TECHNICAL NOTES

U S Department of Agriculture | Natural Resources Conservation Service

TN – AGRONOMY – CA-60
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September 2000

NITROGEN CONTRIBUTION OF ANNUAL LEGUMES AND COVER CROPS -

Conservationists are becoming more proactive in helping clients understand nutrient management and the contribution made by legumes. Regular fertilizer applications on crops need to be adjusted to account for the Nitrogen contributions from legumes in cover crops. Prescribed grazing needs to be managed with consideration of the fertility that legumes contribute to maintaining grasses in the plant ecosystems.

Enclosed are two excellent references.

Agronomy Progress Report No. 266 published by the University of California Davis Department of Agronomy and Range Science discusses the Nitrogen values of 16 annual legumes including legumes found on grazing lands.

The second reference is Chapter 4 from the University of California Division of Agriculture and Natural Resources Publication 3338 - Cover Cropping in Vineyards: A Growers Handbook. This Chapter explains how cover crops influence soil fertility and includes two additional clovers.

We received permission to reprint 100 copies of Chapter 4. Every office could benefit from having Publication 3338 on hand. Full copies can be ordered from their website at

http://anrcatalog.ucdavis.edu

Click on "Agriculture" and then on "Sustainable Agriculture".

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Department of Agronomy and Range Science

AGRONOMY PROGRESS REPORT

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NITROGEN CONTRIBUTION OF ANNUAL LEGUMES

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INTRODUCTION

When we incorporate an annual legume covercrop to use the accumulated nitrogen for the next crop, we need to estimate how much N the covercrop will contribute so we can decide whether and how much supplemental N will be required. It would be nice if a simple field measurement could be done without special drying and laboratory analyses to obtain such an estimate. The two main variables to be dealt with are the nitrogen and dry matter contents of the covercrop tops. Most of an annual legume's N is in the tops, typically 90%. The rest is in the roots and stubble, and we will assume that it is equal to the amount taken up from the soil approximately.

Fortunately the N% and the dry matter percent in the tops vary in fairly predictable ways for the various species of covercrop legumes. The general relationships have been worked out for quite a few legumes. Some others we have approximated based on their evident similarity to the better known ones. However, it is clear that it is a fertile area for further research attention.

A procedure was developed some time ago based on getting the fresh weight of several covercrop samples representative of a field area and multiplying the average fresh weight by a species factor to obtain the N contribution estimate (Williams and Dawson 1980, Miller et al 1989). The method was initially called the "Rule of 16" because the area per sample was 16 square feet from making a square out of four-foot lath, and the multiplying N-factor was also "16" for vetch and peas, the most commonly used covercrops at that time in California (Williams and Hills 1961).

Procedure

We can estimate the nitrogen contribution of legume shoots at plowdown, i.e., the nitrogen available from a covercrop, by the following method:

1. Cut and weigh the fresh covercrop from 16 square feet (4 by 4 feet).

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2. Multiply the fresh weight in pounds by the N-factor for that species (Table 1) to estimate the pounds of nitrogen per acre contained in the covercrop.

3. Repeat this sampling 5 to 10 times over the field, depending on its uniformity, and average the results. Samples should be free of dew.

4. If for example, we harvest an average of 13 pounds fresh weight of purple vetch per 4 x 4 ft. area, we know there are 208 pounds of nitrogen per acre of covercrop (16 * 13= 208).

Table 1. N-factor values for some annual legume species.

	N-factor		N-factor
Purple vetch	16	Subclover	16
Lana woollypod vetch	16	Crimson clover	16
Hairy vetch	16	Rose clover	16
Common vetch	16	Sweet clover	18
Field peas	15	Sour clover	14
Fava bean (Bell)	10	Cowpeas	13
Berseem clover	13	Crotolaria	16
Annual Medicagos	16	Sesbania	16

Calculating N-factor

The research data needed for calculating a species specific "N-factor" are the N concentration (dry basis) and percent dry matter. These values are expressed as proportions (% x .01) for proper multiplication in the factor calculation. These data are commonly obtained, for example, in variety trials for forage yield and quality.

Since we cut and weigh the fresh covercrop tops from 16 square feet (4' by 4') for each sample, to put it on a per acre basis we take 43,560 sq ft per acre and divide by 16 to get the number of 4 x 4's per acre. Then to get the N-factor, that value (2722) is multiplied by the fresh weight N-proportion in the sample, which in turn can be obtained by multiplying the N concentration dry basis (e.g., 3.2%) and the dry matter percent (e.g., 15%) together both expressed as proportions (.032*.15) to get N-factor = 13. We have rounded the numbers for clarity.

Example:
(no. 4 x 4's per acre) * (fresh wt N proportion) = Factor

(43,560 / 16)	* (.032	* .15)	=	13
2722	3.2% N dry	15% DM		

Let's do the calculation for an average 1 lb fresh sample:
(1 lb sample * 2722) * (.0048) = 13 lb N/acre

If we get an average of 6 lb fresh weight per sample, then 6 * 13 = 78 lb N/acre is our estimated N contribution.

<u>Reliability of "N-factors"</u>

How reliable are values of N contribution obtained in this way?

To answer this important question, we will first present some data illustrating the effects of stage of plant development and of repeated cutting on the N-factor to use. In the first data set, for vetch and peas as stage of development advanced both the dry matter percentages and the N-factors increased (last two columns Table 2). However, for the first two sample dates, representing the time when most covercrops are likely to be incorporated, the average is close to "16".

Table 2. N concentration (%) and dry matter (%) for several covercrop legumes by stage of development and date of sampling with resulting N-factor for multiplying by fresh weight from 16 sq ft to get N contribution. Agronomy Farm, Davis CA 1955.

Crop	Stage	Date	N %	DM %	N-factor
Purple vetch	Veg	Mar 15	4.41	11.8	14
	Veg	Apr 7	4.86	13.6	18
	F bloom	May 3	4.21	20.7	24
Canada field pea	E bloom	Mar 15	4.47	11.4	14
	L bloom	Apr 7	4.56	12.9	16
	Gr pod	May 3	3.67	21.8	22
Dixie Wonder pea	E bloom	Mar 15	4.57	12.0	15
	E pod	Apr 7	4.40	15.7	19
	Gr pod	May 3	3.21	24.6	21
Fava bean (Bell)	Bud	Mar 15	3.70	10.0	10
	M bloom	Apr 7	3.00	11.3	9
	Gr pod	May 3	2.20	18.6	11

For the fava bean covercrop the N-factor didn't change much with advancing stage of development, but remained right around "10". The reason is because the N% declined fast enough with advancing maturity to compensate for the increases in DM%.

In the second data set (Table 3), repeated harvests of berseem clover were taken as is usually done until it is decided to plow-down the stand. Under this management DM% rises slowly during the early harvests and the N-factor goes from 9 to 13, averaging about 11 for Joe Burton and Multicut with Bigbee averaging somewhat higher. For the June and July harvests the DM% rises rapidly (N% drops somewhat) and the N-factor rises a good bit for all three varieties but especially for Bigbee.

Table 3. N concentration (%) and dry matter (%) for repeated harvests of Joe Burton*, Multicut, and Bigbee berseem clover cultivars by stage of development and date of harvest with resulting multiplying N-factor used to get N contribution, Agronomy Farm, Davis 1992.

Cultivar	Stage	Date	N %	DM %	N-factor
Joe Burton*	Veg	3/13	3.19	10.9	9
	Veg	4/10	3.11	13.4	11
	Veg	5/6	3.53	13.6	13
	Bud	6/1	2.93	18.8	15
	F bloom	7/1	2.66	25.4	18
Multicut	Veg	3/13	3.06	10.5	9
	Veg	4/10	3.32	12.5	11
	Veg	5/6	3.68	13.2	13
	Bud	6/1	3.19	19.8	17
	F bloom	7/1	2.54	25.9	18
Bigbee	Veg	3/13	3.39	10.0	9
	Veg	4/10	3.91	14.3	15
	Veg	5/6	3.71	13.9	14
	E bloom	6/1	3.42	23.0	21
	Gr pod	7/1	2.85	34.8	27

* Williams, et al 1996.

An expert system program has been developed around the recommendations contained in the Covercrops in California Agriculture Publication (Miller et al 1989). The N-factors generated for that program are included in Table 1.

In general the N-factors are a good approximation for calculating the nitrogen contribution for legume covercrops when these coverops are approaching their early bloom stage, the time when most covercrops are recommended to be incorporated.

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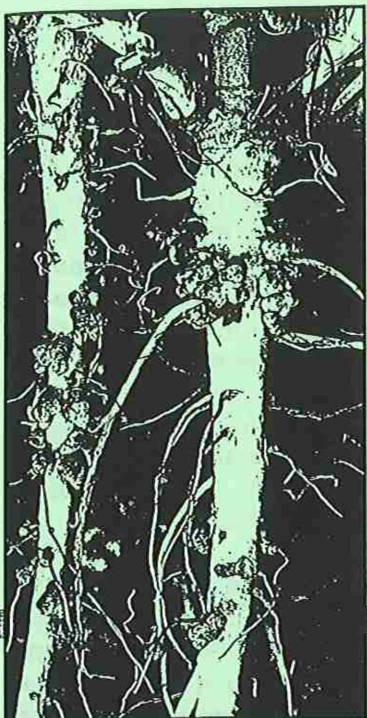

CHAPTER 4

Soil Fertility and Vine Nutrition

Donna J. Hirschfelt

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Since the early 1900s, cover crops have been used to enhance the soil of California vineyards. Although there are many different objectives in using cover crops, their contribution to soil fertility and vine nutrition are perhaps the best documented.

Cover crops have direct and indirect effects on soil fertility and vine nutrition. Incorporation of leguminous green manure cover crops directly adds organic nitrogen to the soil. After mineralization, which begins within weeks after incorporation, this nitrogen is available for vine uptake. In contrast, nonleguminous cover crops often place competing demands on the vineyard nitrogen pool. Decomposition of high-carbon plants such as mature cereals and grasses may tie up nitrogen, making it unavailable for vines.

Cover crops may influence soil fertility indirectly by altering soil organic matter composition and soil structure. Improved soil tilth may result in a more favorable environment for vine root growth and root foraging for nutrients. A cover crop's water use can also influence vine nutrition by lowering soil water content. In dry soils, organic nitrogen mineralizes and becomes available relatively slowly; likewise, potassium uptake is reduced. Conversely, cover crops in wet or waterlogged soils may improve aeration and also improve the uptake of nitrogen and potassium.

The interactions between cover crop, soil fertility, and vine growth are complex and dynamic. If cover crops are to be used as an effective tool in vineyard nutrition management, there must be a clear understanding of these interactions and the variability of all the biological processes involved. Measuring and predicting changes in soil nutrient status can be far more difficult in cover-cropped vineyards than in vineyards managed with chemical fertilizers alone.

From University of California Division of Agriculture and Natural Resources Publication 3338:
Cover Cropping in Vineyards: A Growers Handbook.
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Types of Cover Crop Systems and Soil Fertility Implications

Annual Cover Crops

Green manures. Green manure cover crops are typically planted in vineyards from September to early December. They consist of winter annual grasses, legumes, or forbs. If the green manure is used to add nitrogen, legumes are used alone or in combination with nonlegumes, usually cereals.

The cover crop germinates within several weeks with adequate soil moisture and proper soil temperatures. Most species do not develop substantial biomass until daylength and temperatures increase in late February or early March. The cover crop is usually incorporated into the soil while still green and succulent, usually from late March to early May. At this time the carbon to nitrogen (C/N) ratio is low, so there is rapid decomposition and a net release of nitrogen. The cover crop is often disked or mowed in late March if there is a danger of frost. If reseeding is desired, incorporation may be delayed until the cover crop sets mature seed.

Time of incorporation affects the C/N ratio of the plant material and the amount of nitrogen available for vine uptake. Cereals and grasses have a favorable C/N ratio for decomposition until they flower; decomposition is greatly reduced after bloom. A fairly good rule of thumb is that mature plant materials containing less than 1.3 to 1.5 percent nitrogen on a dry-weight basis will immobilize additional nitrogen as they begin to decompose. Cereals almost always require supplemental nitrogen fertilizer for adequate growth. Thus, when planted alone, their use could be questioned as a positive influence in green manuring. However, their rapid growth, deep, fibrous root systems, and potentially large biomass can provide for early production of organic matter and nutrients. These attributes can be particularly useful in fine-textured or compact soils that tend to restrict cover crop growth. Also, their accumulation and gradual release of nutrients are advantageous in easily leached sandy soils.

Reseeding winter annual cover crops. Annual cover crops may compete for soil nutrients if they are actively growing when vines are taking up nutrients. Once they are incorporated into soil they may either provide or consume nitrogen, depending on their C/N ratio.

Some grass and legume species are grown as reseeding annuals. In these systems the cover crop is allowed to continue growth past flowering in order to set seed. The cover crop may then be incorporated or be mowed and left as a surface mulch. After flowering there is redistribution of nitrogen in the legumes and the seeds tie up considerable amounts of nitrogen. Growers should expect both a delay in nitrogen availability and a reduction of nitrogen mineralization when legumes are allowed to reseed. The exact amount of nitrogen lost for vine uptake depends on the species, cover crop vigor, seed production, and other factors.

Some nitrogen in legume residues left on the soil surface may be lost to volatilization of ammonia. Volatilization is extremely variable, but some researchers report nitrogen losses of 5 to 14 percent (Janzen and McGinn 1991). Loss of ammonia increases with higher temperatures, increased air movement, and lower humidity (Terman 1979). In field experiments with hairy vetch grown in no-till corn, inorganic soil nitrogen was found to be 2 to 4 times higher where the vetch was incorporated into soils compared to mowing alone (Sarrantonio and Scott 1988). Exact amounts are difficult to predict, but grape growers should expect a reduced nitrogen contribution in reseeding systems.

Perennial Cover Crops

Permanent perennial cover crops that grow during the summer usually compete strongly with vines for soil nutrients and water. Research indicates that perennial ryegrass and other sod-type cover crops may significantly reduce vine nutrient status (Tan and Crabtree 1990). Sod-type cover crops are unsuitable in nitrogen-limited vineyards. Although these cover crops may be useful in reducing excessive vine vigor, their impact may take several years. Research in an excessively vigorous, high-nitrogen Thompson Seedless table grape vineyard in the Southern San Joaquin Valley evaluated the impact of a perennial ryegrass–red fescue mixture for 4 years. The cover crop gradually reduced petiole nitrogen levels but did not reduce overall vine vigor and had no impact on fruit quality or vine fruitfulness (Hirschfelt et al. 1993).

Little data is available on the effect of perennial legumes on vine nutrition, since their use is limited. Observations by some growers indicate that perennial legumes contribute little nitrogen to the vineyard.

Grapevine Nutrition

Grapevines have fewer mineral deficiency problems and fertilizer demands than many other horticultural crops and are adaptable to a wide range of soil types and soil fertility. In general, only four nutrients, nitrogen (N), potassium (K), zinc (Zn), and boron (B) are widely supplemented in vineyards. Local areas may require additional phosphorus (P), iron (Fe), magnesium (Mg), and manganese (Mn).

Grapevine nutritional status can be assessed using a combination of laboratory analysis and visual evaluation of the vineyard. Plant tissue analysis of leaf petioles or blades is more useful and reliable than soil analysis because the result represents the concentration of nutrients the grapevine is able to remove from the soil. Lab analysis should always be confirmed by visual evaluation of foliar conditions and vine growth. A publication on tissue sampling, analysis, and foliar deficiency symptoms is available (see Christensen, Kasimatis, and Jensen 1978).

Nitrogen

The nutrient that is most frequently required in vineyards is nitrogen, which can be supplied through commercial fertilizers, compost, manure, or cover crops. Cover crops can be grown to supply nitrogen to the vines and improve the soil structure and the movement of nitrogen through the soil root zone. Conversely, they can be used to take up surplus nitrogen and water from soils, which may reduce excessive vine vigor and also reduce nitrate leaching into groundwater. Decomposition and nitrogen mineralization of cover crop residues may provide a more gradual release and uptake of nitrogen to vines than the use of commercial fertilizers alone. In order to understand the role of cover crops in nitrogen nutrition, it is important to understand nitrogen dynamics in the soil, in the vineyard, in cover crop species, and in the vines.

Nitrogen cycling in soils. Properly timed incorporation of green manure or other cover crop residues can add nitrogen-rich organic matter to soils. Organic forms of nitrogen are not available for plant uptake and are less susceptible to leaching than inorganic forms of nitrogen fertilizers. Figure 4-1 shows the possible fates of nitrogen in the soil. As soil microorganisms break down organic residues containing proteins and amino acids, mineralization occurs and ammonium (NH_4^+) is released. Ammonium may then be taken up by bacteria, and

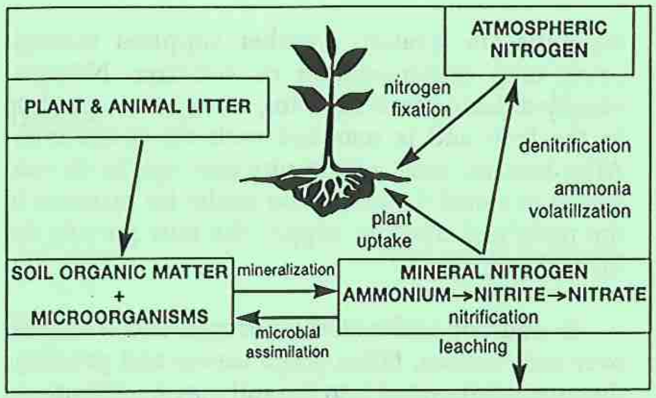

Figure 4-1. Nitrogen cycling (adapted from Chaney, Drinkwater, and Pettygrove 1992).

in a process called nitrification, nitrite (NO_2^-) and then nitrate (NO_3^-) are produced. Plants can take up ammonium and nitrate.

Loss of nitrogen from the vineyard can occur in several ways. Nitrogen may be lost through leaching of nitrate, since it has a negative charge and is not tightly held by the negatively charged clay and organic matter particles. Nitrate thus moves readily downward with deep irrigations and rainfall. In waterlogged soils, oxygen concentration is low, causing some nitrate to be reduced to gaseous nitrogen by anaerobic bacteria and lost to the atmosphere. Some ammonium may be fixed by soil mineral complexes and become unavailable to plants and microbes. Erosion of surface soils may also remove nitrogen from the vineyard.

Some nitrogen may be immobilized for a period of time as it is converted to organic forms in microbial and plant tissues. This nitrogen is unavailable to other organisms or plants. Grass residues with a high C/N ratio may immobilize soil nitrogen for several weeks to months after incorporation.

Vine nitrogen requirements and dynamics in the vineyard. Research has led to a better understanding of grapevine nitrogen needs, uptake, remobilization, and nitrogen cycling in the vineyard. The historical practice of supplementing vineyards with up to 100 pounds per acre (112 kg/ha) of nitrogen during the dormant season has been found to be excessive and inefficient. The greatest need for nitrogen is in the spring during rapid shoot growth. Between bud break and bloom, vines rely heavily on nitrogen stored through the dormant season in the trunk and roots. From bloom to veraison (the beginning of fruit ripening) vines depend mostly on root uptake of nitrogen. This is when nitrogen demands are greatest, whether supplied through cover crop decomposition or fertilizer. Nitrogen supplied during fruit ripening tends to accumulate in the fruit and is removed with the grape crop. After harvest, most of the nitrogen uptake is converted to stored forms (amino acids) for reserves in the roots and trunk to supply the new growth the following spring.

In addition to the stored nitrogen that is carried over each season, fallen grape leaves and prunings that are incorporated into the soil may contribute up to 35 pounds per acre (39 kg/ha) of nitrogen (Williams 1987). It is unknown how rapidly these tissues break down and how much nitrogen is used by vines during the following season, but it probably varies greatly depending on the method of irrigation and soil factors. The primary removal of nitrogen from the vineyard system is through crop harvest. Fruit nitrogen content varies depending on many factors, including cultivar and rootstock. Research on Thompson Seedless in the San Joaquin Valley indicates that 2.6 pounds of nitrogen (1.3 kg/t) may be removed per ton of fruit (Williams 1987).

Although grapes are grown on a wide range of soils and under a wide range of conditions, generally 30 to 50 pounds per acre (33.6 to 56 kg/ha) of supplemental nitrogen is adequate for most vineyards. This amount of nitrogen can easily be supplied by many different legume cover crop systems.

Problems associated with excess nitrogen. For many years grape growers believed that extra nitrogen was "cheap insurance" in crop production. The detrimental effects of excess nitrogen are now well documented. Excess nitrogen may lead to excessive vigor in vineyards. Excessively vigorous vines have increased canopy growth, resulting in shading of crop and fruiting buds; the effect is a decrease in fruit quality and bud fruitfulness. Dense canopies provide favorable microclimates for diseases such as bunch rot and powdery mildew and can impede spray coverage of fruit and foliage with fungicides.

Groundwater contamination by nitrate is widespread in California. It is critical to manage nitrogen sources so that excess nitrate is not present in soils, especially during periods of high rainfall or water saturation. Cover crops may be useful in reducing nitrate leaching in soils. Cover crop residues that are incorporated in the late spring decompose and are mineralized within a few weeks, providing soil nitrogen at a time of rapid vine uptake. Cover crops that grow rapidly in the winter, such as cereal rye, may use soil nitrogen that might normally be leached past the inactive grapevine roots.

Nitrogen fixation by legumes. The main source of environmental nitrogen is the atmosphere, which is approximately 78 percent nitrogen gas. However, this gaseous form of nitrogen is unusable by most plants. Nitrogen fixation is the process of changing gaseous nitrogen into nitrate or ammonium forms usable by plants. Legumes are capable of fixing nitrogen through a symbiotic association with bacteria from the genus *Rhizobium*. Because rhizobia occur in low levels naturally in most soils, the bacteria must be present on legume seed at planting (see chapter 3). The bacteria gain entry into developing roots through root hairs. The plant responds with rapid cell division, creating nodules on the root. Although the nodules look similar to galls created by the root knot nematode, they may be distinguished if closely examined in the field (fig. 4-2). Nodules are easily rubbed off roots and are usually pink to red inside (plate 4-1). Root knot galls do not rub off and are white when dissected.

Nitrogen production and availability. Research indicates that legume cover crops can fix from 50 to

Figure 4-2. Nodules created by nitrogen-fixing rhizobia on berseem clover.

200 pounds per planted acre (56 to 224 kg/ha) of nitrogen (Miller et al. 1989). The amount of fixation depends on the cover crop species, soil pH, soil temperature, soil moisture, soil nitrogen status, and inoculation. Legume nitrogen production is somewhat self-regulating. If there is available nitrogen in the soil, fixation is reduced and legumes use the available soil nitrogen. Although a small amount of nitrogen is stored in the nodules and root system, 75 to 80 percent is rapidly translocated to the stems and foliage and is incorporated as proteins and amino acids. A very small amount of nitrogen is released into the soil surrounding the roots (rhizosphere). The release of nitrogen into the rhizosphere is likely to be the result of sloughing off of old nodules and the decay of roots. When legumes are incorporated into soil, all fixed and assimilated nitrogen in the plant is returned to the soil for a net gain in nitrogen. Decomposition and mineralization occur as previously described, and the nitrogen becomes available for vine uptake.

Research in the San Joaquin Valley has shown that the high-nitrogen 'Lana' woollypod vetch will significantly increase soil nitrate-nitrogen levels within 5 to 6 weeks of incorporation (Hirschfelt et al. 1992). Figure 4-3 shows the influence of cover crop treatment on soil nitrogen levels in the top 4 feet (1.2 m) of a vineyard soil in mid-June.

When cover crops are mowed and left on the soil surface, mineralization takes place more slowly and significantly less nitrogen is available for plant uptake. The exact amount of nitrogen loss is not known under California vineyard conditions, but field crop research in other states indicates that incorporation nearly doubles soil nitrogen content compared to no-till green manure vetch, especially early in the season (Sarrantonio and Scott 1988). In these systems, nitrogen remains in the surface soil and is not available until it is moved into the vine root zone with water. A substantial portion of the nitrogen in these residues may also be lost to the atmosphere by volatilization.

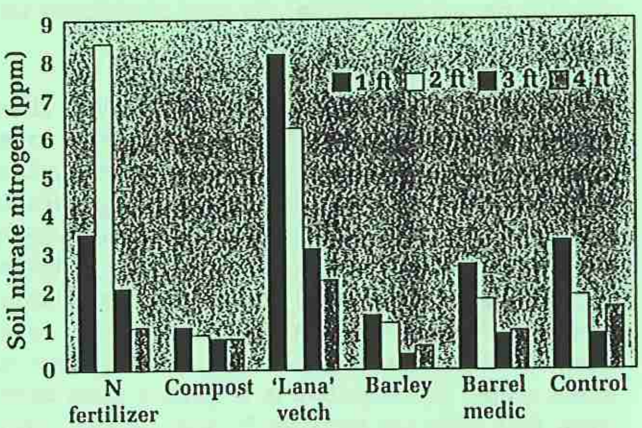

Figure 4-3. Effect of cover crop on soil nitrate-nitrogen in a Thompson Seedless vineyard in the San Joaquin Valley, June 1992.

To determine the actual amount of nitrogen produced by a cover crop, samples must be collected from a measured sample area in the field, such as a 3-foot by 3-foot (0.9-m by 0.9-m) area. The fresh weight must be determined shortly after cutting since weight declines rapidly as succulent plants begin to dry. Cover crop material must be free from dew or rain. It is best to store the weighed, moist sample in a plastic bag in a cooler and deliver it immediately to a lab for an analysis of the percentage of nitrogen. (If there will be a delay in getting samples to a lab, the fresh weight should be recorded, then the sample can be placed in a large, open, brown paper bag to begin drying.) After the nitrogen content is determined, the amount of nitrogen contributed per acre can be calculated as shown in the example in table 4-1.

Grape growers should not need to know the exact amount of nitrogen contributed from cover crops. The range of available nitrogen for several common legumes is presented in table 4-2. Research has demonstrated that vetch cover crops can supply all the nitrogen required in a vigorous Thompson Seedless vineyard in the San Joaquin Valley (Hirschfelt et al. 1993). This fact is supported by grower observations at various locations.

The most important factor in maximizing nitrogen production of legumes is to obtain the greatest amount of legume plant growth. Maximizing growth may require supplemental irrigation and fertilization with phosphorus. However, many legume cover crops are capable of producing more than the 30 to 50 pounds (33.6 to 56 kg/ha) of nitrogen required by the vines, so maximizing nitrogen production is usually not of critical importance. It is important to monitor the vineyard nitrogen status over time and adjust cover crop planting to meet vineyard needs.

There are several ways of utilizing cover crops to manipulate the amount of nitrogen made available to the vines. For example, planting legume cover crops in alternate rows reduces the amount of nitrogen produced and helps facilitate other vine-

Table 4-1. Example calculation of nitrogen contribution by a legume cover crop

In a vineyard with a 'Lana' woollypod vetch cover crop, a total of 8 lb of the vetch was cut from three 1-ft by 3-ft sample areas. A 1-lb subsample was collected and submitted to the lab.

Lab analysis of moisture content	=	82%
Lab analysis of dry weight N content	=	2.8%
Sample dry matter	= =	100% – 82% 18%

To find the amount of N contributed per planted acre of cover crop:

8 lb × 18% dry matter	=	1.44 lb dry matter/3 × 3 ft area
1.44 lb dry matter × 2.8% N	=	0.04032 lb N/9 sq. ft
0.04032 lb N ÷ 9 sq. ft	=	0.00448 lb N/sq. ft
0.00448 lb N/sq. ft × 43,560 sq. ft/acre	=	195.1 lb N/planted acre of cover crop

To determine the amount of N per vineyard acre:

Swath covers 50% of row: 50% × 195.1 lbs	=	97.6 lb N/vineyard acre

Cover crop planted in every other row:

97.6 lb N/vineyard acre ÷ 2	=	48.8 lb N/vineyard acre

Adapted from Frate 1994.

Table 4-2. Estimated amounts of nitrogen fixed by various legumes

Cover crop	N fixed (lb/acre)
'Lana' woollypod vetch (*Vicia villosa* ssp. *dasycarpa*)	50–200
Medics (*Medicago* spp.)	50–100
Subclover (*Trifolium subterraneum*)	184–250
Rose clover (*Trifolium hirtum*)	50–100
White clover (*Trifolium repens*)	114–200
Strawberry clover (*Trifolium fragiferum*)	100–300

Source: Munoz and Graves 1987.

yard operations. Also, the width of the cover crop swath in vineyard middles can be reduced; this is especially useful with vetches, which have a tendency to spread into vine rows.

Planting legume-grass mixtures also reduces nitrogen contribution. On fertile soils, grasses compete with legumes in mixtures and may reduce legume biomass. This competition is partially balanced by the fact that grasses take up large quantities of nitrogen, reducing the soil nitrogen pool and causing the legumes to fix more atmospheric nitrogen. Some growers attempt to attain the optimum soil nitrogen availability by varying the proportion of grasses to legumes in mixes based on vine petiole analysis. This practice has not been experimentally tested and may produce highly variable results from year to year.

The effects of grass cover crops on soil nitrogen depend largely on the grass's maturity at disking. If grasses are incorporated after flowering, when they have a high C/N ratio will be tied up by bacteria and will not be readily available to the vines. If incorporated before flowering, grasses have a lower C/N ratio and will decompose and mineralize relatively quickly.

Vine response. It is difficult to predict how quickly vines respond to the nitrogen released after cover crop incorporation. Research in the San Joaquin Valley has shown that when cover crops were incorporated at the beginning of May, bloom petiole nitrate levels increased when collected approximately 28 days later (Hirschfelt et al. 1993). Throughout the 3 years of the experiment, the vine nitrogen status in the 'Lana' woollypod vetch treatments was similar to treatments receiving 50 pounds per acre (56 kg/ha) per year of nitrogen fertilizer.

Generally, grass cover crops compete with vines and are net consumers of soil nitrogen. Grass cover crops require supplemental nitrogen fertilization, except when soil or irrigation water nitrogen levels are very high. It is common grower practice to apply 25 pounds per acre (28 kg/ha) of nitrogen fertilizer at planting and 25 pounds per acre at time of incorporation. The practice of nitrogen trapping by cover crops is being investigated with some success in other crops. The objective is to plant a grass cover crop that takes up fertilizer N, then breaks down and mineralizes slowly after incorporation.

Summer-active perennial grass covers such as red fescue and perennial ryegrass have been demonstrated to reduce foliar concentrations of nitrogen in Thompson Seedless (Hirschfelt et al. 1993) and Chardonnay (Tan and Crabtree 1990) vineyards. The reduction is greater when nitrogen is limiting in the vineyard system.

Cover Crops and Other Nutrients

Little information exists on the effects of cover crops on the status of other vine nutrients. Uptake of soil phosphorus, potassium, and manganese is reported with different legume and nonlegume species in greenhouse studies (Gardner and Boundy 1983; Atallah and Lopez-Real 1991), but mineralization and crop uptake are not well documented under field conditions.

Perennial ryegrass is reported to have reduced foliar concentrations of sulfur, calcium, boron, and manganese in grapevines (Tan and Crabtree 1990). No difference was reported in the petiole concentrations of potassium or magnesium in Concord (*Vitis lubruscana*) grapevines in New York grown in a permanent sod culture of perennial grasses and perennial broadleaf weeds (Pool, Dunst, and Lasko 1990). After 3 years of cover cropping, 'Lana' vetch, barrel medic, barley, 'Blando' brome, and sudangrass had no effect on petiole potassium, phosphorus, or boron levels.

Cover Crop Fertilization

Fertilization of Legumes

Generally, supplemental phosphorus fertilizer is the only nutrient required for legumes in vineyard cover crop systems. Phosphorous can be applied by broadcasting single-superphosphate on the soil surface during seedbed preparation or banding at planting with a seed drill. Soil tests for phosphate phosphorus are a good indicator for fertilizer need. Table 4-3 can be used to calculate fertilizer requirements (see Graves, Breece, and Jackson 1986).

Other fertilization is not necessary. Nitrogen fertilizer should be avoided since it reduces nitrogen fixation. Sulfur is also necessary for good legume growth, but it is usually not limiting in vineyard soils.

Table 4-3. Phosphate fertilizer requirements for legumes based on available soil phosphorus

Available soil phosphorus (ppm)	Single-superphosphate requirement (lb/acre)
<5	600
5–10	300
>10	150

Fertilization of Grasses

Nitrogen fertilizer is usually required for grass cover crops. A common practice is to apply 25 to 50 pounds per acre (28 to 56 kg/ha) of nitrogen at planting. Many growers will also apply 25 pounds at the time of incorporation (or in the early spring for perennial grasses) to hasten breakdown and mineralization. If cover crops are used to reduce vine vigor and nitrogen status, or if soil or water nitrogen content is excessive, nitrogen fertilizer use should be reduced or eliminated.

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