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Technical Editors:
Anthony E. Hall
Carol A. Frate
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UNIVERSITY OF CALIFORNIA
Agriculture and Natural Resources



Blackeye Bean Production in California

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Blackeye Bean Production in California

Blackeye bean (*Vigna unguiculata* (fig. 1)) is the main type of cowpea grown in California. Originally from Africa, these beans are also known as black-eyed peas in the southern United States. The name is derived from the black spot or “eye” in the center of the creamy-white bean (fig. 2). The primary markets for California-grown, high-quality blackeyes include the dry-packaged and canning industries, with a smaller market for certified planting seed stock. Cowpea varieties are also grown as hay, forage, and green manure crops.

The California [Dry Bean Advisory Board's](#) Blackeye Varietal Council monitors carryover, crop size, and shipments of blackeye beans for both foreign and domestic markets. Although blackeye bean acreage has declined statewide due to rotation to higher-value tree crops, seed yields remain stable, averaging 2,400 pounds per acre since 2010 (NASS 2024). In 2024, the price was \$80 per 100 pounds (hundredweight, cwt).

Other market classes of dry beans grown in California include common beans (*Phaseolus vulgaris*), limas (*P. lunatus*), and garbanzos (*Cicer arietinum*) (Long et al. 2010; Long et al. 2014; Long et al. 2019). As with all beans, blackeye beans are a healthy food choice as they are rich in protein, vitamins, and minerals, low in fat and sodium, and cholesterol-free. As legumes, beans are also healthy for soils as they fix nitrogen, a process of capturing atmospheric nitrogen for plant growth via symbiotic *Rhizobium* bacteria living on plant roots. Growing beans in field crop rotations also helps with pest, weed, and disease control. This publication focuses on blackeye bean production practices for optimizing dry bean yields and quality. However, many of the recommendations concerning growing conditions and cultural practices also apply to southern pea, forage, and edible-pod cowpea varieties (Hall and Frate 1996).

Growth and development

To optimize blackeye bean yields and quality, climatic and soil properties must be taken into consideration prior to planting.

Climate

Blackeye beans are well adapted to late spring and summer growing conditions in California's Central Valley. At planting, they require relatively warm soil



Figure 1. Blackeye bean plants with trailing vines, trifoliolate leaves, and developing green pods. Photo: iStock.com/Hendri.



Figure 2. Blackeye bean seed with the characteristic black spot or “eye” in the center of the creamy-white bean. Photo: istock. com/MahirAtes.

with average temperatures in the seed zone of at least 66°F (19°C) for at least 3 days after sowing. Otherwise, plant emergence will be delayed and stands reduced. Their earliest effective planting dates range from early April for hot spring conditions in Kern County to early June for cooler years and in locations such as Stanislaus County. Early plantings should be made only when clear skies and warm weather are in the forecast for a few days immediately after planting. Blackeye beans require warmer soils for effective emergence than some other warm-season crops, such as corn or cotton. It is often advantageous to plant blackeye beans as soon as it is warm enough; this enables the plant to grow, flower, and set the first and major flush of pods before the hottest summer weather, which typically occurs in late July and early August. Also, late June or July plantings run the risk of fall rain damage after cutting, during harvest.

Under optimal warm, moist soil conditions, blackeye beans emerge 3 to 5 days after planting. Under cool soil conditions, they may take as long as 10 days to emerge, seedlings may be lost to diseases, and leaf growth may be stunted or distorted due to insect pest damage from thrips. If the stand is sparse, the grower must decide whether replanting is necessary. This is a difficult decision; with a typical sowing rate of four seeds per foot of row, a plant stand as low as 50 percent can be tolerated, provided that plants are evenly distributed in the field. With 30-inch rows, vigorous blackeye bean plants spaced 12 inches apart can spread enough to produce the same yields as plants spaced 3 inches apart. Replanting not only involves additional costs but also results in a later planting. Planting later increases the risk of lower yields due to hot weather coinciding with flowering, which limits bloom and pod set and increases the risk of rain damage at harvest.

The vegetative growth stage is slow for the first 2 to 3 weeks after emergence, and then growth is rapid. The first floral buds are produced on the third or fourth node on the main stem (the first node is the position where the first trifoliate leaf is produced). Under cool conditions, the first floral bud can be seen about 50 days after planting, whereas under hot conditions, plant development is more rapid, and the first floral bud can be detected within 35 days. Flowers are produced about 15 days after the first appearance of floral buds; consequently, the

first flowers are produced from 50 to 65 days after planting into moist soil. Individual floral buds produce two or more pairs of flowers on each peduncle (the stalk bearing a flower) with a delay of about 4 days between the appearance of the first and the second pairs.

Plants continue to produce flowers on the main stem and branches for about 25 days. Planting dates, soil moisture, nutrition, and pest management should be designed to protect the first flush of floral buds, flowers, and pods. Effective management typically results in the four flowers on each peduncle producing two to three pods and yields of 25 to 35 cwt per acre from the first flush. Pod set can be reduced by heat stress, a common occurrence in the San Joaquin Valley during July and August. High night temperatures early in the flowering stage reduce pod set, with damage beginning when minimum nighttime temperatures exceed 63°F (17°C) and causing 50 percent reductions in pod set and yield when minimum night temperatures reach 80°F (27°C). Heat stress causes flower drop and inhibits flower bud development, favoring vegetative growth.

The development of individual pods from flower opening to mature pods takes from 17 to 21 days in California, depending upon night temperatures. Under hotter conditions, the pod development period is shorter and smaller seed is produced. For example, the dry seed weight at 10 percent moisture content of the variety California Blackeye 5 (CB5) can vary from 200 to 260 grams per 1,000 seeds (ranging from 1,570 to 2,040 seeds per pound), which can significantly affect yield. With optimal growing conditions, eight seeds on average are produced per pod, even though individual pods can produce as many as fifteen seeds. Plants are cut to permit the plants to dry before threshing. To harvest for the first flush of pods, plants can be cut about 90 days after a late planting under hot conditions or 100 days after an early planting under cooler conditions.

Some growers manage the crop to accumulate a second flush of pods before cutting. When the first flush of flowers is complete, plants produce few or no flowers for about 15 days, and then a second flush of flower production begins. This second pod set can produce up to 20 cwt per acre depending upon the extent of the first pod set, the viability of plants at the end of the first pod set, and subsequent growing conditions. Plants may begin to senesce

at the end of the first flush of pods as a result of a heavy first pod set, heat, drought, or various diseases. If more than 70 percent of the plants have died, the second flush of flowers and pods will be so small that it should be ignored, and irrigation terminated. If the first flush of floral buds and flowers has been damaged by insect pests such as lygus bugs or high night temperatures, most plants will be alive, and a second pod set can be achieved with some yield compensation.

During the second flush, healthy plants produce abundant flowers for about 25 days, and individual pods require 20 more days to reach maturity. Crops can be cut a few days before all pods achieve maturity, but by waiting to accumulate the second pod set a grower can delay cutting to about 140 days after planting. In the southern San Joaquin Valley, the season is sufficiently long to accumulate and harvest two flushes of pods, provided that the crop is planted early. Accumulating a second flush of pods is risky north of Fresno and with late planting in most areas, since rain can destroy a blackeye bean crop in windrows (rows of cut beans pulled together for threshing).

The most effective management practice for blackeye production is to plant as soon as the weather is warm enough and manage the crop for a heavy set (two to three pods per peduncle) of well-filled pods (at least eight seeds per pod) on the first flush of flowers. In some cases, irrigation is terminated after the first pod set and the crop is cut. Where the first pod set is low or the crop has the ability and time to completely produce a substantial second flush, it can be worth the risk to extend the season with additional irrigations, but continued management of insect pests such as lygus bugs will be necessary.

Soils

Economical blackeye bean production is possible on many soil types ranging from coarse sands to clay loams, provided that irrigation is managed so plants are neither water-stressed nor waterlogged. Blackeye beans are more sensitive to anaerobic conditions in the root zone than many crops. Under saturated conditions, plants will be stunted, root systems small and prone to disease, and leaves may turn yellow. Plants will rapidly recover from this condition early in the season if the grower permits the root zone to

become aerated by delaying irrigation or switching to alternate-furrow irrigation. Where surface irrigation is used on soils with low permeability, land should be leveled sufficiently to minimize end-of-field waterlogging. Subsurface drip irrigation systems will also help in managing water in challenging soils.

Blackeye beans have a moderate tolerance to salinity, with greater tolerance than corn but less than wheat or cotton (table 1). Blackeye beans exhibit no yield losses until salinity in the root zone exceeds an electrical conductivity of 4.9 decisiemens per meter (dS/m). For each increase of 1 dS/m above this threshold, yields are reduced by 12 percent (West and Francois 1982). If sources of water with different salinity levels are available, use the low salt water during germination and early vegetative growth when the crop is most sensitive to salinity, and then apply the poorer quality, higher salinity water during pod-filling.

Blackeye beans are less tolerant to high boron levels than alfalfa and much less tolerant than cotton. Boron toxicity results in a distinctive necrosis along the edges of the leaves. Thousands of acres of blackeye beans have been destroyed at the seedling stage due to boron toxicity on the west side of the San Joaquin Valley. The threshold level for boron in the soil water above which yield losses have occurred with blackeye beans is 2.5 parts per million (ppm). At higher concentrations, yield losses were 11.5 percent for each ppm above 2.5.

Cropping systems

Most blackeye beans are grown as a single crop and harvested after producing one or two flushes of pods. In the southern San Joaquin Valley, some blackeye beans are grown as a double crop, with late sowing in June or July after a wheat crop has been harvested. Double crops usually are cut after producing one flush of pods and tend to have lower yields than single crops. Small plantings of blackeye beans are sometimes grown as intercrops in almond orchards when the trees are establishing. However, growing two crops at the same time requires extensive management, and most growers prefer to focus on one crop at a time, especially for a long-term perennial crop like orchards.

In the rolling hill lands on the east side of the valley in Stanislaus County, single crops of blackeye

Table 1. Boron and salt tolerance limits for selected field crops*

Crop	Boron (ppm) [†]	Threshold soil salinity (dS/m or mmho/cm) [‡]
Alfalfa [§]	4.0–6.0	>6.0
Blackeye beans (cowpeas)	2.5	4.9
Common beans	0.5–0.75	1.0
Corn	2.0–4.0	1.7
Cotton	6.0–10.0	7.7
Garbanzo beans	<1.0–2.0	<2.5
Lima beans	0.75–1.0	1.5
Rice [#]	2.5	3.0
Sunflower	0.75–1.0	4.8
Tomato	5.0	2.5
Wheat	0.75–1.0	6.0
Barley	3.0–4.0	8.0

Sources: Maas 1990; Ayers and Westcott 1994.

*Values indicate the concentration tolerated without yield reduction.

[†]In soil water extract in parts per million (ppm).

[‡]Electrical conductivity (EC) of saturated soil extract in decisiemens per meter (dS/m) or millimhos per centimeter (mmho/cm). Value gives maximum soil salinity that does not reduce yield below that obtained under nonsaline conditions.

[§]Research (Putnam et al. 2017) indicates a significant range in both boron and salinity tolerance and a much higher salinity tolerance for some salt-tolerant alfalfa varieties than reported by Ayers and Westcott (1994). Seedling alfalfa will be more sensitive to salinity than established alfalfa.

[#]Irrigation water >2 ppm boron is toxic to rice.

beans are grown in rotation with wheat under sprinkler irrigation. In contrast, in the adjacent level lands to the west, blackeye beans are usually furrow-irrigated and rotated with several different crops, including corn, winter forage mixes, alfalfa, and the occasional field of sweet potato, squash, or watermelon. In Stanislaus County, blackeye beans are sometimes planted flat with 30-inch rows and cut with self-propelled swathers.

In the southern San Joaquin Valley, blackeye bean crops are often grown in rotation with cotton, wheat, corn, alfalfa, sudangrass, and melons. Most of the planted area is on the east side of the valley, but some is on the west side, especially in Kern County. In these areas, blackeye beans are mainly grown on beds with surface irrigation, but some growers use overhead sprinklers. In areas where cotton is a major crop in the farming system, blackeye beans are often grown on wide beds (38 inches is a common width), but most of the blackeye bean crop is currently grown on 30-inch beds.

Several recommendations can be made about blackeye bean cropping systems. Yields can steadily decline when blackeye beans are grown continuously on the same land, due to increased pest, weed, and disease pressure, so alternating them with small grains every other year can be an effective way to maintain yields. Subsequent crops may benefit from having blackeye beans in the rotation for several reasons. Current varieties of blackeye beans can suppress some biotypes of root knot nematode that damage cotton. Also, blackeye beans can increase nutrient availability to subsequent crops by fixing nitrogen in the soil (in association with *Rhizobium* bacteria) and via root associations with mycorrhizae that enhance the uptake of phosphorus and zinc.

Some adjacent crops can cause problems for blackeye beans. For example, alfalfa and cotton are alternate hosts and sources of lygus bugs, a key pest of blackeye beans. Feeding damage by this insect causes substantial damage to floral buds, resulting in reduced yields. When alfalfa is cut or the cotton dries down, lygus will move into nearby blackeye

bean fields, resulting in crop losses. For alfalfa, this problem can be partially avoided by strip-cutting the crop (Long, Goodell, and Baldwin et al. 2025). Cucurbit crops such as melon and squash are also alternate hosts to certain mosaic viruses that can be transmitted to blackeye beans by aphids.

Choice of seed

The California Seed Law ensures that growers are provided with good quality seed for planting in commercial production fields (CDFA 2020). The California Crop Improvement Association (CCIA), based in the UC Davis Department of Plant Sciences, is the official seed-certifying agency for agronomic and vegetable seed in California. Established under the California Seed Law, CCIA ensures that California certified seed is of high quality. Quality characteristics that are required include trueness to variety, varietal purity, low inert matter, and high seed germination, as well as devoid of noxious weeds and problematic seedborne diseases. CCIA is a third-party, nonbiased verifier that seed meets or exceeds California field and seed standards. This includes those of the Association of Official Seed Certifying Agencies and Organization for Economic Cooperation and Development, as well as international seed-certifying agencies that enhance the movement and sharing of seed stocks across states and participating countries. For instance, to be certified in California, cowpea (blackeye) seed must be 99 percent pure with an 85 percent germination percentage (CCIA 2019).

Blackeye bean seed certification is accomplished in a two-stage process. For a new variety to be certified, or approved, its variety description must be submitted to the CCIA Certification Technical Committee for review and a recommendation forwarded to the CCIA board of directors for approval. Then the seed of that certified variety can be repeatedly produced under a limited four-generation system to maintain satisfactory genetic purity and identity of the variety, as per the blackeye bean variety description and standard. This Breeder Class seed is directly controlled by the Blackeye Research Program in the Department of Nematology at UC Riverside. Foundation Class seed is the progeny of Breeder Class or [Foundation Class stock](#) produced by the Foundation Seed Program within the Department of Plant

Sciences at UC Davis and it is the first class that is certified by CCIA. Such production has also been done under contract with a bean grower.

Registered Class seed is the progeny of Foundation Class seed, which serves as planting stock for Certified Class seed, both of which are certified by CCIA. Certified Class seed then proceeds into the market for commercial crop production. Currently, the Foundation Seed Program has four certified blackeye bean varieties: California Blackeye 5 (CB5), California Blackeye 46 (CB46), California Blackeye 50 (CB50), and California Blackeye 77 (CB77) (UC Davis Foundation Seed Program 2023). The latter two are protected under a patent and the Plant Variety Protection Act (USDA 2025), and unauthorized propagation is prohibited. Their seed must be sold by variety name only as a class of certified seed. CCIA cooperates with county agricultural commissioners that assist in inspection of conveyances, combines, and seed warehouses to ensure the maintenance of varietal identity and purity in seed handling.

Choice of variety

Four certified blackeye bean varieties are available for planting in California: CB5, CB46, CB50, and CB77 (tables 2 and 3). The choice of variety will depend on farm location and local pest and disease pressure. Since 1991, the majority of blackeye bean acreage planted in California has been sown to CB46, potentially increasing its susceptibility to insects and newly emerged biotypes of root knot nematode and Fusarium wilt. The other known limitations of the CB46 variety are that plants are more compact than the older CB5 and do not suppress weeds effectively, especially when grown on wide rows (for example, 38 or 40 inches) and with sandy, infertile soils that do not support vigorous shoot growth. Also, CB46 has smaller seed than CB5 (see table 3), and may be less desirable for dry package and export markets.

CB50 has larger and whiter seeds than CB46 but yields best in the Bakersfield area with inconsistent and variable yields in other parts of California. CB77 was developed conventionally by crossing aphid resistance from an African cowpea breeding line into CB46 (Huynh et al. 2021). CB77 shows equivalent grain yield, seed quality, and agronomic

Table 2. Pest and disease resistance for California blackeye (CB) varieties bred for California

Variety	Fusarium wilt (<i>Fusarium oxysporum</i> f. sp. <i>tracheiphilum</i>)		Root knot nematode* (<i>Meloidogyne</i> spp.)		Cowpea aphid (<i>Aphis craccivora</i>)
	Race 3	Race 4	<i>M. incognita</i>	<i>M. javanica</i>	
CB5	susceptible	susceptible	resistant	susceptible	susceptible
CB46	resistant	susceptible	resistant	susceptible	susceptible
CB50 [†]	resistant	resistant	resistant	moderately resistant	susceptible
CB77	resistant	resistant	resistant	moderately resistant	resistant

*Root knot nematode (*Meloidogyne incognita* races 1 and 3 and *M. javanica*) resistance to root galling and reproduction.

[†]CB50 yields best in the Bakersfield area, with inconsistent yields in other regions of California.

Table 3. California blackeye (CB) varietal characteristics bred for California

Variety	Year*	Growth habit	Maturity (days) [†]	Seed weight (g) [‡]	Relative bean yield (%) [§]
CB5	1941	upright vigorous	90	230	100
CB46	1991	upright vigorous	90	210	111
CB50	2009	upright vigorous	95	260	107
CB77	2022	upright vigorous	80	210	128

*Year of release.

[†]Minimal period from planting to cutting of the first main flush of pods in days; with cooler conditions this period can be up to 15 days longer.

[‡]Average dry weight in grams of 1,000 seeds when grown at UC Kearney Agricultural Research and Extension Center near Fresno.

[§]Average main flush yield on fields at UC Kearney Agricultural Research and Extension Center and other sites in the Central Valley of California that did not have obvious levels of Fusarium wilt, as a percentage in relation to CB5.

characteristics to CB46, and also better yield than CB5. Thus, CB77 can be substituted for CB46 and CB5 in production regions where aphids are problematic, and resistance is needed to prevent infestations and reduce pesticide use.

Planting CB5 is not recommended since it is susceptible to Fusarium wilt. Many fields used for blackeye bean production in California have at least low levels of the Fusarium wilt fungus and continued use of CB5 will cause disease levels in the soil to increase and potentially spread to other fields. New varieties being developed by the University of California will have higher and more stable yields resulting from their heat tolerance, resistance to cowpea aphids and lygus bugs, and more complete resistance to Fusarium wilt and a range of root knot nematodes. For updates on new blackeye bean varieties, contact the UC Davis Foundation Seed Program.

Cultural practices

Preplant recommendations for growing blackeye beans and optimizing yields and quality involve good seedbed preparation, assessment of fertilizer needs, and the use of seed treatments, including Rhizobium inoculants for nitrogen fixation.

Land preparation

Seedbeds should be relatively free of clods with no compaction zones that impede root growth or water infiltration, and 2 or 3 inches of dry soil on the surface with moisture underneath. The operations needed to prepare a field vary depending upon soil type, moisture, and previous cropping history and management. Residues from the preceding crop are either removed or incorporated into the soil; incorporation can improve soil structure and water holding capacity. However, incorporated residues may interfere with planting depending upon the amount

of residue and type of planter. In compacted soils, chiseling to a depth of 12 to 14 inches can be beneficial to break hardpans. Specific practices for blackeye production can be found in Frate et al. (2013a; 2013b).

Fields are usually pre-irrigated either in flood basins or furrows. Once fields are dry enough to support wheel traffic, final preparations are made. When planting flat, a light disking followed by a float (a land plane to seal the moisture) is common. When planting on beds, the beds are lightly cultivated to kill any emerged weeds and then shaped. In all cases, excessive losses of soil moisture must be avoided so that seed can be planted into moist soil.

Fertilization

When soils are low or deficient in nitrogen (N), phosphorus (P), potassium (K), sulfur, or zinc, blackeye beans are likely to be responsive to one or more of these fertilizers. Soil testing helps with the development of nutrient management plans for crops. Prior to planting, test the soil from the surface to 6-inch depth to determine the likelihood of crop response to phosphorus, potassium, or zinc fertilizer applications, as well as whether the soil pH could impact bean production. If yields of the previous crop differed within the field, those parts of the field should be sampled separately by taking 12 to 15 cores from the surface to 6-inch depth and mixing them together to make up each sample. For good bean production, the soil pH should be between 6.0 and 8.0. Lime applications should be considered for soils with pH below 5.5. Salinity and boron levels should be determined on samples from the 0 to 6-inch, 6- to 12-inch, and 12- to 24-inch depths if salt or boron toxicity is suspected. Knowledge of field history and past nutrient deficiencies (such as sulfur and boron) or toxicities (such as salt or boron) should be taken into consideration prior to planting blackeye beans.

Organic production of bean crops involves the addition of compost (manures and plant-based) as well as other slow-nutrient-release materials, including cover crops, that must be incorporated into the soil prior to planting. Applying 3 to 5 tons per acre of one of several different types of livestock or poultry manure, incorporated several months before planting, often supplies all of the bean crop's nutrient

requirements. The economics of applying other types of acceptable nutrient sources should also be considered. For growers transitioning into organic bean production in soils that require large amounts of phosphorus, potassium, zinc, or possibly lime, it may be more economical to build up the soil fertility by adding synthetic fertilizers and focus on weed and insect control prior to the 3-year transition period to organic production.

Nitrogen

Blackeye beans are in the legume family and form associations with *Rhizobium* bacteria, which develop nodules on their roots that fix atmospheric nitrogen (N) for the plants (figs. 3A and 3B). To ensure nodulation and nitrogen fixation, it is important to inoculate blackeye bean seed with a specific *Rhizobium* bacteria that includes blackeyes when beans are planted. (See the “Seed treatment” section for more information on inoculating seed.)

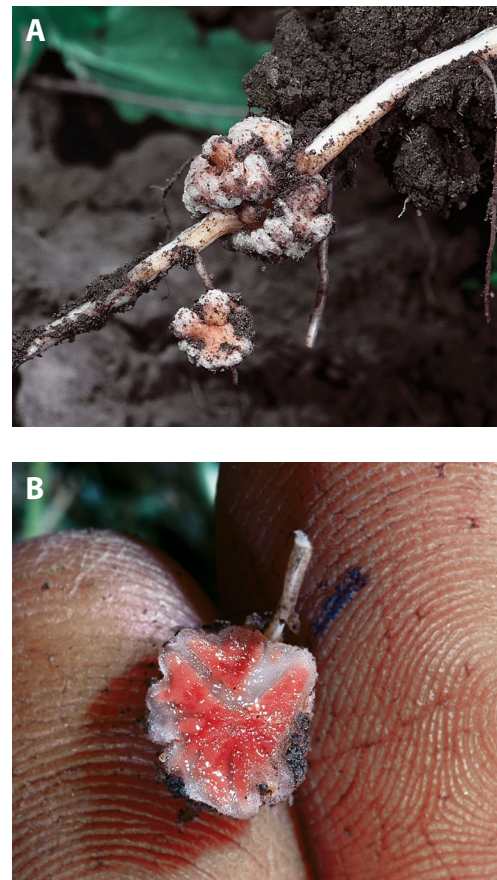


Figure 3. Nitrogen-fixing nodules on roots (A) and pink interior of nitrogen-fixing nodules (B). Photos: Jack Kelly Clark.

However, unlike alfalfa, soybeans, and several other high nitrogen-fixing crops, the relationship between *Rhizobium* bacteria and beans like blackeyes may be able to provide sufficient nitrogen to sustain the highest crop yields. This is generally true of grain legumes, where a large percentage of the plant's nitrogen is found in the seed and the demand for nitrogen exceeds the capacity of nitrogen-fixing nodules to supply that need. Dry, hot weather or periods of soil water saturation further reduce nitrogen fixation. As a result, nitrogen fertilizers are often needed to ensure that the plant receives enough nitrogen for rapid growth and high yields.

Blackeye bean seed has a protein content of about 24 percent and nitrogen content of 4 percent. This means that to achieve a yield of 2,500 pounds per acre or more, the blackeye seed crop needs at least 100 pounds of nitrogen per acre or more. In addition, 30 to 50 pounds per acre of nitrogen are needed for the vegetative portion of the plant. About 20 to 50 percent of the total nitrogen needed is likely supplied from nitrogen-fixing nodules on the plant roots, but the rest has to come from another source.

Fertilization of blackeye beans includes a starter fertilizer such as an 8-24-6 (N-P-K) with 1 to 2 percent zinc applied as a band during planting, 2 inches below and 2 inches to the side of the seed row, at the rate of approximately 50 to 100 pounds dry fertilizer or 5 to 10 gallons liquid fertilizer of similar analysis per acre.

Residual nitrogen levels in the soil (nitrate-nitrogen [$\text{NO}_3\text{-N}$] in the top 24-inch depth) should be determined about 10 days prior to the planned sidedressing (applying fertilizer in a band along the side of growing crop rows) so that the rate of applied nitrogen can be based on soil concentrations. Take soil samples (eight to twelve cores per sample) from the 0 to 6-inch, 6- to 12-inch, and 12- to 24-inch depths at two or three locations in each field and request analysis of nitrate-nitrogen for each sample. The rate of sidedress-applied nitrogen can be determined according to the nitrogen concentration in the top 24 inches of soil (table 4). Another important consideration in nutrient management is the field crop immediately preceding the blackeye planting. For example, much more nitrogen will usually be available in soil following a tomato crop than following corn or wheat.

Table 4. Suggested nitrogen (N) fertilizer rate to be applied in the planned sidedressing*

Average $\text{NO}_3\text{-N}$ in top 24 in. of soil		Fertilizer N
(ppm) [†]	(lb)	(lb/ac)
0–2	0–16	100
2.1–4	17–32	80
4.1–6	33–48	60
6.1–8	49–64	40
8.1–10	65–80	20
>10	>80	0

*Based on nitrate-nitrogen ($\text{NO}_3\text{-N}$) levels for blackeye bean yields of 2,500 to 3,000 pounds per acre.

[†]Parts per million.

For furrow-irrigated crops, at layby (prior to row closure by the canopy of developing plants) or early bloom, fields should be sidedressed during cultivation with aqua ammonia or a similar nitrogen fertilizer. Nitrogen-fixing nodules cannot fuel both plant growth and seed development. Place the shank 4 to 6 inches deep and 12 to 15 inches away from the bean row. Earlier applications will stimulate vegetative growth that does not translate to higher yields (Beverly and Jarrell 1984). For subsurface drip-irrigated fields, inject the nitrogen fertilizer at several intervals in increments through the drip system at a rate suggested by soil sampling for available nitrate-nitrogen, also starting at early bloom. Nitrogen rates can also be reduced somewhat if the irrigation water contains a high nitrate level. The number of pounds of nitrogen applied per acre-foot of irrigation water is calculated by multiplying the parts per million (ppm) nitrate-nitrogen in the irrigation water times the factor 2.72. Since irrigation water sources can vary considerably in nitrate-nitrogen concentrations, testing the water during an earlier irrigation of the field is necessary.

Phosphorus

Phosphorus (P) can be especially important to blackeye bean production in California because of the state's relatively early planting dates and cooler springtime soil temperatures affecting plant-available phosphorus. If a representative soil test indicates a phosphorus deficiency, apply a starter fertilizer containing this element at the rate indicated in table 5, as

pounds of P_2O_5 per acre. The Olsen bicarbonate (HCO_3^- -P) soil test should be used on soils with pH of 6.5 or greater, while the Bray 1-P soil test may be used on soils with pH under 6.5. Soil tests showing very low and low extractable phosphorus levels would be expected to show a yield response to phosphorus fertilization. Crops grown in soils that have test levels in the moderate range are less likely to respond to phosphorus fertilizer applications (see table 5). Adequate phosphorus levels are especially important for strong seedling growth.

Potassium

Potassium (K) should be applied as recommended in table 6. Soil test (ammonium acetate-exchangeable potassium) results that fall in the low range indicate that plants should respond to potassium fertilization. Test levels in the medium range indicate that the plants are less likely to respond to potassium applications. If a representative soil test indicates

potassium deficiency, corrections can be made with a starter fertilizer containing potassium at the rate indicated in table 6, as pounds of K_2O per acre. Few California soils in the blackeye bean growing areas show yield-limiting potassium deficiencies, but sandy soils would be the first to show yield responses to potassium fertilizer.

Sulfur

Sulfur (S) deficiencies may be observed in blackeye beans, particularly if these soils are cold ($<60^\circ F$). Some soils in the Sacramento Valley are likely to be deficient in sulfur, and most irrigation water contains little or no sulfur. Fertilizers such as ammonium sulfate, a common source of sulfur in the past, are no longer used as often as non-sulfur bearing aqua ammonia and other high-analysis fertilizers.

To provide a correction that will last several years, elemental sulfur can be broadcast and incorporated into sulfur-deficient soils at a rate of 50 to 100

Table 5. Phosphorus (P) recommendations for blackeye beans

	Phosphorus, ppm (parts per million)				
Soil test	Very low	Low	Moderate	High	Very high
Bray 1-P*	0–5	6–10	11–15	16–20	21+
Olsen HCO_3^- -P*	0–3	4–7	8–11	12–15	16+
Yield goal (lb/ac)	Application amount (lb P_2O_5 /ac)				
1,800	35	25	15	0	0
2,000	40	30	20	10	0
2,200	45	35	20	10	0
2,400	50	40	25	10	0

*Olsen bicarbonate (HCO_3^- -P) soil test is used on soils with pH of 6.5 or greater, while the Bray 1-P soil test is on soils with a pH less than 6.5.

Table 6. Potassium (K) recommendations for blackeye beans

	Potassium, ppm (parts per million)		
Soil test	Low (ppm) 0–40	Medium (ppm) 41–80	Adequate (ppm) 81–120+
Yield goal (lb/ac)	Application amount (lb K_2O /ac)		
1,800	20	10	0
2,000	20	10	0
2,200	25	15	0
2,400	30	15	0

pounds per acre. Elemental sulfur (90 to 95 percent) must be applied far enough ahead of planting time to ensure its oxidation to sulfate-sulfur, the form used by plants. The time necessary to oxidize elemental sulfur depends on soil temperature and moisture, as well as the size of the sulfur particles applied. Particle size may cause the timeline to change from a few weeks (small particles) to several months (large particles) before the applied elemental sulfur becomes effective. Other materials that provide the readily available sulfate form of sulfur, such as gypsum (calcium sulfate, which is about 17 percent sulfur), can also be used. These materials should be applied at a rate that supplies about 25 to 50 pounds of sulfur per acre and should be incorporated into the top 2 to 3 inches of soil to be most effective.

Zinc

Blackeye beans often respond to zinc (Zn) fertilizer in low-zinc soils, especially those that test below 0.5 ppm as diethylenetriaminepentaacetic acid (DTPA)–extractable zinc (a reagent that measures plant-available zinc in soils). These low-zinc soils may occur on soils low in organic matter, calcareous high-pH soils, or newly leveled land that required extensive cuts and fills. Zinc deficiency may be recognized in bean plants by yellowing, bronzing, and the necrosis of leaf tissue, as well as stunting and poor vining. The best way to diagnose the zinc status of a field is to perform soil tests before planting or conduct tissue tests of the youngest, fully matured leaves.

The most effective application of zinc is a mixed fertilizer containing 1 to 3 pounds zinc per acre in the starter fertilizer. If the zinc deficiency is discovered in the growing bean crop, zinc sulfate can be applied to established plants as a foliar spray at a concentration of 3 to 4 pounds per 100 gallons of water. A spreader-sticker should be added to the solution, and plants should be sprayed “to wet,” which usually requires 10 to 40 gallons of the mix per acre depending on the size of the plants. Chelated zinc may also be used as a foliar-applied correction.

In fields with severe zinc deficiency, a correction that will last for several years can be applied by incorporating zinc sulfate (35 to 36 percent zinc) into the top 6 inches of soil at a rate of 10 to 20 pounds zinc per acre, if the soil pH is less than 7.0.

For soils with pH greater than 7.0, 20 to 30 pounds of zinc per acre should be applied.

Boron

Boron (B) deficiency in bean production is most likely to occur in sandy soils along the east side of the San Joaquin Valley, but it can also occur in locations where soils are inherently low in boron and irrigation water supplies no boron. Plant symptoms include chlorosis and death of young leaves, dead growing points, and distorted blossom development.

Boron toxicity is likely if dry beans are grown in the high-boron soils of San Joaquin Valley’s west side, parts of Yolo County, and several other areas in California. Soil and irrigation water can be sources of boron toxicity for dry beans. Toxicity symptoms include yellowing of leaf tips, interveinal chlorosis, and progressive scorching or death of the leaf margins. Blackeye beans are slightly more tolerant of boron than common dry beans (*P. vulgaris*), but they are still sensitive compared to other crops (see table 1).

A narrow range exists between deficiency and toxicity for boron-sensitive crops, since too much boron reduces yields. Average boron concentrations in the youngest fully mature leaves can be used to estimate plant boron status as follows: deficient (less than 15 ppm), sufficient (20 to 50 ppm), high (50 to 100 ppm), and excessive or toxic (over 100 ppm).

The recommendation for soil application of boron is 0.5 to 1 pound per acre, while the suggested rate for foliar application is 0.1 pound per acre mixed in 30 gallons water. The boron fertilizer used most frequently is sodium borate, which ranges from 10 to 20 percent boron. Solubor is a trade name for a sodium borate that is 20.5 percent boron. This fine granular material is commonly applied as a foliar spray.

Fertilizer application

Take particular care with starter fertilizer placement at planting to avoid salt damage or ammonia toxicity to the germinating bean seed. Do not use urea or diammonium phosphate (18-46-0 or 16-48-0). No fertilizer should be placed in direct contact with seed. As a general rule, monoammonium phosphate (either dry 11-52-0 or liquid 10-34-0) is the preferred fertilizer, and it should be placed no closer

than 2 inches to the side and 2 inches below the bean seed.

Planting practices

The most common spacings for blackeye beans are single rows on either 30-, 38-, or 40-inch beds. The decision on which spacing to use is usually based on the equipment available on a farm and the bed spacings used for other crops. With larger blackeye bean plant varieties such as CB5, narrower row spacings may contribute a slight yield advantage, but it may not be worth the inconvenience involved in adjusting equipment if all other crops are grown on wider beds.

With a variety that tends to be a smaller plant, such as CB46, growers may be concerned that significant yield reductions will result on wider-spaced beds compared to larger plants, such as CB5. In 2 years of trials at UC Kearney Agricultural Research and Extension Center in Fresno County, no significant yield differences were detected between plots on 30- and 40-inch bed spacings (Frate et al. 1990, 1991). However, CB46 grew vigorously at this location, and even on 40-inch beds the plant canopy covered the furrows. On soil types where CB46 tends to be smaller, or when a delayed first irrigation severely stresses CB46, it is common for plants not to cover the furrows during the season. Although high yields have been obtained under these conditions, weed problems are greater due to the lack of crop competition in the furrow area. Harvesting can be difficult if annual morning glory is present. Seed quality can also be affected if black nightshade, hairy nightshade, or ground cherry are present, since seed berries of these weeds can stain beans.

Some growers, particularly in Kern County, have experimented with two rows of CB46 on a 40-inch bed. In these cases, plants covered the furrows, resulting in high yields. Results from 2 years of trials at UC Kearney Agricultural Research and Extension Center were inconclusive as to whether yields increase with this planting configuration (Frate et al. 1990, 1991). Longer knives are required to cut double rows on wide beds, so growers should not plant in this configuration unless they have made previous arrangements for cutting a crop planted on wide beds.

Experiments with CB5 indicate that within-row average spacings of 4 to 12 inches do not alter yields. With more space between plants, the plants grow faster and larger, and this compensates for the reduced number of plants. No detailed studies have been conducted with newer varieties, but it is probable that within-row spacings of 4 to 8 inches may not affect yields, even with the more compact CB46 variety. Due to differences in seed size among varieties and even within a variety, no general recommendations can be made concerning how many pounds of seed to plant per acre. Growers should try to plant four seeds per foot of row, and the equivalent pounds per acre will vary depending on seed size and seed density. Seed should be planted in dry surface soil, 1.5 to 2 inches deep in the moist soil below.

Seed treatment

Most blackeye bean seed is treated with fungicides to protect against seedling diseases, which is more likely to occur when soil temperatures are cool, and seedlings grow slowly. If growing beans organically, pay extra attention to the optimum planting time to ensure seeds quickly germinate and emerge from the soil to help prevent disease problems. This occurs when soil temperatures are at least 66°F (19°C) for at least 3 days after sowing and when clear skies and warm weather are in the forecast for a few days immediately after planting.

Several formulations of *Rhizobium* bacterial inoculant are available for blackeye beans. One formulation is traditional, in which bacteria are placed in a peat carrier. Packages of this type of inoculant need to be kept in cool but not freezing conditions until the contents are applied to seed. Once inoculated, seed should not be exposed to sunlight or hot conditions, since this will kill the bacteria. Another formulation is dry, more heat-tolerant granules that require a separate applicator box. Granular inoculant formulations are recommended over powders because they are applied more effectively near fungicide- and insecticide-treated bean seed. Dry granules are more expensive than the peat-based inoculum.

Inoculum should be used when planting into a field that has never had blackeye beans before, but for other conditions the value of inoculants is not known. However, the peat form of inoculum is rel-

atively inexpensive, and some growers make a routine practice of adding it to seed when fields have not been planted to blackeye beans for several years, as a cheap insurance policy to ensure good nodulation. Cowpea inoculum is available from warehouses that supply blackeye bean seed.

Irrigation management

Blackeye beans are primarily grown in California's Central Valley, in climatic zones 12, 14, 15, and 16 (CIMIS 1999). Virtually all blackeye bean plantings in California are irrigated. Many fields are furrow-irrigated while others are on subsurface drip irrigation systems. In some coarser-textured soils, significant acreage is planted flat and either flood-irrigated within borders or irrigated with overhead sprinklers.

Pre-irrigation

Blackeye bean fields are usually pre-irrigated and then the seed is planted into moist soil. Pre-irrigation can also be used to leach salts and bring the soil profile to field capacity (amount of water the soil can hold) without the potentially harmful waterlogging or cooling effects that can occur if irrigations are applied just after planting or seedling emergence. By bringing the eventual root zone to field capacity early in the season, growers encourage deep root growth and enable the crop to withstand droughts resulting from delayed irrigation or irrigation quantities less than crop water requirements. The amount of water needed for pre-irrigation depends upon prior rainfall, evaporative losses, and the soil's water-holding capacity and depth. If extra water is available, sufficient water should be applied to bring the eventual root zone, which can be as deep as 5 feet, to field capacity. If water is expensive or in short supply, it may be advisable to pre-irrigate with only enough water to bring the first 3 feet of soil to field capacity.

Irrigation scheduling

Timing of the first irrigation varies from 2 to 7 weeks after planting, with many growers irrigating approximately 4 weeks after planting. Where water is in short supply and the soil is not too sandy, the first irrigation can be delayed until floral buds first

appear, which may be as soon as 35 days after planting in very warm to hot weather or up to 50 days under cooler conditions. Since the timing for development of floral buds differs by variety and stress tolerance during vegetative growth, field observations are important for making these initial irrigation decisions. The CB5 variety tolerates drought during the vegetative stage, so it can be water-stressed to the point that the foliage turns bluish with no or limited yield losses. The advantages of imposing a vegetative-stage drought include fewer irrigations, fewer weeds early in the growing season, warmer soil, about 4-inches less crop water use, and plants that develop deeper root systems (provided that there is a good quantity of stored soil moisture). These conditions can enable plants to better withstand drought later in the season.

The crop should be carefully monitored if it is affected by moderate to more extreme drought during the vegetative stage, because drought enhances problems caused by the corn stalk borer (*Elasmopalpus lignosellus*) and charcoal rot (*Macrophomina phaseolina*). When these problems are detected, irrigate the crop as soon as possible since irrigation is an effective means for reducing the impacts of this insect pest and disease. It may also be advisable to apply the first irrigation earlier if the plants appear to be significantly stunted because of factors other than cool weather or when growing the compact variety CB46 on wide beds. Sufficient water should be applied at the first irrigation to replenish soil water used by the plant and lost through soil evaporation during the first 35 to 50 days after planting, which would be about 3 to 4 inches, depending on soil texture. The goal is for the upper 3 to 5 feet of the soil profile (depending on the type of soil and growing conditions impacting root depth) to be brought back to field capacity with this first in-season irrigation.

For economic yields, it is important for the plant to develop a robust root system and the optimum plant leaf area and canopy structure to support the development of seed pods. In no case should the first irrigation be delayed until flowering begins, since the stress imposed by such a delay usually reduces bean yields. Blackeye beans are most sensitive to high temperature and water stress just prior to first flowering through bloom completion, when stresses can impact pollination and fertilization.

Water balance method. Crop water requirements are commonly referred to as crop evapotranspiration (ETc), which is a combination of two processes: evaporation of water from wet soil surfaces and transpiration of water through plant leaf stomata. Crop water needs can be supplied from precipitation, irrigation, and stored soil water. A water balance approach to irrigation scheduling keeps track of the soil water deficit (the difference between the amount of water in the soil and the amount of water a soil can hold) by accounting for water additions and subtractions from the soil root zone. This approach to assess the amount of water available for plants is often feasible to use in semiarid regions and for crops grown in drier seasons, with the assumption that leaching below the root zone is minimal. Evapotranspiration accounts for the biggest subtraction of water from the root zone, while precipitation and irrigation are the largest additions. The water balance method can be used to estimate the intervals between the first, second, and subsequent blackeye bean crop irrigations. Information needed includes initial soil water content in the root zone, evapotranspiration, precipitation, estimates of active rooting depth, and available water capacity of the soil.

Irrigation experiments with CB5 have demonstrated that the total permissible depletion of soil water during flowering and pod-filling stages, without causing yield loss, varied between 50 and 75 percent of available water in the top 3 feet of soil. The optimal percentage depletion varies depending upon local conditions. For example, with a loamy soil that supports strong root development, 75 percent depletion of available soil water could be permitted in the top 3 feet. In contrast, where high-bulk soil density or other factors result in sparse rooting, or in a sandy soil, it may be safer to permit only 50 percent depletion in the top 3 feet. The water available to plants in recently irrigated soil can range from 1 inch of water per foot of soil in sandy loam soils to 2 inches per foot in clay loam soils. The total permissible depletion in a 3-foot soil profile therefore ranges from 1.5 inches (with 50 percent depletion in a sandy loam soil) to 4.5 inches (with 75 percent depletion in a clay loam soil).

If replenishment of root zone water is limited by slow infiltration because of soil surface sealing, it may be necessary to irrigate more frequently than is indicated by the water balance method.

Where possible, slow infiltration problems should be addressed by applications of sulfur or gypsum, depending on soil pH, and deep ripping before cultivation and planting. In some soils, surface sealing becomes more pronounced as the season progresses. In this case, irrigations should be more frequent, with less water applied per irrigation, during the mid- to late growing season.

Monitoring soil moisture. Tensiometers or electrical resistance sensors are a relatively low-cost tool to measure soil matric potential, the relative indicator of soil moisture content. These sensors are especially helpful to determine when blackeye beans should be irrigated, especially during flowering and pod development. Irrigation scheduling should be based on the moisture content in the active root zone, which usually occurs in the top 12 inches, especially for sandy loam soils. Place the sensors between plant rows with their tips in the active root zone (at least 12 inches deep). About 1 day after an irrigation, a tensiometer will read 0 to 10 centibars if the root zone has been recharged. Studies in a fine sandy loam soil indicated that maximum yields can be achieved if soil moisture tensions are maintained below 50 centibars for tensiometers with their tips 12 inches into the soil (Hanson et al. 2004). Use table 7 to estimate tensiometer readings associated with 50 percent available water depletion in other soil textures.

The water balance approach provides only an approximate indication of irrigation needs and may be improved by fine tuning with visual observations. For a blackeye bean crop at the flowering and pod-filling stages, if the canopy develops a bluish-green appearance in the hotter afternoon hours, it probably is not being irrigated often enough and may produce lower yields than a more-frequently irrigated crop. Where a small part of a field exhibits drought symptoms sooner than the rest, the bluish appearance of the canopy may be a good indication that it's time to irrigate the entire field to avoid any damaging levels of water stress. A blackeye bean crop that is irrigated too frequently will have rank vegetative growth (excessive, vigorous plant growth). Plants may have the same potential to produce beans as an optimally irrigated crop, but it could be more difficult to manage and eventually harvest. Blackeye beans with rank vegetative growth are also more attractive to lygus bugs, may lodge

Table 7. Effects of soil texture on tensiometer readings

Soil matric potential tension (kPa or cbars)*	Loamy sand	Sandy loam	Loam and silt loams	Clay loam and medium clay
	Depletion of plant-available water in percent†			
10	0	0	not fully drained	not fully drained
30	40	25	0	0
50	65	55	10	10
70	75	60	25	20
90	80	65	35	25
110	85	68	40	32
130	87	70	47	38
170	95	76	55	46

Source: Hanson et al. 2004.

*Kilopascals (kPa) and centibars (cbar), units of soil moisture tension, where higher readings indicate drier soil conditions.

†Arrows show corresponding soil matric potential tension readings at 50% available water depletion in different soil textures.

(fall over due to broken or bent stems near the base), and can be more difficult to cut, dry down, and thresh.

There is a general misconception that delaying irrigations for long enough to impose moderate or even more severe water stress is necessary to reduce vegetative growth and promote pod set. However, no research data supports this for blackeye beans. This misconception may have arisen from confusion over what the cause and effect are. It is commonly seen that a crop whose first flush of flowers has been damaged by lygus bugs or hot weather will exhibit rank vegetative growth. In such situations, poor pod set is responsible for the rank vegetative growth, because available nutrients and carbohydrates are not being shuttled to developing pods. Another possible explanation is that blackeye beans with rank vegetative growth may appear to have low pod set because it's hard to see pods from the edge of the field. Irrespective of the cause, rank vegetative growth should be avoided, especially if it results in lodging. The key to effective irrigation management during flowering and pod-filling is consistency. During each irrigation cycle, water should be withheld until the crop reaches the same optimal depletion of available soil moisture or shows symptoms of mild water stress.

Irrigation termination. The decision of when to terminate irrigations is difficult and requires the inspection of individual fields and an understanding of how long water in a particular soil can carry the crop. First, it is useful to determine whether sufficient pods have been set from the first flush of flowers. At least three pods per inch of row are needed for 30-inch beds, and at least four pods per inch of row for 40-inch beds. The more-mature pods should be well-filled, averaging eight seeds per pod. These levels of podding will produce approximately 24 cwt of beans per acre. If pod set is lower, the grower should consider continuing irrigations to obtain a second, later-developing major pod set. For this to occur, more than 50 percent of the plants need healthy roots and some green leaves. A second pod set requires enough irrigation to carry the crop for 5 to 7 more weeks.

When growers decide to promote crop drying and maturation, they must determine whether soil contains sufficient water to permit most of the beans to achieve maximum size. Small pods less than 1 inch long will take 2 or 3 weeks to reach maturity under hot versus cooler conditions. The final irrigation will provide enough moisture to carry the crop to maturity for 1.5 to 2 times the optimal irrigation interval used during flowering and pod-filling. For

example, if the optimal irrigation interval is 10 days, then the final irrigation could provide sufficient water for 15 to 20 days. This period could enable most of the young pods on the plant to mature, but any pods set after the final irrigation will not reach full size. Terminating irrigation too early will result in smaller beans. Once the decision has been made to terminate irrigation and the crop has been left without water for longer than the optimal interval, it may not be possible to reverse the decision. The combination of drought and a substantial pod load will cause plants to initiate an irreversible senescence, a stage where plants begin to age and naturally dry down towards the end of the season.

Amounts of water to be applied

The amount of water provided in irrigations should be sufficient to replenish the estimated root zone depth to field capacity, unless slow infiltration rates indicate that less water should be applied. With optimal irrigation intervals that do not exceed the permissible depletion of available soil water, this amount can vary between 1.5 inches in sandy loam soil to 4.5 inches in clay loam soil. Since most irrigation systems do not apply water uniformly, growers should apply more than the minimal water requirements to ensure that drier parts of the field receive adequate water.

The minimum amount of water needed to produce a blackeye bean crop being managed for full yield from one pod set in production regions of California's Central Valley is 24 to 27 inches, depending on the climatic zone, soil type, and effective rainfall (table 8). Irrigating for a second flush of pods could require an additional 8 to 12 inches of water. Irrigation requirements are further increased by any water required to leach salts or compensate for an inefficient irrigation system.

Many surface irrigation systems cannot uniformly apply small quantities of water. A system that will uniformly apply 4 inches or less can be managed to minimize the irrigation requirements of blackeye beans in most soil conditions. If the irrigation system has a minimal application in excess of 4 inches or if the soil is sandy and has a permissible depletion below the minimal amount that can be applied by the irrigation system, water will be wasted as deep percolation and soil nutrient losses can also occur

through leaching. Any of the present irrigation systems typically used with blackeye beans (furrow, flood-irrigated within borders, subsurface drip, or sprinkler-irrigated) can produce high yields if they suit the particular local growing conditions and are well designed and effectively managed.

Subsurface drip irrigation

While installing a subsurface drip irrigation system is not likely to be economical for growing only blackeye beans, it is possible to grow blackeyes as part of a rotation in a field where subsurface drip irrigation was installed for another higher value crop, such as processing tomatoes. The major advantage of these systems is the capability to irrigate more uniformly and efficiently. Subsurface drip irrigation systems allow the user to apply small irrigation amounts frequently to match crop water use. Too much surface soil wetting is avoided when drip irrigation tape or tubing is placed deep enough. Subsurface drip irrigation also reduces weed growth (by keeping soil surfaces dry) and is capable of supplying small-dose, timed fertigation, which can be useful in situations where nutrient deficiencies are noted during the growing season.

When using a subsurface drip irrigation system in blackeye beans, the tape spacing (the distance between lines of drip tape) must be appropriate. The lateral movement of water from the emitters on drip tape varies by soil type; typically, lateral movement is much lower in coarser-textured soils. If the spacing between lines of the drip tape is too great, plants between the tape lines may not receive enough water. Ideally drip line spacing should be the same as crop row spacing, but in finer-textured soils growers have been particularly successful with wider spacings, such as in alternate furrows. Where possible, wider spacing can make the use of subsurface drip irrigation systems more economically feasible.

A second consideration when using subsurface drip irrigation is the installation depth of the drip lines. If the drip tape is to be left in place and reused, it must be installed deep enough so that harvest and field preparation activities can be done over the tape. This usually requires drip tape lines be at least 8 to 10 inches deep.

When deciding how deep to install drip lines, issues such as seed germination and the detection

Table 8. Average crop evapotranspiration (ET_c) in inches per day for blackeye beans*

May 1 planting date	Evapotranspiration (in/day)			
	Zone 12	Zone 14	Zone 15	Zone 16
May 1–15	0.11	0.11	0.13	0.13
May 16–31	0.15	0.15	0.16	0.16
June 1–15	0.28	0.28	0.29	0.31
June 16–30	0.32	0.32	0.33	0.36
July 1–15	0.32	0.34	0.34	0.37
July 16–31	0.31	0.34	0.33	0.36
Aug 1–8	0.18	0.19	0.19	0.21
Seasonal total	24.23	25.10	25.83	27.45
June 1 planting date	Evapotranspiration (in/day)			
	Zone 12	Zone 14	Zone 15	Zone 16
June 1–15	0.13	0.13	0.14	0.15
June 16–30	0.16	0.16	0.17	0.18
July 1–15	0.29	0.31	0.31	0.33
July 16–31	0.32	0.35	0.34	0.37
Aug 1–15	0.30	0.33	0.33	0.35
Aug 16–31	0.26	0.28	0.28	0.31
Sept 1–8	0.14	0.15	0.15	0.16
Seasonal total	23.66	25.10	25.39	27.32

Source: DeTar 2009.

*CIMIS (1999) zones.

and repair of leaks and clogs must also be taken into consideration. If germination using the subsurface drip irrigation system is desired, drip tape should not be installed too deep. While water movement from the tape upward to wet the seedbed is soil-dependent, field experience has shown that installation depths of 10 to 12 inches or less often work for germination, except in sandier-textured soils. Drip tape installation depths greater than this may not adequately wet the seedbed for good germination.

Rodents, especially gophers and voles, are a major problem in subsurface drip irrigation systems because they chew the drip tape, resulting in leaks that are often difficult to find and repair. Preventing the soil from drying out and cracking open after harvest is important to keep voles from accessing the drip lines. Some growers will run an irrigation through the dripline after harvest to close soil cracks and minimize rodent damage.

Irrigation tables

Table 8 shows the average crop evapotranspiration (ET_c) in inches per day for blackeye beans planted on May 1 and June 1 for zones 12, 14, 15, and 16 (CIMIS 1999) and harvested 100 days later for a single flush of beans. This table can be used for both furrow and subsurface drip irrigation—although, in general, furrow irrigation has a 70 to 75 percent water use efficiency (or water application efficiency) whereas subsurface drip irrigation is closer to 85 to 90 percent. The season-total inches of irrigation water needed will depend on the average crop evapotranspiration as well as irrigation method and any practice growers use to improve water application efficiency and uniformity across fields.

The blackeye bean crop coefficients (K_c) that relate crop developmental stage to the crop evapotranspiration used for irrigations (shown in table

8) were adapted from DeTar (2009), based on field evaluations in a sandy loam soil in the San Joaquin Valley. Surface-irrigated, finer-textured soils with higher water holding capacities and less-frequent irrigations are expected to have less soil evaporation early in the season when ground cover is lower, and as a result, somewhat lower seasonal total water use.

Integrated pest management

Managing weeds, insects, nematodes, and diseases in blackeye bean production is essential to maximize dry bean yield and quality. Strategies for managing pests to ensure a healthy blackeye crop include using certified seed, planting pest- and disease-resistant varieties, monitoring fields regularly, and paying attention to agronomic needs, including water and nutrient management. For more information on pest control practices in dry bean production (including blackeyes) as well as pesticides registered for use in dry beans and their use timings, refer to the UC Integrated Pest Management (UC IPM) dry bean [guidelines](#) online as well as UC IPM's Color Photo Guide to Dry Bean Pests (Long, Goodell, and Frate et al. 2025; UC IPM 1996).

Weed control

Effective weed control is critical for blackeye bean production. Weeds consume about as much water as blackeye beans on a plant dry-matter basis. Weeds are also excellent competitors for soil nutrients; for example, nutsedge competes heavily with blackeye beans for nutrients during early growth stages. Taller weeds such as pigweed, foxtail, black and hairy nightshade, and groundcherry can reduce much of the light available and substantially reduce blackeye bean yields. A field can produce only a certain amount of dry matter in a given time, provided that other crop production factors are optimal. If weeds make up a significant portion of the plant population, crop yield will be reduced correspondingly.

Weeds can cause additional production problems. Black nightshade (fig. 4) severely reduces bean quality, since blackeye beans can be stained at harvest by a purple pigment from its crushed berries. A small number of nightshade plants, certainly fewer than would cause significant reductions in yield, can cause substantial bean staining, and it may be



Figure 4. Black nightshade berries (*Solanum nigrum*).
Photo: Jack Kelly Clark.

necessary to remove the weeds from windrows by hand. Large weeds that remain green at threshing also make harvesting difficult by slowing the drying of beans and “balling-up” in the thresher.

Weed control in blackeye beans includes both cultural and chemical control strategies. Cultural control techniques have been quite successful. If possible, choose fields for planting that are free of problem weeds such as black nightshade and nutsedge, which can build up after blackeye beans or other warm-season crops in the rotation (such as cotton). Rotation to crops such as winter cereals that are less hospitable to these weeds, or allow easier control, can reduce nightshade and nutsedge infestations in these fields.

Dry-surface mulch planting, also known as planting into moisture, is one of the most effective cultural weed-control strategies. Fortunately, it is often a normal production practice in blackeye beans. Mulch planting involves planting seed through the dry surface soil into a moist soil layer beneath. The relatively large crop seed has enough moisture and strength to germinate and emerge through the dry mulch, but weed seed, which commonly germinates in the top inch of soil, cannot do so in dry mulch. Irrigation is then delayed until the crop is well established and can outcompete the small weeds that emerge after the first irrigation. Mulch planting uses either stored soil moisture from late winter or spring rains or moisture from pre-irrigation.

Pre-irrigation followed by a shallow cultivation is an excellent way to germinate and destroy weeds that can be potentially serious problems in blackeye

beans. Pre-irrigation should come as close before planting as possible in order to bring up weeds whose soil temperature requirements are similar to those of blackeye beans. Pre-irrigation in winter, for example, would germinate winter weeds that pose no threat during the normal blackeye bean growing season.

Cultivation can be a very effective weed-management practice. Small broadleaf weeds and grasses can be uprooted or smothered in a covering of dry soil. Cultivation is always more successful when weeds are small. Mulch planting allows the crop to reach a size suitable for cultivation while weeds are still in the seedling stage. Care should be taken to avoid irrigation for several hours after cultivation so that cultivated weeds dry out. If irrigation immediately follows cultivation, some weeds can survive.

Registered herbicides and their use timings for weed control for specific dry bean classes in California can be found in the UC IPM guidelines for dry beans (Long, Goodell, and Frate, et al. 2025).

Nematode control

Nematodes are microscopic, wormlike organisms that inhabit soil and plant roots. Of the many types of nematodes in fields only a few are plant parasites, and of these, only root knot nematodes are of concern to blackeye bean growers. These include primarily *Meloidogyne incognita* and *M. javanica*, which are most injurious, as well as *M. arenaria* and *M. hapla*. These nematodes all have a wide host range and are able to attack and reproduce on many crops and some common weeds.

Biology

The root knot nematode has a simple life cycle, living partly in soil and partly in plant roots. The infective juvenile or larva hatches from the egg and moves through soil. After finding a suitable root, the juvenile nematode enters just behind the root tip and feeds on root cells, which enlarge to form a nurse cell system that provides a nutrient source. The nematode develops through additional juvenile stages and becomes an adult male or female. Males leave the root and do not feed much. Females swell up into a pear-shaped form within the root and may produce several hundred eggs each, which are laid in a jellylike mass that may be visible on the root

surface. Once the eggs hatch, the juveniles start another generation of infection. Several generations can occur in a single growing season, each cycle taking about 3 weeks to 1 month in warm, moist soil. Eggs produced late in the season can remain unhatched through winter until the spring. Some juveniles that hatch late in the growing season may survive in the soil to infect a new crop the following spring. Populations of eggs and juveniles decrease during winter by as much as 80 to 90 percent, but the residual population is often sufficient to injure crops the following year.

Plant symptoms

The only distinctive symptom of root knot nematode infection is the presence of root galls caused by the proliferation of root tissue surrounding the developing nematode (fig. 5). A gall may contain one or more female nematodes, which are visible under a hand lens as tiny white pearls when galled roots are cut open. The galls or “knots” on roots can



Figure 5. Healthy bean roots (left) and roots with galls caused by root knot nematode (right). Photo: Jack Kelly Clark.

appear quite small and beadlike in early to midseason, when the infection is getting started. Small galls may be found on small lateral roots throughout the life of the crop. Galls on primary roots may become large (up to $\frac{1}{4}$ or 1 inch in diameter) and coalesce into continuous lengths of unevenly swollen roots. As the season progresses, galled roots are susceptible to infection with secondary root-rotting organisms attracted to galled tissues. This secondary infection leads to rot and the breakdown of galled roots, increasing the damage caused by root knot nematodes.

Infected root systems are less extensive than healthy root systems and have a lower capacity for uptake of water and nutrients. The combination of a reduced supply of soil nutrients and the removal of plant nutrients and carbohydrates by nematode feeding cause plants to become stunted and reduce yields. Heavily infected plants may show symptoms of water and nutrient stress, including wilting, mild yellowing of leaves, and senescence, even in well-irrigated and well-fertilized soils. Stress symptoms are more likely to show toward the end of an irrigation cycle. Less heavily infected plantings may appear quite normal aboveground, even though they sustain significant yield reductions.

Root knot nematodes are commonly associated with soils containing 50 percent or more sand, including sand, loamy sand, and sandy loam soils. Field infestations usually are unevenly distributed, often with irregular, patchy occurrences of damaged plants that coincide with sandy areas within the field. Previous crop patterns can also influence nematode distribution. This may occur when a host crop causing nematode buildup was grown only on one portion of the current blackeye bean field or when a portion of the field was recently fallowed or planted to a nonhost crop, causing a decline in the nematode population. The point of origin of the nematode infestation, such as the location where cultivation equipment with nematode-contaminated soil was brought into the field, can also determine nematode distribution within the field.

Sampling, detection, and diagnosis

The two main approaches for detecting and sampling nematodes are checking for root gall symptoms and collecting and analyzing soil samples.

Root gall symptoms

The visible presence of nematode-induced galls on roots is diagnostic for the presence of root knot nematode. With blackeye beans, as with other leguminous plants, it is important to distinguish between root knot nematode galls (see fig. 5) and nitrogen-fixing root nodules induced by *Rhizobium* spp. (see fig. 3). The primary difference between the two is that the nematode gall is a swollen part of the actual root tissue and cannot be pulled or rubbed off without breaking the root itself, while the *Rhizobium* nodule is not an integral part of the root but rather is attached to the outside of the root and can be removed easily by rubbing with a finger. In addition, nodules tend to be more spherical than galls and are usually pink inside, while galls are the same color as roots inside and out.

Root galls are visible starting about a month after planting and are most obvious from midseason onward. Checking for galls on roots to confirm the presence of root knot nematodes and sampling roots from both stunted and healthy plants within the field can confirm the presence and severity of root knot nematodes. When sampling, dig out the roots of several plants with a shovel, being careful to ease the roots out of the soil in order to obtain both large and small roots. Tap roots on the shovel to remove adhering soil and expose galls or gently wash the soil off the roots. Sketch a simple field map to record the areas sampled and the absence and presence or extent of root galling.

Resistant plants do not form galls or support much reproduction by certain nematodes. For example, the CB5, CB46, and CB77 varieties do not gall when challenged with *M. incognita*. However, *M. javanica* and the root knot (*Rk*)-virulent forms of *M. incognita* induce gall and egg production on roots of these same varieties. Many common weeds, including nightshade, groundcherry, pigweed, and lambsquarter, are hosts for root knot nematode and can be checked for the presence of root galls as indicators of nematode infestation. Other crops in rotation with blackeye beans should also be checked for root galls to help in yearly nematode management planning.

Soil sampling

Samples can be taken at any time, but nematode population levels vary with time of year relative to the crop. Populations are highest in the fall and then drop during winter. Samples taken in the fall may indicate their potential to injure a blackeye bean crop, but the natural decrease in populations during winter should also be considered.

Field sampling to assess nematode species and population levels involves taking soil cores from several subareas of the field that were previously chosen based on poor plant growth, soil type, and crop history differences. If plant injury is unknown, take soil samples from blocks of about 5 to 10 acres throughout the field. Fifteen to twenty cores should be taken from each block and consolidated by block into a plastic bag, kept cool, and given to a diagnostic laboratory for analysis. Sample results will be in numbers of nematode juveniles per weight (usually per kilogram) or volume of soil.

Most laboratories cannot provide a species identification for root knot nematodes or information on their virulence. Previous crop history and field observations can provide indications of the species that might be present. For example, *M. incognita*, unlike *M. javanica*, reproduces on Acala cotton, whereas the reverse is true for alfalfa. Knowledge of whether the root knot infestation is *M. incognita*, *M. javanica*, or a mixture can be useful. If *M. javanica* is present, direct nematode injury is likely, regardless of variety. If *M. incognita* is present, injury to *M. incognita*-resistant varieties CB5, CB46, and CB77 will depend on the virulence of the population. The virulence of *M. incognita* can be determined only by direct observation of its effect on these resistant varieties. This underscores the importance of good field observation and record keeping on the presence and impact of root knot nematodes.

Management options and guidelines

Table 2 summarizes the susceptibility of four commercially available blackeye bean varieties to two of the most serious root knot nematode pests (*M. incognita* and *M. javanica*) and Fusarium wilt. For managing nematodes, a combination of strategies is needed to prevent the selection of *Rk*-virulent nematodes (populations that overcome the *Rk* gene) and loss of resistant plant varieties. This includes crop rotation along with using nematode-resistant

blackeye bean varieties or by fallowing fields. Resistance management (especially by crop rotation) is extremely important, as the *Rk*-virulent *M. incognita* populations might have evolved when blackeye varieties with the *Rk* gene were grown in the same field every year.

Nematicides

Blackeye beans may benefit indirectly if a nematicide treatment for a previous crop with a higher cash value has a residual effect in limiting the buildup of nematode populations. UC Integrated Pest Management [guidelines](#) provide information about nematicides and registered use by crop.

Resistance

California blackeye bean varieties CB5, CB46, and CB77 share the same type of resistance, the single dominant gene *Rk*, which confers resistance against *M. incognita* but not *Rk*-virulent *M. incognita* and *M. javanica* populations in California. In infested fields where resistance is effective, yields are normal or near normal and the nematode reproduction rate is lower, which also benefits subsequent crops in the crop rotation. *M. javanica* is widely distributed; *Rk*-virulent *M. incognita* populations have been found in Tulare and Stanislaus counties and may be present elsewhere. Attempts are underway to develop blackeye bean varieties that are resistant to a broad range of root knot nematodes. New versions of CB5 and CB46 carrying a resistance gene against *M. javanica* are currently being evaluated with expected commercial release for farmers in 2028. CB2, a newer variety that carries a gene conferring reduced root galling symptoms under *Rk*-virulent *M. incognita* infestation, is expected to be released as a certified variety in 2026.

Rotation and fallow

Crop rotations for nematode management alternate blackeye beans with nonhost crops or nematode-resistant varieties of other crops, thereby decreasing nematode population levels. Consequently, when blackeye beans are grown, the reduced nematode population should cause less damage and be more easily controlled. The wide host ranges of root knot nematodes and scarcity of crops with resistant varieties limit the number of nonhost or resistant varieties available for rotation with blackeye beans. The

following are crops suitable for rotation with black-eye beans, along with their specific advantages:

- Resistant tomato varieties greatly reduce *M. incognita* and *M. javanica* populations (Long and Vinchesi-Vahl 2020).
- Acala cotton reduces *M. javanica* and some *M. incognita* populations.
- Weed-free alfalfa reduces *M. incognita*.
- Large lima beans (UC 92 and UC White Ventura N) reduce *M. incognita*.
- Baby lima beans (UC Beija-Flor and UC Cariblanco N) reduce *M. incognita* and *M. javanica*.
- Winter crops such as onions and garlic are not hosts of root knot nematodes.
- Summer weed-free fallow, especially following a small grains winter crop, decreases root knot nematode populations.
- Fumigated or resistant sweet potato plantings reduce nematode reproduction.
- Fields coming out of *Prunus* tree fruit production (almond, nectarine, peach, and plum) grown on the root knot nematode-resistant rootstock Nemaguard should not have damaging root knot nematode population levels.
- Cruciferous crops will help to reduce numbers of root knot nematodes.

Other strategies

Growing nematode-resistant or nonhost cover crops, such as the hybrid cultivar Cahaba white vetch (*Vicia sativa* x *V. cordata*) and certain grasses, can help reduce root knot nematode. In addition, green

manuring by growing and then disking-in green crops of mustard, rapeseed, or nematode-resistant vetch also helps suppress nematode populations. Solarization of moist soil under a plastic tarp likewise can decrease root knot populations.

Root knot nematode and Fusarium wilt

Root knot nematode can influence the expression and severity of Fusarium wilt disease in blackeye beans (table 9). For example, *M. incognita* *Rk*-virulent and *M. javanica* increase the severity of Fusarium wilt disease on the Fusarium-susceptible blackeye bean variety CB5, resulting in greater yield loss from wilt than when nematodes are absent. The other varieties available are genetically resistant to the common Fusarium wilt race 3 in California, unless *M. javanica* is present. The following is known about Fusarium wilt-resistant varieties:

- Fusarium-resistant varieties are effective in controlling wilt disease in the absence of nematodes.
- For CB46 and CB77, when the nematode *M. incognita* is present, including the *Rk*-virulent forms, wilt resistance remains effective. In other words, the nematode is unable to break the protection of the wilt resistance, although the nematode may cause direct injury to the blackeye bean plant.
- In the presence of *M. javanica*, wilt resistance may be reduced by nematode infection such that the severity of wilt symptoms and injury to plants increase to a significant extent.
- Recommendations for controlling wilt disease on blackeye beans focus on using the wilt-resistant bean varieties CB46 and CB77 and avoiding the

Table 9. Resistance and susceptibility of blackeye bean varieties to root knot nematode and Fusarium wilt

Pathogen	Cultivar*	
	CB5	CB46 and CB77
<i>M. incognita</i> , <i>Rk</i> -avirulent	resistant	resistant
<i>M. incognita</i> , <i>Rk</i> -virulent	susceptible	susceptible
<i>M. javanica</i>	susceptible	susceptible
Fusarium wilt, race 3	susceptible, damage worse if <i>Rk</i> -virulent <i>M. incognita</i> or <i>M. javanica</i> present	resistant, unless <i>M. javanica</i> present

*Resistant to most *Meloidogyne incognita* races except *Rk*-virulent isolates (Roberts et al. 1995).

wilt-susceptible bean variety CB5 (see table 9). In fields containing both *Fusarium* wilt and the nematode *M. javanica*, efforts to reduce nematode populations should be considered. Where *M. incognita* is present, wilt resistance should remain effective, although direct plant damage from root knot may occur if the nematodes are the *Rk*-virulent type.

Disease problems

A number of diseases affect both seedling and established blackeye plants, which need to be managed to ensure optimum dry bean yield and quality.

Seedling diseases

Blackeye bean seedling diseases usually are most damaging when soil temperatures are cooler than optimal and plant emergence is delayed, which may be aggravated by deep planting or unduly wet soil, caused by rain or excessive irrigation. The main pathogens that cause seedling diseases are *Pythium ultimum*, possibly one or two other species of *Pythium*, and *Rhizoctonia solani*.

Pythium usually kills seedlings before they can emerge. *Rhizoctonia* can cause the preemergence death of seedlings, but more often it attacks the plants after emergence. A sunken oval canker at the base of the stem is the most characteristic symptom. If the canker girdles the stem the plant usually dies. *Rhizoctonia* cankers are also sometimes seen on older plants.



Figure 6. Healthy green blackeye bean stem (lower) compared to a stem infected by *Fusarium* wilt, which causes a darkening of vascular tissue (upper). Photo: Jack Kelly Clark.

The most effective cultural practice for managing blackeye bean seedling diseases is to plant when soil temperatures favor rapid emergence (66°F [19°C] for at least 3 days after sowing). Since cool weather and unseasonable rain cannot always be predicted, seed treatment with suitable fungicides provides a measure of protection from the loss of seedlings to these fungi. *Pythium* and *Rhizoctonia* differ in their sensitivity to fungicides, so seeds should be treated with fungicides that are active against both pathogens. UC Integrated Pest Management guidelines provide information on fungicides registered for use in blackeye beans (Long, Goodell, Frate, et al. n.d.).

Fusarium wilt

Fusarium wilt, caused by the fungus *Fusarium oxysporum* f. sp. *tracheiphilum*, is a major disease of blackeye beans in California. Disease symptoms are easily recognized in the field as yellowing and dying of lower leaves and vascular discoloration of roots and stems. If the root and stem of the plant are cut slantwise with a sharp knife, the woody tissue will be tan to brown in color with the discoloration extending from the taproot upward through the stem (fig. 6). This symptom, called vascular necrosis, occurs because the fungus is systemic throughout the plant. Roots of blackeye beans are not rotted, but the shoots exhibit early cutout (plant die-off after the first flush of pods) and low yields. Resistant blackeye bean varieties may exhibit some vascular browning of the roots, but the discoloration does not extend into the stem and high yields are maintained in wilt-infested fields. Other crops grown in rotation with blackeye beans (such as corn and wheat/triticale silage) are not known to be susceptible to *Fusarium* wilt.

The *Fusarium* wilt fungus produces spherical spores called chlamydospores in diseased tissue. These spores can survive in soil for many years, even in the absence of blackeye beans or other cowpeas. In spring the spores germinate and penetrate roots, colonizing water-conducting tissues of the plant and impairing water uptake and movement in the plant. Spores of the fungus from infected stems can be deposited on seeds during the threshing process, but no evidence suggests that the fungus can be transmitted inside the seed. However, *Fusarium* spores

on the seed and in the soil can spread the disease to other fields.

A pathologic race is a strain that is indistinguishable by spore morphology from other races but is more pathogenic to several varieties of blackeye beans. At least four pathologic races of the *Fusarium* wilt are known. Currently race 3 is widely distributed in California. Race 4 is problematic in some fields in California, but the extent of the infestations is unknown. The only effective way to control *Fusarium* wilt is to use resistant varieties (see table 2). Because spores persist in soil and plant debris for many years, rotation to other crops does not provide effective control.

Root rots (established plants)

Several root rot diseases affect blackeye beans and in some cases have been directly implicated in early cutout, a condition that causes high numbers of plants to die after producing the first flush of pods. Several root-rotting fungi associated with cutout include *Fusarium solani* f. sp. *phaseoli* and *Thielaviopsis basicola*, as well as *Fusarium* wilt. *Fusarium* wilt causes discoloration in the vascular system that extends from the roots into the aboveground stems and petioles. *F. solani* causes rust-colored lesions on the root, while *Thielaviopsis* root lesions are dark brown to black. Cutout appears to be more severe in fields with soil compaction or water stress (too much or too little water), especially during times of reproductive growth. In fields where cutout was caused by *Fusarium* wilt, choose a wilt-resistant variety. If cutout was caused by *F. solani* or *Thielaviopsis*, crop rotation may help limit these pathogens in the soil.

Ashy stem blight or charcoal rot, caused by *Macrophomina phaseolina*, is most frequently seen too late in the season to cause reductions in yield. The disease is characterized by a faded-tan stem color and a scattering of small black specks embedded in the diseased stem surface and woody tissue. These “ashy” particles are sclerotia, dark masses of tightly knotted fungal material that can live for years in soil. Ashy stem blight is a potentially serious disease, but its occurrence early in the season has been limited to fields subject to long periods of drought stress or high temperatures. The only known control method is irrigation to minimize drought stress.

Rhizoctonia root rot occasionally occurs on the upper taproots of older plants as discrete,

reddish-brown lesions. Infections of plants older than 4 weeks are not common and usually only cause minor damage. Roots severely infected with any root rot pathogens will not be able to uptake water during times of high demand. In general, infected plants tend to be small with yellowing leaves that undergo early senescence and produce low yields.

Pythium disease, also called wilt or stem rot, refers to a disease caused by *Pythium aphanidermatum*, a water mold, which occurs when soils are waterlogged and temperatures are high (over 100°F, or 38°C). Symptoms include rapid wilting of the plant within 24 to 48 hours of irrigation, and a sunken brownish lesion on the stem at the soil surface. Discoloration may extend up the stem for 1 to 2 inches. *Phytophthora drechsleri* can also cause root rot on cowpeas in waterlogged soil. Good field preparation and irrigation management can help prevent these diseases. Avoid flood irrigation or furrow irrigation that rises over the top of the bed. Do not irrigate during extremely high temperatures, if possible.

Bacterial diseases

Bacterial blight, caused by *Xanthomonas campestris* pv. *vignicola*, has been found only on rare occasions in California in southern pea varieties of cowpea grown for seed. Southern peas grown in rainy conditions in other states contract the disease and it becomes seedborne. When infected seeds are grown in California, the disease can spread, especially if the crop is grown under overhead irrigation. California blackeye bean varieties are susceptible to this disease, and even though no infected blackeye beans have yet been detected in California, we include the symptoms here because it is a damaging disease.

The initial symptoms of bacterial blight infection show up as tiny, watersoaked dots on leaves. These dots remain small as the surrounding tissue dies and turns tan or orange with a yellow halo, and lower leaves senesce. Brown cracking may occur on the stem and peduncles. In California, growers can avoid the disease by using certified disease-free seed and surface irrigation systems to produce seed of either southern peas or blackeye bean varieties.

Viral diseases

A number of viruses can infect blackeye beans, resulting in significant yield losses. These primarily include beet curly top virus and mosaic-inducing viruses. Curly top virus disease is transmitted by the beet leafhopper. Plants infected early by this virus are stunted and do not recover. Mosaic-inducing viruses cause leaves of infected plants to have a mottled appearance with simultaneous yellow and dark green coloring. Mosaic viruses usually cause only minor problems, but are more prevalent with late-planted blackeye beans and can be seedborne, so have implications for certified seed production.

Of the mosaic viruses, cucumber mosaic is the most widespread, but southern bean mosaic, blackeye bean cowpea mosaic, and alfalfa mosaic viruses also have been detected in blackeye beans in California. Cucumber, southern bean, and blackeye bean cowpea mosaic viruses are seed-transmissible in blackeye beans. In general, cucumber mosaic virus is not linked to significant yield losses in blackeye beans, but in mixed infections with blackeye bean cowpea mosaic virus, plants can be severely stunted and blackeye bean cowpea mosaic virus by itself can substantially reduce yields. Cowpea aphids can transmit both cucumber and blackeye bean cowpea mosaic viruses.

The primary method for controlling cucumber, southern bean, and blackeye bean cowpea mosaic viruses involve using certified disease-free seed and avoiding late planting in parts of the southern San Joaquin Valley where viral diseases are most prevalent. For virus identification, contact your local University of California Cooperative Extension Farm Advisor on how to collect and submit plant samples for disease identification.

Insect and mite pest management

The integrated pest management (IPM) approach relies on multiple strategies for managing pests, including host plant resistance, biological control, mechanical and cultural practices, and pesticides when needed. IPM recognizes that different types of insects are present in fields at any time during the growing season. Some of these insects can cause substantial yield reductions, some are of limited concern, and some play beneficial roles in regulating other insects. Key pests should receive the most

attention. The impacts of various insects differ depending on the stage of development of blackeye bean plants. Understanding the vulnerable stages of crop development and which insects most affect these stages is critical to an IPM approach.

For blackeye beans, the period from initiation of flower buds to pod-filling is extremely important. Feeding by lygus bugs or stink bugs can substantially damage flower buds and pods, resulting in lower yields or an extended season. If carbohydrate supplies are reduced while pods are filling (whether because aphids or mites are sucking plant sap or armyworms have eaten away leaves), blackeye bean yields will be reduced. Other field crops sensitive to lygus bugs include cotton, alfalfa seed, sunflower seed, and tomatoes.

Surrounding field crops can have both positive and negative effects on pest populations in blackeye beans. Understanding these effects is important for effective pest management.

Lygus bugs (*L. hesperus*, *L. elisus*)

Lygus bugs are commonly occurring insects that are major pests of blackeye beans as well as alfalfa seed, cotton, safflower, and various other beans. They are also found on numerous weeds that occur in roadsides, orchards, vines, and rangelands. Lygus bugs inject digestive enzymes into plants through their piercing-sucking mouthparts. The enzymes break down plant tissue, allowing the bugs to suck out the nutrients. Feeding on tender tissue, such as growing points, floral buds, or young, developing seeds results in flower drop and yield losses, as well as shriveled, discolored, and blemished beans (called stings).



Figure 7. Lygus bug (*L. hesperus*), the major pest of blackeye beans. Photo: Jack Kelly Clark.

Description and biology

Lygus bug adults are about ¼-inch long and vary in color from yellowish green to reddish brown (fig. 7). The adult has a triangular pattern resembling a cape in the center of its back. Immature insects (nymphs) are smaller and usually green with reddish antennae. Later instar nymphs have black dots on their backs. Eggs are difficult to see because they are laid into plant tissue such as leaf blades or soft stems.

Lygus bug adults migrate to bean fields from other crops or weeds. Lygus adults overwinter on plants in uncultivated areas and rangelands surrounding the Central Valley, in weedy orchards, or on plants along rivers or sloughs. They reproduce on these host plants during late winter. If conditions are favorable, one or more generations of lygus bugs may occur on these hosts, but eventually the insects are forced to migrate as the weedy vegetation dries out. Depending on these events and the date of blackeye bean planting, lygus movement into beans can occur when the crop is vulnerable during the bud and flower stages. Monitor surrounding crops that harbor lygus (for example, safflower), and control them before they migrate into blackeye bean crops, especially when they are most susceptible to damage.

Damage

Lygus bugs damage floral buds by feeding on them. This injury, often called bud blasting, is most damaging during the first flush of buds. While the plant does have some compensatory powers to replace these lost flowers, too much loss will set the crop back and reduce yield. Lygus also feed on developing pods, disfiguring beans and reducing the number of beans per pod (fig. 8).

Management

Lygus bugs can be managed with an IPM approach. This includes effective monitoring and multiple control approaches. Sampling involves taking a series of 10 sweeps across the top of two rows of blackeye bean plants. It is important to sample four to six areas of the field and include plant growth stages present in the field. The current action threshold is an average of five lygus bugs per ten sweeps (0.5 lygus bug per sweep) during the floral-bud through



Figure 8. Lygus bug feeding injury on blackeye beans includes small dead seeds and seeds with brown spots (stings) in pods. Photo: Jack Kelly Clark.

small-pod stage and one lygus bug per sweep later in the season. The counts include both adults and nymphs. Fields should be sampled in the morning because lygus bugs drop and hide in the canopy when it gets hot, making them difficult to find.

Chemical treatments are required when the population exceeds these thresholds. Insecticides registered for use on blackeye beans are described in the UC Integrated Pest Management guidelines for dry beans. Be aware that insecticides to control lygus bugs are broad-spectrum and nonspecific, and will reduce the number of general predators, which can lead to secondary outbreaks of mites and summer worm (caterpillar) pests.

Be familiar with neighboring crops surrounding blackeye bean fields. For example, lygus bugs will migrate from alfalfa hay (a preferred host) during cutting and move into blackeye beans. Where possible, the harvest dates of multiple alfalfa fields should



Figure 9. Cowpea aphid (*Aphis craccivora*). Adults are shiny black with dark-jointed white legs while nymphs are grayish in color. Photo: Jack Kelly Clark.

be staggered to provide lush habitat for lygus bugs as well as vital biological reserves for beneficial insects. Safflower is also a preferred host. If lygus is present in safflower, be sure to control this pest when the crop starts to senesce to prevent adults from migrating out and damaging sensitive crops nearby.

Aphids (cowpea aphid [*Aphis craccivora*] and bean aphid [*A. fabae*])

Aphids are soft-bodied insects (fig. 9) that feed directly on the plant's vascular system via piercing-sucking mouthparts. These insects have complicated life cycles involving winged and wingless forms and can reproduce sexually or asexually depending on the time of year. Generation times can be less than 2 weeks, causing aphid populations to increase rapidly.

Damage

Aphids excrete honeydew, a sugary waste product. When fungi feed on the honeydew, a black, sooty mold develops on plant surfaces, which can reduce photosynthesis. In addition, aphids compete with developing beans for carbohydrates. Early in the growing season, excessive populations can stunt and kill plants. Besides reducing yields, honeydew from late-season populations can result in stickier, lower quality beans, and threshing is more difficult. Aphids also transmit viral diseases.

Management

A new aphid-resistant blackeye variety (CB77) is now commercially available (see table 2). For aphid-susceptible varieties, no sampling method is available for aphids and no quantifiable action threshold has been established. The natural mortality of aphids is usually high due to predation and parasitism. Important predators include ladybird (ladybug) beetles in the spring and green lacewings in the summer. Applications of broadspectrum insecticides for lygus bug or summer worm (caterpillar) management can reduce populations of beneficial insects and allow aphid populations to increase. Also, early-season use of insecticides to control aphids often leads to the buildup of other insect pests.

Armyworms (*Spodoptera* spp.)

Armyworm eggs are laid in masses on leaves. They are covered with scales, which give them a white, cottony appearance. Larvae hatch and feed together near the egg mass, and the leaf may be skeletonized. The beet armyworm caterpillar larva is olive green with a dark back and a broad, pale stripe along each side and, usually, a dark spot on the second true leg. The yellow-striped armyworm is darker and less green, with a broad stripe on both sides. Armyworms can become as long as 1.5 inches. Many plants serve as hosts for armyworms including alfalfa, cotton, and various vegetables. Important weed hosts include pigweed (*Amaranthus* spp.) and goosefoot (*Chenopodium* spp.).

Damage

Armyworms are mostly leaf feeders and can cause problems if they defoliate plants to an extreme level, but if the defoliation is moderate bean yields may not be affected. A more serious problem is armyworm feeding on flower buds and developing pods, which can cause direct yield losses. Populations are more damaging during late summer.

Management

No established sampling procedure exists for armyworms and no specific thresholds have been established. When insecticide applications are required due to extensive defoliation and pod damage, the larger and more difficult-to-control armyworm larvae may not be adequately controlled by microbial insecticides. Most pesticides used for lygus bugs control armyworms.

Natural biological control is a major factor in managing armyworms and keeping numbers below damaging levels. Many general predators will feed on small larvae including spiders, big-eyed bugs, damsel bugs, and lacewings. Several parasitoid wasps are useful in managing armyworms, including *Hypo-soter*, which can destroy up to 100 worms during an individual lifetime. Blackened worms hanging limply from leaves indicate a viral disease infection that is controlling the worms.

Spider mites (*Tetranychus* spp.)

Spider mites are small, web-spinning pests that have eight legs and are related to spiders. Three species



Figure 10. Spider mite damage to leaves, causing yellowish stippling on the upper leaf surface. Photo: Jack Kelly Clark.

are found on blackeye beans including two-spotted, Pacific, and strawberry mites (same ones that infest cotton). Mite colors range from creamy brown to light green. Spider mites can complete a generation in 7 to 10 days in summer and form dense colonies under their webbing.

Damage

Spider mites damage beans by piercing plant cells and sucking juices from infested leaves and pods. Damaged leaves have stippling on the upper surface and a grayish webbing on the undersurface where most feeding takes place (fig. 10). Pods can also become infested with mites.

Management

Spider mite numbers may be held at very low levels by various insect and mite predators, particularly early in the season. By reducing weed populations and roadside dust, growers can give mite predators an advantage, as dust embedded in the webbing seems to reduce the effectiveness of predators. In addition, dusty plants transpire less, so the surface temperature of the dusty leaf is higher and allows a more rapid turnover of mite generations. Mite problems are less severe in sprinkler-irrigated fields.

Biological control is an important part of spider mite management. Therefore, the use of insecticides that reduce naturally occurring predators increases mite problems. When treating for lygus bugs, it is important to know what the mite population is in the field. If mites are found easily on older leaves at early bloom, an acaricide may be advisable in a tank mix in addition to the lygus treatment.

No systematic sampling techniques are available for mites in blackeye beans. Infestations usually begin on lower parts of the plant and move upward as populations increase. One way to check for mites is to pick older leaves at random and inspect them for stippling, then turn the leaves over to look for mites. No action thresholds have been established for mite numbers and yield losses in blackeye beans.

Cowpea storage weevils (*Callosobruchus maculatus*)

This relatively small beetle (less than ¼ inch) is dull in color with white, red, or blackish markings. Several species infest blackeye beans, but all belong to the seed beetle family and have short, broad snouts. The adult body is teardrop-shaped, wider at the back than the front. Eggs are laid on the dried pod and larvae burrow into the seed. Immature larvae grow entirely within the bean seed and then emerge as adults. The entire life cycle takes about a month. Under storage conditions, weevils may breed throughout the year.

Damage

This postharvest pest seriously affects bean quality and can result in lower prices for the crop. Infestations can begin in the field or during storage.

Management

Sanitation is the key to managing cowpea storage weevil. Old beans are the source of infestations in the field. Harvesters and storage areas should be cleaned to eliminate weevils, which are sources for the next crop. Commercial warehouses usually fumigate beans in storage to prevent weevil damage. Beans used for seed are usually treated with different fumigants than beans that will be sold for food.

Harvesting

Harvesting is perhaps the most critical operation in the production of dry blackeye beans. Weather conditions become uncertain in late September, with threats of wind and rain increasing as the season advances. Serious losses in yield and quality can result from improperly timed harvest operations. Blackeye beans that are subjected to rain while in windrows, for as short a period as 3 days, can be completely destroyed by pod rots. In contrast, a

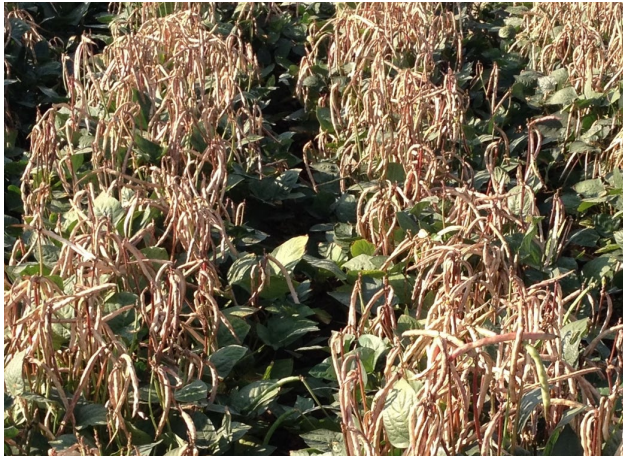


Figure 11. Blackeye bean plants with trailing vines, trifoliate leaves, and mature pods nearing harvest.

standing crop can tolerate some rain, even when mature, provided it has the opportunity to dry out.

Cutting

Cutting can start when most pods have at least turned yellow (fig. 11) and beans in any green pods show a definite “eye,” the distinctive black spot on the pale, cream-colored beans that gives the blackeye bean its name. Beans in green pods that are not fully developed and do not show an eye will shrivel in the windrow, become lighter, and be blown out of the thresher, along with other plant material during harvest.

Cutting and windrowing should be done when pods are tough enough to prevent shattering, that is, the loss of seed when pods break open and seeds fall to the ground. These operations are usually performed at night or early in the morning when dew is present, and they end when pods become dry and shatter. Self-propelled swathers that cut the beans just above the soil surface and windrow them in a single operation are effective, especially for blackeye beans planted without beds. In the more traditional method, custom-made four-, six-, or eight-row tractor-mounted bean cutters are used with sickle bars, circular saws, or rollers to separate the plants in front of the tractor wheels. Rear- or belly-mounted V-shaped knives about 5 feet long with guide rods are used to cut plants 2 to 3 inches below the soil surface and bring two rows of plants into one windrow. Plants dry more quickly and uniformly if the windrow is loose. For more upright varieties—those with pods set higher on the plants—growers

sometimes direct-harvest the standing crop with a grain combine.

Threshing

Blackeye beans are easily damaged during threshing (seed harvest) and usually require specially designed harvesters (including self-propelled and pull-types) to accommodate the massive vines with a minimum of cracking and splitting of beans. Handling beans with great care is especially important for beans used for planting seed stock, as aggressive handling (such as dropping seed bags) causes internal injury, resulting in poor seed germination. To prevent seed damage, harvest fields in the morning when there is some dew and travel slowly through the field (Long and Bonilla 2019).

Blackeye beans are handled in bulk from the thresher to the warehouse using bobtail trucks or, more commonly, trucks with grain beds. Thresher-run beans contain dirt, stones, and trash, as well as split, broken, or discolored beans. Beans are cleaned at the warehouse to bring the lot to the highest possible grade that can be economically achieved. Blackeye beans are cleaned using a screen-air separator machine. Properly adjusted and used, this machine will remove all undesirable materials from beans except dirt and stones of certain sizes, discolored beans, and certain mixtures of other types of beans. Bean lots that contain excessive dirt after screen-air separation often are run over a gravity separator to remove dirt and rocks. Bean lots are also run through an electric-eye color sorting machine to further clean beans and ensure that they meet food safety standards.

Marketing

Producers should become familiar with blackeye bean marketing processes since they can have a major impact on the crop’s profitability. Beans, excluding soybeans, are not traded on the commodities market, nor are they government subsidized. Most growers have contracts with warehouses to ensure a guaranteed price prior to planting, though some have direct contracts with buyers. The sale price of blackeye beans is almost entirely the result of supply and demand, with lower prices occurring when there are too many beans on the market.

Blackeye beans can be stored, so they do not have to be marketed at harvest. As such, the carryover from the prior crop year can be just as important as the current crop size in determining the supply and market price.

Growers have a number of marketing options. They can join and benefit from a cooperative marketing organization and still have the opportunity to direct-market some of their beans. They can also take their beans to a cooperative warehouse that does not market beans and use cooperative strategies to gain more information about marketing. Growers can also use a privately owned warehouse, which usually will assume most of the responsibility for selling delivered beans. In some years, preseason contracts for blackeye bean crops are available, eliminating the uncertainty of marketing.

Markets for blackeye beans

The main domestic market for blackeye beans is dry-packaged beans sold in supermarkets. Packagers purchase beans by the truckload and frequently in hopper-car quantities, then convert them to consumer-sized packages. The other domestic market for blackeye beans is the canning industry, which, although relatively small, can influence the demand and therefore the price for blackeye beans at certain times of the year.

While many countries import blackeye beans from the United States, only 10 to 30 percent of the crop is exported in an average year. Beans may be sold to a dealer involved in exporting or the dealer might purchase them for resale to a company specializing in export markets. The export market is more affected by price than domestic markets.

Industry structure

Blackeye beans are usually processed, stored, and marketed through privately owned warehouses or farmer-owned cooperative warehouses. Producers involved in marketing depend on warehouse managers for help. Warehouse managers are the people bean dealers normally call about the availability of beans. Most warehouse managers act as commission agents, both by linking the producer and dealer through various communications and furnishing the dealer with bean samples from the warehouse.

Warehouse managers also help producers gather and interpret market information, such as the availability of preharvest contracts and statistical information on factors such as crop size and movement. Market demand, prices, and crop movement are hard to predict and should be monitored closely by producers. Because the almost daily communication among producers, warehouse managers, dealers, packagers, canners, and exporters makes the market, and warehouse managers and dealers are in the middle, it is up to everyone to keep communications flowing. The dealer must be constantly aware of what the packager or canner is willing to pay as well as what the producer is willing to sell for, because the various parties seldom agree on the value of blackeye beans.

Producers should remember that periods of inactivity are commonplace in the blackeye bean market. The willingness of producers to sell their crop is not the only thing necessary to affect a transaction. Someone must be willing to buy it, which usually means the dealer must have a customer with a need. While consumption of blackeye beans is year-round, certain periods of consumption and marketing are more active than others.

In general, about half of the blackeye bean crop moves during the last 4 months of the calendar year, which is the first 4 months of the marketing year. This movement is largely in preparation for the New Year's rush, a purchasing pattern based on the tradition of eating blackeye beans on New Year's Day for good luck the rest of the year. During this 4-month period, opportunities to sell blackeye beans are usually available if producers are willing to move them at market price. At other times of the year the price may be higher, but it is not always as easy to find buyers. Summer months are slow because some consumers, especially those in the primary market of the southeastern United States, have access to fresh blackeye beans. Demand begins to build again in September as packagers use up old stock. The California [Dry Bean Advisory Board](#) keeps track of dry bean inventory (receiving and shipping) for dry bean varieties grown in California.

Bean quality considerations

Marketing blackeye beans is more challenging than selling any other California dry bean variety, largely

because of variations in quality. What looks like a U.S. No. 1 grade can easily be U.S. substandard, and vice versa. Grades for beans are defined in the U.S. Standards for Beans (USDA 2023). These grades are based on the proportions of damaged beans, weevil-bored beans, nonblackeye beans, foreign material, and off-color beans. Most transactions are based to some degree on these USDA grades. However, the actual graded certificates are only important for export or government orders, or when a dispute occurs over the quality of a given lot of beans.

Most blackeye beans are sold based on the USDA grade and samples submitted to the prospective buyer, with visual quality playing an important role in marketing. Better quality beans not only bring a higher price, but the beans are more marketable because more consumers are willing to buy them.

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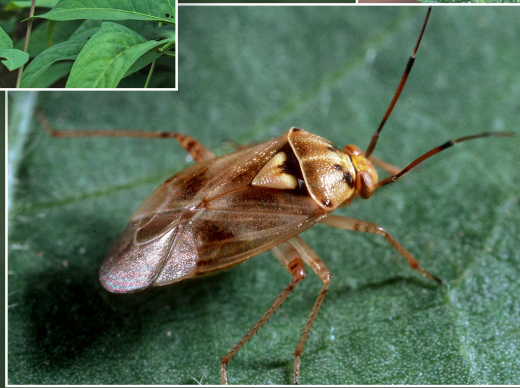
Blackeye Bean Production in California, Second Edition



Blackeye bean plants



Spider mite damage to leaves



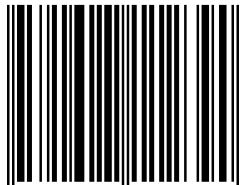
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