ALTERNATIVE ANNUAL FORAGES—Now and in the Future

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ABSTRACT

A range of alternative annual forage crops that could be grown in California are reviewed. We have grouped these into three general categories, fall-seeded annual cereals and grasses, fall seeded annual legumes, and summer annuals (excluding corn, which is covered elsewhere in this proceedings). This review is not comprehensive, but provides an overview of some of the annual species that can be grown in California, with the aim to encourage further experimentation by growers and researchers. These alternative annual forages include winter cereal forages such as wheat, oats, and triticale, winter grasses such as ryegrass, winter-grown legumes such as peas, vetch, faba beans and berseem clover, and summer annuals such as sudangrass, millets, soybeans and cowpeas. Annual forages including corn silage currently occupy greater than 800,000 acres in California. These types of annuals may increase in importance in the future due to their high yields, ability to help recycle various waste products (manures, effluent), and high degree of flexibility in rotations, and the potential to adjust rapidly to water supply and market fluctuations.

Keywords: small grain forage, alternative forages, soybeans, cowpeas, sudangrass, millet, and berseem

REASONS TO CONSIDER ALTERNATIVE ANNUAL FORAGES

Why should one be interested in alternative annual forage crops? While few would question the importance and value of alfalfa, our principle forage crop, there are several reasons why annuals have found a place among California forages. These annuals, considered in aggregate including corn silage, occupy nearly 800,000 acres, or 4/5 of the current alfalfa acreage.

Annual forages are generally considered under several circumstances. One is to fill in when overall supplies become tight. Producers can generally respond more quickly by planting annual forages to fill their immediate needs. A second case is incorporating annual forages in rotation as a part of regular forage production program for dairy or beef production. This can offer considerable flexibility and versatility to respond to price and demand changes. Winter annual forages paired with summer annual forages (e.g. corn silage and sudangrass hay) may be the type of combination that maximizes the forage output per acre and possibly also the best net return per acre. Annual forages may also be part of a regular alfalfa forage program by rotating out of alfalfa with annual forages for a period of time (1-2 years) before reseeding.

It is also possible that combinations of annual forages may be superior in Water-Use-Efficiency (production of dry matter per unit of water) to perennial forages when water supplies are tight [One should be careful with these comparisons due to differences in quality—these differences

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are significant between grasses and perennial legumes such as alfalfa]. However, regardless of water use efficiency, with a significant lack of predictability in water supplies in some areas, annual forages provide high degree of flexibility compared with perennials.

In this article, we provide an overview of several annual alternative forages of which we are familiar. We have not included corn silage, which is covered elsewhere in this publication. The purpose here is not to provide a comprehensive listing or report—many of these forages require further research and adaptation studies. We lack in-depth yield and quality information for many of these species. Our purpose is mostly to provide a starting point for consideration of annual alternative forages, to encourage further experimentation on the part of growers and researchers. We have decided to group these into three general groups, fall-seeded annual cereals and grasses, fall-seeded annual legumes, and summer annuals.

FALL-SEEDED ANNUAL CEREAL FORAGES (Wheat, Triticale, Rye, Oats, Barley)

In acreage, small grain forages are the most important harvested forage alternative in California. The sum total acreage is greater than 400,000 acres per year, with the majority being oat hay (compared with 1 million acres of alfalfa and about >300,000 acres of corn silage). Wheat, triticale, rye, oats, and barley - are widely adapted, highly versatile forages used for pasture, green chop, silage, or hay. Although overshadowed in the past by alfalfa and corn silage, cereal forages are a major crop in many parts of the U.S. and world, and are becoming increasingly important because of their significant economic and environmental benefits (see Table 1). Depending on which cereal variety is chosen and how it is managed, cereal forages can meet a full range of forage needs for dairy and beef production. The best choice for a given situation depends on the nutritional needs of the animals to be fed, and the conditions in which the crop will be produced.

Digestibility of the Fiber and Protein. The key factor in matching cereal forage to nutritional needs of dairy or beef animals is the content and digestibility of the fiber in the forage. Although some equate higher fiber content with lower quality, it is actually the digestibility of the fiber that is the true determinant of forage value. The most important factor in determining the content and digestibility of fiber in cereal forages is the state of plant development. The vegetative plant prior to head emergence is highly digestible. Its indigestible fiber and extent of lignin bonding are both low. As the plant progresses through heading and flowering, lignin and lignification increase and digestibility drops rapidly. Later, as the grain fills, overall digestibility levels off and may even rebound as the accumulation of highly digestible nutrients in the grain counters lignification and the loss of digestible compounds in the stem and leaves.

Protein. In addition to changes in fiber and digestibility, protein content also changes as the cereal forage plant progresses through its life cycle. Crude protein concentration is highest while the plant is vegetative prior to stem elongation and head emergence, and drops rapidly as the plant progresses through heading and flowering. As the grain fills, protein levels off or drops more slowly as it accumulates in the grain but declines in the leaves. Protein levels are highly responsive to uptake of nitrogen, so N fertilizers are important.

Table 1. Features and benefits of Cereal Forages	
Features	**Benefits**
Annual Growth Habit	Quick source of forage. Quick payback on production cost. Flexible in crop rotations. Allows quick response to changing economic and production conditions.
Cool Season Crop	Efficient use of soil moisture. Less vulnerable to drought. Double crop options with warm-season crops. Complement warm-season crops in workload, production inputs, and feed supply. Reduce soil erosion. Aid management of nitrogen and manure during cool season. Utilizes nitrogen and prevent runoff and percolation into ground water.
Product Options	Versatile source of products for a variety of needs: Vegetative or boot stage for high quality forage. Post-boot stage for high yields of intermediate quality forage. Grazing, grain and straw applications.
Competitive with Weeds	Minimize costs, regulatory requirements, and undesirable effects of herbicides. Helps control weeds in the rotation. Helps establish new stands of alfalfa and enhance declining stands when interseeded.
Relatively Few Economic Pests	Minimize costs, regulatory requirements, and undesirable effects of pesticides. Low risk of loss to pests if crop variety is chosen prudently.
Widely Adapted	Wide range of species and varieties allow production under almost all conditions. Tolerates heavy applications of manure and manure water.
Low Input Requirements	Low input cost and financial risk. Equipment required is modest, and commonly already owned for other enterprises.
Rotational Benefits	Help control pests that affect other crops in the rotation, reducing production costs and increasing yields.

Matching Nutritional Needs. Managers can take advantage of the changes in cereal forage digestibility and protein by matching forages to the varying nutritional needs of dairy and beef animals. Successful matching involves making the right choice of variety and properly timing planting and harvest. Among cereal grains, the wide array of species, varieties, maturity, plant types and nutritional attributes offers many options economically matching the feed to the need (Table 2). Optimizing the production and use of cereal forages involves the interaction of variety, planting date, harvest date and type of forage desired.

Choice of Species/Variety - Choice of variety determines to a large degree the quality and quantity of forage produced. Varieties differ greatly in maturity, which affects timing of harvest, which in turn affects yield, protein and digestibility. The first step in choosing a cereal grain variety for forage production is knowing how it will be used.

Table 2. Generalized Comparison of Cereal Forage Species

	Fast Early Growth	High Grain Yield	Tolerance to Disease	Tolerance to Sodic Soils	Tolerance to Drought
Wheat	♦♦	♦♦♦	♦♦♦	♦♦	♦♦
Triticale	♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦
Rye	♦♦♦♦	♦	♦♦♦♦	♦♦♦	♦♦♦♦
Oats	♦♦♦	♦	♦	♦	♦
Barley	♦♦♦♦	♦♦	♦	♦♦♦	♦♦♦

Choosing a Harvest Window. The next step is to choose a species or variety that is in the desired state of development during the optimal harvest window. If high digestibility and protein are the most important, for example, then it is best to choose a variety that does not reach boot stage until the risk of weather problems is reduced (a late variety or species). For high yields of grain-rich forage, the best choice is an earlier maturing variety that is in dough stage during the desired harvest time. In addition to maturity, varieties differ in other important characteristics that affect forage quality and harvest stage. These include tillering, leaf-to-stem ratio, grain-to-stem ratio, and nutrient content, all of which help determine which variety is the best choice.

Maturity at Harvest—a Critical Factor. All cereal grains decrease in digestibility as they mature from boot to milk stage, but cereal grain varieties that produce high grain yields partially rebound in digestibility going from the milk to the soft dough stage as a result of the grain filling. Oats, rye, and varieties of other small grains that do not produce high grain yields generally continue to decrease in digestibility as the plant reaches the dough stage because the higher digestibility of the grain is overshadowed by the increasing lignin and decreasing digestibility of the other parts of the plant. Varieties that do not produce high grain yields are a poor choice for dough-stage harvest.

Choice of variety also should reflect agronomic characteristics such as tolerances to drought, disease, salt, and applications of manure water. The variety must be matched well with crop production plans and conditions as well as with the nutritional needs of the livestock to which it will be fed.

The importance of variety is reflected in the wide diversity among triticale varieties. Triticale is a species of cereal grain created by crossing wheat with rye. The resulting combination is then selected for either grain or forage production. Some triticale varieties are ideal for boot-stage harvest because of their heavy growth of tillers and leaves, and maturity late enough to still be in the boot stage when weather is warmer, drier, and more favorable for harvest. Other varieties of triticale are ideal for soft-dough harvest because of their heavy grain yield and earlier maturity. Some of those have a high enough grain-to-stem ratio to be suitable for feeding high-producing dairy cows; others produce extremely high forage yields but are best matched with dry cows and heifers. The latest varieties of triticale are capable of significantly higher grain yields than the best locally adapted wheat.

Seeding Date. There is a best time to plant cereal grains. For most situations in the Central Valley of California, for example, the best time to plant is from the middle of November to the end of December. Planting earlier than this increases the risk of foliar disease, lodging and freeze damage from spring frosts. Early-maturing varieties that are planted too early may be ready for harvest when weather conditions are still cool and wet, and there is a high risk of weather damage to the windrowed forage.

Time of Harvest. Optimal harvest timing depends on the weather, crop sequence, variety and the desired type of forage product. The general "harvest window" during which cereal forages are best harvested is determined by climate and, in some cases, crop rotation. The best time for harvesting a specific crop within that general window depends on whether harvest at boot or dough is desired. It also depends on the characteristics of the variety, especially whether it is early, mid or late maturing. Once the decisions about harvest stage and variety are made, the

ideal harvest time in terms of forage quality can be determined. Of course weather conditions, intentions to double-crop and harvest logistics may lead to departures from that ideal.

ANNUAL RYEGRASS

Ryegrass is one of the most widely grown cool- season grasses in the world, and one of the most palatable. Ryegrass is an important alternative winter-annual crop in the Central Valley of California, particularly for dairy producers. Annual ryegrass can also be grown as a cool-season species in many regions in California as a hay or grazing crop. Annual ryegrass (*Lolium multiflorum Lam. Or L. perenne L. ssp. Multiflorum*), also called 'Italian' ryegrass, is a forage species, and different than cereal rye (*Secale cereale*), which is a grain crop or cover crop.

There is a wide range of diversity in this group of bunch grasses, including both annual and perennial (Lolium perenne L.) types, which can be interbred. Ryegrass is indigenous to Europe, Asia, and North Africa. Annual ryegrass varieties establish rapidly, and produce substantial yields in 2 to 5 cuttings, most commonly, 2-3 in California. Ryegrass grows best on fertile, well-drained soils but can be grown on soils where it is too wet at certain times of the year, situations unsuitable for alfalfa. Dairies particularly value ryegrass due to its high palatability and its ability to accept large quantities of lagoon water or solid manures. Ryegrasses are heavy users of water and will perform less than optimum during a drought or periods of extended low or high temperatures, thus are well suited to the moderately cool wet winters of California's Central Valley or coastal valleys. The ryegrasses are considered to be high quality forage and their high digestibility makes them suitable for all types of ruminants.

Varieties. There are a range of varieties or types of ryegrass within the 'Annual Ryegrass' umbrella, ranging from the 'Westerwold' types (L.multiflorum var. westerwoldicum), to 'intermediate' types which are crosses between annual and perennial Lolium species. 'Westerwold' types are high yielding annuals commonly used in California, but have less heat tolerance than other types of annual ryegrass. There are a range of 'Italian' type annual ryegrasses, some of which may be higher in quality. There are a range of maturity and growth types, and varieties differ in quality. These should be regarded as a group of ecotypes of annual ryegrass. Several studies are underway in Stockton and Modesto to understand the differences in yielding patterns (few cuts to many, high or low yielding at first cut, maturity influences), and quality characteristics of these ryegrass varieties. Some may behave as biennials or short-lived perennials.

Tetraploid or Diploid. There are two basic groups within the Italian and perennial ryegrass species: diploids and tetraploids. This is based on the number of chromosomes within each plant cell. Tetraploid ryegrasses have double the number of chromosomes (four) compared with diploid types (which have paired chromosomes). Tetraploid ryegrasses tend to have larger leaves, fewer but larger tillers, and may produce a more open growth pattern. Tetraploids may be more suited for production in a legume mixture than the diploid perennial ryegrasses. Tetraploids have been shown to have a higher percentage of sugars in the forage than diploids, which explains their higher digestibility and grazing preference over diploids in research studies. Both the seed and seedlings of tetraploid varieties are larger, but the growth following emergence and persistence is often greater for diploid varieties.

Methods and Uses. Ryegrass is relatively easy to establish and can be seeded from September through January in California's Central Valley. Ryegrass can be no-till seeded into some types

of stubble, if the seed can be covered. Normally ryegrass germinates in a matter of 7-10 days, or even less under ideal conditions. Seeding rates vary from 15 lbs/acre to 35 lbs/acre depending upon precision of seeder and whether it is sown in combination or alone. It is a cool-season grass, so should be seeded at a time to take advantage of the cool growth periods, primarily in the fall and very early spring. Ryegrass growth and vigor is reduced during summer months, and it eventually dies. Two to three cuts are most common before the stand dissipates in summer.

There are nearly 3 million acres of annual ryegrass grown in the US, mostly used for winter pasture in the Southeast. Ryegrasses may be sown alone or in combination with legumes or small grains. Combinations of ryegrass and peas, berseem clover, vetch or small grains have proved interesting combinations for a palatable winter fresh-cut feed or silage crop, although some of these crops will not survive multiple harvests, while ryegrass will, as will berseem. Ryegrass can be dominant in mixture, so seeding rates should be low in a mixture. Hay production in the early part of the year in many parts of California is difficult due to significant, high-moisture yields and difficulty of curing. Thus, ryegrass is often used for silage, greenchop, or grazing. As an optimum compromise between quality and yield, many experts recommend harvesting annual ryegrass in the boot to early-heading stage.

Linkage with N-Uptake, waste recycling. Ryegrass is an important crop, along with small grains, corn, alfalfa, and other forages, to help with recycling of different types of wastes. As a high-yielding palatable grass with high winter growth rates, annual ryegrass is able to absorb large amounts of nitrogen from manure, effluent, or biosolids applications. Research from Oregon has shown that 400 lbs of N is contained in the harvested ryegrass forage. Rates and timing of manures and fertilizers must be appropriate to the growth conditions and climatic conditions of the region. Nitrate accumulation may be an issue under some excessively high N applications, as is the case with many grass forages, including small grains and corn. Ryegrass differs in nutritional characteristics from small grain forage or corn—it is considered one of the most palatable when harvested in a vegetative stage or grazed. Often, mixtures of ryegrass with small grains or legumes may be appropriate, depending upon the importance of forage quality compared with the importance of yield or N uptake.

FALL SEEDED ANNUAL LEGUMES
(peas, vetch, fava beans, berseem clover)

There are a number of fall-seeded annual grain legumes, such as peas, vetch, fava or bell beans, and finer-stemmed forages such as berseem clover, medics, arrowleaf clover, and Persian clover which can be used in California for forage production. These are generally lower-yielding than cereal forages, but have the advantages of higher fiber digestibility, palatability, and higher protein content—for many uses they are typically higher in feeding value than cereal forages (though this also depends greatly upon cutting schedule and other factors). Legume forages, as a rule, are more rapidly degraded in the rumen, which improves intake and feeding value.

Peas and Vetch are most often used in a blend with annual forage cereal grains while the bell beans and the berseem clover are planted as a straight crop when used for forage. Annual legumes are often added to a forage program for the protein they can produce and quality characteristics.

Planting and Harvest dates. Annual legumes can be planted in the Central Valley of California in October, November and December. Harvest will depend on the product desired; whether you are looking for higher quality at earlier maturity harvest, or higher tonnage with intermediate quality at later maturities. Consult with your Cooperative Extension Farm Advisor and seed suppliers for optimum timing in your particular area.

Peas, vetch and fava beans are best planted 1 to 2 inches deep. Planting with a grain drill works best, but producers can broadcast then disc to cover the seed if care is taken not to incorporate seed too deeply. Best results are to seed into moist ground or plant and sprinkle up the crop. Berseem clover should be planted at a depth of 1/8 to 1/4 inch deep. Legumes perform best when planted on well drained soils.

Soil Fertility. Legumes such as peas, vetch, and clover can fix their own nitrogen when the seed has been properly inoculated with bacteria, so nitrogen fertilization is not needed (unlike grasses, which benefit from N fertilizers). Each species may require a specific inoculum which should be applied with the seed at planting, especially if that crop has not been grown on that field previously. It must be noted that when commercial nitrogen fertilizer is added to legumes, whether straight seeded or in a blend, the bacteria that actually fix the nitrogen can become lazy and nitrogen fixing declines. After evaluating results from a soil test, producers can determine the need to add other nutrients (e.g. P, K, and S) as indicated. When legumes are planted with cereal grains, the nitrogen need should be determined by the need of the grain less what is already in the soil and less an estimate of what the legume can contribute to the grain. Forage production and quality will both be affected by variety selected, soil and season conditions for your area, and having the proper fertility.

PEAS

Peas (*Pisum sativum*) are an excellent source of forage that can produce high protein with high digestibility. They are planted in the fall in the Central Valley of California and often in blends with oats, triticale, barley, wheat or rye. When being used in a blend it is important to identify a pea variety and a grain that match up well in desired maturity for the product you are looking for. When blending, the producer generally identifies the harvest stage desired of the small grain first, and then selects a pea variety that reaches its desired maturity when the grain is at harvest stage. If the pea is too immature at harvest, it will not have reached its production potential, if the pea is too mature it will have declined in quality and digestibility. Since peas are most often added to enhance quality, this "maturity matching" will be quite important.

If a producer wants boot stage annual grain, the pea can be anywhere from pre-bloom to full bloom to flat pod stage to compliment and enhance the quality. Tonnage wise, peas hit maximum foliage production at full bloom but do add further weight during early pod development accompanied by a small decline in quality.

Stage of Growth. If a producer wants soft dough stage annual grain silage, the optimum pea stage would be with pods filled with peas but with the plant still fresh and green. This stage still offers good pea quality with maximum pea tonnage. If a producer is planning baled hay, there is an added caution to watch. When pea pods fill with the pea seed, the pod wall thickens up and will dry more slowly than the cereal grain and the rest of the pea plant. If baled too early the pods may start small mold spots right at the pods. This can be avoided by harvesting before the

pea seeds start much development in the pod or by watching the pod dryness to decide the time to bale.

One further factor to consider when choosing the pea is the digestibility of the variety. In general, white flowered peas have higher digestibility than colored flower peas. Depending on the purpose of the feed this may or may not be important. Producers should also be aware that the pea variety that produces the most tonnage when seeded by itself is not always the best producer in a blend. There can be significant differences between varieties for adaptability to forage use.

Blends. When a seed supplier sets up a pre-made blend they are using their knowledge to bring together compatible varieties. Then producers must ask whether that blend is designed for high quality boot stage harvest or for the high tonnage but intermediate quality of soft dough harvest. The pea and grain varieties for each of these purposes may likely be different.

Peas have most often been found in forage blends so that the grain can help hold up the pea as it grows. Today there are pea varieties that will stay standing even to later harvest stages. These varieties are semi-leafless types where the leaves on each branch have been converted to tendrils. These tendrils tie together and hold each other up. Forage quality and tonnage ability of these types can still be very good thus improving straight peas as an option.

VETCH

When used for forage, common vetch (*Vicia sativa*) is most often used in a blend with cereal grains, similar to peas. Vetch is slower to establish than peas but has high production capabilities. The same process is needed to find a cereal variety that is compatible with the vetch. Since it is slower to establish than peas the optimum cereal variety to plant with vetch may be different than one planted with peas.

As with peas, vetch is a cool season legume that fixes nitrogen for itself. This nitrogen can also be available to the companion cereal grain it is planted with. The nitrogen fixing of most legumes is greatest the last few weeks leading up to full bloom. Therefore if the forage is to be harvested at boot stage of the cereal grain there is not much time for the crop to utilize nitrogen fixed by the vetch. This should be taken into account when designing the fertility program. If the forage is to be taken all the way to the soft dough stage of the grain there is more time for the crop to utilize nitrogen from the vetch. In general vetch has the ability to fix more nitrogen than peas depending on the timing of harvest.

Vetch can also be used for forage when seeded by itself. Remember that vetch is a vining crop that will lay down as the maturity progresses. Time your forage harvest according to the quality and tonnage balance desired as with all forages, but also note that lodged vetch forage can have logistical issues with wet cool weather.

One other caution with vetch is that if allowed to go to seed producers sometimes have it volunteer back as a weed. If the crop is harvested before going to seed this issue should be minimal.

FAVA BEANS (ALSO CALLED FABA OR BELL BEANS)

Fava beans (*Vicia faba L.*) are often found in cover crop blends in the Central Valley of California. While use for forage in this area is minor, fava beans are an important forage source in other parts of the world. A main attractive point of fava beans as forage is that with selecting a forage type variety the tonnage can be as high as 20 or more tons of green weight per acre. Fava beans are also a very excellent nitrogen fixing crop. While all legumes fix nitrogen, fava beans have the potential to contribute more to the soil than vetch and peas.

BERSEEM CLOVER

Berseem Clover **(***Trifolim alexandrinum***)** is an annual upright clover well adapted to the clay loam and sandy loam soils of California as a fall-planted crop. It can be used for grazing (bloat tolerant), or for hay or greenchop applications. There are several other annual clovers and legumes, including Persian clover, Arrowleaf clover, medics and Crimson clover that can be grown, but research trials during the past 10-15 years have shown berseem to be the most well-adapted and highest yielding upright annual clover species for California (for harvested forage). Berseem varieties are also available for some colder regions as a spring-planted forage legume.

Varieties. Most lines currently in use of berseem are so-called 'multiple cut' lines, that is, varieties that can be harvested up to 4-5 times before the crops dissipates in the summer. This is an advantage of other fall-sown legumes, such as peas, which can be harvested once. Some varieties that are 'single cut' may be available in the near future, varieties which are appropriate for a quick, single-cut yield. The University of California has released two berseem lines, Multicut and Joe Burton, which are high yielding under California conditions.

Yields. Yields in long-term California studies have averaged about 6.5-7 tons/acre DM at Davis, CA, and higher yields (up to 9 tons dm) in more southern California locations, such as Imperial Valley. Berseem is generally harvested from very early spring (Feb-April) through mid-late June or July. After July, productivity declines greatly. In the Sacramento Valley, 4-5 cuts are common. We would recommend seeding berseem earlier in the fall than is common for small grains or ryegrass—late September or October in most parts of the state, since the legume seedlings benefit from early warm temperatures. It can be seeded very early spring in short-seasoned environments, but growers should be aware that berseem is susceptible to frost damage.

Berseem is more flooding tolerant than alfalfa, and can be successfully overseeded into existing alfalfa stands, with the potential to increase yields 1-2 tons in that system. Berseem is highly resistant to the alfalfa weevil, and may eliminate the need for insecticides in overseeded alfalfa.

Quality. Forage quality of berseem is very similar to alfalfa, perhaps a little higher in TDN and a little lower in CP than alfalfa, when cut at the same cutting schedule. Berseem clover is highly palatable to livestock. A 'brownish' tinge of berseem hay may initially limit marketability, but dairies that have fed berseem hay have found it to be quite palatable and high in feeding value. Drawbacks at this point include difficulties of managing heavy, high-moisture early harvests and leaf disease (Phoma blackstem) in the early growth period. Berseem clover, however, is interesting alternative forage either for a short rotation situation for high-quality forage, or as an overseeded crop into existing alfalfa fields.

Further information on berseem can be found at http://alfalfa.ucdavis.edu

SUMMER ANNUAL FORAGES

Summer annuals are those species that are heat-tolerant and productive as late planted annual forage crops. Planting dates are typically late April, May, June, or even July in California. The most important annual summer forage crops currently grown in California are corn silage and Sudangrass. California is the second largest corn silage producer in the US, whereas most Sudangrass grown in California is exported to the Far East. However, beyond these two important alternative summer forages, growers have few other options for summer annual forages. Summer annuals may provide high flexibility, and can be planted as an emergency crop or in rotation with winter annual crops, or after an alfalfa crop.

In 2001, we conducted a field trial at UC Davis in 2001 to evaluate many of these species. Additional studies are planned for 2002. Further evaluation is required to understand their adaptation, quality, and uses to California Conditions. In this section, we will review several types of summer-grown forages that can be grown in California.

SUDANGRASS

Sudangrass (*Sorghum bicolor*) is currently the major crop of choice for summer annual hay production in California. Substantial acreage (>100,000 acres) of sudangrass have been grown in the Imperial Valley during the last ten years for export to Japan, but in recent years, some of this acreage has moved into the Sacramento and upper San Joaquin Valleys. It has declined slightly in importance in recent years due to competition from other coarse forages, such as grass-seed straw from Oregon and oat hay from Australia.
Sudangrass is considered medium or low in feeding quality, but has outstanding yield potential. Little of the sudangrass crop enters into the dairy or horse markets, but some is used for dry cows or beef operations. Sudangrass is likely the 'one to beat' when considering yield potential of summer annuals alternatives. 'Piper' is still the predominant variety grown throughout the state—this is a line released from Wisconsin in the 1940s—in spite of breeding efforts over the past few decades. Some have raised questions as to whether this is the optimum variety for California conditions, but since yield considerations, not quality tend to be paramount for the export market, Piper has persisted in popularity. Export markets demand small diameter stems, low nitrates, and good, light color—they are less concerned about analytical values than subjective quality estimates. Sudangrass requires significant quantities of N fertilizers to maximize yields. UC studies in the desert have shown that up to approximately 70 lbs N/acre (soil plus fertilizer) per harvest period are needed. However, sudangrass is a famous nitrate accumulator, and growers need to be careful to avoid excessive applications and drought stress to prevent high nitrate concentrations in the forage.

Sudangrass is California's most important summer-annual hay crop.

Prussic Acid. All of the sorghum species, including sudangrass, are capable of building up high levels of Prussic acid, also known as HCN or hydrocyanic acid in the leaves. This occurs when environmental conditions are unfavorable for growth. Thus, rapidly growing new shoots after a frost or after a rain that terminated a drought can cause HCN problems. Cultivars differ in their

HCN accumulation potential. Prussic acid causes death by interfering with the ability of red corpuscles in the blood to transfer oxygen. Since prussic acid deteriorates over time, hay or silage that contained HCN at harvest is usually safe after storage for three or more weeks.

Nitrates. Nitrate poisoning is also a hazard of sudangrass production, as well as the other summer annual grasses. Nitrate accumulation can occur with any species (particularly grasses), but sudangrass is a famous nitrate accumulator. Caution should be used when fertilizing, especially during the first growth period, since residual nitrogen in the soil may be substantial. Nitrate accumulates in plants that were fertilized with N at high rates (or with high soil residual) then subsequently limited in their growth. Drought or deficit irrigation are frequent causes of nitrate accumulation, but it can also be the result of heavy cloud cover, shading, cool temperatures, or frost. Nitrates are reduced to nitrites in the digestive tract, oxidize the iron in hemoglobin, and interfere with oxygen transport. Symptoms in animals include muscle tremors, labored breathing, staggering, bluish mouth, and chocolate brown blood.

All summer annual grasses, as well as many other forage and weedy species (pigweed and lambsquarters in particular), can cause nitrate poisoning. Nitrate does not break down over time. Consequently, hay may cause nitrate poisoning many months after a growth high in nitrate was cured and harvested. If you have doubts, have your hay tested by a laboratory, since animals may die or be injured by nitrate poisoning. Controlling access to toxic forage and dilution with other feeds are the only toxicity control measures available.

MILLETS

Millets are heat loving group of grasses that may have some applications for forage systems. They are considered 'coarse' annual tall grass forages, in the same general group as sudangrass. They may be considered for emergency forages or as late planted alternative forage crops. There is little production information on the adaptation of millets for California conditions, but they are more widely grown in dryer areas of Texas through Nebraska.

Pearl Millet (Pennisetum americanum (L) Leeke, formerly P. glaucum). Pearl millet is an annual erect heat-tolerant cereal grass grown widely in Africa and India as a food crop and forage crop. Pearl Millet is likely the highest yielding of the millet group that can be considered for forages. Pearl Millet may grow 2 to 5 m tall. Leaf blades have finely-serrated margins and are long and pointed. Although seeding can be as early as March in southern Texas, it may occur in May, June or later, depending upon the latitude, elevation and intended use. Late seeding may be done to provide early or late summer grazing or green-chopping. A single large growth may be desired by some producers for preservation as silage. Dates of seeding may be adjusted to ensure compatibility with other crops in double-cropping sequences. Seeding before soil temperature at a depth of 10 cm reaches 12 to 13 C can be hazardous, but later or multiple plantings often are made to equalize forage production throughout the season. In some climates, late summer or early autumn plantings also may be appropriate. Pearl Millet is more sensitive than sorghum or Sudangrass to lower temperatures. Early plantings of sorghums exposed during germination or the seedling stage to dawn temperatures of 5 to 10 C may survive while pearl millet seedlings are killed. Stems are pithy. Leaf initiation is constant and successive primordia are increasingly larger. Tillering occurs freely from axillary buds from each node and, in some cultivars, may occur from nodes 20 cm or more above ground level. The inflorescence is a thick, cylindrical spike 2 to 4 cm in diameter and 20 to 50 cm long. (Information from http://forages.orst.edu/topics/species/sumanngra/).

Foxtail Millet (*Setaria italica L. Beauv.)* Foxtail millet, grown for hay, offers producers flexibility in crop choice because of its low water use: 10 to 12 inches (precipitation plus soil water use) to produce a crop—it is being used in wheat-fallow systems in the Midwest to produce a hay crop during the summer off-periods. In Colorado studies, 'Golden German' has the highest yield potential, followed by White Wonder, Butte, and Manta varieties. Crude protein ranged from 9.7 to 13 % and ADF in the 35-38% range.

Foxtail Millet

TEF

Tef (*Erogrostis tef*) is the major cereal crop of Ethiopia, where it occupies a sizeable percentage of the arable land. Its cultivation can be traced back to earlier than 3,000 BC. Tef grain is primarily used to make the traditional Ethiopian flatbread: 'Injera'. Due to the heat-loving characteristics of tef, and its ability to rapidly establish in the summer months, tef has received some interest as a summer annual rotation or emergency crop. Montana has released 'Bridger' tef as a summer emergency forage for dryland conditions. Seeding rates of the tiny seed (millions can occupy one hand), are in the range of 1-5 lbs/acre. Its narrow, soft leaf structure may enable it to fit into some systems as a short-seasoned grass crop for the hay market or as an overseeded crop into old alfalfa fields. It has been observed to grow quite well during the summer months with limited irrigation applications. Other Erogrostis species are weeds, so some care to limit the spread of this species may be important. The yield potential of tef may be a limitation in terms of economic returns, especially in comparison with alfalfa, corn and sudangrass.

Tef

SOYBEAN

Soybean (Glycine max), which originated in China, was first used as a hay or grazing crop in the US after it was introduced in 1765. As late as 1924, a million acres were planted for hay, but today virtually all soybean in the US is grown for grain. It is currently the second largest crop in the US (behind corn--alfalfa is third in value)— estimated at more than $18 billion each year. California is not a player in soybean grain production, thus not much is known about soybean performance (especially for forage) under irrigation in the West, and less still about its forage quality. Several new USDA lines with late maturity have been bred by Dr. Tom Devine, based in Beltsville, MD. These can be used for forage either in monocultures or mixed crops with corn, sorghum, millet, or sudangrass. Harvesting of soybean as forage may be challenging to balance optimum pod and seed production with preventing loss of leaves. To reduce leaf loss, grain loss, and potential for rain damage, the soybeans it is probably preferable to harvest soybean as silage rather than as hay. Some of the Midwestern recommendations for harvest: soybeans should be wilted to 60 to 70 percent moisture for soybeans ensiled in a trench, bunker, concrete stave or bag-type silo, or 50-60% for an oxygen-limiting silo. Of the harvested soybean forage, stems will likely have the lowest

Soybean (forage type)

quality. If chopped and ensiled, livestock will less likely sort out the lower quality stem as compared to when soybeans are made and fed as long-stemmed hay. If harvested as hay, a mower-conditioner should be used and a longer curing time expected as compared to alfalfa. Mixtures of soybean with corn or other coarse forages are common.

COWPEA

Cowpea (*Vigna unguiculata (L.) Walp.)* is an important warm-season legume grown as a grain, vegetable, and forage crop in Africa, Asia, and the Americas. California-grown cowpeas (blackeyes) are currently important specialty crops for some growers in the San Joaquin Valley. Similar to soybean, cowpea has historically been grown as a forage crop (hence the name), and is still grown as a forage or vegetable crop in many areas of the world. Many of the cowpea lines exhibit vigorous growth in the summer, high forage quality, and excellent yields. Recently, UC Riverside has released several vigorous 'vegetative' lines suitable as a summer rotation plow-down crop to provide nitrogen to subsequent specialty crops. These lines are currently being tested at UC Davis, along with traditional seed-type cowpea lines, and appear excellent in their adaptation. Cowpeas are prone to lodging and can be susceptible to aphid and viruses. It is possible to make hay out of Cowpeas, but the plant stature (very viney) and moisture content of stems and pods may be a challenge—thus ensiling or greenchopping may be appropriate.

Cowpea

FENUGREEK

Fenugreek (*Trigonella foenumgraecum*) is a plant native to the near East Mediterranean and India. It is not likely a 'summer annual' but should be classified with the winter-grown crops, although the optimum planting date is not known. Its name, meaning 'Greek hay' indicates is possible origins in animal agriculture, but its most common use world wide currently is as a spice or medicinal plant. Egyptians and East Indians commonly use fenugreek seeds for medicinal or spice purposes or roast the seeds and use them as coffee. They also eat sprouted seed and fresh leaves. People in India use the leaves as a vegetable and the seed as a spice and traditional medicine. Studies in Alberta, Canada, have shown that the nutritive value of fenugreek forage to be comparable to that of early bloom alfalfa. It contains steroidal sapogenins such as diosgenin which are thought to increase livestock growth rates. Feeding studies in have shown this crop to be comparable to alfalfa in ruminant growth rates and forage quality measurements. Fenugreek is not a likely candidate for a summer-annual cropping system, but is better suited to cooler growing conditions, such as the fall, winter or spring seasons.

Fenugreek

LABLAB BEAN

Lablab bean (Dolichos lablab L. or Lablab purpureus) Lablab, hyacinth bean, Egyptian bean, or dolichos is a vigorous tropical legume grown for seed or forage, ornamental, or as a cover crop. It has a distinctive white hilum (rim around the seed) that distinguishes lablab from other beans.

It is grown as a food crop in some parts of Asia, however soaking of the seeds may be necessary due to anti-nutritional compounds in the seeds. It is listed on North Carolina's poisonous plant list. It has been grown as a food for wildlife in some areas, and has been ranked, along with soybean and cowpea as preferred forages. It is reportedly grown in Australia as a forage crop for both hay and grazing, where they report it to be higher yielding than cowpea. Lablab is considered to be highly drought resistant, but susceptible to poor drainage or flooding.

Lablab

SUMMARY

None other than President Thomas Jefferson originally championed the value of research efforts to develop new crops for agriculture in the 1790s. Today, many growers are concerned about the profitability of agriculture and look to crop alternatives to help meet their needs. Several of the species described here may have a place in California forage production. Others may be just curiosities. Further work to describe their particular characteristics as forages and their functional value in rations is needed. The diversity of crops should be looked upon as a resource to contribute to improved agricultural productivity in the future. Annual forage crop alternatives may provide a high degree of flexibility to respond to changing resource and market conditions, as well as high productivity.