LEGACY

The Official Newsletter of the Amaranth Institute

Volume VI **1993** No. 1

1993 AMARANTH MEETING TO BE IN AMES, IOWA, AUGUST 19-20

The 1993 annual meeting of the Amaranth Institute has been scheduled for Friday, August 20. A tour of the Plant Introduction Station plots will be held the previous evening, Thursday. The Friday meeting will be held on the Iowa State campus, in Ames, IA.

The meeting this year will take a somewhat different approach in that there will be few, if any research presentations. During the morning of August 20, the format will be a workshop to systematically review what has been learned by producers and researchers about amaranth production. The outcome of this morning workshop will be a revision of the Amaranth Production Guide, last updated in 1990. During the afternoon session, the emphasis will shift to utilization and marketing, with some presentations from invited speakers. The tour was shifted to Thursday evening instead of Saturday morning to allow participants to make their trips a one-night instead of a two-night stay.

Announcements of the meeting and registration forms will be sent out this spring to the Legacy mailing list and others interested in amaranth. Registration will cost $10 for students and $25 for others. Contact Rob Myers, University of Missouri, for more information (314-882-0317).

IN THIS ISSUE:

From the Amaranth Institute President
by Robert Myers p. 2-4

Amaranth in Rotations
by Tom Frantzen p. 4-5

Tissue Culture for Amaranth Crop Improvement
by Taraknath Chakravarty p. 5-7

Hybrid Seeds for Increased Amaranth Grain Yield
by David Brenner p. 9-11

Planting Black Seeds
by David Brenner p. 11

© 1993 Amaranth Institute
ISSN 1056-1196

FROM THE AMARANTH INSTITUTE PRESIDENT

Dr. Robert Myers
Assistant Professor of Agronomy
University of Missouri
Alternative Crops Project

University of Missouri, Agronomy Department, 210 Waters Hall, Columbia, MO, 65211, phone 314-882-0317.

As the 1992-93 President of the Amaranth Institute, I've been asked to share a personal perspective on amaranth for this issue of Legacy. I'll start by relating how my interest in amaranth developed, and then focus on some of the current challenges we face in developing the amaranth industry and conducting research on the crop.

Having grown up on a very traditional corn and soybean farm in central Illinois, and having gone through some rather typical undergraduate courses covering mainstream agriculture, I never really gave much thought to alternative crops until I reached graduate school. Within a few weeks of my start in the agronomy graduate program at University of Minnesota (summer, 1983), I found myself on a tour of Dr. Bob Robinson's alternative crop plots, as part of an orientation course for new graduate students. It was a time of year (late July or early August) when most of the crops were growing vigorously, and I was really struck by the potential for using some of these crops to diversify agricultural systems. However, at that time, and for the next two years, my research interests were focused on the soybean physiology project which I was an assistant on. Bob Robinson retired in the meantime, and I didn't hear much more about alternative crops until Dr. Dan Putnam arrived to take over the alternative crops project at Minnesota. I gradually got acquainted with Dan, and somehow, whether through an article I read or comments Dan made, I became interested in amaranth as an alternate crop. In the summer of 1987, I remember visiting some of Dan's amaranth plots, since they were near the corn research plots I was working on for my Ph.D.

I do clearly remember the event that cemented my interest in amaranth. In late August or early September of 1987, Dan invited me to accompany him to a farm in southern Minnesota which was raising amaranth. The grower, who turned out to be Ed Hubbard, was holding a tour of his amaranth fields. It was a bright sunny day, and the crimson amaranth fields were blazing with color. The amaranth plants were quite robust, and after listening to comments by Mr. Hubbard and others present at the tour, I became convinced that amaranth really did have unfulfilled potential.

Sometime after returning to campus, Dan and I agreed to coauthor a short University extension publication on amaranth. The background research I did for that article pointed out to me, as many others have realized, just how little has really been done to develop amaranth as a modern crop.

Not long after finishing the amaranth guide in the winter of 1988, I completed my Ph.D. and left for a year and a half in Washington, where I worked on a number of ag policy issues for the U.S. House of Representatives Committee on Agriculture. One of my first tasks as a legislative staffer was to work on some legislation on alternative crops and products that was being moved through the Senate and House. The focus of those measures was really on commercializing new agricultural products, with only brief references to the fact those could come from either traditional or non-traditional crops. The legislative proposals finally passed as part of the 1990 Farm Bill, and are now implemented in the form of the Alternative Agricultural Research and Commercialization Center, operated by USDA.

Unfortunately, the chances for funding work related to amaranth through the AARC center do not appear very good at this point in time.

This work with policy related to alternative crops and products kept me thinking about amaranth and other alternative crops. More than once, I found myself explaining the idea of alternative crops to senior legislative staff on the House and Senate Agriculture Committees (keep in mind most of these staff have no agricultural training or background). Among the options I had following my stay in Washington was the chance to go to University of Missouri to start a new research project on alternative crops, which I chose to do in the fall of 1989.

Even before I arrived in Missouri, I knew that amaranth would be one of the alternative crops I would initially focus on (the others being canola and crambe — we have now deemphasized crambe and added sesame and pearl millet to our set of "core" crops). Early field tests proved that amaranth was adaptable to Missouri conditions, as it is to many areas, and so we expanded our work with it. It is now the primary crop I and my assistants work with. We planted close to 20 research fields of amaranth in 1992, representing 12 different production studies that included amaranth.

Given the focus that we have developed on amaranth at University of Missouri over the past few years, I have been led to reflect frequently on the dynamics that could help amaranth get out of the holding pattern it currently seems to be in (in terms of acreage and market size). Although my research has really been on reducing the risk and improving the efficiency of growing amaranth, I have been fully aware that markets are the constraining factor in more widespread adoption of amaranth. Thus, I have encouraged other University of Missouri researchers to begin utilization studies on amaranth that could lead to increased interest in using amaranth in food, feed, or industrial products. Fortunately, North Dakota State University and others have increased their work on amaranth utilization, so overall the chance of identifying more selling points for amaranth has improved.

Last week, I had the chance to talk at length with some mid-management individuals from Ralston Purina, who were visiting the University of Missouri to discuss the use of new food ingredients that University researchers were working on (Ralston Purina is one of the major national manufacturers of breakfast cereals, pet foods, and other cereal grain based products). After asking them many questions about the possibility of using amaranth in one or more of their products, it became clear they felt three criteria needed to be met. (1) There has to be a sufficient supply immediately available at the time the company is ready to use it, an amount they defined as a half million to million pounds of amaranth for a product test run in regional market (it appears such a supply is currently available stockpiled in the U.S.). (2) There needs to be a much lower price than they were currently being asked to pay, which they quoted at $0.80 to $1.00 per pound depending on supplier — they indicated they were willing to pay a premium over other food grains, but no more that $0.20 to $0.25 per pound (farmers and researchers I have talked to indicate this is a price that could still prove profitable in the long run). (3) They wanted to see clear indication of demand for the product. This last point is the hardest one for those of use involved in amaranth to overcome, because of the way Ralston Purina apparently defines demand. Although they were quite willing to acknowledge that amaranth had some desirable properties, such as high lysine, they felt there was no demand for such traits (for example, they said more lysine would not be a selling advantage in their products due to consumer ignorance of proteins and amino acids). The Ralston Purina representatives indicated that

their normal way to identify demand was to use a randomly selected group of consumers in focus group sessions, to see if a significant number would buy the product. As I think about the relatively small degree of name recognition canola has after massive advertising campaigns and numerous products on the shelf, I find it hard to believe that amaranth will achieve significant name recognition in the near future. Not only would a significant portion of these "consumers off the street" have to be familiar with amaranth, but they would actually have to want the product.

It would seem there are only two ways amaranth is going to make it into the major leagues of the ag and food industry. Either a high level executive at a major company is going to have to make a "leap of faith" decision about using amaranth in products, or new selling points are going to have to be developed. For example, one of the nutraceutical properties of amaranth being researched could prove to indeed be valuable, and achieve market recognition, in the way that oat fiber has, or the unique starches of amaranth could become in demand. The Ralston Purina representative pointed out to me that individuals at their company who had made a "leap of faith" on a product like amaranth in the past (in others words, a product was introduced with out clear indications of demand) were individuals who had usually been fired by the company. Given the conservative business culture of most of the major food and ag corporations, it will be difficult to find a corporate champion of amaranth.

This leads us back to utilization research. I think that the route with the highest probability of success lies here, although we should keep looking for a corporate champion and developing consumer interest. If the initial findings on starch properties and/or nutraceutical use are confirmed, it may be possible to make companies more interested. In the meantime, I hope I and other researchers, as well as producers, can continue to find ways of producing amaranth efficiently and in a reduced risk fashion, so that we are ready if the markets do open up. To some extent, success will be dependent on obtaining more funding for amaranth. Most of the university research with amaranth, to my knowledge, is done without any dedicated funding. At least three of the university scientists doing field research with amaranth have either stopped or will soon curtail their amaranth research. Thus, one of my goals as this year's president of the American Amaranth Institute is to seek out additional research funding at the national or international level for amaranth.

Although I have pointed to a number of challenges facing the crop, I remain optimistic about amaranth's chances, and like many of you, committed to bringing about renewed use of this ancient crop.

AMARANTH IN ROTATIONS

Tom Frantzen
1155 Jasper Ave.
New Hampton, IA 50659

Row crop agriculture in the central U.S. is dominated by corn and soybeans. The increasing incidence of extended diapause corn rootworms and soybean cyst nematode points to the dangers of growing such monocrops. To improve the cultural, biological, and economic diversity on my farm in northeast Iowa, I began growing grain amaranth in 1990. I've continued growing amaranth through the 1991 and 1992 seasons. No cultural problems were encountered while growing amaranth during these three seasons.

In 1991, I laid out a replicated plot to compare rotational effects of amaranth and soybeans on a following corn crop. Using ridge tillage methods, I planted a field that grew corn

in 1990 to 4 rows of soybeans and 4 rows of grain amaranth in alternating strips. This design allowed for side by side replicated comparison of rotational effects the following year.

In 1992, I planted this field of alternating amaranth/soybean strips to corn. Ridge tillage was used and all of the cropping variables were kept constant (variety, fertilizer, pest and weed control). Large differences were observed during the 1992 growing season.

Corn following grain amaranth emerged at the same time as corn following soybeans. When the corn reached the 6 leaf stage, severe color and growth effects were observed. Corn following amaranth was significantly shorter and showed severe discoloration. The leaves were very purple. At the 8" plant height stage (corn after soybeans), soil nitrate nitrogen levels were measured. Both rotations produced soil nitrate N readings of 35 ppm. Soil moisture readings were taken on July 3rd with help from Iowa State University Extension associate, Rick Exner. No difference in soil H_2O were found. Large growth differences continued through the 1992 growing season. At ear silk stage, leaf tissue samples were taken from each of the 6 replicated strips. Corn following amaranth had significantly higher Ca and Mg levels then corn following soybeans ($p < .05$). No other significant differences were observed in the leaf tissue levels. Nitrogen levels were adequate in all of the tissue tests. (Rick Exner, Practical Farmers of Iowa-Iowa State University Extension Associate '92)

Seven replicated pairs were compared for yield, grain moisture, and test weight at harvest. Corn following amaranth was significantly wetter ($p < .05$) by 5.7%, and yielded 31.0 bushels less per acre.

The rotational trial will be repeated in 1993. Plans call for another rotational study comparing soybean yields after amaranth vs. soybean yields after corn.

TISSUE CULTURE FOR AMARANTH CROP IMPROVEMENT

Taraknath Chakravarty. Plant Research Lab., School of Life Sciences, Jawaharlal Nehru University, NEW DELHI-110067. INDIA.

INTRODUCTION:

Amaranths are hardy, fast growing pseudocereals. They are one of many little known and under-exploited crops that show promise as a global resource. Amaranths supply nutritious grains as well as tasty leafy vegetables (Saunders and Becker, 1984). Amaranth leaves are good sources of vitamins, Ca^{2+}, Fe^{2+}, etc. Many amaranth species are prolific weeds, including *Amaranthus spinosus*, *A.hybridus*, and *A.retroflexus*. These weeds are important in view of desirable traits such as: rapid maturation, disease resistance, and adaptability, which might be genetically manipulated into the cultivated grain forms (Report from National Research Council, 1984). In India, *A. paniculatus* seeds, most commonly known as *rajgeera*, are consumed in the form of candies or boiled with rice. This plant has high oxalate/nitrate ratio in its leaves, which lowers palatability because of the chance of deposition of calcium oxalate crystals in human kidneys. Tissue culture work will be done to raise genetically engineered plants with foliage low in oxalate/nitrate content. This will help boost amaranths as a vegetable all over the world.

AMARANTH TISSUE CULTURE ACHIEVEMENTS AND THEIR POTENTIAL FOR CROP IMPROVEMENT:

Regeneration:

Amaranths are recalcitrant for resuming whole plant growth from tissue culture. Very little work has been done on the tissue culture of amaranths. Flores et al. (1982) studied in vitro growth and morphogenetic responses from leaf and hypocotyl explants of a number of *Amaranthus* species. Callus formed from leaf discs; and shoots were formed from hypocotyl segments (Flores and Teutonico, 1986). Bagga et al. (1987) achieved in vitro regeneration of plants from hypocotyl segments of *A. paniculatus*. Attempts to culture protoplasts have resulted in limited cell divisions (Flares and Teutonico, 1986). In *A. paniculatus*, direct root and shoot formation and embryo-like structures were regenerated from callus, through the manipulation of different hormones, on different media from 10-day old hypocotyl callus in our laboratory. NAA was used to promote root growth (Hertel et al. 1969). Callus tissues from *Sorghum bicolor* (Nadar, 1975) failed to differentiate into plantlets even though mature embryos were found to be present. This was because such callus had the ability to synthesize endogenous auxin and thus proliferated as non-morphogenic calli. A similar phenomena was observed in our study, where the embryos developed callus without regenerating plantlets. More work must be done before in vitro regeneration of amaranth plantlets is possible.

Our laboratory has reported (Arya et al. 1993) on morphogenesis in in vitro cultured immature inflorescence of *A. paniculatus*. This study was evaluated with particular reference to exogenous supply of growth regulators which caused morphogenetic responses (shoots and plantlets) depending on the concentrations of growth regulators used. It has been well demonstrated that morphogenetic expression in tissue cultures is the cumulative effect of subtle interactions and balances among growth regulating substances. These findings can be exploited to improve crop quality and productivity.

Flowering:

Although flowering in tissue culture has been observed in several plant species, its occurrence is little understood (Scorza, 1982). In vitro flowering can be used to either study specific aspects of flowering or the whole reproductive mechanism from explants either in the vegetative or reproductive states. Tisserat and Galletta (1988) induced in vitro flowering in amaranths. Their studies opened the possibilities of studying the mechanism responsible for the cessation of flowering in vitro. As we reported (Arya et al. 1993), in addition to the advantages of regenerating plantlets from inflorescences and getting flowers in vitro, the studies suggest a possibility of obtaining transformed transgenic plants which could be used in amaranth crop improvement programs.

FUTURE SUGGESTIONS:

Work remains to be done for amaranth crop improvement. Important genes could be microinjected into isolated protoplasts. Transformation of amaranths using *Agrobacterium* strains is another potent field for amaranth crop improvement. In this connection, it may be mentioned that one of the genes of seed storage protein from amaranths has been cloned by Raina and Datta (1992) in our institute and a gene from a basidiomycetous fungus *Collybia velutipes* for oxalate decarboxylase has also been cloned (Mehta and Datta, 1991) in our institute. This gene could

be transferred to amaranths to reduce oxalate content, so as to improve the palatability of the leaves.

ACKNOWLEDGEMENT:

I thank Prof. Sudhir K. Sopory, of the School of Life Sciences, Jawaharlal Nehru University, New Delhi, for his suggestions and comments during the preparation of this manuscript.

REFERENCES CITED:

Arya, I.D., T.N. Chakravarty and S.K. Sopory. 1993. Development of secondary inflorescence, vegetative structures and plantlets in in vitro inflorescence culture of *Amaranthus paniculatus*. Plant Cell Reports. (In Press).

Bagga, S., K. Venkateshwarulu and S.K. Sopory. 1987. In vitro regeneration of plants from hypocotyl segments of *Amaranthus paniculatus*. Plant Cell Reports 6: 183-184.

Flores, H.E., A. Thier and A.W. Galston. 1982. In vitro culture of grain and vegetable amaranths (*Amaranthus* spp.). Am. J. Bot. 69: 1049-1054.

Flores, H.E. and R.A. Teutonico. 1986. Amaranths (*Amaranthus* spp.): potential grain and vegetable crops. In: Biotechnology in agriculture and forestry (Bajaj, Y.P.S. ed.). Springer-Verlag Berlin, Heidelberg. vol. 2. Crops I. pp.568-578.

Hertel, R., M.L. Evans, A.C. Leopold and H.M. Sell. 1969. The specificity of the auxin transport system. Planta 85: 238-249.

Mehta, A. and A. Datta. 1991. Oxalate decarboxylase from *Collybia velutipes*, purification, characterization, and cDNA cloning. J. Biol. Chem. 266, 35: 23548-23553.

Nadar, H.M. 1975. Utilization of tissue culture techniques in *Sorghum*. Ph.D. Dissertation, University of Nebraska. Lincoln.

National Research Council. 1984. Amaranth: Modern prospects for an ancient crop. National Academy Press, Washington DC. pp.1-53.

Raina, A. and A. Datta. 1992. Molecular cloning of a gene encoding a seed specific protein with nutritionally balanced amino acid composition from *Amaranthus*. PNAS (USA). 89:11774-11778.

Saunders, R.M. and R. Becker. 1984. *Amaranthus*: a potential food and feed resource. In: Advances in Cereal Science and Technology. (Y. Pomeranz, ed.), St. Paul, MN. American . Association of Cereal Chemists. vol.XI. pp.357-396.

Scorza, R. 1982. In vitro flowering. Hort. Rev. 4:106-127

Tisserat, B. and P.D. Galleta. 1988. In vitro flowering in *Amaranthus*. Hort. Sci. 23: 210-212.

EDITOR'S NOTE:

Amaranthus paniculatus is the same species as *Amaranthus cruentus*, the name used most often in the United States. This nomenclature confusion is explained by Jonathan D. Sauer (1967).

Sauer, Jonathan D. 1967. The grain amaranths and their relatives: a revised taxonomic and geographic survey. Ann. Missouri. Bot. Gard. 54: 103-137.

NOTICES

Iron Bioavailability from Vegetable Amaranths. Anusuya Rangarajan and Dr. John F. Kelly
Department of Horticulture
Michigan State University
East Lansing, MI 48824

Vegetable amaranths are popular greens consumed in many regions of the world where

iron deficiency anemia may be a problem. These types accumulate high levels of total iron, but the actual bioavailability of that iron may be low. Studies are being conducted in our lab to explore the genetic variability of iron bioavailability of several amaranth species, to determine if iron nutritional quality may be enhanced through plant breeding. In preliminary research, *Amaranthus tricolor* lines had the highest total and bioavailable iron, however, this species had the smallest percent of total iron available. The potential for increasing the fraction of bioavailable iron in *A. tricolor* is currently being explored.

Chilies to Chocolate: Food the Americas Gave the World. 1992. edited by N. Foster and L.S. Cordell. The University of Arizona Press.

This book includes a chapter by Daniel K. Early about the renaissance of amaranth. Early tells of his observations since 1972, of expanding amaranth use on four continents. He also describes traditional amaranth use and religious history.

Grain Amaranths: the Future Food Crop. 1991. by B.D. Joshi and R.S. Rana, National Bureau of Plant Genetic Resources, New Delhi.

This book is a summary of amaranth geography, genetics and grain yield progress in India. Copies are available form: The Head, National Bureau of Plant Genetic Resources, Regional Station, Phagli, Shimla-171 004, INDIA.

Special Issue on Grain Amaranth: New Potential for an Old Crop. Food Reviews International 1992 8(1):1-190

This issue was edited by J.R. Bale and C.S. Kauffman. It includes ten papers on amaranth research in Mexico, Guatemala, Peru, Kenya, and Thailand.

Therapeutic Dietary Composition Containing Amaranth (United States Patent 5186963) Karen Howman, 733 Cedar Run, Waldorf, MD 20603

This patent was granted on February 16, 1993 for a high potency dietary composition for treating patients suffering from malnutrition and other related disorders including low birthweight infants, and adult patents with chronic illness. It improves on other formulas because it is tolerated better than milk based products, and it is very high in protein, and calories.

The Fourth Chinese Symposium for Research and Development of Grain Amaranths, March 21-23, 1992

The symposium was held at the Institute of Crop Breeding and Cultivation, Chinese Academy of Agricultural Sciences, in Beijing, China. Sixty papers were presented to over 130 attendees. The Chinese have 53,773 hectares of land in grain amaranth production

AMARANTH INSTITUTE BOARD OF DIRECTORS 1992-93

President
Robert L. Myers
Agronomy Department
University of Missouri
210 Waters Hall
Columbia, MO 65211
314-882-0317

Treasurer/Memberships
Terry Cunningham
Rte. 1 Box 255
Twin Lakes, MN 56089
507-852-3465

Secretary/Newsletter Editor
David Brenner
Plant Introduction Station
Iowa State University
Ames, Iowa 50011
515-292-6502

William Breene
Food Science and Nutrition
University of Minnesota
1988 Brewster St.
St. Paul MN 55108

Cal Oliverius
Box 25
Albin, WY 82050

Mike Irwin
Rte. 2, Box 157
Lodi, WI 53555

Daniel Putnam
Agronomy and Plant Genetics
University of Minnesota
1991 Upper Buford Circle
St. Paul, MN 55108

HYBRID SEEDS FOR INCREASED AMARANTH GRAIN YIELD

David M. Brenner
Amaranth Curator
North Central Regional Plant Introduction Station
Iowa State University, Ames, Iowa 50011

The use of hybrid seeds could result in higher amaranth grain yields. In other crops, rapid yield increases have been achieved with hybrids. For example, mean sorghum yields doubled in the United States in the late 1950's when sorghum hybrids were introduced (Dogget, 1976). This hybrid vigor results from crosses of two unrelated varieties of one crop. The hybrid vigor is useful in the F_1 generation of plants. In the following F_2 generation the plants "segregate", so the crop may have uneven sizes and maturity dates. Segregation has been observed by Kulakow and Jain (1985, 1987) in amaranths. Hybrids have also been used to combine desired traits that are useful in crop improvement in following generations regardless of F_1 hybrid vigor.

Kulakow and Jain (1987) have evidence from comparing F_1 and F_2 hybrids that supports the potential for increased amaranth grain yields with F_1 hybrids. However, the advantages of these hybrids compared to their parents have not been measured directly in amaranth grain production. Hybrid plants can be as much as 88% heavier than their parents; these massive F_1 hybrid plants could be useful for forage production (Lehmann et al., 1991).

Making pollinations to produce hybrid amaranth seeds is difficult because the tiny flowers are hard to manipulate (unlike corn). Under field conditions, approximately 5% to 30% of the flowers are pollinated by neighboring plants, and the remainder are self pollinated (Jain et al., 1982). Tedious hand pollination can be used to produce small quantities of hybrid seeds (Kauffman, 1981). Large quantities of 30% hybrid seeds can be produced by interplanting the parents, but the hybrid plants must be distinguished from non hybrids by marking characteristics such as stem color (Kulakow and Jain, 1987, Lehmann et al. 1991). A third way to make hybrids is with male-sterile mother plants. These male sterile plants have non-viable pollen, so they cannot self-pollinate, and all their seeds are hybrid. This approach has been very successful with sorghum (Dogget, 1976), and many other crops (Kaul, 1988). Male sterility in amaranths has been explored by Jain et al. (1984), Peters and Jain (1987), and by Gudu and Gupta (1988). Peters and Jain (1987) described in detail the diagnostic characteristics of male sterility

including the easily observed green rather than yellow anther color of their male sterile amaranths.

At the North Central Regional Plant Introduction Station I am assembling male sterile accessions for preservation and distribution to researchers. We have five accessions of *Amaranthus hypochondriacus* sent to us by Dr. Ingrid Peters of Centro Nacional de Pesquisa de Floresta, Parana, Brazil. We also have six accessions selected from the cultivar K343 which is similar to the cultivar PLAINSMAN, and one accession from the cultivar PLAINSMAN. I made the selections in 1992. These male sterile accessions from K343 have white or black seeds, but were grown from rare black seeds in a predominantly normal white-seeded seed lot; the accession from PLAINSMAN was first grown from a rare translucent (Okuno and Sakaguchi, 1982) seed in a normal PLAINSMAN seed lot. Male sterile plants from cultivars are valuable because they could be higher yielding than male-sterile plants from other sources.

Male sterility is known in only one amaranth species, *A. hypochondriacus*. It has not been reported in *A. caudatus*, *A. cruentus* or the other *Amaranthus* species.

In other crops where male-sterile seed production is used, "gene-cytoplasmic" male sterility is the most efficient method (Kaul, 1988). For this gene-cytoplasmic method, male sterile plants are found that transmit male sterility to 100% of their progeny, so that hybrid seeds can be produced on a large scale. Peters and Jain (1987) developed a gene-cytoplasmic male sterile system, that includes fertility restoration in the final cross so that growers could use F_1 hybrids that have full male fertility. Most available male sterile amaranths have "genic" inheritance so that at most 50% of the progeny of a male sterile plant are male sterile. Historically male sterility used by plant breeders has been found as a natural mutation. However, biotechnology has been used to create gene-cytoplasmic male sterility in some crops (Marian et al., 1990) and this method might someday be used for amaranths.

REFERENCES CITED:

Dogget, H. 1976. Sorghum. p. 112-117. In N.W. Simmonds (ed.) Evolution of crop plants. Longman Group Limited, London.

Gudu, S.,and V.K. Gupta. 1988. Male-sterility in the grain amaranth (*Amaranthus hypochondriacus* ex-Nepal) variety Jumla. Euphytica 37:23-26

Jain, S.K., H. Hauptli, and K.R. Vaidya. 1982. Outcrossing rate in grain amaranths. J. Hered. 73:71-72

Jain, S.K., P.A. Kulakow, and I. Peters. 1984. Genetics and breeding of grain amaranths. p. 174-191 In Proceedings of the Third Amaranth Conference. Rodale Press, Inc., Emmaus, PA.

Kauffman, C.S. 1981. Grain amaranth varietal improvement: breeding program. Rodale Press, Inc., Emmaus, PA.

Kaul, M.H.L. 1988. Male sterility in higher plants. Springer-Verlag, Berlin.

Kulakow, P.A., and S.K. Jain. 1985. The inheritance of flowering time in *Amaranthus* species. J. Genet. 64:85-100

Kulakow, P.A., and S.K. Jain. 1987. Genetics of grain amaranths: IV. Variation and early generation response to selection in *Amaranthus cruentus* L. Theor. Appl. Genet. 74:113-120.

Lehmann, J.W., R.L. Clark, and K.J. Frey. 1991. Biomass heterosis and combining ability in interspecific and intraspecific matings of grain amaranths. Crop Sci. 31:1111-1116.

Marian, C., M. De Beuckeleer, J. Truettner, J. Leemans, and R. B. Goldberg. 1990. Induction of male sterility in plants by a chimaeric ribonuclease gene. Nature (London) 347:737-741.

Okuno, K., and S. Sakaguchi. 1982. Inheritance of starch characteristics in perisperm of *Amaranthus hypochondriacus*. J. Hered. 73:467.

Peters, I., and S.K. Jain. 1987. Genetics of grain amaranths III. gene-cytoplasmic male sterility. J. Hered. 78:251-256

PLANTING BLACK SEEDS

David M. Brenner
Amaranth Curator
North Central Regional Plant Introduction Station
Iowa State University, Ames, Iowa 50011

At the Amaranth Institute meeting last year, I sat at a table with growers, and we talked about the infrequent black seeds in seed lots for planting. In amaranth food grain, these black seeds are wholesome, but they are a cosmetic disadvantage. Some growers go through their planting seed and pick out the black seeds with tweezers, while others growers use conditioning machines to remove most of the black seeds, and other growers leave the black seeds in.

In 1992, I experimentally planted black seeds from a commercial PLAINSMAN seed lot that had few black seeds. In the resulting population of 76 plants, 39% percent of the plants looked like PLAINSMAN but had black seeds, 13% percent had weedy characteristics and black seeds, and 28% percent had white seeds and looked like PLAINSMAN, 16% had white seeds and weedy characteristics. In a control planting of only white PLAINSMAN seeds none of the 141 plants had weedy characteristics or black seeds. Therefore removing the black seeds before planting should clean up the harvest, and reduce the need to rogue out off types in the field. Although this is not surprising it is an under-appreciated way to reach high grain standards.

PUBLICATIONS FOR SALE

1990 Amaranth Grain Production Guide, 36 pp.

1988 *Legacy*, Vol. 1, (includes review of amaranth carbohydrates)

1989 *Legacy*, Vol. 2, (includes review of amaranth proteins)

1990 *Legacy*, Vol. 3, (includes review of amaranth pigments and seed shattering)

1991 *Legacy*, Vol. 4, (includes review of amaranth lipids and release of the variety "Plainsman")

1992 *Legacy*, Vol. 5, (includes review of anti-nutritional factors in amaranth grain, and tarnished plant bugs)

Legacy is the annual newsletter of the Amaranth Institute, a non -profit organization of amaranth producers, researchers, and others interested in amaranths. Legacy is sent free to members of the Institute, or can be sent to non-members for $4 per issue
(current or back issues).

The first copy of the Amaranth Grain Production Guide and of all volumes of Legacy are available without charge to members.

AMARANTH INSTITUTE MEMBERSHIP

The 1993 member's dues are: $30. For members with addresses outside the United States of America the dues are: $40 individual, including individuals at institutes, $50 for institutions, and $60 for private companies.

Legacy is edited by David Brenner and Todd Vens, North Central Regional Plant Introduction Station, Iowa State University, Ames, Iowa 50011. Manuscripts and information for publication in *Legacy* are welcome.

LEGACY
C/O DAVID BRENNER
NORTH CENTRAL REGIONAL
PLANT INTRODUCTION STATION
IOWA STATE UNIVERSITY
AMES IA 50011