Within- and Between-family Variability for Important Bulb and Plant Traits among Sexually Derived Progenies of Garlic

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Abstract. Until recently, there has been no large-scale production of true seeds in garlic (Allium sativum L. and A. longicuspis L.). The recent discovery of male fertile garlic accessions stimulated research on the genetics and breeding of garlic. However, there is no information regarding the phenotypic characteristics of garlic populations generated from true seeds. We evaluated the first generation of sexually derived families of garlic for bulb and clove weight, number of cloves per bulb, flower stalk height, number of leaves, plant height, and days required to achieve bulb maturity. Significant variations were observed within and among families for these important traits.

Due to its obligatory vegetative reproduction system, breeding in garlic has been exclusively done by the selection of clonal mutants. Lampasona et al. (2003) observed that there is no segregating population generated from cross hybridization in garlic, it has not been possible to study stability and inheritance of phenotypic variation obtained through clonal selection. There are no studies in the literature on the use of sexual breeding methods in garlic (Simon and Jenderek, 2003). The recent discovery of male fertile garlic accessions from central Asia (Etoh, 1983, 1986; Hong and Etoh, 1996) and the ability to produce large quantities of true seeds (Etoh et al., 1988; Hong et al., 2000; Inaba et al., 1995; Jenderek, 1998; Pooler and Simon, 1994) opened an avenue for utilizing classical breeding methods and conducting genetic studies in this crop. The ability to produce true seeds is a breakthrough for the genetic improvement of garlic. Through sexual reproduction, it is possible to combine the desired traits from different clones into a single cultivar. Therefore, understanding the genetic structure of garlic populations derived from true seeds is essential for future breeding work.

Recently, Jenderek and Hannan (2004) reported the presence of variation in reproductive characteristics and seed producing potential for selected garlic accessions in the USDA collection. Jenderek (2004) reported on selected morphological characteristics among S garlic progenies. However, to our knowledge, no other literature describes quantitative characteristics of bulbs and plants for populations generated from true seeds. The main objective of this study was to characterize the first generation of sexually derived garlic families for selected, economically important morphological characters.

Materials and Methods

Plant material. True seeds were produced from six garlic accessions that were obtained from the USDA germplasm collection maintained at the Western Regional Plant Introduction Station in Pullman, Wash. (Table 1).

In October 1999, 50 to 60 cloves from each accession were planted in the field at Parlier, Calif. At flowering stage, each accession was caged separately using insect-proof net and blue bottle flies (Protaphormia terraenovae Robineau-Devoidy) were used as pollinators. In August and September 2000, open-pollinated seeds were harvested from plants of each accession and bulked per accession. If all bulbs from one plant introduction (PI) traced back to a single plant, the seed harvested off asexual propagules (clove) would be an S family. However, if a PI traced back to more than one plant, the sexual seed from bulbs of this PI would represent a mass pollination among genetically diverse individuals. As a result, we will refer to the seed from each accession as a sexually derived family. From November 2001 to February 2002, seeds of each sexually derived family were germinated in petri dishes. The germinated seeds were transferred to test tubes with half strength MS medium (M-5524; Sigma-Aldrich Co., St. Louis). At 2 to 3 leaf stage, the seedlings were transferred to plastic pots (343 mL) containing a artificial planting medium (Sunshine Mix No. 4; Sun Gro Horticulture Canada Ltd., Vancouver, Canada) and placed in a greenhouse. In February 2002, at three- to four-leaf stage, seedlings were transplanted to the field at 5 cm spacing between plants. Each plant was randomly numbered for evaluation purposes. Standard practices for growing garlic in California were used (Mann and Little, 1957). The first seed derived bulbs were harvested separately (per plant) in August 2002.

In Fall 2002, the seed derived cloves of each sexually derived family were planted back to the field with random cloves from their respective parental accessions. The experimental design was a randomized complete block design with four replications, with one plant in each replication. The bulbs were harvested in July to August 2003, and data of selected plant and bulb characteristics were taken from each plant.

In the 2003–04 growing season, the experiment was repeated for selected sexually derived progenies and a random sample of their maternal clones.

Data were collected for bulb weight (in grams); number of cloves per bulb; mean clove weight (in grams) (calculated by dividing the bulb weight by the number of cloves per bulb); flower stalk height in cm (measured from the base to the top of the flower umbel); number of leaves per plant (only in 2003); plant height in cm (measured from the plant base to the tip of the longest leaf; evaluated only in 2004); and days to physiological bulb maturity (the number of days from planting to 1/3 leaves dry).

SPSS, version 11.5, software (SPSS, 2002) was used to analyze the data. ANOVA tables were calculated and means of the individual lines were compared to their respective maternal plant using Dunnett’s t test.

Results and Discussion

Relatively few sexually derived progenies were evaluated in each family and the number of surviving progenies varied due to the seed producing ability of the parental plants, low seed germination, poor seedling survival in vitro or poor survival in the field. Number of progenies evaluated in 2002–03 for maternal

Table 1. Garlic accessions used to develop sexual families at the National Arid Land Plant Genetic Resource Unit, Parlier, Calif.

| Seed family | Accession number | Allium species | Origin |
|-------------|------------------|----------------|--------|
| P2          | PI 540319        | A. sativum     | Poland |
| P41         | PI 493099        | A. longicuspis | Moldova |
| P42         | PI 493116        | A. sativum     | Czech Republic |
| P52         | PI 540356        | A. sativum     | Georgia |
| P61         | PI 540316        | A. sativum     | Former Soviet Union |
| P66         | PI 540315        | A. longicuspis | Former Soviet Union |
Plants were in P2 at 262 d (Table 3), i.e., 38 days to physiological bulb maturity varied significantly within and between the families. The earliest was observed in P2 (9.0/plant) while the largest number of cloves per bulb was observed in P52 and P41 (61.9 and 7.3 g, respectively). Two sexual progenies in P52 and P41 (40.3 cloves/bulb) (Table 2). The lowest clove weight was observed in the P61 family (0.5 g) (Table 2). The smallest bulbs were observed for number of cloves per bulb and clove weight, number of cloves per bulb, clove weight among sexually derived families of garlic, evaluated in 2002–03. Large bulbs with large cloves were observed in families P2 (70.3 and 6.4 g, respectively) and the largest in P41 family (7.7 g) (Table 2). The smallest bulbs were observed in family P66 (0.9–3.4 g) (Table 2). Significance among the families based on an F test.

Table 4. Means (±SD) and range for bulb weight, number of cloves/bulb, and clove weight among sexually derived families of garlic, evaluated in 2003–04.

| Seed family | No. of lines evaluated | Bulb wt (g) | Clove no. | Clove wt (g) |
|-------------|------------------------|-------------|-----------|-------------|
|             | Avg | Range | Avg | Range | Avg | Range |
| P2 | 32 | 38 ± 18.9 | 9.4–70.3 | 9 ± 3.4 | 5.3–17.0 | 4 ± 1.8 | 1.6–6.9 |
| P41 | 7 | 38 ± 16.5 | 22.2–61.9 | 9 ± 2.3 | 6.0–12.3 | 5 ± 2.4 | 2.5–7.7 |
| P42 | 5 | 20 ± 12.6 | 8.6–40.0 | 10 ± 1.7 | 7.5–11.8 | 2 ± 1.0 | 0.9–3.4 |
| P52 | 6 | 27 ± 14.0 | 6.0–47.9 | 11 ± 2.1 | 7.5–13.5 | 2 ± 1.2 | 0.8–3.3 |
| P61 | 44 | 24 ± 7.2 | 6.6–35.7 | 17 ± 8.9 | 5.8–40.3 | 2 ± 1.0 | 0.5–3.9 |
| P66 | 4 | 33 ± 8.9 | 26.5–37.9 | 13 ± 3.4 | 9.3–15.8 | 3 ± 1.2 | 1.7–3.7 |
| Significance | 0.01 | 0.01 | 0.01 |

Significance level among the families based on an F test.

Table 5. Means (±SD) and range for flower stalk height, plant height, and days to maturity among sexually derived families of garlic, evaluated in 2003–04.

| Seed family | No. of lines evaluated | Flower stalk ht (cm) | No. of leaves | Days to maturity |
|-------------|------------------------|----------------------|---------------|-----------------|
|              | Avg | Range | Avg | Range | Avg | Range | Avg | Range |
| P2 | 32 | 99 ± 19.3 | 70.8–140.5 | 12 ± 1.9 | 9.0–17.0 | 238 ± 7.0 | 210–262.0 |
| P41 | 7 | 101 ± 19.3 | 70.8–128.0 | 13 ± 2.5 | 10.0–16.5 | 245 ± 5.2 | 230–251.0 |
| P42 | 5 | 78 ± 15.9 | 55.5–99.0 | 12 ± 1.5 | 10.5–12.8 | 241 ± 6.1 | 231–249.0 |
| P52 | 6 | 66 ± 12.1 | 50.0–77.0 | 12 ± 1.8 | 10.5–14.0 | 246 ± 7.5 | 231–255.0 |
| P61 | 44 | 79 ± 15.7 | 40.5–100.0 | 13 ± 2.1 | 10.3–15.8 | 237 ± 8.3 | 227–248.0 |
| P66 | 4 | 102 ± 9.7 | 91.3–110.5 | 11 ± 1.3 | 10.0–12.3 | 244 ± 5.2 | 239–249.0 |

Significance level among the families based on an F test.

In conclusion, significant variations were observed for a number of traits studied within and among sexually derived garlic families in both growing seasons. Several progenies exhibited unique morphological characteristics not observed in their respective maternal parents for most traits studied, implying that vegetative propagation of garlic over the centuries has produced highly heterozygous plants. Sexual families generated from these plants could be an important source of unique phenotypes for garlic improvement.
Literature Cited

Etoh, T. 1983. Germination of seeds obtained from a clone of garlic, *Allium sativum* L. Proc. Jpn. Acad. 59(Ser. B):83–87.

Etoh, T. 1986. Fertility of the garlic clones collected in Soviet Central Asia. J. Jpn. Soc. Hort. Sci. 55:312–319.

Etoh, T. 1997. True seeds in garlic. Acta Hort. 433:247–255.

Etoh, T., Y. Noma, Y. Nishitarumizu, and T. Wakanmoto. 1988. Seed productivity and germinability of various garlic clones collected in Soviet Central Asia. Mem. Fac. Agr. Kagoshima Univ. 24:129–139.

Hong, C.J. and T. Etoh. 1996. Fertile clones of garlic (*Allium sativum*) abundant around the Tien Shan mountains. Breeding Sci. 46:349–353.

Hong, C.J., T. Etoh, and S. Iwai. 2000. An attempt of crossbreeding in garlic. Mem. Fac. Agr. Kagoshima Univ. 36:17–28.

Inaba, A., T. Ujjie, and T. Etoh. 1995. Seed productivity and germinability of garlic (in Japanese). Breeding Sci. 45(Suppl. 2):310.

Jenderek, M.M. 1998. Generative reproduction of garlic (*Allium sativum* L.) [Rozmanazanie generatywne czosnku (*Allium sativum* L.)] (in Polish). Zeszyty Naukowe Akademii Rolniczej im. H. Kollataja w Krakowie 57:141–145.

Jenderek, M.M. 2004. Development of S families in garlic. Acta Hort. 637:203–206.

Jenderek, M.M. and R.M. Hannan. 2004. Variation in reproductive characteristics and seed production in the USDA garlic germplasm collections. HortScience 39:485–488.

Lampasona, S.G., L. Martinez, and J.L. Burba. 2003. Genetic diversity among selected Argentinean garlic clones (*Allium sativum* L.) using AFLP (amplified fragment length polymorphism). Euphytica 132:115–119.

Mann, L.K. and T.M. Little. 1957. Growing garlic in California. Univ. Calif. Veg. Crops Ser. 89:1–10.

Pooler, M.R. and P.W. Simon. 1994. True seed production in garlic. Sexual Plant Reproduction 7:282–286.

Simon, P.W. and M.M. Jenderek. 2003. Flowering, seed production, and the genesis of garlic breeding. Plant Breeding Rev. 23:211–243.

SPSS Inc. 2002. SPSS for windows release 11.5. Chicago.

Zepeda, A.H. and J.A Laborde. 1997. Number of cloves per bulb: Selection criteria for garlic improvement. II. Results with “Taiwan” type, p. 271–277. In: J.L. Burba and C.R. Galmarini (eds.). Proceedings of the first international symposium on Edible Alliaceae, 14–18 Mar. 1994, Mendoza, Argentina.