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# Advances in New Alliums

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The genus *Allium* L., Amaryllidaceae includes numerous economically important vegetables used primarily for their unique flavors. Most people recognize the main vegetable alliums, such as bulb onion and shallot (*A. cepa*), garlic (*A. sativum*), leek (*A. ampeloprasum* var. *porrum*), and chive (*A. schoenoprasum*). However, there are numerous cultivated vegetable alliums of more regional importance, including kurrat (*A. ampeloprasum* var. *kurrat*) which is eaten as a pickled leaf primarily in Egypt, elephant garlic (*A. ampeloprasum* var. holmense), rakkyo (*A. chinense*), and Chinese chives (*A. tuberosum*) (Jones and Mann 1963). Other minor use *Allium* species were thoroughly listed by Fenwick and Hanley (1985).

Alliums are also cultivated as ornamentals. Well known to gardeners are *A. gigantheum*, *A. aflatunense*, and *A. caesium*, which are prized for their large umbels and many brilliantly colored flowers. Wild and less well-known alliums offer potential as perennial ornamentals, including *A. unifolium*, *A. moly*, or *A. schubertii*. Japanese researchers at the Hokkaido Agricultural Experiment Station have collected these and other unique alliums towards the goal of developing new and beautiful ornamentals.

## FERTILITY IN GARLIC

Garlic is an obligate apomictic plant and is primarily propagated asexually by cloves (Jones and Mann 1963). Flowering garlics can also be propagated by small bulbils that form in the umbel. One of the most exciting *Allium* research developments over the last 10 years is the identification and selection of fertile garlic plants. Etoh (1986) described male-fertile garlic plants from Soviet Central Asia. This stimulated research on the environmental conditions conducive to flower induction and the production of true seed in garlic (Pooler and Simon 1994). Of course, plants grown from this first generation of seed were weak and commercially unacceptable. Private companies producing dehydrated onion and garlic products have used these results to produce copious amounts of true garlic seed. The economic potential of this seed is enormous. Plants grown from true seed are either virus-free or have significantly reduced virus titers, eliminating the need for meristem culture to cleanse the plant of viruses (Walkey et al. 1987). The phenotypic diversity among garlic strains is well known (Engeland 1991). It is not known how much of this diversity is due to mutations or rearrangements in the garlic genome versus independent domestication of garlic strains from progenitor populations. Imagine the phenotypic diversity that could be generated from crossing among garlic strains and selection for unique appearance or flavor, higher solids for dehydration, etc. Over the long term, efficient seed production could reduce the time required to produce seed cloves from individual garlic plants for commercial level production. On average the increase of garlic per generation is approximately seven, meaning that one garlic clove will produce seven cloves of sufficient size to produce the next generation. If hybrid garlic could be sexually produced from true seed, the number of phenotypically uniform plants could be increased to reduce the time to commercial production. Over my lifetime, I predict that sexually produced garlic will be the most exciting new commercially used allium.

## FLAVOR STUDIES

Another major new product will be alliums with defined flavor and health-enhancing attributes. The rest of this manuscript will concentrate on the genetic and environmental factors that influence the flavor of onion, generally with selection or environmental manipulations towards low pungency, and the antithrombotic and anticarcinogenic potential of onion and garlic.

The alliums produce unique flavors savored by almost all of the world's cultures. These flavor compounds are formed when the enzyme alliinase acts upon the flavor precursors, alk(en)yl-L-cysteine-sulfoxides (ACSOs), to produce thiosulfinates (Block 1992). Alliinase is located in the vacuoles and is released when the alliums are cut, damaged, or bruised (Lancaster and Collin 1981). The enzyme acts quickly upon the cytoplasmic ASCOs to produce a suite of thiosulfinates. Different ASCOs exist among *Allium* species and different amounts of ASCOs may exist among onion cultivars (Lancaster and Kelley 1983; Lancaster and Boland 1990; Randle et al. 1995). The total flavor experience is the result of the action of alliinase on the different amounts of individual flavor precursors (Lancaster and Boland 1990). However, little is known about which specific ASCOs, or combinations there of, give specific flavors.

**Onion Pungency**

The relative pungency of onion has both genetic and environmental components. The onion is very efficient to uptake and sequester sulfur from the soil. The acquisition of sulfur and its distribution to various metabolic pathways may have been an important survival mechanism for the alliums; grazing animals maybe learned to avoid the alliums because of their strong taste. Production of onion in a low sulfur environment reduces the pungency of onion (Platenius and Knott 1941; Freeman and Mossadeghi 1970). A case in point is the Vidalia onion, produced on extremely low sulfur soils in 13 counties and parts of 7 others in the state of Georgia, US. The federal marketing order mandates that the Vidalia onion must be a Granex-type onion, meaning that it must have the phenotype of Granex, a hybrid released in 1952 by the USDA and the Texas Agricultural Experiment Station. The distinctive flat shape of the Vidalia onion comes from the Yellow Bermuda 986A female used to produce the hybrid Granex seed. Granex-type cultivars are generally low in pungency, but reach extremely low levels grown under the low sulfur soils of the Vidalia valley.

A genetic component for low (or high) pungency also exists (Lin et al. 1995; Simon 1995; Wall et al. 1996). Onion breeders routinely measure enzymatically derived pyruvate as an indicator of onion pungency. When the enzyme alliinase converts the ACSOs to the thiosulfinates, a byproduct is pyruvate (Schwimmer and Weston 1961). The amount of pyruvate produced is directly related to the onion pungency, as determined by taste panels (Schwimmer and Guadagni 1962; Wall and Corgan 1992). Higher pyruvate production indicates higher pungency, either due to greater concentrations of the substrate ACSOs, greater activity or concentration of alliinase, or both. Selection for less enzymatically derived pyruvate reduces the pungency of the onion (Wall et al. 1996). Another potential trait for selection would be the sugar content of onion; however, little work has been directed towards the genetic bases of sugars in the onion bulb.

A very interesting and potentially economically important molecular manipulation of onion is being attempted by researchers at Crop and Food Research, Lincoln, New Zealand. Drs. Jane Lancaster and Colin Eady, among others, are attempting to use antisense technology to manipulate onion pungency. The gene encoding alliinase has been cloned (Damme et al. 1992). The New Zealand group is trying to introduce a backward (antisense) copy of this gene into the onion genome. Antisense genes are known to reduce the expression of the wild-type (sense) copy of the gene (Eguchi et al. 1991). In onion, antisense of the alliinase gene should reduce the amount of functional alliinase present in the plant, but hopefully not eliminate all alliinase and allow the production of some onion flavor. The result could be low pungency onions that possess important production characteristics such as firmness and long dormancy. However if the same thiosulfinates were responsible for flavor and antiplatelet activity (see below), antisense alliinase could reduce both.

**Antiplatelet Activity of Onion**

It is well known that the alliums possess unique thiosulfinates that condition antithrombotic benefits, including antioxidant activity (Yang et al. 1993; Yin and Cheng 1998), reduced serum cholesterol (Bakhsh and Khan 1990), and enhance in vitro antiplatelet activity (Ariga et al. 1981; Block et al. 1984; Lawson et al. 1992; Goldman et al. 1995; Bordia et al. 1996). This latter effect is important for cardiovascular heath by reducing the probability that platelets aggregate in the blood, a major cause of heart attacks and strokes. The antiplatelet activity of onion has been primarily measured in vitro using platelet aggregometry. Correlations between measurements in vitro and in vivo have not been reported.

There is a significant environmental effect on the antiplatelet activity of onion. Goldman et al. (1996) demonstrated that growing onions in the presence of high sulfur increased both the pungency and antiplatelet activity of the bulb. This means that high sulfur soils or medium should produce highly pungent bulbs that tend to show greater antiplatelet activity. Because most people will not eat highly pungent onions fresh, it becomes an important research goal to determine which compounds condition each trait and whether the high pungency can be separated from greater antiplatelet activity.

**Garlic-Onion Hybrids**

An interesting combination of flavors and health-enhancing compounds may be available from a sexual hybrid between garlic and onion. Ohsumi et al. (1993) generated this interspecific hybrid using garlic as the female and pollinating with bulb onion. The ovules were extracted and cultured to rescue the embryo. The interspecific hybrid was intermediate in phenotype between garlic and onion. This plant possesses unique combinations of the flavor compounds from onion and garlic. Interestingly, combinations of thiosulfinates from various alliums may show more health-enhancing effects than those from individual alliums (Morimitsu et al. 1992). I expect that this garlic-onion hybrid will be asexually propagated because of extreme sterility. Nevertheless, the garlic-onion hybrid could represent a new commercially produced allium with potentially unique flavors and antiplatelet activities.

**Flavonoids**

Flavonoids are a second class of health-enhancing compound produced by the alliums. These compounds are complex carbohydrates that exist in many different forms (Crozier et al. 1997). The flavonoids tend to accumulate in the outer cell layers exposed to sunlight and protect the photosynthetic compounds from auto-oxidation. Flavonoids in the alliums have been shown to have significant anticarcinogenic and antithrombotic activities (Leighton et al. 1992). In onion, the primary flavonoid is quercitin (Price and Rhodes 1997). Dr. Leonard Pike and colleagues at Texas A&M University has studied the relative amounts of quercitin in onion bulbs. As expected, the highest amount of quercitin is present in the outer rings of the bulbs and decreases significantly towards the interior of the bulb. Red onions have greater amounts of quercitin than yellow; yellow onions possess greater amounts than white bulbs (Bilyk et al. 1984; Trammell and Peterson 1976; Patil and Pike 1995). Even though we discard the outer dried or partially dried scales of onion bulbs, red onions still possess potentially significant amounts of quercitin. Patil et al. (1995) demonstrated that the environment has an effect on the amount of quercitin in the onion bulb, indicating that the production environment is an important consideration for quercitin-enhanced onions. There is no information on the genetic control of the amount or distribution of quercitin in onion bulbs.

**Selenium**

Selenium is a micronutrient required in small amounts in the human diet (Young 1981). Selenium has been shown to reduce tumor growth in rats and may possess anticarcinogenic properties in humans (Ip et al. 1992). Selenium is closely related to sulfur, is efficiently taken up by the alliums (Morris 1970), and may be substituted for sulfur in metabolic pathways. When onion or garlic is grown under higher selenium concentrations, the amount of this element relative to sulfur is increased and selenium-enhanced onion and garlic can be artificially produced.

## CONCLUSION

It is an exciting time for the alliums. The research efforts of many scientists around the world will bring new alliums to the marketplace. New ornamental alliums are available and may become more common in our gardens. New onion or garlic cultivars with unique flavor and defined health-enhancing attributes are on the horizon and should increase consumption. Sexually produced garlics may reduce the cost of production and create new garlics to open up new and unique markets. Because onion, garlic, and other cultivated alliums are common part of our meals, I expect that these new alliums will increase consumption and not significantly reduce the production of more classical types presently used by us all.

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