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EC98-151 Amaranth: Production Manual for the Central United States

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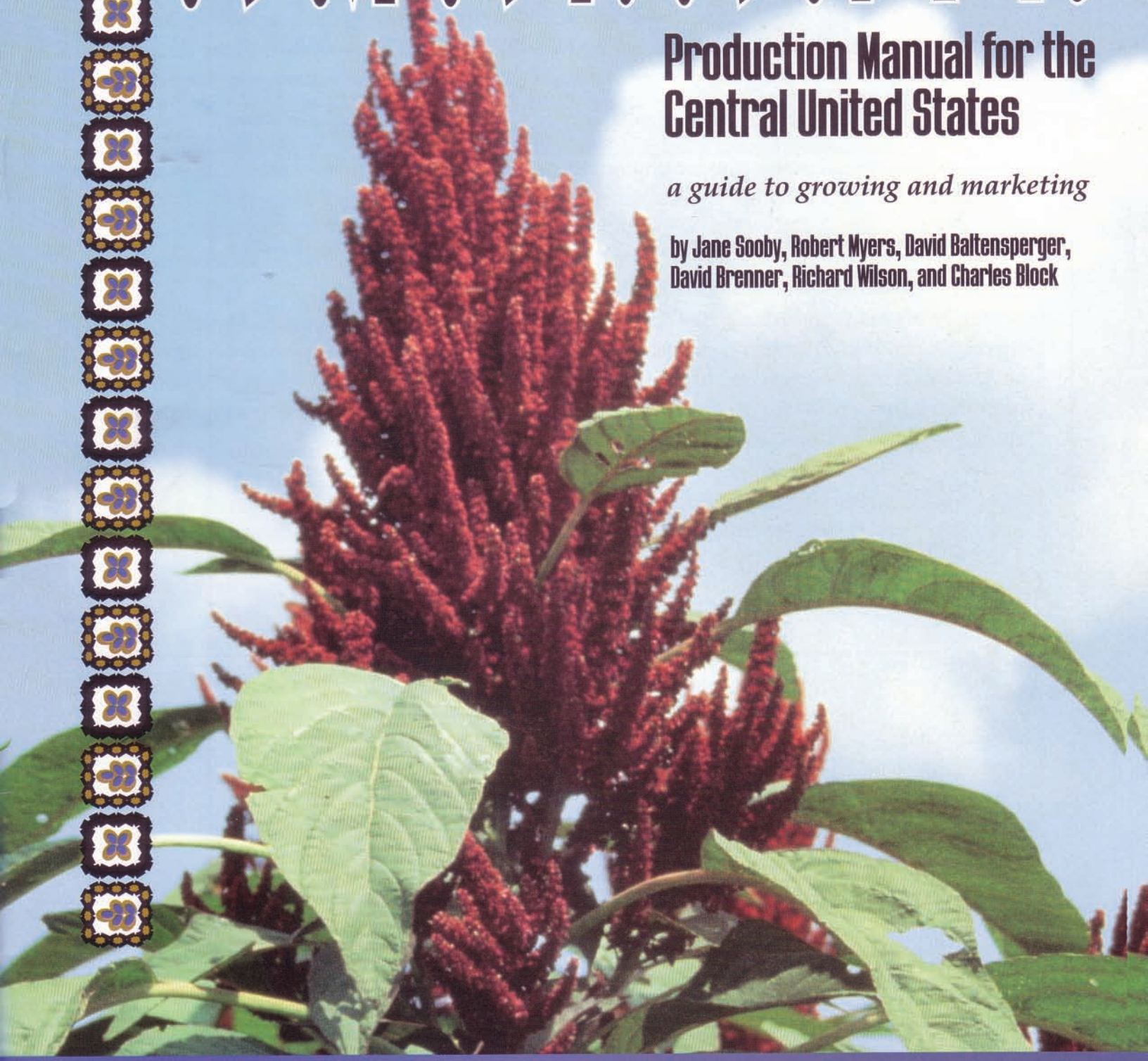
AMARANTH

Production Manual for the Central United States

a guide to growing and marketing

by Jane Sooby, Robert Myers, David Baltensperger, David Brenner, Richard Wilson, and Charles Block



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Thanks also to Leon Weber at the Rodale Institute for providing photographs. The original *Amaranth Grain Production Guide,* published in 1990 jointly by the Rodale Research Center and the Amaranth Institute, was the inspiration for this manual and is a useful reference. Another valuable resource on amaranth research and production is the Amaranth Institute's newsletter, *Legacy* (see *Appendix 1* for address).

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Cover photo: Flowering head of *Amaranthus hypochondriacus* cv. 'Plainsman.' Amaranth is an indeterminate plant which continues to produce new flowers throughout the season, so grain maturity will vary even on a single head.
Photo by R. Myers

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Production Manual for the Central United States

A guide to growing and marketing

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Introduction

Amaranth is a small-seeded grain crop with a dramatic history. It was a staple of the Aztec diet and used for annual tributes to the Aztec emperor until the Spanish conquered the Aztecs in the 1500s. Amaranth production spread from Latin America, and by the 1700s, amaranth was grown throughout Europe for use as an herb and an ornamental. In the late 1800s, amaranth was reportedly being grown in the mountain valleys of Nepal and parts of east Africa.

During the 20th century, it has been grown in Asia, Africa, Europe and North and South America. People around the world use the grain or leaves in a variety of recipes. In India and South America, popped amaranth appears in many confections. Amaranth also is used medicinally and as a protein supplement for infants and children. In the United States, amaranth is grown mainly for the natural and health food markets. Robert Rodale, magazine publisher and promoter of regenerative agriculture, popularized the grain in the 1970s by touting it as a possible solution to world hunger.

Amaranth is a broadleaf plant well-adapted to a range of arid and humid environments. The grain has a high protein content with relatively high lysine levels. In the United States it is grown on a small scale, much of it organically, in areas such as the northern Great Plains and upper Midwest where hot, dry summers and reliable fall freezes start drying the grain in the field at harvest time. In more southern areas such as Missouri, amaranth normally senesces and dries down in September or early October before the first hard frost.

Amaranth is a crop that can fit into many dryland rotations, performing well following wheat, proso millet, or other grain crops. A grower considering amaranth production should spend considerable time identifying markets and ensuring there are adequate storage facilities for the grain before planting. Demand for amaranth may increase, but currently markets are very limited.

Table I. Amaranth at a glance.

Acreage in the U.S.	2,000-3,000 acres (800-1200 ha)
Average U.S. yield	600-1200 pounds/acre (670-1340 kg/ha)
Potential yields*	2500-3500 pounds/acre (2800-3900 kg/ha)
1997 price per pound—conventional	40¢
1997 price per pound—organic	80¢
World's largest amaranth grain producer—1997	Believed to be China
Protein content of grain	14-16 percent

**Data from research plots indicate that amaranth grain yield can reach this level, but more work is needed on variety breeding and production practices before these yields will be common.*

Chapter 1
Field Preparation and Planting

Planting Date, Depth, and Moisture Conditions

Amaranth is a warm-season crop. Optimal germination occurs when soil temperature is 65-70°F (18-21°C) and there is moisture at planting depth. Mid-May to mid-June is generally considered the optimal planting time in the central United States. Yields decline when amaranth isn't planted until early July. In western Nebraska and North Dakota, which experience very hot summers, growers tend to plant around the first week of June to delay seed fill until after the hot, dry August weather.

Amaranth flowering date is determined both by heat units and day length. Early planted fields will flower after accumulating enough heat units, while later planted fields will flower as soon as the days are short enough. The number of days from planting to maturity is heavily influenced by planting date and latitude so it is difficult to make specific observations on length of growing season. In the United States, most cultivars are adapted to a growing season of 95-130 days. *Amaranthus cruentus* cultivars are least sensitive to day length and are more widely adapted than *A. hypochondriacus* *(see page 9 for amaranth varieties).*

When planted into a relatively dry seed zone, some amaranth seeds may sprout while other seeds will wait until rainfall, leading to a ragged plant stand. Optimal stands and yields are produced when seeds are planted into moisture. Best germination rates occur when amaranth seed is planted 1/2 inch (1.3 cm) or less and good seed-to-soil contact is made. Soil moisture must be present at the seeding depth during germination and stand establishment. A firm seedbed helps keep moisture near the surface.

Seedbed Preparation

The guiding principle in planting amaranth is good seed-to-soil contact, so soil clods must be minimized. Growers use varying amounts of tillage to break down residue and firm up the seedbed. One farmer in western Nebraska rips and chisels wheat stubble in the fall, then disks and rodweeds in the spring to break down the residue, smooth out the soil, and remove weeds.

Another farmer handles wheat stubble by using a sweep plow in the fall after harvest, disks, then uses a chisel and/or chisel sweep operation to roughen the soil surface and catch snow. In the spring, he'll do a light disking and/or use chisel sweeps. If there's heavy residue, he'll sweep again. If there's a lot of rain, volunteer wheat will germinate and he'll work the field another time or two to clear these weeds. Finally, he uses a rod weeder or field cultivator to firm and smooth the seedbed.

Another grower burns wheat stubble off if it is excessive and plows the ash back to conserve the nutrients. He has noticed nitrogen tie-up with stubble breakdown if the field is not plowed. He chisels fields with less stubble. He'll moldboard plow to 8 inches (20 cm), then work the ground from one to three times with a field conditioner or a spring-tooth harrow. Finally, he goes over the field with a roller packer to pack the soil and seal in moisture, leaving a good, firm seedbed.

No-till

In more arid regions, planting amaranth no-till holds the potential for conserving soil moisture and protecting seedlings from wind erosion and competing weeds; however, one disadvantage is that no herbicides are labeled for use on amaranth.

An Iowa grower found that the undisturbed residue created habitat for the common stem borer after four years of no-till on ridges. Plowing was necessary to disrupt the stem borer's habitat.

Research from Minnesota shows that planting into oat or alfalfa stubble did reduce weed competition, but also reduced amaranth grain yields compared to planting into a tilled fallow seedbed by decreasing soil temperatures and slowing germination. Data from North Dakota were inconclusive, with no-till resulting in the greatest percent seed germination at one location and the least at another. Where no-till resulted in the highest seed germination rate, the residue protected young seedlings from rains that washed away seedlings in plots that had been moldboard plowed. Chisel plow and ridge till also had low germination rates in this trial. In Missouri, researchers noted that no-till establishment into wheat residue was possible but difficult because of insect damage to seedlings and because of the challenge of maintaining a consistently shallow seeding depth through thick wheat residue.

Ridge Till

Using ridge till for amaranth production shows promise in level or gently sloping fields, especially those with poorly drained soils. Ridge till is well-adapted to furrow

irrigated fields and also may be used in center-pivot-irrigated and dryland fields. In ridge till, 4- to 6-inch (10-15 cm) high ridges are built up in fields using cultivation and seed is planted into the ridges. Cultivation easily controls weeds between the ridges and is the only option for amaranth production since no herbicides are labeled for amaranth.

Advantages of ridge till include improved weed control, warmer soil temperature, and better soil moisture. Disadvantages include: more early weeds; need for equipment modifications; the need for all traffic in the field to follow the ridges; and ridge maintenance.

Seeding Rate, Row Spacing, and Planting Equipment

Amaranth has a very small seed, ranging from 500,000 to 1,000,000 seeds per pound (1.25 to 2.5 million seeds per kg). Seed size influences everything from planting to harvest to storage and requires that equipment and storage bins be tight to reduce loss from leakage.

Bin-run amaranth has a highly variable germination rate, ranging from 40 percent to 90 percent, depending on harvest and post-harvest handling of the seed. Foundation or certified seed should have a germination rate of 85 percent or better. Plainsman is the only variety available as foundation seed through the Nebraska Crop Improvement Association. To compensate for factors such as late planting, deep planting, or low moisture, seeding rate should be increased. Research in Missouri showed that grain yield was not different for five seeding rates ranging from 1/4 to 4 pounds per acre (1/3 to 4 1/2 kg/ha). Two factors are responsible for this: the ability of the plants to increase seed production per plant when plant numbers per acre are low, and self-thinning of amaranth stands when planted densely. Changes in plant shape are seen with different seeding rates: lower plant densities result in bushier plants with thick stalks, while inflorescence branching and stem size decrease in higher plant densities. These differences could affect ease of harvest.

Seeding rate studies show that in dryland production, 1/2-1 pound of seed per acre (1/2-1 kg/ha) gives satisfactory stands that compete well with weeds; however, often it is too difficult to attain this low seeding rate with standard equipment so a seeding rate of 1 1/2-2 pounds per acre (1.7-2.2 kg/ha) is typically used *(Table II)*. For irrigated production, seeding rate should be doubled in order to better compete with weeds and take full advantage of the available moisture.

Amaranth seeds usually germinate quite readily, and when planted shallow (e.g., just under 1/2 inch [1.3 cm]), will emerge within three to four days in warm soil (more than 68° F or 20° C). Seedlings are weak, however, and a crusting soil, heavy rains, or blowing soil particles can easily reduce or prevent stand establishment *(Figure 1)*. Some amaranth varieties have red seedlings that turn green as they grow bigger. During initial development, some plants develop much more rapidly

Table II. Planting amaranth in the central United States.

Date	Mid-May to mid-June
Rate	1/2-2 pounds/acre dryland, 2-3 pounds/acre irrigated (1/2-2.2 kg/ha dryland, 2.2-3.4 kg/ha irrigated)
Depth	1/2 inch (1.3 cm)
Row spacing	20-30 inches [51-76 cm]

Figure 1. Amaranth seedlings are susceptible to desiccation by heat or strong winds. Some varieties have red seedlings that turn green as they grow larger.

than others and vigor differences are accentuated by plant-to-plant competition within a row. Although a mature amaranth canopy is 3-7 1/2 feet (1-2 m) tall, individual plants within a row may be as small as 2-4 inches (5-10 cm) with tiny grain heads.

Amaranth should be planted as a row crop with spacing to match the cultivation equipment since cultivation is the primary weed control method. Some growers use 20-inch (51-cm) row spacing to increase the amount of residue left by the amaranth crop for soil protection. Research in Missouri showed that narrower row widths — 7 1/2 and 15 inches (19 and 38 cm) — provided good early-season weed control but caused extreme competition between plants, resulting in earlier flowering and maturity, reduced plant height, and lower yields. The researchers concluded that it may be possible to find a reduced seeding rate that would work effectively with a narrow row spacing, but that narrow rows are not recommended when using a standard seeding rate of 2 pounds/acre (2.2 kg/ha).

Many options are available for planting equipment. Most farmers adapt their equipment to carefully place the tiny amaranth seed. Grain drills may be used by plugging seed holes to achieve desired row spacing. Some farmers use the Gandy or insecticide boxes on their corn and soybean planters to meter out seed at the desired planting rate. Usually the seed runs down a tube from the box and through the center of a double disk opener. This allows the seed to be planted at the correct depth. Double press wheels allow good seed-to-soil contact on either side of the seed, but leave the soil directly over the seed loose, preventing crusting problems.

Other equipment that has planted excellent amaranth stands include a John Deere vegetable planter using celery plates and a Milton sugarbeet planter. Several models of air seeders may be modified to handle the small seed size.

The four primary causes of poor amaranth stand establishment are soil crusting, low moisture, poor seed-to-soil contact, and uneven planting depth. Wind-driven soil blasting of seedlings also has been a problem in some areas. Avoiding these situations should result in a good stand of amaranth.

Fertility Requirements

Most growers apply little or no fertilizer to amaranth or they manage it as they would wheat *(Table III)*. Though amaranth grain yields increase with increased nitrogen fertilizer rates, nitrogen fertilizer also promotes vegetative growth which can result in increased lodging, especially under irrigation. Only small amounts of nitrogen fertilizer should be applied (20 to 40 pounds per acre [22 to 45 kg/ha] in the Great Plains and 40-80 pounds per acre in the Midwest [45-90 kg/ha]). It is always a good practice to test the soil for residual nutrients before planting. A grower in western Nebraska uses 20 lbs/acre phosphorus (22 kg/ha) and 40 lbs/acre nitrogen (45 kg/ha) on dryland amaranth and 20 lbs/acre phosphorus (22 kg/ha) and 80 lbs/acre nitrogen (90 kg/ha) on irrigated amaranth.

Table III. Guidelines for fertilizing amaranth planted after wheat in the High Plains.

A more exact approach to using amaranth in dryland production after growing wheat or other small grains involves taking soil samples to determine residual nutrient levels and basing fertilizer rates on these and desired yields. Use this formula for the nitrogen calculation:

Total N (soil residual N + applied N) x 16 = Yield goal (pounds/acre)

For example, suppose soil testing indicates a residual nitrogen content of 10 pounds nitrogen per acre. You would like a yield of 1200 pounds per acre. The total nitrogen needed for 1200 pounds of yield is 1200/16 = 75 pounds total nitrogen. Since residual nitrogen is 10 pounds, 65 pounds nitrogen needs to be applied (75 - 10 = 65). The following chart can be used to calculate how much nitrogen and phosphorus fertilizer to apply for desired yield levels, based on a rate of 6 pounds per acre nitrogen and 1 pound per acre phosphorus for every 100 pounds of expected yield.

Yield goal	Total nitrogen required	Total phosphorus required
(pounds grain/acre)	- - - - - - - - - - - pounds/acre - - - - - - - - - - -	
800	50	8
1000	63	10
1200	75	12
1600	100	16
2000	125	20

Amaranth nitrogen needs are modest enough that often they can be supplied by organic sources, including residual nitrogen from cover crops. Manure, fish emulsion, and rich composts are other nitrogen sources used in organic production. An advantage of organic fertilizers is that they also are a source of phosphorus, potassium, and micronutrients. Many organic producers use legumes in rotation or grown along with the amaranth as a source of nitrogen. An organic grower in western Nebraska plants clover into amaranth either at planting or during a subsequent cultivation to bring nitrogen into the cropping system. Research in Missouri showed a good response when amaranth followed Austrian winter pea, hairy vetch, or crimson clover cover crops *(see Cover Crops section in Chapter 4)*. Research in Minnesota on potassium and phosphorus requirements of amaranth showed no significant response of grain yields to increasing rates of phosphorus and potassium, indicating that amaranth does not have a great demand for these nutrients. Soil tests showing low phosphorus or potassium levels may warrant taking some action to make these nutrients more available, however.

Variety Selection

There are three cultivated grain species of the genus *Amaranthus*: *A. cruentus, A. hypochondriacus,* and *A. caudatus.* Cultivated varieties are distinguished from their weedy pigweed relatives, such as *A. retroflexus* and other species, by having light-colored seed coats compared with the weeds' black seeds. Pigweed species also tend to be more branched and have less vegetative growth than grain amaranths. The grain amaranths normally present no more of a weed problem after a crop than volunteer corn or volunteer wheat. Volunteer amaranth can be easily controlled with cultivation or herbicide.

A. cruentus and *A. hypochondriacus* are the species most often grown for grain in the United States. *A. hypochondriacus* includes the highest yielding varieties bred for production in the central United States, including 'Plainsman.' These varieties are day-length sensitive. *A. cruentus* is the most widely adapted species because of its relative insensitivity to day length and its tolerance of heavy soils.

A. caudatus varieties are best adapted to high elevations in the tropics and subtropics. Most of these varieties exhibit virus-like symptoms in temperate climates and fail. However, an ornamental variety of *A. caudatus*, 'Love Lies Bleeding,' is well-adapted to temperate zone conditions and is grown for its spectacular foliage and seed head.

A. tricolor is a black-seeded vegetable and ornamental species from Asia. In the United States, *A. tricolor* plants are prone to stem diseases which cause them to die suddenly.

Plant breeders have developed many varieties with differing traits such as maturity date and height. *Table IV* summarizes yield data and growth traits of 11 amaranth varieties grown in regional variety trials over five years. Performance varies quite a bit from state to state due mostly to weather or stand establishment differences. Within states, yields vary quite a bit from year to year, as well. Most low yields were caused by poor fall weather conditions leading to preharvest loss from shattering or lodging. Poor stand establishment was a factor in some cases.

In general, tall varieties are susceptible to lodging, especially when over-fertilized, but they are more competitive with weeds such as foxtail. Medium and short varieties such as Plainsman, K432, and D136 have less lodging, with D136 showing the most resistance to lodging.

Amaranth yields can reach a high of 3000 pounds per acre (3360 kg/ha) under dryland conditions, though the average is closer to 650-1100 pounds per acre (730-1230 kg/ha). Lower yields have been found in western Nebraska, the current center of United States amaranth production, largely due to the strong winds that arise in late summer and cause severe shattering. This indicates one of the current plant breeding needs for this crop: developing a head that better retains its seeds.

According to plant breeders in Iowa and Nebraska, traits they may be breeding for in the future include larger seed, brighter white seed, different colors of seed, various starch properties, disease and insect resistance, less shattering and lodging, and determinate growth characteristics.

Table IV. Amaranth variety growth traits and yields in five states. Trials in all states except Colorado were grown under dryland conditions. Colorado trials were irrigated. Mean yields are shown with actual range of yields indicated in parentheses.

Variety	*Species*	*Maturity*	*Height*	*Avg. grain yield Colorado*[1]	*Avg. grain yield Missouri*[2]	*Avg. grain yield Minnesota*[3]	*Avg. grain yield Nebraska*[4]	*Avg. grain yield North Dakota*[5]
				lb/acre				
Plainsman	*A. hypochondriacus*	mid	medium	1570 (700-2310)	750 (200-1730)	1180 (490-1710)	960 (640-1550)	1040 (230-1770)
D70-1	*A. hypochondriacus*	mid	tall	—	790 (260-1370)	—	720 (350-1480)	1010 (160-1730)
D136-1	*A. hypochondriacus*	late	medium	—	860 (330-1230)	1010 (690-1500)	340 (50-980)	210 (20-430)
K432	*A. hypochondriacus*	early	short	1530[6]	690 (220-1400)	1330 (740-1820)	830 (610-1460)	1040 (350-1570)
K433	*A. hypochondriacus*	early	short	1210[6]	790 (190-1570)	—	880 (650-1330)	1030 (710-1600)
K593	*A. hypochondriacus*	mid	medium	—	660 (160-1390)	—	780 (330-1600)	1060 (580-1580)
Amont	*A. cruentus*	late	tall	—	840 (290-1720)	1370 (1020-1970)	610 (190-1090)	1730 (1110-2350)
K266	*A. cruentus*	late	tall	1220 (880-1500)	760 (330-1470)	1460 (1070-2060)	440 (220-760)	1300 (970-1960)
K283	*A. cruentus*	mid	tall	1600 (1070-2140)	630 (240-1300)	930 (440-1330)	460 (200-780)	1310 (680-1650)
K436	*A. cruentus*	mid	tall	—	650 (210-1340)	—	340 (120-630)	1030 (550-1740)
A200 D	*A. cruentus*	mid	medium	—	790 (350-1740)	1000 (730-1260)	710 (290-1490)	880 (70-1760)
Average (rounded to nearest ten)				1430	750	1180	640	1060

[1]Based on two years of data from Ft. Collins, two years of data from Rocky Ford, and one year of data from Mead.
[2]Based on three years of data from Columbia and two years of data from New Franklin.
[3]Based on five years of data from Rosemount, two years of data from Grand Rapids, and one year from Albert Lea, Lamberton, and St. Paul.
[4]Based on four years of data from Sidney.
[5]Based on three years of data from Fargo and three years of data from Prosper.
[6]Based on 1 year's data.

Data from Myers, R.L. 1994. Regional amaranth variety test. Legacy 7:5-8. Values have been rounded to the nearest ten.

Chapter 2

Management During the Growing Season

Weed Control

Weed control can be a significant challenge in amaranth production because no herbicides are labeled for use on the crop. Weed control begins by planting amaranth in fields that do not have severe weed infestations. Cultural practices are critical to reducing weed competition, which can reduce yield and diminish grain quality.

Amaranth's late planting date allows time to remove weeds with tillage prior to planting. Where springs tend to be moist, tilling several weeks before the amaranth planting date will promote germination of weeds that may compete with the crop. These can then be killed with shallow tillage. Each tillage operation, however, will cause some soil moisture loss.

Tilling two to three weeks before planting to stimulate weed germination then killing weeds with Roundup immediately before planting has been most effective in reducing weed competition in Nebraska research trials. Planting must be done with minimal soil disturbance for this to work.

R. Myers

Figure 2. Pigweed (*Amaranthus retroflexus*) often infests amaranth fields yet is easily distinguished from the cultivated types by its foliage. In seed production fields, pigweed must be hand-rogued before it flowers to avoid outcrossing with the cultivated variety and contamination with black seed.

Amaranth seedlings grow slowly at first and are most susceptible to weed competition in the first three to five weeks after planting. Many growers cultivate three or four times during this period, hilling around the base of the plants at the last cultivation to reduce lodging. Some growers find that weed competition is more of a problem in irrigated production, so they increase seeding rate to outcompete the weeds and cultivate more. One strategy is to use a grain drill to plant narrower rows (6-inch [15-cm]) that crowd out weeds, although research indicates that cultivation controls weeds better than planting narrow rows.

Seed production fields should be hand-rogued prior to flowering to eliminate off-types, especially black-seeded types including pigweed *(Figure 2)*. This is essential to avoid outcrosses that cannot be separated from the seed prior to planting. Buyers for whole grain markets severely reduce the price for lots contaminated with dark seed, making hand-roguing the most efficient option. It is extremely difficult to separate amaranth grain from pigweed seed. On the average, amaranth has a larger seed, but as much as 50 percent of the amaranth may be lost when cleaning a seed lot with 5 percent to 0.01 percent contamination. On an average yield of 1,000 pounds (454 kg) and a price of 40¢ per pound, this can cost the producer $200 per acre, which can make hand-roguing or hoeing very cost-effective.

Warm-season annual weeds which share the same life cycle as amaranth are most troublesome in amaranth fields. These weeds include pigweed, lambsquarters, foxtail grass, and kochia. Avoid planting amaranth into fields that have infestations of these weeds.

Most growers raise amaranth in rotation with other crops, which helps control weeds by changing the environment annually *(see Chapter 4)*. This practice also creates the opportunity to rotate with crops that can be treated with herbicides to eradicate warm-season annual weeds.

Researchers in Minnesota investigated no-till amaranth production. Planting amaranth

into oat or alfalfa stubble did reduce weed competition but also reduced amaranth grain yields compared to planting into a tilled fallow seedbed by decreasing soil temperatures and slowing germination.

A good overall weed control strategy for amaranth is:

1. Plant clean, certified seed. Planting black seeds will produce weedy plants that will make more black seed. Some of these plants will resemble weeds and others will resemble the cultivated variety, making it hard to rogue them out of the field.
2. Plant into fields largely free of other warm-season annual weeds such as pigweed, lambsquarters, grassy foxtail, and kochia.
3. Control weeds immediately prior to planting.
4. Cultivate to suppress weeds during the first three to five weeks of growth.

Water Requirements

Amaranth requires soil moisture to germinate but needs little water to grow. In eastern North Dakota dryland production, total water use for a crop ranged from 10 1/2- 12 1/2 inches (27-32 cm) in average years and half that in a cooler, moister year. In irrigated production in northern Mexico, 19 1/2-30 inches (49 1/2-76 cm) total was applied with three to six irrigation sessions during the growing season.

Amaranth has evolved so that it can produce under moisture stress. Amaranth will extend its taproot under water-stressed conditions. Taproots have grown as deep as 4 1/2 feet (1.4 m) in western Nebraska when no rains fell after stand establishment. A taproot 8 feet (2.4 m) long was reported in China. Amaranth also uses other drought-adaptive strategies: the C_4 photosynthetic pathway, which is more water-efficient; indeterminate flowering, or flowering throughout the season instead of all at once, which allows the plant to take advantage of late-season rains; and wilting when under extremely dry conditions. When amaranth wilts, it can bounce back to full vigor if rains come within a few days of wilting.

Another characteristic of amaranth is its ability to withstand high salinity levels in irrigation water and still produce a crop. In fact, NASA investigated amaranth as a plant that can tolerate high salt levels in water and provide "spacecraft life support functions" by recycling air and water and providing food. (Leaf vegetable varieties were used in this research.) In Israel, salty water is used to irrigate amaranth at a rate equivalent to 35750 cubic feet per acre (250 cubic meter/dunam [1000 meters squared]).

Irrigated Production

Though amaranth does not require irrigation, yields may increase and stabilize under irrigation *(Figure 3)*. Research has shown that grain yield increases as quantity of water applied increases up to 25 inches (63 1/2 cm) of total moisture, and that too much irrigation will result in greater stem growth and more lodging. Amaranth grows well under hot dry conditions so most related research has been conducted under these conditions. In determining whether to irrigate amaranth, irrigation costs, potential income from the crop, and increased weed control pressure should be considered.

A grower in western Nebraska uses a moisture probe to monitor soil moisture in his amaranth field. When he can't probe deeper than 12 inches (30.5 cm), he sprinkles the field with water, adding it in 1/8-inch (3-mm) increments. In this environment, anything more than this is too much and runs off while anything less evaporates without reaching the plant. He spends about half of what he would pay to irrigate corn in a season.

This farmer feels that to withhold irrigation prior to harvest in order to dry down the crop "robs you of yield." He continues irrigating until the plant is mature and begins to dry down naturally or is killed by frost.

Insect Pests

by Richard L. Wilson[1]

Lygus Bug

The most prevalent insect infesting grain amaranth is the lygus bug, *Lygus* spp. (primarily the tarnished plant bug, *Lygus lineolaris*

J.Sooby

Figure 3. Amaranth growing under pivot irrigation in western Nebraska. Though amaranth does not require irrigation, yields may increase and stabilize under irrigation; however, it can also lead to lodging.

R. Myers

Figure 4. *Lygus lineolaris*, the primary insect pest on amaranth in the United States.

[Palisot de Beauvois]). The lygus bug *(Figure 4)* is a destructive pest on more than 300 plant species. It can complete a life cycle in 30 days and several generations in a growing season.

The lygus bug is a sucking insect that damages the crop by feeding on succulent plant tissue. Feeding on the developing floral buds, immature blossoms, and the developing embryos damages amaranth grain. Damaged grains are shrunken and discolored. Fortunately, the damaged grains are lighter in weight than normal grains and can be removed during cleaning. Lygus bug feeding sites also can provide entryways for amaranth diseases.

Studies have been conducted at the USDA-ARS North Central Regional Plant Introduction Station, Ames, Iowa, to examine the interaction of lygus bugs with amaranth plants. The female lygus preferred to lay her eggs on amaranth heads, but when heads weren't available, leaves were preferred over stems (Wilson and Olson, 1990). When at least 12 lygus bugs were caged on an amaranth head for eight weeks, the seed weight was decreased by 80 percent compared to untreated checks. In 1987, a naturally occurring lygus bug infestation significantly reduced seed weight by 28.2 percent (Olson and Wilson, 1990).

At the North Central Regional Plant Introduction Station, amaranth germplasm has been evaluated for new sources of resistance to lygus bugs. Several accessions with some resistance to this pest have been identified.

Other Insect Pests

Other insect pests have been observed on amaranth. Wilson (1989) reported on the feeding of five insect pests (other than lygus bugs) commonly found in the Midwest: fall armyworm, *Spodoptera frugiperda* (J. E. Smith); European corn borer, *Ostrinia nubilalis* (Hübner); corn earworm, *Helicoverpa zea* (Boddie); cabbage looper, *Trichoplusia ni* (Hübner); and the cowpea aphid, *Aphis craccavora* (Koch). All of these insects, except for the European corn borer, fed on the amaranth lines tested.

Additional pests observed on amaranth are the amaranth weevil, *Conotrachelus seniculus* (LeConte), blister beetle, *Epicauta* spp., the spinach flea beetle, *Disonycha xanthomelas* (Dalman), and several species of grasshoppers.

The amaranth weevil can cause occasional severe plant lodging. It is found throughout the United States where wild and weedy amaranths grow. Female adult weevils lay eggs in a plant's stem near the soil surface. The larvae tunnel into and ultimately weaken the root system. The entrance and exit holes from egg laying and larval tunneling provide additional entrance areas for pathogens. Resultant root rots magnify the initial damage caused by insect feeding.

Blister beetles feed on pollen and leaves. If found in large numbers, they can cause leaves to have a very ragged appearance. In one case in Missouri, large colonies of blister beetles ate all of the leaf material in some small plots.

The spinach flea beetle will feed on leaf tissue of immature plants. This small insect (about 1/5 inch [5 mm] long) will chew small rounded or irregular holes in the leaves, providing an entrance for plant pathogens. Heavy feeding can kill the plant. Some flea beetles carry and transmit diseases among other crops. Damage by this insect is sporadic on amaranth.

Alfalfa web worm was a severe problem in one year out of five in Missouri field trials, causing stunting and significant leaf damage during early vegetative growth. Corn rootworm beetle also has been observed frequently feeding in amaranth grain heads but not in large numbers.

The economic importance of the damage caused by these insects on amaranth has not been studied, except for the lygus bug. While a large variety of insects feed on amaranth, the crop can tolerate most of them.

Insect Control

Many insect pests of amaranth are not always present, and if present, they may not cause damage sufficiently severe to justify chemical control. The need for chemical control should be determined on an individual field basis.

Few chemicals[2] are registered for use on amaranth. Two worth noting are Diatect Multipurpose Insecticide (Diatect International, Inc., Smith Center, Kansas) and Pyrenone® Crop Spray (AgrEvo Environmental Health, Montvale, New Jersey). Both products contain pyrethrins and are registered to control lygus bugs, blister beetles, European corn borer, flea beetles, and several other insect pests. Natural pyrethrin and other

[1]Entomologist, USDA-ARS North Central Regional Plant Introduction Station, Iowa State University.

[2]Mention of a proprietary product does not constitute endorsement by the USDA-ARS, University of Nebraska Cooperative Extension, or cooperating agencies.

organic products may be permitted for organic amaranth production. Contact an organic certifying agency for more information.

Disease in Amaranth

by Charles C. Block[3]

Growers generally have experienced few major disease problems in amaranth. This may be due to the relatively small acreages planted or to minimal research directed at identifying disease problems. As with any crop, diseases may increase as amaranth expands in range and acreage.

Damping-off

Damping-off is the most important disease of amaranth. Damping-off can be caused by several common soil-inhabiting fungi such as *Pythium*, *Rhizoctonia*, *Fusarium*, and *Aphanomyces*. These fungi attack the seeds, stems, or roots, especially in cool and wet soils or low areas of a field. Amaranth seedlings are particularly vulnerable from planting until plants are 2-3 inches (5-8 cm) tall. Once plants reach 4-6 inches (10-15 cm), the stems are usually thick enough to prevent further damping-off. Resistant varieties eventually may be developed, but until then good cultural practices are the key to limiting damage from damping-off. There are no registered fungicide seed treatments.

Symptoms of Damping-off:

- Pre-emergence damping-off is indicated by poor or spotty stands, especially in poorly drained or heavy soils.
- Post-emergence damping-off is indicated by plants wilting and falling over at the soil line. The stem collar and roots are soft, water-soaked, and turn brown or black.

Conditions Favoring Damping-off:

- Cold, wet soils (fungi are very active at 50-60°F [10-15°C]).
- Poorly drained spots in a field.
- Early planting and high populations.
- Excessive nitrogen, especially nitrate nitrogen. Ammonium forms have been shown to inhibit *Pythium*.

Preventing Damping-off:

- Ensure good soil drainage.
- Avoid too much nitrogen fertilizer, which also contributes to lodging.
- Plant when soil temperature is above 60°F (15°C).
- Control planting depth.

Leaf Diseases

In the humid tropics, such as Nigeria, Benin (Dahomey), and India, a wet rot of leaves, flowers, and stalks caused by the fungus *Choanephora cucurbitarum* is often a serious problem (Adebanjo 1989; Ikediugwu 1981). This disease is favored by tropical climates and is unlikely to become a problem for amaranth growers in the Midwest and northern Great Plains. The fungus does occur in the United States but primarily on summer squash, where it appears as a fuzzy black growth attacking flowers and young fruit.

We have occasionally observed white rust (*Albugo bliti*) on redroot pigweed (*A. retroflexus*), but it seems to cause little damage. White pustules are visible on the underside of infected leaves. Circular leaf spots with red margins and tan centers (0.1-0.2 inches [2-5 mm] in diameter) caused by the fungus *Cercospora* have been reported on several amaranth species (Chupp 1953), but little damage was noted.

Virus-like stunting and leaf curl symptoms have been observed in the Nebraska Panhandle but the cause has not yet been identified. At this time, little is known about potential virus problems in amaranth production. Amaranth is known to be susceptible to many viruses, including cucumber mosaic virus and beet western yellows virus (Horvath 1991).

Stem and Root Diseases

At the North Central Regional Plant Introduction Station, a crown and root rot disease complex associated with tunneling in the plant stem by the amaranth weevil was observed and *Pythium*, *Rhizoctonia* and *Fusarium* fungi were isolated from these stems. Symptoms were generally unnoticed until the plants lodged or suddenly turned brown and died. The roots appeared healthy but the crown area was soft and decayed.

Pythium stem canker and lodging was reported on flowering plants in Missouri (Mihail and Champaco 1993). Tan cankers with distinct black borders developed at the soil line when high temperatures (more than 82°F [28°C]) coincided with prolonged periods of saturated soil.

Two soybean diseases have been reported on amaranth: pod and stem blight caused by *Phomopsis* spp. (Cerkauskas et al. 1983) and charcoal rot caused by *Macrophomina phaseolina* (Mihail and Champaco 1993). Both fungi infect the stems. They are not a real problem at this time, but amaranth growers should be aware of these diseases.

Root-knot nematodes of the genus *Meloidogyne* can reproduce on amaranth roots (Reddy et al. 1980; Bafokuzara 1983), but are not considered to be a pest of economic importance in the United States.

[3]Plant pathologist, USDA-ARS North Central Regional Plant Introduction Station, Iowa State University.

Chapter 3
Harvesting, Cleaning, and Storing Amaranth

Harvesting may pose one of the biggest challenges in bringing in a good amaranth crop. As one grower put it, "Amaranth is easy to grow but hard to harvest." The main difficulty is seed shatter, both in the field before it can be harvested and during combining. Solutions to both of these problems are described in this chapter.

Crop Maturity and Harvest Date

There are two distinct approaches to timing amaranth harvest based on the regional climate. In the High Plains or northern areas with a short growing season, a killing frost begins drying amaranth in the field usually in October. Amaranth is harvested as soon as possible after the killing frost. Because the plants are full of moisture at this stage, the crop must be dried in the field for about two weeks before it can be combined.

In regions with a longer growing season such as Missouri and Maryland, amaranth will senesce and dry down naturally in late September through mid-October prior to late fall frosts. Current cultivars turn brown in the head and leaves during senescence, then drop almost all their leaves. Once senescence begins, stalk strength declines, making the plants more susceptible to lodging. In areas where amaranth naturally senesces, the grain is harvested when the heads have turned brown.

Amaranth is an indeterminate plant which continues to produce new flowers throughout the season, so grain maturity will vary even on a single head. Regions of the United States where amaranth has been raised successfully include Nebraska, South Dakota, North Dakota, Missouri, Minnesota, Montana, California, Colorado, Kansas, Iowa, and Maryland. Though amaranth is a widely adapted plant and can be grown almost anywhere, harvest can be more difficult in warm and moist regions because the plants and heads may be too wet to harvest with ease. There are no approved desiccants to dry amaranth artificially.

Amaranth seed maturity for common varieties such as Plainsman can be determined by looking at the outer seed coat *(Figure 5)*. Mature seeds will have a solid "opaque" white or tan appearance. Seeds that are less mature and contain higher moisture will have a glossy or translucent appearance. Research in Missouri showed that translucent-looking seeds have a lower average seed weight, lower germination rate, and higher moisture than opaque seeds.

The largest threat to amaranth yields in the central United States is shattering, or seed falling out of the head, due to wind. Seed shatter is not usually a significant problem where amaranth naturally senesces prior to a killing frost. Shatter potential is a significant factor to keep in mind when deciding when to harvest. One farmer said, "Last year we had 200 pounds per acre. The wind blew and then we had 100 pounds per acre. The wind blew again and we had 50 pounds per acre." Researchers investigating harvest date in North Dakota harvested at six-day intervals after initial seed shatter and concluded that amaranth should be harvested as soon as possible after a killing frost to avoid lowered grain yield and quality. Time must still be allowed for grain to dry in the field.

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Figure 5. Translucent-looking seeds (top) are less mature and contain more moisture than more mature, opaque seeds (bottom), which have higher germination rates and seed weights.

Solutions to the Shattering Problem

Some strategies exist to reduce losses due to shattering. Because the risk of shattering caused by winds increases the longer the crop is kept in the field, some farmers harvest when the grain is wetter than recommended at harvest *(see page 17)* and then dry it.

Another approach is to plant a barrier to protect the amaranth crop. A taller crop such as sunflower or corn planted around the amaranth field can act as a windbreak. The taller crop also may be planted as an intercrop. Some farmers have planted a 16-row border of sunflowers as a windbreak around a field of amaranth planted so closely in a solid stand that there is no need for cultivation. This system may require increased fertilizer and water, but may be worthwhile. The two crops could be harvested simultaneously and the seed easily separated with screens.

Grain Moisture and Storage

Like any grain, amaranth must be stored at low moisture levels, around 10-12 percent, to avoid mold and spoilage, especially since long-term storage is often necessary. Grain moisture should be tested in the field and this information used to determine when to harvest. Some farmers have started drying amaranth, reducing the risk of shattering loss from waiting until the grain reaches an acceptable moisture level in the field *(see page 17)*.

Storage bins should be clean, tight, and in good repair so that the tiny seed doesn't pour out from any cracks. They also should be impervious to rodents. Because of the varying market for amaranth, all growers should be prepared to store their grain for up to two years, depending on market conditions.

T. Frantzen

Figure 6. Harvesting amaranth with a combine from a ridge-tilled field.

Harvesting Equipment

Though some farmers have tried windrowing the crop to dry the grain in the field, they've found that windrowing is not desirable. "If it touches the ground," one farmer explained, "it picks up soil particles the same size as the seed. You can't clean it."

North Dakota research indicates that plots harvested with a combine experienced 25-30 percent grain loss compared with hand harvested plots, and that seed germination was significantly lower in mechanically harvested plots than in hand harvested plots. These findings show that great care must be taken during harvest to avoid seed damage (Figure 6).

Many farmers harvest amaranth successfully using row crop headers on their combines. Soybean headers work well on tall varieties and wheat headers can be used with semidwarf varieties. "A reel header will slap the heads and make them shatter," said one grower. If a reel header is the only choice, it may help to remove several of the reel bats or raise the cylinder height to minimize loss.

Though many farmers successfully harvest using standard combines, the tiny amaranth seed tends to slip through the combine and fall to the ground. A canvas or draper type of header may be used to catch the seed. Most of these come with a bat reel with no fingers, but a pick-up reel is better for lifting heads that have fallen over.

Combine Speed

It is important to set the cylinder speed to a low rate to avoid crushing and damaging the amaranth seed. Recent studies on the effect of cylinder speed on seed quality showed that seed germination was reduced even when combined at a cylinder speed of 437 rpm. The authors recommend lowering the combine speed as much as possible. Although the grain is extremely small, both the sieve and chaffer should be open $^1/_2$ inch (1.3 cm). To aid in removing trash from the amaranth, a $^1/_8$-inch (3-mm) wire mesh may be attached to the top of the sieve.

Western Nebraska farmers leave the combine settings similar to those for wheat and reduce the cylinder speed as much as possible.

In general, clearance between cylinder and concave must be adjusted for the tiny grain. Air flow should be reduced so grain is winnowed but not blown away. Clover and alfalfa screens will improve the machine's cleaning performance.

Grain Moisture Level and a Drying Strategy

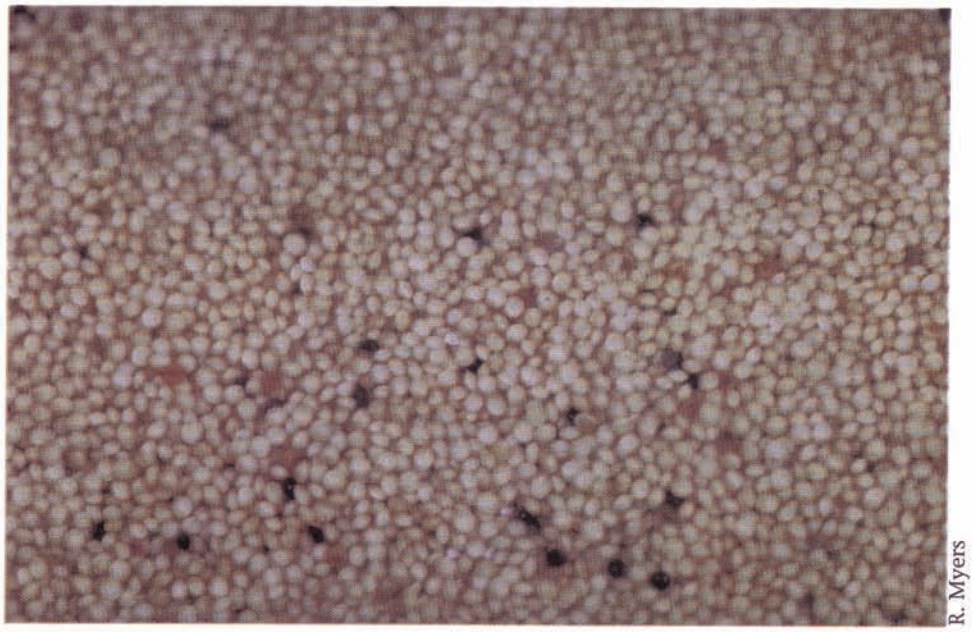
Many farmers may be tempted to allow their crop to dry down in the field until the grain is close to the ideal storage moisture of 10-12 percent. Some farmers, however, are harvesting at higher moisture levels.

"I know one thing. I've waited for the grain to dry down in the field for too many years now. I can combine a lot wetter than what I thought I could," said Phil Sanders, an amaranth grower in Dalton, Nebraska. Sanders harvested his amaranth when it tested 22 percent moisture.

Sanders can harvest a wetter crop because he has constructed a drying apparatus in a Quonset hut at his farm. He bought 300 feet of 4-inch slotted sewer pipe, taped it together and coiled it into a flat spiral. He attached it to an aeration fan to move air through the pipe and piled the grain — which had already been run through a rotary screen and had the chaff blown off — on top of the pipe. By the day after harvest, moisture was down to 15 percent. Within a few days it was down to 13 percent, an acceptable level for storage.

Sanders offers the following advice for growers drying their own amaranth:

1. Only use air, not heat, to dry the grain or popping quality may be destroyed.
2. Don't stack the grain any deeper than 4-5 feet (1-1.5 m).
3. Keep the air going continuously, don't turn off the fan until the desired moisture level is achieved. Use stirrators in bins if available.



R. Myers

Figure 7. Careful harvest is esssential to ensuring high quality grain for the demanding health food market. Presence of any dark seed may bring down the price considerably.

Cleaning

Grain buyers look for clean, high-quality grain free of black seeds, mold, and other contamination *(Figure 7)*. Because amaranth has such a small seed, cleaning must be done with care. As mentioned previously, if a lot of soil is picked up during harvest, it will be difficult to separate the small soil particles from the tiny grains. It's important that the cleaning process begin during harvest by ensuring that heads do not touch the ground.

One farmer in western Nebraska does an initial cleaning (scalping) right after harvest. The grain is augured through a rotary screen that removes large sticks and stems while being blown with a fan to remove chaff. Since much of the moisture is held by the chaff, this helps dry the grain quicker.

After drying, grain is cleaned again by passing it through screens and running it over a gravity table. This equipment separates particles that are the same size but different densities, like amaranth and pigweed seed. Often growers send their seed to professional cleaners; however, quality of cleaning can vary and many growers find it more economical to invest in cleaning equipment and do it themselves. In more high-tech operations, optical sorters are used for the final stage of cleaning to get rid of all black seed.

Chapter 4
Cropping System Considerations

Amaranth needs to be approached as one part of the overall farming enterprise. It is best to work amaranth production into the farming system gradually, beginning with low acreage and increasing as your growing and marketing experience increases. It is not a get-rich-quick proposition. Prices for organic amaranth give a good return but markets may not always be available. It is imperative that a market be identified before growing the crop. Many growers have raised a good crop and ended up storing it indefinitely for lack of a buyer.

This chapter describes some aspects of the farming system to consider with amaranth production.

Amaranth's Role in Rotations

Most growers bring amaranth into their existing rotation. Not only is this good farming practice, but pigweed pressure tends to build when amaranth is grown continuously. Also, continuous amaranth production may create circumstances favorable to disease.

In areas with about 20 inches (51 cm) of rainfall, amaranth can be treated as a sorghum crop, having similar growth, moisture, and nutrient requirements. Amaranth is produced in sorghum growing areas of Wisconsin and Missouri. In drier areas of Nebraska, Wyoming and South Dakota, amaranth is often brought in after wheat as a summer crop, followed by fallow or a cover crop. It can be grown where sunflowers are grown.

Sometimes introducing amaranth into a rotation has had mixed results. One farmer in Iowa reported that corn yields decreased by 31 bushels/acre (35 kg/ha) after amaranth compared with corn after soybean, a difference not accounted for by nitrogen levels. However, bringing amaranth into the rotation increased yields over continuous corn: the following year, corn after corn yielded less than corn after amaranth. Soybeans after amaranth yielded the same as soybeans after corn.

Rotation studies using amaranth were done in Missouri between 1990-1994. Researchers concluded:

1. Amaranth didn't have an allelopathic (toxic) effect on crops planted after it;
2. Amaranth crop residue did not present a problem for planting and stand establishment of the following crop;
3. Residue levels after a winter of decomposing were greater than with soybeans but less than with corn;
4. There did not seem to be insect or disease buildups in continuous amaranth over a four-year period.

Amaranth would grow equally well after soybeans, wheat, or canola; stand establishment can be a problem for amaranth after corn in minimum-till situations.

Strip Cropping and Intercropping

On-farm research in central Iowa looked at three-crop and four-crop strips, with the four-crop strips set up as four rows each of four crops in this order: corn (after amaranth), amaranth (after soybeans), soybeans (after oats), and oats underseeded with red clover (after corn). According to the cooperating farmer, Tom Frantzen, "Four-crop strips were more productive than the three-crop strips and worked better, especially as far as the beans go, because the amaranth got along well next to the corn and the amaranth and soybeans got along well. Those four-crop strips are very compatible." Frantzen encountered common stalk borer problems after a few years of this rotation in a no-till environment *(see Chapter 1 section on no-till)*.

Amaranth in an intercropping system was researched in central Missouri for two years. Amaranth was intercropped with the edible legume cowpea in a modification of an African planting design that intercrops cowpea with pearl millet. Amaranth was planted in alternating rows with cowpea 15 inches (38 cm) apart; in alternating two-row strips 30 inches (76 cm) apart; and in six-row strips 30 inches (76 cm) apart. Three nitrogen fertilizer rates were applied to examine nitrogen dynamics. When no nitrogen was applied, amaranth yields were higher in alternating rows with cowpeas than when grown in a solid amaranth stand, indicating that the cowpea could provide a nitrogen source for the amaranth. The study concluded that amaranth and cowpea can be effectively intercropped.

Double Cropping

Double cropping involves producing two crops in the same crop year. To explore the potential of amaranth as a double crop in Missouri, a study was done in which plots at three locations were fall-planted to canola, wheat, or left fallow as a control. These winter crops were harvested in mid- to late June and followed by amaranth, buckwheat, pearl millet, sunflower, and soybean planted as a double crop. In two of the four years of the study, amaranth after fallow yielded better than amaranth after wheat or canola; however, in two of the four site-years, amaranth yielded 1070 pounds/acre (1198 kg/ha) or better after wheat or canola. Amaranth after wheat and after canola yielded the same

though stand establishment was easier in canola than in wheat residue. Though sunflower was the highest yielding double crop in this study, an amaranth double crop would have made the greatest profit.

Cover Crops

The many benefits of growing a cover crop include protecting soil from erosion, reducing weed pressure, maintaining soil organic matter, and providing nitrogen in the case of legume cover crops. Research was done in Missouri on the effects of cover crops on the subsequent amaranth crop. Austrian winter pea, crimson clover, hairy vetch, and rye were planted as cover crops with control plots left fallow. Pea and fallow plots were further split into tilled and no-till treatments. Cover crops were sprayed with paraquat then mowed before amaranth was planted in early June. Austrian winter pea boosted amaranth yields an average of double the unfertilized control plots, about 1070 pounds/acre (1198 kg/ha) compared with 536 pounds/acre (600 kg/ha). Amaranth after pea and hairy vetch was taller and more vigorous than amaranth after rye or fallow plots. On the flip side, lodging increased in plots following pea. Rye reduced amaranth vigor compared to control plots which was only partially offset by the addition of nitrogen fertilizer, confirming rye's allelopathic effect on amaranth and its pigweed relatives. Researchers were surprised to find that amaranth after rye had much greater plant populations later in the season than amaranth after legumes or fallow. They speculate that reduced vigor caused by rye also impaired the normal self-competition that characteristically thins amaranth stands. No-till establishment went well when amaranth was planted into cover crop residue that had been burned down with herbicide and then mowed.

Organic Production

Because much of the United States market for amaranth is in the health food industry, there is a market for organic amaranth. Consumers interested in the high protein content of amaranth and its colorful Native American history often have an interest in eating high-quality organically produced food. The same cautions apply to organic amaranth as for conventional amaranth: thoroughly research your markets before making a large investment in amaranth production.

General guidelines for organic production are that no synthetic chemicals may be applied to the ground for three years prior to it being certified as organic, and an active soil-building plan must be in place on the farm. Currently, the USDA is working on a national standard of organic production which must be followed for a farmer to legally use the term "organic" in marketing a crop.

For current information, see the section on fertility in *Chapter 1* for a brief description of organic fertilization practices. For further information, contact an organic certifying organization or your county extension office.

Amaranth as a Forage

Though seldom grown and little researched as a forage in the United States, this may be the largest role amaranth plays on a global level. The main use of amaranth in China is as a forage for pigs. Over 128,000 acres (52000 ha) reportedly were grown as forage in China in 1992 and double this acreage was grown in the former Soviet Union. Much of the published research on amaranth as forage has been done in China and Mexico.

Amaranth forage is fed as hay or silage. University of Minnesota research showed that amaranth forage harvested at the bud stage had 14-18 percent protein, 30-40 percent acid detergent fiber, and 43-53 percent neutral detergent fiber. At maturity, protein was 11-13 percent, acid detergent fiber was 38-45 percent, and neutral detergent fiber was in the upper 40s to lower 50s. Dry matter yields ranged from one-and-one-quarter to five tons per acre. Amaranth, like alfalfa, may be cut more than once in a season. Lambs were raised successfully on pelletized amaranth as the sole forage and found it palatable.

Some literature warns that nitrate accumulation can be a problem for amaranth grown under particularly droughty and stressful situations, so nitrate content should be closely monitored if amaranth will be used as a forage.

Chinese researchers substituted 10 percent amaranth meal for the following components of hog rations: 4 percent of corn meal, 3 percent of wheat bran, and 3 percent of soybean and oil seed cakes. Lean pigs raised to 44-132 pounds (20-60 kg) on this diet reduced 12.7 percent of their total feed intake and increased daily weight gain by 13 percent. For this study, amaranth was harvested when the seeds in the center of the panicle were ripe and the leaves were still green. They found that the amino acid balance in fresh amaranth balances the amino acid complement of pigs' rations.

In China, grain yields were 2000-2700 pounds/acre (2250-3000 kg/ha) and fresh green leaf and stem yields were 26800-40000 pounds/acre (30000-45000 kg/ha). Amaranth was successfully fed to chickens, cows, sheep, ducks, rabbits, martens, fish, and shrimp in Chinese studies.

Chapter 5
Industrial Uses and Marketing[4]

Overview
by Robert L. Myers

Market demand for amaranth has fluctuated over the last decade, but there has been steady use of the crop for breakfast cereals, snack foods, and mass-produced multigrain bread products *(Figure 8)*. Most typically, amaranth products are sold in the health food sections of grocery stores, in specialty food stores, or through direct marketing. Amaranth to date has only appeared in "mainstream" products when used as a minor component of multigrain foods.

Amaranth's development in the United States has benefitted from the formation of private companies that have focused exclusively or in part on amaranth products and have done much of the work to build public awareness of the crop. The Amaranth Institute, a small, non-profit organization of scientists, growers, and agribusiness, also has supported development of the crop through information exchange, promotional activities, and annual meetings.

Although the United States has been the leading producer of grain amaranth used in retail food products, the largest production acreage in the last decade is believed to have been in China where the main use is reportedly as forage for hogs.

Although grain amaranth has a variety of potential uses, its only commercial market in the United States has been for food products. A few small companies have been the primary buyers and processors of amaranth, including Arrowhead Mills (Texas), Health Valley (California), and American Resources (Minnesota). These companies sell amaranth both in processed foods, such as cereals, breakfast bars, crackers, and cookies, and also as amaranth flour and whole grain. In the early 1990s, large food processors began buying amaranth for use in multigrain products such as sandwich breads and cereals. Although this trend has led to a broader use of amaranth, market demand has not risen dramatically due to the small amount used.

J. Sooby

Figure 8. Cereals are some of the most popular health foods in the United States containing amaranth grain.

The small but gradually growing market for amaranth as a food grain is based on its nutritional characteristics, and to some extent, on its historical interest as the "lost crop of the 'mystic' Aztecs." The nutritional characteristics are positive, with protein content ranging from 14 to 16 percent and a well-balanced amino acid profile including a relatively high amount of lysine. Amaranth is also high in fiber and low in saturated fat. The grain can be popped or flaked and works well in mixes with flours of other grains, including for extrusion processing.

Amaranth, like most grains, has potential for use in industrial products. The oil fraction of the grain is unusually high in squalene, a chemical that sells for tens of thousands of dollars per ton. However, the percent of squalene in the grain is still small and may not be economical to extract.

Greater promise lies within the starch fraction of the grain. Like quinoa, amaranth has very small, microcrystalline starch granules, about one-tenth the diameter of corn starch. The physical characteristics of the starch grains have been cited as being of potential value for both industrial and food product uses, though none have been commercialized to date.

Markets remain relatively small and undeveloped, in part because there is a general lack of familiarity

[4]Chapter 5 contains portions of the following paper, and permission to reprint it is gratefully acknowledged: R.L. Myers, 1996. Amaranth: New Crop Opportunity. *In* Janick, J., ed. Progress in new crops. Proc. third national symposium on new crops, Oct. 22-25, 1995. Alexandria, VA: ASHS Press. pp. 207-220.

with amaranth in the public and private sectors. To achieve a higher level of market penetration, amaranth will have to become more publicized, prices will have to fall (although a premium could still be commanded), and availability will have to increase. Distance to buyers is a problem for many current amaranth growers. Specialized products such as the starches or other seed components could lead to increased marketing opportunities.

Marketing Strategies

Even farmers who have been growing amaranth for many years need to work hard to find a market for their grain. The price tends to move up and down depending on availability on the world market. In 1997, for instance, an influx of certified organic amaranth from Peru on the world market reduced demand for American amaranth in Europe, usually a significant market for organic amaranth.

Seasoned farmers who market amaranth suggest that new growers contact a grain broker or trader and let them know how much amaranth grain will be available and the price that's expected. Also contact some of the health food companies that use amaranth and find out if they will forward contract for a crop. Be aware that they have high quality standards and will expect to receive only the highest quality grain.

Be cautious when selling amaranth grain and get any contract to purchase in writing. Unfortunately, one of the hardest things for farmers in selling amaranth is getting paid for grain that they have shipped, so be careful and make sure the person you are dealing with has a legitimate business.

Another approach to marketing amaranth is to develop and sell a value-added product that uses amaranth. Fermented amaranth grain is used as a coloring and flavoring agent in soy sauce in China. Amaranth also has been used as a thickening agent in barbecue sauce and as a popped ingredient in confections. Remember that product development creates a whole set of regulations to deal with in processing, packaging, etc.

Quality Concerns

Because amaranth contains more oil than other cereal crops, rancidity can be a problem. Make sure grain is dried and cleaned at harvest and stored where it's inaccessible to rodents and has adequate air circulation to keep it dry.

Mold is another potential spoiler of amaranth grain. Food companies check amaranth for many organisms including yeasts, molds, *Salmonella*, and *E. coli*. Harvest, cleaning, and storage practices on the farm have a direct impact on the quality of the grain and presence of these organisms.

Appendix 1.

Sources of Information on Amaranth

Compiled by David Brenner.

Books

"Cornucopia: a Source Book of Edible Plants," by Stephen Facciola. Kampong Publications, 1870 Sunrise Dr., Vista, California, 92084. (This book has an excellent list of sources for 47 kinds of *Amaranthus*.)

"Andersen Horticultural Library's Source List of Plants and Seeds," available from: Anderson Horticultural Library, Minnesota Landscape Arboretum, 3675 Arboretum Drive, Box 39, Chanhassen, Minnesota, 55317-0039. (This book lists sources for 36 kinds of *Amaranthus*.)

Production Information

Amaranth Institute
c/o Jim Lehmann
Box 216
Bricelyn, Minn. 56014
The Amaranth Institute annual membership dues are $10.

David Baltensperger
Panhandle Research and Extension Center
4502 Ave. I, Scottsbluff, Nebr. 69361
Phone: 308-632-1261
e-mail: agri037@unlvm.unl.edu

Robert Myers
The Jefferson Institute
601 W. Nifong Blvd., Ste. 5A
Columbia, Mo. 65203
Phone: 573-449-3518

Appendix 2

Sources of Amaranth Seed and Marketing Information

Compiled by David Brenner and David Baltensperger.

The amaranth grain available in health food stores will generally perform well as seed.

Albert Lea Seed House, Tom Ehrhardt, P.O. Box 127, Albert Lea, Minn. 56007, phone 800-352-5247. Amaranth buyer and processor. Amaranth sold as grain for processing.

Cheyenne Gap Amaranth, 19385 Hwy. 18, Luray, Kan. 67649-9217, phone 785-698-2457. Offers six commercial production cultivars and fifteen experimental cultivars

Ecology Action, 5798 Ridgewood Road, Willits, Calif. 95490. Carries *Amaranthus* cv. Love-Lies-Bleeding (ornamental).

V&J Seed Farms, Inc., P.O. Box 82, Woodstock, Ill. 60098, phone 815-338-4029. *Amaranthus* weed species.

Garuda International, Inc., P.O. Box 5155, Santa Cruz, Calif. 95063, phone 831-462-6341, fax 831-462-6355. Amaranth grain buyer for export.

Golden Organics, David Rickard, 1111 Washington Ave., Suite 110, Golden, Colo. 80401 phone 303-273-5942, fax 303-278-6746. Broker for large amaranth grain lots.

J. L. Hudson, seedsman, P.O. Box 10858, Redwood City, Calif. 94064. *Amaranthus* cv. Love-Lies-Bleeding (ornamental).

Johnny's Selected Seeds, Foss Hill Road, Albion, Maine 04910-9731, phone 207-437-4301. Love-Lies-Bleeding (ornamental).

Native Seeds/Search, 2509 N. Campbell Ave. #325, Tucson, Ariz. 85719, fax 520-327-5821. *Amaranthus* cv. Hopi Red Dye (ornamental).

Nebraska Crop Improvement Association, 267 Plant Sciences Hall, Lincoln, Nebr. 68583-0911, phone 402-472-1444. Sells cv. 'Plainsman' foundation seed for certified seed production.

Nu-World Amaranth, Inc., P.O. Box 2202, Naperville, Ill. 60567, phone 630-369-6819, fax 630-369-6851. Amaranth food products, seeds, and grain.

Salt Spring Seeds, Box 33, Ganges, B.C., BC VOS 1EO, Canada. *Amaranthus* cv's. MT-3, R-158, and K432 (grain).

Seeds of Change, P.O. Box 15700, Santa Fe, NM 87506-5700, phone 1-505-438-8080, fax 505-438-7052. *Amaranthus* cv's. Elephant Head (ornamental with a determinate inflorescence) and Love-Lies-Bleeding.

Southern Exposure Seed Exchange, P.O. Box 170, Earlysville, Va. 22936, phone 804-973-4703, fax 804-973-8717. *Amaranthus* cv. K432 (grain), *A. cruentus*, golden amaranth, and others.

The following growers sell seed of *Amaranthus* cv. Plainsman (K343):

Kenneth Disney, Lodgepole, Nebr., 308-483-5673.
Calvin Oliverius, Albin, Wyo., 307-246-3270.
Sanders Farms, Inc., Dalton, Nebr., 308-377-2231.

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Amaranth is a small-seeded grain crop with a dramatic history. Once a staple in the diet of the Aztec Indians, today it is grown throughout the world. In the United States much of the production is small-scale and organic, grown mainly for the natural and health food markets. There also has been steady use of the crop for breakfast cereals, snack foods, and mass-produced multigrain bread products. Amaranth is a broadleaf plant well-adapted to a range of arid and humid environments. As a crop it fits into many dryland rotations, performing well following wheat, proso millet, or other grain crops. This manual draws on farm expertise and up-to-date research for information on growing and marketing amaranth.