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Differences in onion pungency due to cultivars, growth environment, and bulb sizes

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Abstract

This study was conducted to determine the effects of genetic and environmental factors on onion pungency, estimated as pyruvic acid levels. Genetically identical clones were grown at three different field locations and in a greenhouse. Onion pungency was significantly influenced by clone type, location, and their interaction. Genetic differences were the major determining factor of onion pungency (81.3% of total variation). Location, including all environmental factors, and the clone × location interaction comprised 11.4% and 7.3% of the total variation, respectively. The magnitude of the pungency difference among field-grown onions was about 1.5 μmol/ml. The pungency levels were not positively correlated with soil sulfur nutrition levels, which ranged from 16 to 97 ppm. Within clones, onion pungency levels were loosely inversely correlated with increasing bulb weight. The clones proved to have the most uniform pungency (8% CV), followed by hybrids (10.6% CV) and open-pollinated cultivars (21.3% CV). We have demonstrated that genetic factors were determinant of onion pungency. Environmental factors influenced pungency to a lesser degree. Therefore, choosing cultivars with low pungency, ideal growing environments and proper sulfur nutrition control, are key factor in producing sweet onions.

Keywords: *Allium cepa* L.; Flavor; Breeding; Pungency; Pyruvic acid

1. Introduction

The pungent flavor of the onion is produced when onion cells are ruptured, releasing the enzyme alliinase (EC 4.4.1.4). Alliinase reacts with flavor precursors, *S*-alk(en)yl-cysteine sulfoxide, to produce many volatile S compounds, along with pyruvic acid and ammonia (Lancaster and Boland, 1990). The lachrymatory factor, thiopropanal S-oxide, is the main compound responsible for onion pungency, while many other sulfur volatile compounds contribute to pungency of the onion (Lancaster and Boland, 1990). This flavor chemistry is complex and unstable, thus difficult to measure. Therefore, pyruvic acid concentration in onion juice (μmol/ml) is used as an indicator of pungency (Schwimmer and Weston, 1961).

The composition and concentrations of flavor precursors differ by species and cultivars (Yoo and Pike, 1998). Previous studies on onion pungency have reported that flavor strength could be greatly affected by cultivar, soil type and other environmental factors. Several studies have been conducted to determine the influence of soil sulfur (S) nutrition level on pungency (Freeman and Mossadeghi, 1970; Randle, 1992a,b; Randle and Bussard, 1993; Hamilton et al., 1997). In a greenhouse study, onions grown at either 2 or 123 ppm S had pyruvic acid concentrations of 1.9 or 5.5 μmol/ml, respectively (Hamilton et al., 1997). This study also reported significant clonal variation in pungency under the same high S nutrition levels. Similarly, the pungency of individual cultivars varied widely in response to different concentrations of soil S (Randle, 1992a).

Onion pungency varied significantly within a growing field, according to a survey that used mapping technology along with a global position system (Randle et al., 1998). Pungency distributions from a Vidalia onion field in Georgia were associated with elevation changes in the field and soil type differences. While the Vidalia region is ideal for producing sweet onions by taking advantage of low sulfur conditions, most onion fields in the South Texas have much higher S nutrition, over 100 ppm S. Irrigation water contained 71 ppm S (Hamilton et al., 1998). Therefore, the strategy being used in Georgia to produce sweet onions – that is, selecting fields with ideal growing conditions and controlling S nutrition – cannot be implemented in other areas with high S nutrition in native soil and in irrigation water.

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These studies have demonstrated that onion pungency varies greatly as a result of environment and cultivar. These field studies have used commercial onion cultivars of open-pollinated or hybrid onions, which express genetic diversity. Complete separation of environmental effects from genetic effects requires the use of genetically identical plants. The genetic uniformity of clones has been thought to be greater than those of hybrid and open-pollinated cultivars, but no study has been done, to our knowledge, to test this hypothesis.

In this study, we produced genetically identical clones that were grown in three fields and a greenhouse, in order to expose the plants to different environments. This allowed us to determine the variation in pungency as a direct result of the environmental effects. We also examined the relationship between bulb size and pungency. Additionally, we compared pungency among clones, hybrids, and open-pollinated lines.

2. Materials and methods

2.1. Clonal plant materials

Fifteen clonal onion plants obtained in our breeding program or from commercial cultivars (Table 1) were grown from immature flower bud cultures as described by Pike and Yoo (1990). Each clone originated from a single plant to ensure genetic uniformity. When the plants reached about 5 cm long in the culture tubes, they were transplanted to seedling trays (52 cm × 25 cm × 7.5 cm) and allowed to grow to a length of approximately 20 cm. The clonal plants were transplanted to fields or a greenhouse in early December.

2.2. Production of clonal onions in the fields

Three locations in the Rio Grande Valley areas, including Weslaco (26°15′N, 97°98′W), Donna (26°20′N, 98°15′W) and Edinburg (26°35′N, 98°25′W) were selected for this study. The soil type in the fields is a silt-loam, and onions have been commercially grown in the area for years. Thirty onion plants were transplanted into beds (102 cm wide), spaced uniformly along two rows 15 cm apart. Transplants were divided into field groups such that each group contained an equal distribution of different bulb sizes. Commercial growers managed the plants throughout the experimental period. Onion bulbs were harvested in mid-May, when 50% of foliage had collapsed.

2.3. Production of clonal onions in the greenhouse

Another set of clonal plants were grown in a greenhouse at College Station, TX (30°6′N, 96°3′W) in 4.5 l size pots (three plants per pot). Pots were filled with Pro Mix BX (Premier Horticulture Inc., Quakertown, PA, USA) and watered with a commercial fertilizer solution with 54 ppm S (Steiner, 1961). The onion bulbs were harvested in mid-May.

2.4. Production of open pollinated and hybrid cultivars

Eight experimental hybrid lines from Seminis Seeds (Oxnard, CA) and eight breeding lines from our breeding program (Table 1) were planted in early October at the fields in Donna and Edinburg, respectively. Except for the seeding process, the onions were cultivated similarly as the clonal plants. After the bulbs were harvested, 10 representative bulbs were selected from each plot and tested for pungency.

2.5. Pungency comparison between fields

Ten medium-sized (7.5–10 cm diameter) onion bulbs were selected from each of eight clones grown at three fields. The goal of this study was to compare pungency among the three fields in a commercial production area. Pungency was measured for each bulb. Data were compared by analysis of variance (ANOVA) using the general linear model procedure in

Table 1
List of clones, open-pollinated onions, and hybrids used in this study

Clones	Description of clones (color)	Open-pollinated	Hybrids
1015-2A	TG 1015Y selection (Y)	41043	04D0 1001
1015-129	TG 1015 Y selection (Y)	41046	04D0 1002
1015-506	TG 1015 Y selection (Y)	41049	04D0 1003
10503-W53	Breeding line (W)	41056	04D0 1004
10507-W58	Breeding line (W)	41057	04D0 1005
10623-R5	Breeding line (R)	41062	04D0 1006
10623-R8	Breeding line (R)	41065	04D0 1007
10542-133	Breeding line (Y)	41066	04D0 1008
60708-2	Breeding line (Y)	(VFIC breeding lines, all yellow)	(Seminis Seeds, all yellow)
60708-2-1	Breeding line (Y)		
60708-7	Breeding line (Y)		
60708-10	Breeding line (Y)		
60708-18	Breeding line (Y)		
90048	Breeding line (Y)		
TEW	Texas Early White (W)		

All clones were originated from a single plant selection. Genetic backgrounds of the open-pollinated lines from our breeding program and hybrids from Seminis Seeds were not determined. Y, R, and W in color indicate yellow, red, and white, respectively.