moderate seeding rate of 10-20 lb./A to keep the stand from getting too rank. Vetch seed pods will grow above the twining vetch vines and use the grain as a trellis, allowing you to run the cutter bar higher to reduce plugging of the combine. Direct combine at mid-bloom to minimize shattering, or swath up to a week later. Seed is viable for at least five years if properly stored (361).

If you want to save dollars by growing your own seed, be aware that the mature pods shatter easily, increasing the risk of volunteer weeds. To keep vetch with its nurse crop, harvest vetch with a winter cereal and keep seed co-mingled for planting. Check the mix carefully for weed seeds.

COMPARATIVE NOTES

Hairy vetch is better adapted to sandy soils than crimson clover (344), but is less heat-tolerant than LANA woollypod vetch. See *Woollypod Vetch* (p. 185).

Cultivars. MADISON—developed in Nebraska—tolerates cold better than other varieties. Hairy vetches produced in Oregon and California tend to be heat tolerant. This has resulted in two apparent types, both usually sold as "common" or "variety not stated" (VNS). One has noticeably hairy, bluish-green foliage with bluish flowers and is more cold-tolerant. The other type has smoother, deep-green foliage and pink to violet flowers.

A closely related species—LANA woollypod vetch (*Vicia dasycarpa*)—was developed in Oregon and is less cold tolerant than *Vicia villosa*. Trials in southeastern Pennsylvania with many accessions of hairy vetch showed big flower vetch (*Vicia grandiflora*, cv WOODFORD) was the only vetch species hardier than hairy vetch. EARLY COVER hairy vetch is about 10 days earlier than regular common seed. PURPLE BOUNTY, released in 2006, is a few days earlier and provides more biomass and better ground cover than EARLY COVER.

Seed sources. See *Seed Suppliers* (p. 195).

MEDICS

Medicago spp.

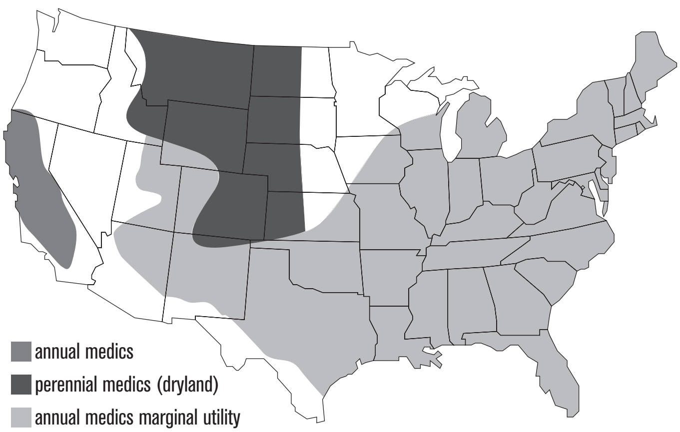
Also called: black medic, burr (or bur) medic, burclover

Type: Winter annual or summer annual legume

Roles: N source, soil quality builder, weed suppressor, erosion fighter

Mix with: Other medics; clovers and grasses; small grains

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



Once established, few other legumes outperform medics in soil-saving, soil-building and—in some systems—forage, when summer rainfall is less than 15 inches. They serve well in seasonally dry areas from mild California to the harsh Northern Plains. With more rainfall, however, they can produce almost as much biomass and N as clovers. Perennial medics are self-reseeding with abundant "hard seed" that can take several years to germinate. This makes medics ideal for long rotations of forages and cash crops in the Northern Plains and in cover crop mixtures in the drier areas of California.

Annual medics include 35 known species that vary widely in plant habit, maturity date and cold tolerance. Most upright varieties resemble alfalfa in their seeding year with a single stalk and short taproot. Medics can produce more than 100 lb. N/A in the Midwest under favorable conditions, but have the potential for 200 lb. N/A where the plants grow over winter. They germinate and grow quickly when soil moisture is adequate, forming a thick ground cover that holds soil in place. The more prostrate species of annual medic provide better ground cover.

Significant annual types include: **burr** medic (*M. polymorpha*), which grows up to 14 inches tall, is semi-erect or prostrate, hairless, and offers great seed production and N-fixing ability; barrel medic (*M. truncatula*), about 16 inches tall, with many mid-season cultivars; and snail medic (*M. scutellata*), which is a good biomass and N producer.

Southern spotted burr medic is a native *M. polymorpha* cultivar with more winterhardiness than most of the current burr medics, which are imported from Australia. See *Southern Burr Medic Offers Reseeding Persistence* (p. 154). Naturalized burr medic seed is traded locally in California.

Annual medics broadcast in spring over wheat stubble in Michigan reduced weed number and growth of spring annual weeds prior to no-till corn planting the following spring. Spring-planted annual medics produced dry matter yields similar to or greater than alfalfa by July (373, 376).

Black medic (*M. lupulina*) is usually called a perennial. It can improve soil, reduce diseases, save moisture and boost grain protein when grown in rotations with grains in the Northern Plains. GEORGE is the most widely used cultivar in dryland areas of the Northern Plains. Black medic produces abundant seed. Up to 96 percent of it is hard seed, much of it so hard seeded that it won't

Jess Counts on GEORGE for N and Feed

STANFORD, Mon.—Jess Alger can count on 13 inches of rainfall or less on his central Montana farm, occasional hail damage, too few solar units to raise safflower or millet, some bone-chilling winters without snow cover—and George. That's GEORGE black medic.

On-farm tests showed he got 87 lb. N/A and 3 percent organic matter on his Judith clay loam soils. He initially seeded the medic on 10-inch row spacings with barley at 10 lb./A, his standard rate and seeding method. He grazed the medic early in the second year, and then let it go to seed. In Year 3, he sprayed it with glyphosate in order to establish a sorghum-sudangrass hybrid as emergency forage on May 15. He had several inches of growth when frost hit about June 10 and killed the tender grass.

The medic came on strong. He let it mature to its full 12 inches to harvest it for seed. "It was already laying over, but the pickup guards on my combine helped to gather in about half the seed." The other half pumped up the seed bank for years ahead.

He did a comparison with side-by-side fields of spring wheat. One followed a spring wheat crop, the other he planted into a six-year-old stand of GEORGE medic. The medic/wheat interplant yielded 29 bushels per acre—six bushels less than the other field. But the interplanted grain tested at 15 percent protein, a full percentage point higher. Those are high yields for Alger's area, partly due to timely summer rain. "The yield drop with medic was mostly a weed problem with Persian darnel," Alger explains, "but I now have that mostly under control."

Jess continues to fine-tune his system to maximize income and weed management. He became certified organic in 1999. He maintains the medic seed bank with no-till plantings of GEORGE with a nurse crop of Austrian winter peas. He is experimenting successfully with rye instead of summer fallow.

If weed pressure is high, medic fields are grazed closely to prevent weeds from going to seed, then plowed. Otherwise, he no-tills winter wheat into standing medic so he can leave most of the medic in place, bury less seed and allow GEORGE to rest more securely in his field.

Updated in 2007 by Andy Clark

germinate for two years. Second-year growth may be modest, but coverage improves in years three and four after the initial seeding if competition is not excessive (422) and grazing management is timely.

BENEFITS

Good N on low moisture. In dryland areas, most legumes offer a choice between N production and excessive water use. Medics earn a place in dryland crop rotations because they provide N while conserving moisture comparable to bare-ground fallow (230, 380).

Fallow is the intentional resting of soil for a season so it will build up moisture and gain fertility by biological breakdown of organic matter. Black medic increased spring wheat yield by about 92 percent compared with spring wheat following fallow, and also appreciably raised the grain protein level (379). GEORGE grows in a prostrate to ascending fashion and overwinters well with snow cover in the Northern Plains.

April soil N value after black medic in one Montana test was 117 lb./A, about 2.5 times the fallow N level and the best of six cultivars tested, all of which used less water than the fallow treatment (378). In North Dakota, however, unrestricted medic growth depressed yield of a following wheat crop (73).

Great N from more water. Under normal dryland conditions, medics usually produce about 1 T dry matter/A, depending on available soil mois-

Southern Spotted Burr Medic Offers Reseeding Persistence

While annual medics, in general, are hard seeded, they usually cannot tolerate winters north of the Gulf South. Southern spotted burr medic (*Medicago arabica*) shows promise as a winter legume that can reseed for several years from a single seed crop in Hardiness Zone 7 of the Southeast.

Once as widely grown as hairy vetch in the mid-South region of the U.S., burr medic persists in non-cropland areas because it is well adapted to the region (326, 327). A local accession collected in northern Mississippi exhibits better cold hardiness and insect resistance than commercially available (Australian) annual medics.

In a replicated cold-hardiness trial spanning several states, spotted burr medic flowered in mid-March, about two weeks after SERENA, CIRCLE VALLEY or SANTIAGO burclover, but two weeks before TIBBEE crimson clover. The burr medic flowered over a longer period than crimson, matured seed slightly sooner than TIBBEE but generally did not produce as much biomass.

The big advantage of spotted burr medic over crimson clover was its ability to reseed for several years from a single seed crop. In studies in several states, the native medic successfully reseeded for at least two years when growth was terminated two weeks after TIBBEE bloomed. Only balansa clover (see *Up-and-Coming Cover Crops*, p. 191) reseeded as well as spotted burclover (105). The burr medic cultivar CIRCLE VALLEY successfully reseeded in a Louisiana no-till cotton field for more than 10 years without special management to maintain it (103).

Research in the Southeast showed that if Southern spotted burr medic begins blooming March 23, it would form viable seed by May 2, and reach maximum seed formation by May 12. By allowing the cover crop to grow until 40 to 50 days after first bloom and managing the cropping system without tillage that would bury burclover seeds too deeply, Southern spotted burclover should successfully reseed for several years.

Native medic seed is being increased in cooperation with the USDA-Natural Resources Conservation Service's Jamie Whitten Plant Materials Center, Coffeeville, Miss., for possible accelerated release to seed growers as a "source-identified" cover crop.

Insect pests such as clover leaf weevil (*Hypera punctata* Fabricius) and the alfalfa weevil (*Hypera postica* Gyllenhal) preferentially attack medics over other winter legume cover crops in the Southeast, and could jeopardize seed production. These insects are easily controlled with pyrethroid insecticides when weevils are in their second instar growth stage. While not usually needed for single-season cover crop benefits, insecticides may be warranted in the seeding year to ensure a reseeding crop for years to come.

ture and fertility. When moisture is abundant, medics can reach their full potential of 3 T/A of 3.5 to 4 percent plant-tissue nitrogen, contributing more than 200 lb. N/A (201, 422).

Fight weeds. Quick spring regrowth suppresses early weeds. Fall weeds are controlled by medic regrowth after harvest, whether the medic stand is overseeded or interplanted with the grain, or the grain is seeded into an established medic stand. In California orchards and vineyards where winters are rainy instead of frigid, medics mixed with other grasses and legumes provide a continuous cover that crowds out weeds. In those situations, medics help reduce weed seed production for the long-term.

Boost organic matter. Good stands of medics in well drained soil can contribute sufficient residue to build soil organic matter levels. One Indiana

Hard-seeded medics are ideal for reseeding systems in orchards and vineyards.

test reported a yield of more than 9,000 lb. dry matter/A from a spring-sown barrel medic (164).

Reduce soil erosion. Medics can survive in summer drought-prone areas where few other cultivated forage legumes would, thanks to their hard-seeded tendency and drought tolerance. Low, dense vegetation breaks raindrop impact while roots may penetrate 5 feet deep to hold soil in place.

Tolerate regular mowing. Medics can be grazed or mowed at intervals with no ill effects. They should be mowed regularly to a height of 3 to 5 inches during the growing season for best seed set and weed suppression. To increase the soil seed bank, rest medic from blooming to seed maturation, then resume clipping or grazing (285, 422, 435).

Provide good grazing. Green plants, dry plants and burs of burr medic provide good forage, but solid stands can cause bloat in cattle (422). The burs are concentrated nutrition for winter forage, but lower the value of fleece when they become embedded in wool. Annual medics overseeded into row crops or vegetables can be grazed in fall after cash crop harvest (376).

Reseeding. Black medic has a high percentage of hard seed. Up to 90 percent has an outer shell that resists the softening by water and soil chemicals that triggers germination (286). Scarified seed will achieve 95 percent germination, and 10-year old raw seed may still be 50 percent viable (422). Burr medic seed in the intact bur remains viable for a longer time than hulled seed (120).

Their status as a resilient, reseeding forage makes medics the basis for the "ley system" developed in dry areas of Australia. Medics or subterranean clover pastured for several years on Australian dry-lands help to store moisture and build up soil productivity for a year of small grain production before being returned to pasture. This use requires livestock for maximum economic benefit. GEORGE black medic is prostrate, allowing other grasses and forbs to become the overstory for grazing. It is well-suited to cold winter areas of Hardiness Zone 4, where it can stay green much of the winter (6).

Elayne Sears

BLACK MEDIC (Medicago lupulina)

Quick starting. Black medic can germinate within three days of planting (286). About 45 days after mid-April planting in southern Illinois, two annual medics were 20 inches tall and blooming. In the upper Midwest, snail and burr medics achieve peak biomass about 60 days after planting. An early August seeding of the annuals in southern Illinois germinated well, stopped growing during a hot spell, then restarted. Growth was similar to the spring-planted plots by September 29 when frost hit. The plants stayed green until the temperature dipped to the upper teens (201).

Widely acclimated. Species and cultivars vary by up to seven weeks in their estimated length of time to flowering. Be sure to select a species to fit your weather and crop rotation.

MANAGEMENT

Establishment

Annual medics offer great potential as a substitute for fallow in dry northern regions of the U.S. with longer day length. Annual medics need to fix as much N as winter peas or lentils and have a competitive establishment cost per acre to be as valuable as these better-known legume green manures (383).

Medics are widely adapted to soils that are reasonably fertile, but not distinctly acid or alkaline. Excessive field moisture early in the season can significantly reduce medic stands (373). Acid-tolerant rhizobial strains may help some cool-season medics, especially barrel medic, to grow on sites that otherwise would be inhospitable (422).

To reduce economic risk in fields where you've never grown medic, sow a mixture of medics with variable seed size and maturation dates. In dry areas of California, medic monocultures are planted at a rate of 2 to 6 lb./A, while the rate with grasses or clovers is 6 to 12 lb./A (422).

Establishment options vary depending on climate and crop system:

• **Early spring—clear seed.** Drill $\frac{1}{4}$ to $\frac{1}{2}$ inch deep (using a double-disk or hoe-type drill) into a firm seed bed as you would for alfalfa. Rolling is recommended before or after seeding to improve seed-soil contact and moisture in the seed zone. Seeding rate is 8 to 10 lb./A for black medic, 12 to 20 lb./A for larger-seeded (snail, gamma and burr) annual medics. In the arid Northern Plains, fall germination and winter survival are dependable, although spring planting also has worked.

Medics earn a place in dryland rotations because they provide N while conserving moisture.

• **Spring grain nurse crop.** Barley, oats, spring wheat and flax can serve as nurse crops for medic, greatly reducing weed pressure in the seeding year. The drawback is that nurse crops will reduce first-year seed production if you are trying to establish a black medic seed bank. To increase the soil seed reserve for a long-term black medic stand (germinating from hard seed), allow the medic to blossom, mature and reseed during its second year.

• **Corn overseed.** SANTIAGO burr medic and SAVA snail medic were successfully established in no-till corn three to six weeks after corn planting during a two-year trial in Michigan. Corn yield was reduced if medics were seeded up to 14 days after corn planting. Waiting 28 days did not affect corn yield, but medic biomass production was reduced by 50% (219).

Where medic and corn work together, such as California, maximize medic survival during the corn canopy period by seeding early (when corn is eight to 16 inches tall) and heavy (15 to 20 lb./A) to build up medic root reserves (47, 422).

• **After wheat harvest.** MOGUL barrel medic seeded after wheat harvest produced 119 lb. N/A in southern Michigan, more than double the N production of red clover seeded at the same time (373). In Montana, mid-season establishment of snail medic after wheat works only in years with adequate precipitation, when it smothers weeds, builds up N, then winterkills for a soil-holding organic mulch (72).

• **Autumn seeding.** Where winters are rainy in California, medics are planted in October as winter annuals (436). Plant about the same time as crimson clover in the Southeast, Zones 7 and 8.

Killing

Medics are easy to control by light tillage or herbicides. They reseed up to three times per summer, dying back naturally each time. Medics in the vegetative stage do not tolerate field traffic.

Field Management

Black medic>small grain rotations developed in Montana count on successful self-reseeding of medic stands for grazing by sheep or cattle. A month of summer grazing improves the economics of rotation by supplying forage for about one animal unit per acre. In this system, established self-reseeding black medic plowed down as green manure in alternate years improved spring wheat yield by about 50 percent compared to fallow (380).

Black medic is a dual-use legume in this adapted "ley" system. Livestock graze the legume in the "medic years" when the cover crop accumulates biomass and contributes N to the soil. Cash crops can be no-tilled into killed medic, or the legume can be incorporated.

A well-established black medic stand can reduce costs compared with annual crops by coming back for many years. However, without the livestock grazing benefit to supply additional utilization, water-efficient legumes such as lentils and Austrian winter peas will probably be more effective N sources. Further, the long-lived seed bank that black medic establishes may be undesirable for some cash crop rotations (383).

Use of medics for grain production in the upper Midwest has given inconsistent results. Berseem clover may be a better choice in many situations. In a series of trials in Ohio, Michigan, Wisconsin and Minnesota, medic sometimes reduced corn yield and did not provide enough weed control or N to justify its use under current cash grain prices, even when premiums for pesticide-free corn were evaluated (141, 219, 373, 374, 376, 456, 457). One Michigan farmer's situation is fairly typical. He established annual medic at 10 lb./A when his ridge-tilled corn was about knee-high. The legume germinated, but didn't grow well or provide weed suppression until after corn dry-down in mid-September. The medic put on about 10 inches of growth before winterkilling, enough for effective winter erosion protection (201).

Black medic and two annual medics produced 50 to 150 lb. N/A when interplanted with standard and semi-dwarf barley in a Minnesota trial. Annual MOGUL produced the most biomass by fall, but also reduced barley yields. GEORGE was the least competitive and fixed 55 to 120 lb. N/A. The taller barley was more competitive, indicating that taller small grain cultivars should be used to favor grain production over medic stand development (289).

Midwestern farmers can overseed annual medic or a medic/grass mixture into wheat in very early spring for excellent early summer grazing. With timely moisture, you can get a hay cutting within nine to 10 weeks after germination, and some species will keep working to produce a second cutting. Regrowth comes from lateral stems, so don't clip or graze lower than 4 or 5 inches if you want regrowth. To avoid bloat, manage as you would alfalfa (201).

Annual medics can achieve their full potential when planted after a short-season spring crop such as processing peas or lettuce. Wisconsin tests at six locations showed medic produced an average of 2. 2T/A when sown in the late June or early July (399). Early planting in this window with a late frost could give both forage and N-bearing residue, protecting soil and adding spring fertility. Take steps to reduce weed pressure in solid seedings, especially in early July.

In another Michigan comparison, winter canola (*Brassica napus*) yields were similar after a green manure comparison of two medics, berseem clover and NITRO annual alfalfa. All the covers were clear (sole-crop) seeded in early May after pre-plant incorporated herbicide treatment, and were plowed down 90 days later. Harvesting the medics at 60 days as forage did not significantly lessen their green manure value (373).

With abundant moisture, medics can produce more than 200 lb. N/A.

In the mid-Atlantic at the USDA Beltsville, Md. site, medics have been difficult to establish by over-seeding at vegetable planting or at final cultivation of sweet corn.

Pest Management

Under water logged conditions for which they are ill-suited, annual medics are susceptible to diseases like *Rhizoctonia, Phytophthora* and *Fusarium*.

Burr medic harbors abundant lygus bugs in spring. It also appears to be particularly prone to outbreaks of the two-spotted spider mite, a pest found in many West Coast orchards (422).

Pods and viable seeds develop without pollinators because most annual medics have no floral nectaries (120).

COMPARATIVE NOTES

Snail medic produced about the same biomass and N as red clover when both legumes were spring sown with an oats nurse crop into a disked seedbed in Wisconsin. Yields averaged over one wet year and one dry year were about 1T dry matter and 60 lb. N/A (141).

Medics can establish and survive better than subterranean clover in times of low rainfall, and are more competitive with grasses. A short period of moisture will allow medic to germinate and send down its fast-growing taproot, while subclover needs more consistent moisture for its shallower, slower growing roots (422). Medics are more susceptible than subclover to seed production loss from closely mowing densely planted erect stalks. Burr and barrel medics are not as effective as subclover at absorbing phosphorus (422).

Medics may survive where true clovers (*Trifolium* spp.) fail due to droughty conditions (422) if there is at least 12 in. of rain per year (292).

Medics are easy to kill with light tillage or most herbicides.

Medics grow well in mixtures with grasses and clovers, but don't perform well with red clover (422, 263). Once established, black medic handles frost better than crimson or red clover.

GEORGE grows more slowly than yellow blossom sweetclover in spring of the second year, but it starts flowering earlier. It uses less water in the 2- to 4-foot depth than sweetclover, soybeans or hairy vetch seeded at the same time.

Annual Medic Cultivars. Species and cultivars of annual medic vary significantly in their dry matter production, crude protein concentration and total N. Check with local or regional forage specialists for cultivar recommendations

Burr medic (also called burclover) cultivars are the best known of the annual medics. They branch profusely at the base, and send out prostrate stems that grow more erect in dense stands (422). They grow quickly in response to fall California rains and fix from 55 to 90 lb. N/A, nearly as much as true clovers (294, 422). Most stands are volunteer and can be encouraged by proper grazing, cultivation or fertilization.

Selected cultivars include SERENA (an early bloomer), and CIRCLE VALLEY, both of which have fair tolerance to Egyptian alfalfa weevil (435). SANTIAGO blooms later than SERENA. Early burr medics flower in about 62 days in California, ranging up to 96 days for mid-season cultivars (422).

Naturalized and imported burr medic proved the best type of burclover for self-reseeding cover crops in several years of trials run from northern California into Mexico in the 1990s. While some of the naturalized strains have been self-reseeding for 30 years in some orchards, Extension specialists say the commercial cultivars may be preferable because they are widely available and better documented.

Established burr medic tolerates shade as a common volunteer in the understories of California walnut orchards, which are heavily shaded from April through November. However, in Michigan trials over several years, SANTIAGO (a burr medic with no spines on its burs) failed to establish satisfactorily when it was overseeded into corn and soybeans at layby. Researchers suspect the crop canopy shaded the medic too soon after planting, and that earlier overseeding may have allowed the medic to establish.

There are at least 10 cultivars of **barrel medic**. Dates of first flowering for barrel medics range from 80 to 105 days after germination, and seed count per pound ranges from 110,000 for HANAFORD to 260,000 for SEPHI (422). A leading new cultivar, SEPHI, flowers about a week earlier than JEMALONG, commonly used in California (251, 422). SEPHI, a mid-season cultivar, has a more erect habit for better winter production, is adapted to high- and low-rainfall areas, yields more seed and biomass than others, has good tolerance to Egyptian alfalfa weevil and high tolerance to spotted alfalfa aphid and blue green aphid. It is susceptible to pea aphid.

Snail medic (*M. scutellata*) is a prolific seed producer. Quick germination and maturity can lead to three crops (two reseedings) in a single season from a spring planting in the Midwest (373). MOGUL barrel medic grew the most biomass in a barley intercrop, compared with SANTIAGO burr medic and GEORGE black medic in a four-site Minnesota trial. It frequently reduced barley yields, particularly those of a semi-dwarf barley variety, but increased weed suppression and N and biomass production (289).

In a Michigan test of forage legumes for emergency forage use, MOGUL **barrel** medic produced 1.5 T dry matter/A compared to about 1 T/A for SAVA **snail** medic and SANTIAGO **burr medic** (*M. polymorpha*). Nitrogen production was 66 lb./A

SWEETCLOVERS

Yellow sweetclover *(Melilotus officinalis)* and white sweetclover *(M. alba)*

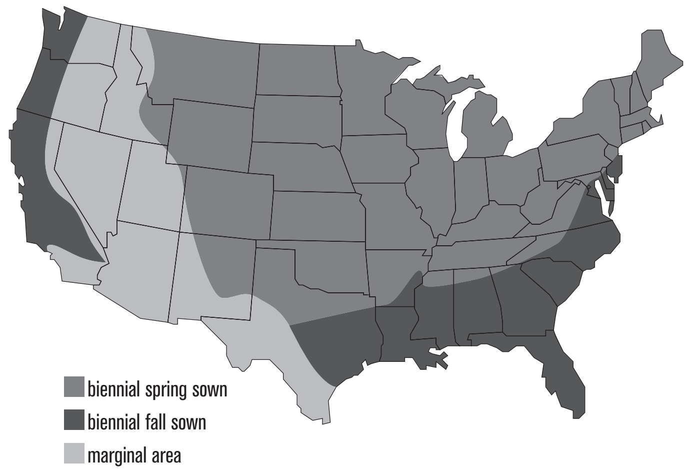
Also called: HUBAM (actually a cultivar of annual white sweetclover)

Type: biennial, summer annual or winter annual legume

Roles: soil builder, fertility source, subsoil aerator, weed suppressor, erosion preventer

Mix with: small grains, red clover

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



Within a single season on even marginally fertile soils, this tall-growing biennial produces abundant biomass and moderate amounts of nitrogen as it thrusts a taproot and branches deep into subsoil layers. Given fertile soils and a second season, it lives up to its full potential for nitrogen and organic matter production. Early in the second year it provides new top growth to protect the soil surface as its roots anchor the soil profile. It is the most drought-tolerant of forage legumes, is quite winter-hardy and can extract from the soil then release phosphorus, potassium and other micronutrients that are otherwise unavailable to crops.

Sweetclover thrives in temperate regions wherever summers are mild. *Annual* sweetclovers (HUBAM is the most well known) work best in the Deep South, from Texas to Georgia. There, they establish more quickly than the biennial types and produce more biomass in the seeding year in southern regions.

In this chapter, "sweetclover" refers to *biennial* types unless otherwise noted.

Sweetclover was the king of green manures and grazing legumes in the South and later throughout the Midwest in the first half of this century. Sweetclover is used as a cover crop most commonly now in the Plains region, with little use in California.

Types

Biennial *yellow* sweetclover can produce up to 24 inches of vegetative growth and 2.5 tons dry matter/A in its establishment year. During the second year, plants may reach 8 feet tall. Root mass and penetration (to 5 feet) are greatest at the end of dormancy in early spring, then gradually dissipate through the season (443).

A distinguishing sweetclover feature is bracts of tiny blooms through much of its second year. *White* biennial sweetclovers are taller, more coarsely stemmed, less drought tolerant, and produce less biomass in both the seeding and second years. White types bloom 10 to 14 days later than yellow, but bloom for a longer season. They reportedly establish more readily in New York (450). Tall, stemmy cultivars are better for soil improvement (120, 361, 422).

Marianne Sarrantonio

YELLOW SWEETCLOVER (Melilotus officinalis)

Both yellow and white sweetclover have cultivars bred for low levels of coumarin. This compound exists in bound form in the plant and poses no problem during grazing. However, coumarin can cause internal injury to cattle when they eat spoiled sweetclover hay or silage.

Annual sweetclover (*Melilotus alba var. annua*) is not frost tolerant, but can produce up to 9,000 lb. dry matter/A over a summer after being oversown into a grain crop or direct seeded with a spring grain nurse crop. The best-known annual sweetclover cultivar is HUBAM, a name often used for all annual white sweetclover. While its taproot is shorter and more slender than that of its biennial cousins, it still loosens subsoil compaction.

BENEFITS

Nutrient scavenger. Sweetclover appears to have a greater ability to extract potassium, phosphorus and other soil nutrients from insoluble minerals than most other cover crops. Root branches take in minerals from seldom-disturbed soil horizons, nutrients that become available as the tops and roots decompose (361).

Research in Saskatchewan during a 34-year period showed that phosphorus (P) availability increased in *subsoil* layers relative to *surface* layers, peaking at an 8-foot depth. Winter wheat and safflower, with deeper root systems than spring wheat, could tap the deep P buildup from the legume roots and fallow leaching, whereas spring wheat could not. The vesicular-arbuscular mycorrhizal (VAM) fungi associated with legume roots contribute to the increased P availability associated with sweetclover (69, 70).

N source. A traditional green manure crop in the upper Midwest before nitrogen fertilizer became widely available, sweetclover usually produces about 100 lb. N/A, but can produce up to 200 lb. N/A with good fertility and rainfall. In Ohio, it contained about 125 lb. N/A by May 15, increasing to 155 lb. by June 22. Illinois researchers reported more than 290 lb. N/A.

Abundant biomass. If planted in spring and then given two full seasons, biennial sweetclovers can produce 7,500 to 9,000 lb. dry matter/A (3,000 to 3,500 lb./A in the seeding year, and 4,500 to 5,500 lb./A the second). Second-year yields may go as high as 8,500 lb./A.

Hot-weather producer. Sweetclover has the greatest warm-weather biomass production of any legume, exceeding even alfalfa.

Soil structure builder. Kansas farmer Bill Granzow says sweetclover gives his soils higher organic matter, looser structure and better tilth. See *Sweetclover: Good Grazing, Great Green Manure* (p. 174). HUBAM annual sweetclover also improved soil quality and increased yield potential in 1996 New York trials (451).

Compaction fighter. Yellow sweetclover has a determinate taproot root up to 1 foot long with extensive branches that may penetrate 5 feet to aerate subsoils and lessen the negative effects of compaction on crops. White types have a strong tap root that is not determinate.

Drought survivor. Once established, sweetclover is the most drought tolerant of all cover crops that produce as much biomass. It is especially resilient in its second year, when it could do well in a dry spring during which it would be difficult to establish annual cover crops. The yellow type is less sensitive to drought and easier to establish in dry soils than the white type.

Attracts beneficial insects. Blossoms attract honeybees, tachinid flies and large predatory wasps, but not small wasps.

Widely acclimated. Self-reseeding sweetclover can be seen growing on nearly barren slopes, road rights-of-way, mining spoils and soils that have low fertility, moderate salinity or a pH above 6.0 (183). It also can tolerate a wide range of environments from sea level to 4,000 feet in altitude, including heavy soil, heat, insects, plant diseases (120) and as little as 6 inches of rain per year.

Livestock grazing or hay. If you need emergency forage, sweetclover has a first-year feed value similar to alfalfa, with greater volume of lesser quality in the second year.

MANAGEMENT

Establishment & Field Management

Sweetclover does well in the same soils as alfalfa. Loam soils with near-neutral pH are best. Like alfalfa, it will not thrive on poorly drained soils. For high yields, sweetclover needs P and K in the medium to high range. Deficient sulfur may limit its growth (153). Use an alfalfa/sweetclover inoculant.

In temperate areas of the Corn Belt, drill yellow sweetclover in pure stands at 8 to 15 lb./A or broadcast 15 to 20 lb./A, using the higher rate in dry or loose soils or if not incorporating.

In drier areas such as eastern North Dakota, trials of seeding rates from 2 to 20 lb./A showed that just 4 lb./A, broadcast or drilled, created an adequate sole-crop stand for maximum yield. Recommended rates in North Dakota are 4 to 6 lb./A drilled with small grains at small-grain planting, 5 to 8 lb./A broadcast and harrowed (sometimes in overseeding sunflowers), and 6 to 10 lb./A. broadcast without incorporating tillage (183).

An excessively dense stand will create spindly stalks that don't branch or root to the degree that plants do in normal seedings. Further, the plants will tend to lodge and lay over, increasing the risk of diseases. So for maximum effect of subsoil penetration or snow trapping, go with a lighter seeding rate.

Sweetclover produces 50 percent or more hard seed that can lie in soil for 20 years without germinating. Commercial seed is scarified to break this non-porous seedcoat and allow moisture to trigger germination. If you use unscarified seed, check hardseed count on the tag and do not count on more than 25 percent germination from the hardseed portion. The need for scarification to produce an adequate stand may be over-rated, however. The process had no effect on germination in six years of field testing in North Dakota—even when planting 70 percent hard seed still in seed pods.

Winter-hardy and drought tolerant, this biennial can produce up to 200 lb. N/A with good fertility and rainfall.

Seed at a depth of $^1/_4$ to $^1/_2$ inch in medium to heavy textured soils, and $^1/_2$ to 1.0 inch on sandy soils. Seeding too deeply is a common cause of poor establishment.

Seed *annual* white sweetclover at 15 to 30 pounds per acre. Expect 70 to 90 lb. N/A from 4,000 to 5,000 lb. dry matter/A on well-drained, clay loam soils with neutral to alkaline pH.

A press-wheel drill with a grass seed attachment and a seed agitator is suitable for planting sweetclover into a firm seedbed. If the seedbed is too loose to allow the drill to regulate seeding depth, run the seed spouts from the grass and legume boxes to drop seed behind the double-disk opener and in front of the press wheels. Light, shallow harrowing can safely firm the seedbed and incorporate seed (183).

In the Canadian Northern Plains, dribble the seed through drill box hoses directly in front of the presswheels for quick and easy establishment (32).

If your press-wheel drill has no legume box or grass-seed attachment, you can mix the legume and small grain seed, but mix seed often due to settling. Reduce competition between the crops by seeding a part of the companion crop first, then seed a mix of the clover seed and the balance of the grain seed at right angles (183).

Sweetclover: Good Grazing, Great Green Manure

Bill Granzow taps biennial yellow sweetclover to enhance soil tilth, control erosion and prevent subsoil from becoming compacted. He uses common varieties, either from the elevator or one his father originally bought from a neighbor.

Granzow, of Herington, Kan., produces no-till grain and runs cattle in an area midway between Wichita and Manhattan in the east-central part of the state. Granzow overseeds sweetclover into winter wheat in December or January at 12 to 15 lb./A using a rotary broadcaster mounted on his pickup. Sometimes he asks the local grain cooperative to mix the seed with his urea fertilizer for the wheat. There's no extra charge for seed application. Alternately, Granzow plants sweetclover at the same rate with March-seeded oats.

Yellow sweetclover has overgrown Granzow's wheat only when the wheat stand is thin and abnormally heavy rains delay harvest. The minimal problem is even rarer in oats, he says.

He uses yellow sweetclover with the companion wheat crop in four possible ways, depending on what the field needs or what other value he wants to maximize. For each, he lets the clover grow untouched after wheat harvest for the duration of the seeding year. He used to disk the sweetclover at least twice to kill it. Now 100% no-till, he sprays with Roundup and "a little bit of 2,4-D." Second-year options include:

- **Grazing/green manure.** Turn in livestock when the clover reaches 4 inches tall, let them graze for several weeks, spray to kill, then plant grain sorghum within a couple of days. He feeds an anti-bloat medication to keep cattle healthy on the lush legume forage.
- **Quick green manure.** Spray after it has grown 3 to 4 inches, then plant sorghum. This method contributes about 60 pounds of N to the soil. He knocks back persistent re-growing sweetclover crowns in the sorghum by adding 2, 4-D or Banvel to the postemerge herbicide mix.
- **Green manure/fallow.** Kill at mid- to full bloom, leave fallow over summer, then plant wheat again in fall. This method provides about 120 lb. N/A, according to estimates from Kansas State University.
- **Seed crop.** He windrows the plants when about 50 percent of the seedpods have turned black, then runs the stalks through his combine. To remove all of the hulls, he runs the seed through the combine a second or third time.

Despite the heavy growth in the second year, yellow sweetclover matures and dies back naturally. If the residue is heavy, he sets the drill a bit deeper for planting.

He rates fall sweetclover hay from the seeding year as "acceptable forage." He's aware that moldy sweetclover hay contains coumarin, a compound that can kill cattle, but he's never encountered the problem. Second-year yellow sweetclover makes silage at initial to mid-bloom stage with 16 percent protein on a dry matter basis.

"Mixed with grass hay or other silage, it makes an excellent feed," he says, adding value to its cover crop benefits and giving him farming flexiblity.

Updated in 2007 by Andy Clark

Spring seeding provides yellow sweetclover ample time to develop an extensive root system and store high levels of nutrients and carbohydrates necessary for over-wintering and robust spring growth. It grows slowly the first 60 days (153). Where weeds would be controlled by mowing, no-till spring seeding in small grain stubble works well.

Broadcast seeding for pure sweetclover stands works in higher rainfall areas in early spring where soil moisture is adequate for seven to 10 days after planting. No-till seeding works well in small grain stubble.

Frostseeding into winter grains allows a harvest of at least one crop during the life cycle of the sweetclover and helps control weeds while the sweetclover establishes. Apply sweetclover seed before rapid stem elongation of the grain. Cut grain rate about one-third when planting the crops together.

Sweetclover spring seeded with oats exhibited poor regrowth after oat harvest in two years of a Wisconsin study. To establish a sweetclover cover crop in this way, the researchers found sweetclover did not fare well in years when the combine head had to be run low to pick up lodged oats. When oats remained upright (sacrificing some straw for a higher cut), sweetclover grew adequately (402).

You can plow down spring-planted yellow sweetclover in late fall of the planting year to cash in early on up to half its N contribution and a bit less than half its biomass.

Plant biennial sweetclover through late summer where winters are mild, north through Zone 6. Plant at least six weeks before frost so roots can develop enough to avoid winter heaving. In the Northern Plains into Canada, it should be planted by late August.

First-year management. Seeding year harvest or clipping is usually discouraged, because the energy for first-year regrowth comes directly from photosynthesis (provided by the few remaining leaves), not root reserves (361, 402).

Top growth peaks in late summer as the plant's main taproot continues to grow and thicken. Second-year growth comes from crown buds that form about an inch below the soil surface. Avoid mowing or grazing of sweetclover in the six- to seven-week period prior to frost when it is building final winter reserves. Root production practically doubles between Oct. 1 and freeze-up.

Sweetclover establishes well when sown with winter grains in fall, but it can outgrow the grain in a wet season and complicate harvest.

Second-year management. After it breaks winter dormancy, sweetclover adds explosive and vigorous growth. Stems can reach 8 feet before flowering, but if left to mature, the stems become woody and difficult to manage. Plants may grow extremely tall in a "sweetclover year" with high rainfall and moderate temperatures.

Nearly all growth the second year is topgrowth, and it seems to come at the expense of root mass. From March to August in Ohio, records show topgrowth increasing tenfold while root production *decreased* by 75 percent (443). All crown buds initiate growth in spring. If you want regrowth after cutting, leave plenty of stem buds on 6 to 12 inches of stubble. You increase the risk of killing the sweetclover plant by mowing heavier stands, at shorter heights, and/or at later growth stages, especially after bloom (183).

Before it breaks dormancy, sweetclover can withstand flooding for about 10 days without significant stand loss. Once it starts growing, however, flooding will kill the plants (183).

Killing

For best results ahead of a summer crop or fallow, kill sweetclover in the second year after seeding when stalks are 6 to 10 inches tall (183, 361). It can be killed by mowing, cultivating or disking once it reaches late bloom stage (32). Killing sweetclover before bud stage has several benefits: 80 percent of the potential N is present; N release is quick because the plant is still quite vegetative with a high N percentage in young stalks and roots; and moisture loss is halted without reducing N contribution. Sweetclover may regrow from healthy crowns if incorporated before the end of dormancy. For optimum full-season organic matter contribution, mow prior to blossom stage whenever sweetclover reaches 12 to 24 inches high before final incorporation or termination (361). Mowing or grazing at bloom can kill the plants.

In dryland areas, the optimum termination date for a green manure varies with moisture conditions. In a spring wheat>fallow rotation in Saskatchewan, sweetclover incorporated in mid-June of a dry year provided 80 percent more N the following spring than it did when incorporated in early July or mid-July—even though it yielded up to a third less biomass at the June date. Mineralization from sweetclover usually peaks about a year after it is killed. The potential rate of N release decreases as plants mature and is affected by soil moisture content (147).

During its second season, yellow sweetclover can grow 8 feet tall while roots penetrate 5 feet deep.

In this study, the differences in N release were consistent in years of normal precipitation, but were less pronounced. Little N mineralization occurred in the incorporation year. Nitrogen addition peaked in the following year, and has been shown to continue over seven years following yellow sweetclover (147).

In northern spring wheat areas of North Dakota, yellow sweetclover is usually terminated in early June just at the onset of bloom, when it reaches 2 to 3 feet tall. This point is a compromise between cover crop gain (in dry matter and N) and water consumption. A quick kill from tillage or haying is more expensive and labor-intensive than chemical desiccation, but it stops moisture-robbing transpiration more quickly (153).

Grazing is another way to manage second-year sweetclover before incorporation. Start early in the season with a high stocking rate of cattle to stay ahead of rapid growth. Bloat potential is slightly less than with alfalfa (153).

Pest Management

Sweetclover is a rather poor competitor in its establishment year, making it difficult to establish pure sweetclover in a field with significant weed pressure. Once established, it provides effective weed control during the first fall and spring of fallow, whether or not it is harvested for hay, incorporated or left on the soil surface (33).

Sweetclover residue is said to be allelopathic against kochia, Russia thistle, dandelion, perennial sowthistle, stinkweed and green foxtail. Repeated mowing of yellow sweetclover that is then left to mature is reported to have eradicated Canada thistle. Letting sweetclover bloom and go to seed dries out soil throughout the profile, depleting the root reserves of weeds.

Sweetclover weevil (*Sitonia cylindricollis*) is a major pest in some areas, destroying stands by defoliating newly emerged seedlings. Long rotations can reduce damage, an important factor for organic farmers who depend on sweetclover fertility and soil improvements. In the worst years of an apparent 12 to 15-year weevil cycle in his area, "every sweetclover plant across the countryside is destroyed," according to organic farmer David Podoll, Fullerton, N.D. "Then the weevil population crashes, followed by a few years where they're not a problem, then they begin to rebuild."

Cultural practices have not helped change the cycle, but planting early with a non-competitive nurse crop (flax or small grains) gives sweetclover plants the best chance to survive weevil foraging, Podoll says. Further research is needed to develop management techniques to control the weevil.

In a three-year Michigan trial of crop rotations to decrease economic losses to nematodes, a yellow sweetclover (YSC)>YSC>potato sequence out-yielded other combinations of rye, corn, sorghum-sudangrass and alfalfa. Two years of clover or alfalfa followed by potatoes led to a yield response equivalent to application of a nematicide for control of premature potato vine death (78). Legume-supplied N coupled with an overall nutrient balance and enhanced cation exchange capacity from the cover crop are thought to be involved in suppressing nematode damage (271).

Crop Systems

In the moderately dry regions of the central and northern Great Plains, "green fallow" systems with water-efficient legumes can be substituted for bare-ground or stubble mulch fallow. In fallow years, no cash crop is planted with the intent of recovering soil moisture, breaking disease or weed cycles and maximizing yields of following cash crops. The retained residue of "brown" fallow lessens the erosion and evaporation of tillage-intensive "black fallow," but "green fallow" offers even more benefits in terms of soil biological life, biodiversity, beneficial insect habitat, possible harvestable crops and alternate forages.

Rapeseed (*Brassica campestris*) is a summer annual cash crop in the dryland West that can serve as a nurse crop for sweetclover. A Saskatchewan study of seeding rates showed optimum clover yield came when sweetclover was sown at 9 lb./A and rapeseed was sown at 4.5 lb./A. The mixture allows an adequate stand of sweetclover that provides soil protection after the low-residue rapeseed (255).

Sole-cropped oilseed species (rapeseed, sunflower, crambe and safflower) require herbicides for weed control. Many of these materials are compatible with legumes, offering a post-emergent weed-control option if the covers do not adequately suppress weeds. The covers greatly reduce the erosion potential after oilseed crops, which leave little residue over winter (153).

Interplanting works with tall crops. A Wisconsin researcher reported success drilling sweetclover between the rows when corn was 6 to 12 inches tall. Overseeding sweetclover into sweet corn works even better due to greater light penetration.

Soil water availability at cover crop planting and depletion during growth are always a concern in semi-arid regions. The potential benefits must be balanced against possible negative effects on the cash crop.

Sweetclover overseeded into sunflowers at last cultivation succeed about half the time, North Dakota trials show. Dry conditions or poor seed-to-soil contact were the main reasons for not getting a stand. A heavier seeding rate or earlier planting will tend to increase stand. Band-seeding sweetclover over the row with an insecticide box at sunflower planting proved more successful in the trial. The method also permits between-row cultivation (153).

Even though legume green manures in another North Dakota study used about 2.8 inches (rainfall equivalent) more water than fallow, they led to a 1-inch equivalent increase over fallow in soil water content in the top 3 inches of soil the following spring (14).

Sweetclover is the best producing warm-season forage legume, even topping alfalfa.

One green fallow option is planting yellow sweetclover with spring barley or spring peas. This is challenging, however, because barley can be overly competitive while herbicide compatibility is a concern with the peas.

Further north into the Canadian Great Plains, sweetclover depleted soil moisture by September of year 1, but by May of year 2, soil moisture was greater due to snow trapping, increased infiltration and reduced evaporation (32).

Fred Kirschenmann of Windsor, N.D., controls spring weed flushes on his fallow after sunflowers with an initial shallow chisel plowing then a rod weeder pass or two before planting sweetclover with a nurse crop of buckwheat or oats (or millet, if there is less soil moisture). He harvests buckwheat, hoping for a 900 lb./A yield, then lets the clover grow and overwinter. In early summer, when he begins to see yellow blossoms, he disks the cover, lets it dry, then runs a wide-blade sweep plow just below the surface to cut apart the crowns. The biomass contribution of the sweetclover fallow builds up organic matter, he says, in contrast to the black-fallow route of burning up organic matter to release N. Preventing humus depletion holds back the dreaded kochia weed.

In temperate areas you can overseed spring broccoli with HUBAM annual sweetclover, let the cover grow during summer, then till it in before planting a fall crop. Alternatively, you can allow it to winterkill for a thick, lasting mulch.

In Pennsylvania, Eric and Anne Nordell seed sweetclover after early vegetables (in June or July) and allow it to grow throughout the summer. It puts down a deep taproot before winter, fixes nitrogen and may bring nutrients to the soil surface from deep in the soil profile. See *Full-Year Covers Tackle Tough Weeds*, p. 38.

Other Options

First-year forage has the same palatability and feeding value as alfalfa, although harvest can reduce second-year vigor. Second-year forage is of lower quality and becomes less palatable as plants mature, but may total 2 to 3 tons per acre (120).

Sweetclover tolerates a wide range of harsh environments, poor soils and pests.

Growers report seed yield of 200 to 400 lb./A in North Dakota. Minimize shattering of seedpods by swathing sweetclover when 30 to 60 percent of its pods are brown or black. Pollinating insects are required for good seed yield (183).

Hard seed that escapes harvest will remain in the soil seed bank, but organic farmer Rich Mazour of Deweese, Neb., sees that as a plus. A 20- to 30-percent stand in his native grass pastures comes on early each spring, giving his cattle early grazing. Once warm-season grasses start to grow, they keep the clover in check. In tilled fields, sweep cultivators and residue-management tillage implements take care of sweetclovers with other tap-rooted "resident vegetation," Mazour says.

COMPARATIVE NOTES

Sweetclover and other deep-rooted biennial and perennial legumes are not suited for the most severely drought-prone soils, as their excessive soil moisture use will depress yield of subsequent wheat crops for years to come (163).

When planting sweetclover after wheat harvest, weeds can become a problem. An organic farmer in northeastern Kansas reports that to kill cocklebur, he has to mow lower than the sweetclover can tolerate. Annual alfalfa can tolerate low mowing (205).

After 90 days' growth in a North Dakota dryland legume comparison, a June planting of yellow sweetclover produced dry matter and N comparable to alfalfa and lespedeza (*Lespedeza stipulacea Maxim*). Subclover, fava beans (*Vicia faba*) and field peas had the best overall N-fixing efficiency in the dryland setting because of quick early season growth and good water use efficiency (331).

Cultivars. Yellow cultivars include MADRID, which is noted for its good vigor and production, and its relative resistance to fall freezes. GOLDTOP has excellent seedling vigor, matures two weeks later, provides larger yields of higher quality forage and has a larger seed than MADRID (361). Yellow common and YUKON joined GOLDTOP and MADRID—all high-coumarin types—as the highest yielding cultivars in a six-year North Dakota test (269).

Leading white biennial cultivars are DENTA, POLARA and ARCTIC. POLARA and ARCTIC are adapted to very cold winters. Best for grazing are the lower-producing, low-coumarin cultivars DENTA and POLARA (white) and NORGOLD (yellow).

Seed sources. See *Seed Suppliers* (p. 195).

Cover Crops

Legume Covers Legume cover crops deliver more nitrogen to the soil and decompose more quickly than non-legume covers.		
Name	**Growth habit**	**Description**
Berseem clover	Summer annual	This summer annual is the least winter hardy of the clovers, making it a good choice for a winter-killed cover before corn. Good for producing biomass; fixes nitrogen (N) at 75-200 pounds/acre.
Cowpea	Summer annual	Good drought tolerance and well adapted to hot weather and poor soils. Can reach plow-down maturity in as little as 60 days. Good for attracting beneficial insects. N contribution=150-200 lb/ac.
Crimson clover	Winter annual	Earliest spring regrowth among the winter annuals, making it a popular spring and summer green-manure crop. Striking deep red blossoms. Reseeds well after winter. N=70-130 lb/ac.
Field pea	Winter annual	Strong nitrogen fixer breaks down easily, yielding quick nitrogen (which can leach out of your system if not managed properly). Grows well in cool, moist conditions; overwinters well. Harvest as high-quality hay and for seed. Austrian winter peas have even higher cold tolerance. N=90-150 lb/ac.
Hairy vetch	Winter annual or biennial	Robust nitrogen-fixing ability and high-nitrogen, viny biomass production in spring that smothers spring weeds. Residue breaks down readily, requiring enough soil organic matter to keep N from being leached during wet spring weather. Good as a cover mix with rye. N=90-200 lbs/ac.
Medics	Annual or perennial	Reseeds effortlessly years after initial sowing. Good in low-moisture areas. N=50-120 lbs/ac.
Red clover	Winter annual	Dependable, adapted to a variety of regions and climates, low-cost and winter hardy. Good for frost-seeding into a standing crop. N=70-150 lbs/ac.
Subterranean clover	Winter annual	Low growing and self-reseeding. Used in western climes between trees in orchards. N=70-150 lbs/ac.
Sweet clover	Winter annual	A tall-growing biennial with a deep taproot. Good for producing biomass. N=90-170 lbs/ac.
White clover	Winter annual	Often used as a living mulch, this short plant stands up well to mowing and foot and equipment traffic. (Three types: 'Dutch white', 'New Zealand' and 'Ladino'.) N=80-200 lbs/ac.

Non-legume covers, grasses These covers are preferred for erosion control and for longer-lasting residue.	
Name	Description
Annual ryegrass	A reliable performer that will thrive anywhere there is adequate moisture. It holds soil well and is a good scavenger of nitrogen.
Cereal rye	The most cold-tolerant of the cereals. May be seeded late in the fall and still give good soil protection, produce abundant biomass (vegetation) and scavenge nitrogen. Grows well throughout the U.S. and is a good weed suppressor, both by shading out weeds and by acting allelopathically. Organic farmers commonly use it as a mulch, rolling it down or mowing it in spring before seeding soybeans right into it. Does well in a mix with winter annual legumes such as hairy vetch.
Barley	Grows well in dry or light soils, and in poor soils that need rebuilding. Delivers more biomass in a shorter time than any other cereal. Out-competes weeds well by stealing all their water.
Oats	A low-cost, reliable performer that can be fall planted to winter-kill in USDA Cold Hardiness Zones 6-7 and colder. Likes cool, wet weather. Produces ample biomass and softens the soil with its root compounds. A good nurse crop for legumes.
Winter wheat	Offers most of the benefits of the other cereal cover crops while doing double duty as a cash crop, with less potential to become a weed problem. Slower to mature in spring.
Sorghum-Sudangrass	No other cover produces as much biomass for building up soil organic matter as this warm-season cover crop (we're talking 5 tons per acre!). Potentially marries the allelopathic properties of sorghum with the productive tillering of Sudangrass.

Non-grass, non-legume covers These covers, such as such as mustards, rape and buckwheat offer nectar resources for beneficial insects and can work as bio-fumigants, releasing natural compounds into the soil that have been shown to suppress some pests and pathogens.	
Name	Description
Mustard	Becoming more popular, particularly in California where it is used as a bio-fumigant to control nematodes and soil-borne diseases, and break weed cycles. Sown in fall and tilled in spring.
Buckwheat	A warm-season cover that winter-kills easily, grows quickly, loosens tight soils with an abundant root system, suppresses weeds well with ample fan-like leaves and some allelopathy, attracts beneficial insects, does well in poor soils, disks down like butter, and is known to improve the availability of phosphorous through the release of acidic compounds from its roots.

More about cover crops http://www.newfarm.org/columns/intern/2007/0107/slocum.shtml.

Hardy Legumes								
Crop species	Hardi-ness, °F	Seeding rate, lb/ac(1)	Seeding depth, in.	Seed inoculant	When to plant(2)	When to mow/roll(3)	Biomass, tons/ac(4)	Main benefits(5)
Bigflower vetch(6)	<-10	20-40	0.5-1.5	pea/vetch	early fall	Fls or SK	1-2	N, B, P, TS
Comments: Sets seed & dies in May, germinates in fall								
Hairy vetch	-10-15	20-40	0.5-1.5	pea/vetch	early fall	Fls (May)	1-3	**N, B**, P, TS, W
Comments: Best winter legume for cooler regions								
Sweet clovers	-10	6-20	0.25-1	alfalfa/ sweet clover	Apr-Aug*	Fls (May)	1.5-3	**SS, P, N**, W, NR, TS
Comments: Several varieties, most biennial w/ deep taproot; some semi-hardy annual *Annual varieties—plant summer to winter-kill								
Crimson clover	0-10	15-30	0.25-0.5	clover	late sum.	Fls (May)	1.5-3	N, NR, B, P, W
Comments: Slow-release N; can self-seed well; best winter legume for milder regions								
Subclovers	0-15	10-30	0.25-0.5	clover	late sum.	SK	1.5-4	**B, W, N,** NR, P
Comments: Drought tolerant; may inhibit small-seeded crops								
Austrian winter peas	5-10	70-120	1-3	pea/vetch	late sum.	Fls (May)	1.5-3	**N**, B, P, TS
Comments: Rapid N release & mulch breakdown								

Semi-Hardy Legumes								
Crop species	Hardi-ness, °F	Seeding rate, lb/ac(1)	Seeding depth, in.	Seed Inoculant	When to plant(2)	When to mow/roll(3)	Biomass, tons/ac(4)	Main benefits(5)
Lana vetch	10-15	10-60	0.5-1	pea/vetch	early spr. late sum.	Fls (~July) WK	1.5-4.5	**N, B**, P, TS, W
Comments: Similar to hairy vetch, less hardy; very high biomass if it overwinters								
Spring field peas	10-20	70-120	1-3	pea/vetch	early spr.	Fls (July)	1-2.5	N, B, P, TS
Comments: Better than Aus. peas for spring planting								
Lupines(6)	15-20	70-120	0.75-1	lupine	early spr. late sum.	Fls WK		**N, P**, B, SS
Comments: Easy to mow-kill. Bitter var. disease-resistant but unsuitable for livestock								
Purple vetch	20	30-80	0.5-1	pea/vetch	early spr. late sum.	Fls (~July) WK	1.5-4	**N, B**, P, TS, W
Comments: Fastest growing & maturing spring								
Berseem clover	20	8-20	0.25-0.5	clover	mid-late sum.	WK	2-4	**N**, NR, B, P, W, TS
Comments: Late flowering, hard to mow-kill; fresh residue may inhibit small-seeded crops								
Bell/fava beans	20	80-150	1-3	pea/vetch	early spr. late sum.	Fls (June-July) WK		**N, B**, P, SS
Comments: Excellent nectar source for beneficials; small-seeded (bell) varieties best								

Tender Legumes								
Crop species	Hardi- ness	Seeding rate, lb/ac(1)	Seeding depth, in.	Seed Inoculant	When to plant(2)	When to mow/roll(3)	Biomass, tons/ac(4)	Main benefits(5)
Soybeans	tender	40-100	1-2	soybean	after frost	Fls or WK	1.5-2.5	**N**, B, TS
Comments: Forage varieties give greatest biomass								
Cowpeas	tender	30-100	0.75-7.5	cowpea	when soil is >/= 65°F	Fls or WK	1-3	**N, B**, W, P, TS
Comments: Drought-tolerant, requires heat, suppresses nematodes, easy to grow								
Sunn hemp(6)	tender	10-50	0.5-1	cowpea	after frost	Fls or WK	2.5-4	N, W
Comments: Fibrous, persistent mulch, tolerates acid or droughty soil, slow-release N								
Lablab bean(6)	tender	10-40	1	lablab	after frost	Fls or WK	2+	**N**, W
Comments: Drought-tolerant, easy to mow-kill								

Hardy Non-Legumes							
Crop species	Hardi-ness, °F	Seeding rate, lb/ac(1)	Seeding depth, in.	When to plant(2)	When to mow/roll(3)	Biomass, tons/ac(4)	Main benefits(5)
Winter rye	-40	60-160	0.75-2	fall	Fls (May)	2-5	**W, NR**, K, TS, B
Comments: Tolerates poor & acid soils, may tie up N, can initially inhibit small-seeded crops							
Winter wheat	-25	60-120	0.5-1.5	fall	Fls (June)	1.5-3.5	W, NR, K, TS
Comments: Later and harder to mow-kill than rye							
Triticale(6)	<-10	60-120	0.5-1.5	fall	Fls	1.5-4	W, NR, TS
Comments: Wheat/rye cross, taller than most wheat							
Little barley(6)	0-10	15-35	0.25-0.5	early fall	SK		**W**, TS
Comments: Self-seeding winter annual, experimentally grown with subclover							

Semi-Hardy Non-Legumes							
Crop species	Hardi-ness, °F	Seeding rate, lb/ac(1)	Seeding depth, in.	When to plant(2)	When to mow/roll(3)	Biomass, tons/ac(4)	Main benefits(5)
Barley	10-15	50-125	0.75-2	early spr. late sum.	Fls WK	1.5-5	**W**, NR, B, TS
Comments: Drought-tolerant, likes light soils, deep-rooted if grown over winter							
Spring oats	15-20	80-140	0.5-2	early spr. late sum.	Sd (milk) WK	1-4	**W, NR**, TS, B
Comments: Tolerates acid soils, less N tie-up than rye; may slightly inhibit small seeds							
Black oats(6)	20	15-20	0.5	late sum.	WK or Fls	2-4	**W, NR**
Comments: Experimental; easy to mow-kill							
Fodder/oil radish(6)	20	10-20	0.5	late sum.	WK		**SS, W**, B
Comments: Not recommended before brassica veg.							

Tender Non-Legumes							
Crop species	Hardi-ness	Seeding rate, lb/ac(1)	Seeding depth, in.	When to plant(2)	When to mow/roll(3)	Biomass, tons/ac(4)	Main benefits(5)
Buckwheat	tender	60-80	0.5-1.5	May-Aug	Fls or WK	1-1.5	**B, W, P**, TS
Comments: Short life cycle, residues decay rapidly; can become weed by reseeding							
Sorghum-Sudan hybrid	tender	35-50	0.5-1.5	when soil is 70°F	Sd or WK	3-5	**W, SS**, NR
Comments: Mow at 3-4 ft to promote deep rooting; allelopathy may inhibit some crops							
Foxtail millet(6)	tender	25-30	0.25-0.5	after frost thru July	Sd or WK	1.5-2	W, NR, TS
Comments: Fast growing, drought-tolerant, no hard seed, thus low potential to become weed							
Pearl millet(6)	tender	5-30	0.25-0.5	mid sum.	WK best	1.5-2	W, NR
Comments: Hard to mow-kill, very tall							
Japanese millet(6)	tender	20-30	0.5-1	after frost	Sd or WK	1.5-2.5	**W**, NR
Comments: Quick maturing (45 days)							

1 Lower rates for drilling, higher rates for broadcast seeding.
2 After frost = spring frost-free date until midsummer; late sum. = ~6-8 weeks before fall frost.
3 Fls = mow/roll at full bloom (legumes) or pollen-shed (grasses); Sd = mow/roll when seed partially developed (green or milk stage); WK = winterkill; SK = sets seeds and dies down in late spring; seeds germinate in late summer or early fall. No mowing needed for WK or SK.
4 Estimated aboveground biomass for cover crop grown until full bloom, immature seed stage, or winterkill in Zones 6b-8b of southeastern U.S., including VA, NC, SC, KY, TN, GA, AL. Total biomass including roots + exudates is 50-100% more. Biomass for grass + legume covers may exceed either one grown alone.
5 B = harbors beneficial insects; N = fixes nitrogen; NR = takes up and holds soluble soil N; P = makes soil phosphorus more available; K = makes soil potassium more available; W = effectively suppresses weeds; SS = opens subsoil; TS = conditions/mellows topsoil. All cover crops add organic matter and protect soil from erosion. Boldface = particularly strong effect (N fixation potential 150+ lb/ac, N recovery 70+ lb/ac; weeds suppressed by allelopathy and strong competition).
6 These species experimental in Virginia no-till systems; planting recommendations and biomass information are preliminary only.