AMARANTH:
GRAIN & VEGETABLE TYPES

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INTRODUCTION

Amaranth [*Amaranthus hypochondriacus, A. cruentus* (Grain) & *A. tricolor* (Vegetable)] is a plant with an upright growth habit, cultivated for both its seeds which are used as a grain and its leaves which are used as a vegetable. Both the leaves and seeds contain protein of an unusually high quality. The grain is milled for flour or popped like popcorn. The leaves of both the grain and vegetable types may be eaten raw or cooked. The amaranths that are grown principally for vegetable use have better tasting leaves then the grain types.

Amaranth has been cultivated for more than 8,000 years, dating back at least to the Mayan civilization of South and Central America. It was a staple of the Aztecs and was incorporated into their religious ceremonies. In 1516 the conquistadors prohibited the growing of amaranth. In that area today only a limited amount of grain is grown, most of which is popped and mixed with honey to make "alegria" candy. However, much of the genetic base has been maintained because amaranth has continued growing in the area as a weed.

Amaranth is considered native to South and Central America, but over 400 varieties are found throughout the world in both temperate and tropical climates. Vegetable amaranth has been used in China for 400 years, and is commonly found in the Caribbean and Africa.

Amaranths are moderately branched from a main stem. Grain types form large loose panicles at the tips of the stems. Vegetable types form flowers and seeds along the stems. They are indeterminate in growth habit, but may set seed at a smaller size during short days. Grain amaranth grown in winter at ECHO (southern Florida) began flowering at less than half of the height of amaranth growing in May. Grain types may grow 1 to 2 meters tall and produce yields comparable to rice or maize. Amaranth has the "C-4" photosynthetic pathway (along with such plants as corn and sorghum), which enables it to be uniquely efficient in utilizing sunlight and nutrients at high temperatures. It is more drought-resistant than corn.

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NUTRITIONAL VALUE

As can be seen in Table I, amaranth is quite nutritious. Amounts of vitamin C, iron, carotene, calcium, folic acid and protein are especially high. There are reports that the incidence of blindness in children due to poor nutrition has been reduced with the use of 50 to 100 g of amaranth leaves per day. On a dry weight basis, the content of protein in leaves is approximately 30%.

TABLE I. The proximate composition of grain and raw leaves of amaranth (100 g portions).

Component	Vegetable	Grain
Moisture	86.9 g	9.0 g
Protein	3.5 g	15.0 g
Fat	0.5 g	7.0 g
Total carbohydrates	6.5 g	63.0 g
Fiber	1.3 g	2.9 g
Calories	36	391
Phosphorus	67 mg	477 mg
Iron	3.9 mg	--
Potassium	411 mg	--
Vitamin A	6100 i.u.	0
Riboflavin	0.16 mg	0.32 mg
Niacin	1.4 mg	1.0 mg
Ascorbic acid (C)	80 mg	3.0 mg
Thiamin (B_1)	0.08 mg	0.14 mg
Ash	2.6 g	2.6 g
Calcium	267 mg	490 mg

Compiled from J.N. Cole, *Amaranth: from the Past, for the Future*, Rodale Press, Emmaus, PA (1979)

The presence of rather high amounts of oxalic acid and nitrates places some limitation on the quantity of amaranth leaves that can be consumed daily. The amount of oxalic acid is roughly the same as that found in spinach and chard. Excessive amounts (over 100 g per day?) may result in a level of oxalic acid that begins to reduce the availability of calcium in humans. This is especially a concern if calcium intake levels are low to begin with. Nitrate in vegetable portions of amaranth is a concern because it is hypothesized that nitrates may be chemically changed in our digestive tracts into poisonous nitrosamines. Evidence for this is lacking at the present time. Nevertheless, over 100 g per day may be an unsafe amount to eat, according to scientists. Boiling the leaves like spinach, then discarding the water reduces the levels of both oxalic acid and nitrates.

Amaranth grain has more protein than corn, for example, and the protein is of an unusually high quality. The protein is high in the amino acid lysine, which is the limiting amino acid in cereals like maize, wheat and rice. The protein is also relatively rich in the sulfur-containing amino acids, which are normally limiting in the pulse crops (e.g. beans). The "protein complement" of amaranth grain is very near to the levels recommended by FAO/WHO. It has a protein score of 67 to 87. Protein scores are determined by taking the ratio of the essential amino acids to the level for those amino acids recommended by FAO/WHO, and multiplying by 100. By comparison, wheat (14% protein) scores 47, soybeans (37%) score 68-89, rice (7%) scores 69, maize (9%) scores 35. Although amaranth is

theoretically close to the ideal, combining it with another grain increases the quality to very close to the FAO/WHO standards.

Weight gain studies with rats point out, however, that the actual nutritional value is considerably less than would be expected from the above considerations. This is apparently due to certain anti-nutritional factors in raw amaranth. Performance is improved somewhat by cooking. For example, Dr. Peter Cheeke at the University of Oregon compared the rate of weight gain by 120 gram rats fed a corn-soybean diet to rats fed a diet of corn and seed from *A. hypochondriacus*, either raw or cooked. The average daily gain for rats on the corn-soybean diet during the first 20 days was 3.9 grams. Rats fed the corn-amaranth diet gained only 0.3 grams per day. The average daily gain for rats fed corn and cooked amaranth was 1.6 grams. Raw amaranth seed is extremely unpalatable to rats (i.e. they will not eat it readily). Cooked seed also does not seem to be very palatable, though it smelled good to Dr. Cheeke. In another study, Dr. Cheeke found that after 11 days on a corn-amaranth diet, rats (which weighed 120 g initially) "had an unthrifty hunched-up appearance, and exhibited symptoms typical of semi-starvation".

We phoned Dr. Cheeke to get his perspective on the seriousness of these negative results. He told us that there are definitely toxins and/or anti-nutritional factors in the raw grain, and that it is less of a problem with cooked grain. He said that a scientist in Australia had been feeding raw amaranth seed to poultry as the major component of the diet. He found that chickens went into spasms, convulsions, and finally died. This unidentified factor causes liver damage. Other problems are caused by saponins, including unpalatability. But to keep this in perspective, Dr. Cheeke pointed out that there are few raw foodstuffs that do not have problems. Raw soybeans contain 10 kinds of toxins. Raw kidney beans will kill rats, but cooking eliminates the problem. The key seems to be to use the grain in moderate amounts, and to cook it. We asked whether we could say that there would be no problem unless people had little other than amaranth to eat. He thought that this was probably a fair statement. It is our opinion that more research needs to be done before we can recommend amaranth grain as a major ingredient in animal feed. To our knowledge it has not been shown whether these factors decrease the value of amaranth in human nutrition. Until more work is done, however, the feeding trial results must moderate our otherwise enthusiastic promotion of grain amaranth.

CULTIVATION

VEGETABLE TYPES

There appears to be considerable latitude in choice of plant densities. One approach is to plant dense stands (5-10 cm spacing), and harvest by uprooting when the plants are 5-7 weeks old. Another common approach is to sow less densely (15-30 cm spacing), and harvest by cutting the stem tips and plucking tender leaves periodically beginning when the plants are about 15 cm tall (4-6 weeks old).

Seeds may be planted in a nursery for subsequent transplanting or sown directly where plants are to be grown. Transplanting is a very efficient use of seeds, and allows the growing area to be weeded just before the seedlings are transplanted. The very small size of the seeds, however, means that a few seeds go a long way. The number of seeds saved is probably not a sufficient justification for the extra work involved in transplanting. On the other hand, gaining a two-week jump on the weeds can be significant because amaranth seedlings are not vigorous growers when very young. Planting in a nursery also reduces risk of loss due to disease such as damping off.

Direct seeding involves much less labor, but incurs a greater risk of poor stand due to diseases and predators of young seedlings and to poor competition with weeds in the crucial initial couple of weeks. If direct seeding is used, sowing should probably be in rows to facilitate cultivation.

Whether sown in the nursery or field, seeds need to be planted about 4 mm deep (or covered with 4 mm of soil) for good germination. Because of the shallow depth, special care must be taken to prevent drying out of the soil until

plants are established. Transplanting or thinning may be done in about two weeks when plants should be 5-10 cm tall. Delay in transplanting for even one week can reduce total yield.

When harvesting by repeated clippings, a two- or three-week interval is common through the end of the season (usually the shortened days of fall). Both the yield and quality of leaves are higher with more frequent clippings.

When the vegetative stage ends and flowering begins, subsequent harvests are lower in both quality and quantity. Short days, water stress or other environmental stresses may promote flowering. The stress that comes with delayed transplanting also can cause the plants to flower more quickly. It is reported that plucking flower heads from the plant may prolong the vegetative phase of growth.

Amaranth is generally considered tolerant of nematodes and is even recommended as a rotation crop to reduce nematode populations for subsequent crops. However, one article reports the presence of root knot nematodes on amaranth roots. Control of nematodes is such a serious problem that it is important to know whether or not amaranth can be used to control them and/or whether it can be planted where nematodes are a problem. We will include this question in our list of research projects that could be done at Christian colleges. It is possible that the discrepancy in reported results is because varieties differ in their susceptibility to nematodes.

Amaranth is susceptible to damping-off disease, root rot, and caterpillars and stem borers. It thrives in 30-35^{o} C temperatures. It tolerates poor fertility and drought. However, plant quality is poor under stressful conditions. There is good response to fertilizer.

GRAIN TYPES

Recommendations for plant spacing vary widely for grain amaranth. One recommendation is to space 23 cm between plants and 75 cm between rows. This corresponds to a planting density of 38,000 plants per hectare (15,400 per acre). Seeding rates up to nine times this density have been used successfully! It would seem that if harvesting is to be done by hand the less dense spacings are advisable. This results in fewer but larger heads that can be harvested more quickly. Closer plant spacing may be advisable for mechanical harvesting.

The decision as to whether to transplant or direct seed is subject to the same considerations that were discussed for vegetable amaranth. Cultivation is essential until plants have reached a size where the leaf canopy can shade out weeds. After the plants are about 30 cm tall, it is helpful to mound soil from the centers of the rows up around the plants. This helps to reduce lodging (plants blowing over in the wind), suffocates weeds around the plant, and uproots weeds between rows.

Grain amaranth is grown from tropical lowlands to 3500 m in the Himalayas. In the tropics, altitudes above 1000 m are considered best. Although it tolerates droughts and low fertility, it does much better under conditions that are considered ideal for maize (corn). It may be intercropped with maize, beans, peppers or squash. In some pure stands it has yielded as well as the world average yields for maize or rice (2000 kg/ha). Loss of the tiny seeds by shattering before or during harvest can be a problem, especially with mechanical harvesting. (There are approximately 1100 seeds per gram of amaranth.)

The seeds are mature when they can be easily separated from the heads upon rubbing between the hands. Seeds can be chewed to test whether they have passed beyond the "dough stage". Heads should be cut from the stalk and side branches as soon as possible after they have reached maturity. Heads should be dried if necessary, keeping green plant parts to a minimum. Once dry, the seeds are knocked from the heads, sifted through an ordinary window screen, and winnowed to remove chaff. Although three or four farmers are planting small (around 10 acre) plots in the USA, as of this writing (1982), there appear to remain serious problems with mechanical

harvesting. Primary among these problems are the tendency for plants to lodge, and the loss of grain during harvesting.

Grain should be dried to about 9% moisture for safe storage. It is reported that grain remains viable for up to seven years. We left heads stacked in a building for 5 summer months (high humidity and temperatures in the 90's). Viability still appears to be high.

HARVEST

Basically, you must thrash it like mankind has always done until the invention of the thrashing machine. The three stages include let the heads dry out, knock the grain from the heads, and winnow the grain. Many of you live where local folks know far more than I about such techniques. For others, here is what we do with small quantities of seed (which must be kept separate from other varieties).

Cut the heads when the grain appears to be mature, and put them somewhere to dry. If left too long much of the grain may shatter (fall to the ground).

Grain easily shatters from the dried heads. Put a few heads in a burlap bag and beat it against the cement floor a few times to knock it loose, or strike the bags with a stick. Then place the grain in a 5-gallon bucket (many other containers would be suitable). You will notice that a lot of chaff comes along with the grain. This is where winnowing comes in.

Place an empty 5-gallon bucket in front of a fan and, cautiously at first, pour some grain and chaff into the empty bucket. A steady wind will accomplish the same thing as the fan, but a gusty wind will cause problems. The grain is denser and will fall closer to the fan than the chaff. Quickly one begins to get a feel for how far the buckets should be from the fan, and at what height to hold the one bucket in order for the grain to land in the empty bucket and the chaff to blow far enough to miss it. Pour the grain back and forth until it appears to be clean.

Final cleanup can be done by swirling and shaking the grain around gently. Remaining chaff will "float" to the top like ice in water, and can be removed by hand.

PREPARATION

Vegetable amaranth leaves and stems or entire plants may be eaten raw or cooked as spinach. As discussed earlier, however, cooking and discarding the water will remove potentially harmful oxalates and nitrates.

The seeds from grain amaranth can be ground for use as a good quality flour for breads or pastries. It must be combined with wheat flour for a yeast dough. The Organic Farming and Research Center (Rodale) has used a 50:50 ratio successfully, but they suggest that the percent of amaranth could be even greater if desired. They state that "amaranth flour contributes to the sweetness and moistness of a baked good".

Alternatively, seeds can be popped like popcorn. The people at Rodale say that popped amaranth can be used: in confections bound with sorghum, molasses or honey; in high-energy granola and granola bars; in cheese spreads; to flavor salad dressings; in breading for chicken and fish; in crackers, pie crusts and breads; and as toppings for casseroles and desserts.

Several recipes can be found in the book *Amaranth: from the Past, for the Future* by Rodale Press.

OTHER READING MATERIAL

We found the research results published in *Proceedings of the Second Amaranth Conference* to be especially helpful. It is available from Rodale Press, Emmaus, PA 18049 for $15.00. For those interested in larger-scale production, *Amaranth Grain Production Guide 1982* would be helpful. As far as we know there is no charge. Order it from Rodale Press. Rodale has other material that would be helpful if you wish to pursue the subject in depth.