Twenty-two cover-crop cultivars were compared with an unseeded control. *Left,* subterranean clover; *center,* balansa clover; and *right,* bur medic.

self-reseeding annual legumes such as medic, subterranean clover and other clover species were useful in vineyards as cover crops, even if annual reseeding was required.

This trial was initiated to evaluate the performance of a broader range of cultivars and species of self-reseeding annual clovers. Additionally, we wanted to investigate whether cover crops increased seasonal vineyard water-use. Measurements required to quantify consumptive use were beyond the scope of this work, so we settled on assessing vine water status with pressure chamber measurements to see if vines growing with these cover crops were more stressed than those under WLOODJH 2XU JRDO ZDV growers who prefer clean tillage (bare soil free of any vegetation) of the vine- \DUG ÁRRU GXULQJ WKH JURZLQJ VHDVRQ WR GHWHUPLQH LI WKH egy, including the conservation of winter rainfall stored in the root zone, were outweighed by potentially increased soil erosion from fall and winter rainfall RQ WKH XQSURWHFWHG

Self-reseeding legumes tested

Experimental design. A randomized complete block experimental design was used with four replications of each selection for 22 annual legume cultivars and an unseeded control, for a total of SORWV 7KH H[SHULPHQW ZDV taken in a 1-year-old upland vineyard DW IHHW SODQWHG LQ FORQH RQ URRWVWRFN ZLWK YLQHV VSDFHG IHHW D apart as dormant bench grafts. The site had formerly been planted to walnut trees for 27 years.

Species. The species evaluated were selected to represent a broad range of winter dormancies and hard-seed production. These species have been used successfully in other agricultural regions with Mediterranean climates as self-reseeding forage crops. Species planted included subterranean clover, medic, Persian clover, balansa clover, crimson clover, rose clover and a control of resident vegetation (table 1). In each replicated plot, the selection was hand-seeded at an appropriately high rate so as not to be a limiting factor (at OHDVW SRXQGV SHU DFUH RQ 2FW 2003, in two adjacent row middles four vines long (20 feet) by 5 feet wide.

Site preparation. The site was limed at 5 tons per acre before the vines were planted in 2001, resulting in a soil pH of 6.5. Phosphorus fertilizer with sulfur (0-36-0-20) was applied at 200 pounds per acre to the entire trial to insure WKDW WKH SKRVSKRUXV would not be a limiting factor to cover-crop growth.

Irrigation. The vines were irrigated with a drip system suspended beneath the vines. Two drip emitters with an output of 0.5 gallon per hour each were spaced 2.5 feet apart beneath each vine. Irrigation was applied uniformly to the YLQH\DUG ÁRRU JDOORQV SHU YLQH SHU ZHHN The grower timed each irrigation set, starting and turning off the irrigation SXPS DIWHU SUHFLVHO\ the vineyard received 12 weekly irrigaWLRQV EHJLQQLQJ -XO\ gallons per vine. In 2005, the vineyard received 10 weeks of irrigation starting -XQH IRU D WRWDO RI

Harvest measurements. Plots were HYDOXDWHG IRU 6\UDK KDUYHVW 'DWD ZDV WDNHQ LQFOXGLQJ SHUFHQW RI WKH SORW DUHD FRYHUHG by each cover crop (visual estimation); height (measured with a yard ruler by taking the average height at four spots); and biomass production (measured by clipping the plant material contained within three 1-foot-square wire frames). Biomass was oven-dried DW ƒ) DQG ZHLJKHG- 7KHVH PHDVXUH

PHQWV ZHUH WDNHQ DJDLQ 2QO\ SHUFHQW FRYHU were made on May 12, 2006.

'DWD ZHUH DQDO\]HG ZLWK and means were compared with 'XQFDQ·V PXOWLSOH UDQJH FRQÀGHQFH LQWHUYDO

i>vÊÜ>ÌiÀÊ«œÌiÌ̀>• DQG 2005, leaf-water-potential measurements were made on cloudless days with a pressure bomb by sampling between 11 a.m. and 1 p.m. (full solar noon) using fully expanded, sunlit leaves. Sampling began early in the season, once the cover crops stopped growLQJ DQG ZHUH GU\LQJ GRZQ one replication of each cover crop was chosen at random and a grape leaf was selected from a vine in the center of the plot that had the same cover crop growing in the two adjacent middles to the vine row. Twenty-two vines were chosen in the cover-crop area, and 22 were chosen in an adjacent clean-tilled area of the vineyard. (This was the practical number of samples that could be taken during the solar noon period.)

Leaves were removed, placed in a small plastic bag, inserted into the pressure chamber and secured as quickly as possible. Pressure was applied slowly until sap was extruded from the end of the emerged petiole. The pressure at this point was noted on the gauge of the pressure bomb and recorded. Sampling areas were rotated weekly so that no VSHFLÀF VDPSOLQJ RUGHU (i.e., the cover-cropped area was samSOHG ÀUVW RQH ZHHN DQG ZDV VDPSOHG ÀUVW WKH QH

Weekly or biweekly observations KRXUV were made at the same marked vines. When leaf water potential reached PRUH WKDQ EDUV L-UULJ DWHG ZHHN -XQH potential was measured until week 10 DIWHU WR SUHYDLO ZKHQ cipitation occurred in June 2005 and irrigation was initiated later, since leaf water-potential was lower later into the growing season. The sample sizes were reduced to 12 vines in both the cover-cropped and tilled areas, since fewer plots had successfully regenerated.

0RQLWRULQJ EHJDQ RQ -XO the vineyard was irrigated following pressure bomb measurements on July 21. Monitoring continued for 2 more ZHHNV XQWLO $XJ

Pests. The plots did not have any pest problems such as diseases, mites, insects or vertebrates, and no interventions or treatments were made.

Cover-crop performance

:H IRXQG VLJQLÀFDQW between many of the cover-crop species in biomass production, plant height and percent cover of the sward (table 1).

Biomass production. :LQWHU relatively dry, and precipitation was lower than usual. Rain did not begin until November, and precipitation in March and April was less than 1 inch (23.7 inches for the season). All the cover crops germinated and grew, but overall biomass for the entire trial was lower than in 2005, when precipitation was 2.5 LQFKHV LQ 2FWREHU DQG April and May (26.72 inches for the season). In 2006, total precipitation exceeded 50 inches in the Clear Lake basin.

,Q DYHUDJH ELRPDV ZDV WRQV SHU DFUH WRQ ¶7RUUHDGRU· PH (‘Flame’ crimson clover) per acre; by comparison, the resident vegetation (control) produced 0.7 ton per acre. In 2005, average biomass was 2.07 tons per acre, ranging from 1.5 tons (‘Santiago’ bur medic) to WRQV ¶1LWUR· 3HUVL compared to 1.1 tons per acre produced by the resident vegetation.

Biomass is converted into soil carbon over time, which helps to improve soil quality and increase microbial DFWLYLW\ LPSDUWLQJ the agroecosytem. If a goal of cover crops is to increase biomass grown in the vineyard, then many of the selections performed well compared to resident vegetation. (Nitrogen fertilizer may spur resident vegetation to produce more biomass, but this requires more energy.) Dominant species in the resident vegetation included annual bluegrass (*Poa annua*), shepherd’s purse (*Capsella bursa-pastoris*), annual ryegrass (*Lolium multiflorum*), chickweed (*Stellaria media*), scarlet pimpernel (*Anagallis arvensis*) and annual sowthistle (*Sonchus oleraceus*).

Height. All of the cover-crop selections that we studied were low-statured and would not hinder vineyard operations or create high levels of humidity near the vine canopy in late spring (table 1). By contrast, some annual

Cover crop	Biomass [illegible]	Biomass 2005	Height [illegible]	Height 2005	Cover [illegible]	Cover 2005	Cover [illegible]
	. . . . . tons per acre		. . . . . inches		. . . . %		
Subterranean clovers (dormancy category)*							
Antas (LS)	1.89 efg†	2.08 cde	6.5 ab	10.2 abc	87.5 def	85.0 b	85.0 g
#AMEDA-3	1.13 cde	2.32 def	4.4 a	9.0 ab	73.7 cde	68.7 ab	88.7 g
Denmark (LS)	1.06 cde	2.40 def	4.2 a	10.2 ab	62.5 bcd	70.0 ab	85.0 g
OSSE-3	1.25 cde	2.14 cde	4.0 a	11.2 a	75.0 cde	86.2 b	82.5 g
+OALA-3	0.94 ab	1.96 bcd	4.5 a	7.5 a	57.5 abc	61.2 ab	90.0 g
-T"ARKER-3	1.64 def	2.54 ef	4.7 a	11.2 bc	92.5 fg	92.5 c	87.5 g
Nungarin (ES)	1.07 bcd	1.94 bcd	3.7 a	8.7 ab	47.5 a	60.0 ab	60.0 de
Seaton Park (ES)	1.06 bcd	1.66 bc	3.9 a	8.5 ab	60.0 bc	65.0 ab	73.7 ef
4 RIKKALA-3	1.07 bcd	2.00 bcd	4.0 a	8.7 ab	55.0 ab	55.0 a	61.2 de
7OOGENELLUP-3	0.96 ab	1.86 bcd	3.8 a	9.0 ab	67.5 cde	57.5 ab	70.0 ef
York (ES)	1.10 bcd	2.18 cde	3.8 a	11.2 bc	75.0 cde	85.0 b	83.75 g
Medics							
Jester	1.83 efg	2.06 cde	9.0 bc	10.0 abc	90.0 efg	60.0 ab	35.0 cd
Parabinga	0.87 ab	2.08 cde	5.7 a	10.7 abc	75.0 cde	70.0 ab	70.0 ef
Santiago	1.03 abc	1.50 bc	6.4 ab	10.2 abc	76.3 cde	73.7 ab	40.0 cd
Torreador	0.79 a	1.58 bc	5.6 a	8.5 ab	52.5 a	60.0 ab	86.2 g
Other clovers							
"ALANSA"OLTA	1.53 def	2.20 def	10.8 c	13.2 cd	95.0 fg	82.5 b	80.0 g
"ALANSA0ARADANA	1.60 def	2.32 def	11.0 c	12.0 cd	97.5 h	86.2 b	81.2 g
Crimson Flame	2.39 i	2.38 def	17.0 e	16.0 e	97.5 h	93.7 c	50.0 de
Persian Lightning	2.10 gh	2.38 def	13.6 d	12.0 cd	100.0 h	75.0 b	6.2 a
Persian Nitro	1.58 def	2.40 ef	9.5 c	11.0 bc	90.0 efg	62.5 ab	27.5 bc
Rose Hykon	2.15 gh	1.88 bcd	10.5 c	10.7 bc	97.5 h	67.5 ab	11.2 ab
Rose Overton	1.76 efg	2.34 def	9.5 c	12.2 cd	86.2 def	65.0 ab	7.7 ab
Control (resident vegetation)	**0.70 a**	**1.10 a**	[illegible]	**7.0 a**	**100 h**	**100 d**	**100 h**
Trialwide average	[illegible]	**2.07**	[illegible]	**10.1**	[illegible]	[illegible]	**59**

9EARLYSEASON3MIDSEASON,3LATESEASON

o AESFOLLOWEDBYTHESAMEETTERWITHINOLUMNAREOTSIGNICANTLYDIFFEREN as determined by Duncan’s multiple range test at 95% level.

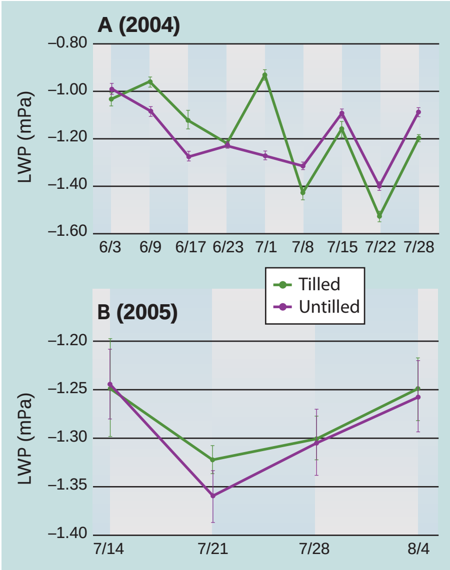
cover-crop species used in vineyards such as oats (*A. fatua*), purple vetch (*V. benghalensis*) and bell (fava) beans FDQ JURZ XS WR IHHW KLJK Average cover-crop height in this trial ZDV LQFKHV UDQJLQJ IURP ('Gosse' subterranean clover) to 17.0 inches (‘Flame’ crimson clover). In 2005, the cover crops grew taller because of increased precipitation. The average height was 10.1 inches, ranging from 7.5 inches (‘Koala’ subterranean clover) to 16 inches (‘Flame’ crimson clover).

Cover. Percent cover of the sward measures how successful a species is in germinating and competing with weeds, and how persistent the stand is over time (i.e., how sustainable a planting is). In this trial, cover varied considerably by species (tables 1 and 2). The subterranean clovers increased over time, while medics gradually declined (although ‘Torreador’ persisted well and increased in percent cover). The other clovers de FUHDVHG GUDPDWLFDOO 2QO\ EDODQVD FORYHU S

SHUFHQW FRYHUV DERYH IRU selections after 3 years. We believe that our visual estimations were accurate, but since they may vary by 5% to 10%, the means comparisons may be overstated LQ WKH 129 1RQHWKHOHVV cover above 70% indicates that the cover crop has germinated and grown well during that season.

Clover-cropping with annual self-reseeding legumes KDG GLIIHUHQW HIIHFWV ,Q dry spring, there were slight but significant QLÀFDQW GLIIHUHQFHV EHWZH

Cover crop	[illegible]	2005	[illegible]
	. . . . %		
Subterranean clovers	70	70	80
-EDICS	75	65	60
Other clovers	95	75	40
Trialwide average	75	75	60



[illegible] moisture status in millipascals (mPa), with and [illegible] “Tilled” means all cover crops were turned under with a disk; “untilled” means the dried aftermath of annual cover crops was left on the surface of the vineyard floor. Tilled, a standard grower practice, is the control. 1[illegible] bomb readings taken from all 22 cover crops [illegible] randomly within the untilled portion of the [illegible] weeks of July 2 and 22; in 2005, irrigation was during the weeks of July 21 and 28.

D Q G F R Y H U F U R S S H G D U H D V irrigation began on July 2, vines in the cover-cropped areas had more negative leaf-water-potential values, indicating that they were under greater water stress. However, after irrigation began, vine water status with the cover crops recovered to a greater extent than with the tilled treatment. The tillage may have caused increased surface evaporation. In 2005 more rain fell in late V S U L Q J D Q G W K H U H Z H U H differences between vine moisture status in the different treatments.

It is not possible to analyze in detail the impact of the different surface treatments on evapotranspiration, since we did not measure the impact of the treatments on the storage of winter rainfall. However, the fact that vine water status with cover crops was only modestly lower than with tillage prior to irrigation, and actu- D O O \ V R P H Z K D W K L J K H U irrigations, indicates that cover-crop water usage did not result in excessive plant water stress. In 2005, there were Q R V L J Q L À F D Q W G L I I H U

water potential in either the pre- or S R V W L U U L J D W L R Q S H U L likely because there was more rainfall later in the spring and presumably higher soil water levels as the summer progressed in 2005. We conclude that while cover crops certainly consume water, the magnitude of this evapotranspiration must be relatively small D Q G P D \ E H R I I V H W E \ L tration and storage of winter rainfall. Additionally, the dried vegetation aftermath in cover-cropped areas offers considerable protection against ero- V L R Q Z K H Q I D O O U D L Q V E H Q H À W W R Z D W H U T X D O precipitation.

Choosing cover crops for vineyards

Numerous species performed well in the initial year of seeding. Top performers for biomass production included the crimson, balansa, rose and subterranean clovers, similar to previous stud- L H V % X J J H W D O As a group, the medics did not grow as well as subterranean clovers under Lake County conditions. However, they persisted better than some of the others tested, including Persian, ‘Flame’ crimson and rose clovers.

Persistence is dependent on the production of hard seed that can survive for several years before germinating, as well as successful germination each season. Subterranean clover has a G H À Q L W H D G Y D Q W D J H amount of hard seed. Most importantly, it can actually preplant its seeds into the ground; seedpods develop on pegs O L N H S H D Q X W V D I W H U seed matures in the soil, protected from feeding by birds and rodents. The seed is then ready to germinate when conditions are optimal.

Balansa clover also performed well, although its percent cover of the sward declined somewhat over time. This spe- F L H V L V O L N H O \ W R S O L À F D O O \ P D N L Q J L W S an insectary plant for generalist predatory and parasitoid insects and mites.

The cover crops that declined over time in this study were usually displaced by annual weeds also found in the control plots. In our practical experience, it is not unusual for subterranean clover and bur medic stands to increase and decrease over time, since rainfall and distribution can greatly affect seed emergence at the beginning of their growth period in the fall.

All of the species tested are suitable as cover crops for vineyards in the North Coast region, and many performed well at our high-elevation test site. While some may not persist for long, they would still be useful as cover crops even if they require annual reseeding. Subterranean clovers persisted the best of the cover-crop species that we evaluated. Subterranean clovers are categorized by the amount of winter dormancy that is required E H I R U H À R Z H U L Q J D Q G W K H U H G X Y H Q J H W D Q L V J L Y H - J U R Z ing will occur in the spring (table 1). These cultivars with short winter dormancy are best for warm winter areas with limited rainfall, because they complete their growth cycles in less time. Cultivars with longer winter dormancies are best suited for areas with longer winters and more rainfall, and they tend to produce more biomass than cultivars with shorter winter dormancies. Selections from all the dormancy categories also performed well, although in practice, most growers are using long-dormancy selections such as ‘Antas’, ‘Koala’ and ‘Mt. Barker’.

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