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Early Orange Mass 400, Early Orange Mass 402, and Late Orange Mass 404: High-carotene Cucumber Germplasm

Philipp W. Simon and John P. Navazio[1]
Vegetable Crops Research Unit, Agricultural Research Service, U.S. Department of Agriculture, Department of Horticulture, University of Wisconsin, Madison, WI 53706

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Cucumber (*Cucumis sativus* L.) cultivation dates back ≈3000 years to India, its site of domestication. It spread throughout South Asia, China, and eventually to Europe 1000 years ago (Brothwell and Brothwell, 1969). Consumed fresh or processed, cucumber is regarded for its texture but generally not for its nutritional value.

The carotenoid pigments, which condition cucurbit fruit color are an important source of vitamin A (Simon, 1992). In contrast to other cucurbits that possess bright orange, red, yellow, or green internal fruit color, fruits of cucumber typically lack mesocarp or placental pigmentation. Orange or yellow internal fruit color exists in cucumber accessions from Asia and the Mideast (Kooistra, 1971; Qi et al., 1983). To provide an improved source of nutrients for consumers, Early Orange Mass 400 (EOM 400), Early Orange Mass 402 (EOM 402), and Late Orange Mass 404 (LOM 404) were derived from the crosses between U.S. pickling cucumber lines (*Cucumis sativus* L. var. *sativus*) and the orange-fruited Xishuangbanna cucumber (*C. sativus* L. var. *xishuangbannesis* Qi et Yuan) (XIS), PI 509549, from the People's Republic of China.

Origin

In Fall and Winter 1987–88, crosses were made in greenhouses at the Univ. of Wisconsin, Madison, between XIS (PI 509549) and 10 U.S. pickling cucumber cultigens (cultivars, breeding lines, and accessions) that contain no detectable yellow or orange internal fruit color. XIS was the male parent in all crosses because of its delayed production of pistillate flowers. Few fruit of PI 509549 were produced due to low incidence of pistillate flowers. As also previously reported (Jinfeng et al., 1994), mature fruit length : diameter was shorter in XIS (1.5:1 to 3:1) than typical U.S. processing cucumbers (2.8:1 to 3.4:1). Internal color of mature fruit was white, yellow, or orange, while immature fruit color was white or pale yellow.

From these original matings, seeds from 73 F_2 and BC_1 crosses (XIS used as the recurrent parent) were planted at the Univ. of Wisconsin Agricultural Research Station near Hancock, in Summer 1988. To eliminate the delayed flowering habit, plants that produced no fruit in the field were not propagated beyond the field season. Fruit that matured in the field were harvested at full seed maturity and rated for relative intensity of yellow and orange pigmentation in mesocarp and endocarp tissue (collectively referred to as "flesh"). Seeds were harvested and kept only from segregants exhibiting a relatively dark yellow or orange flesh color. Half-sib families derived from seven Wis. SMR18 backcrosses [(SMR18 x XIS) x XIS] and four 'Addis' backcrosses [('Addis' x XIS) x XIS] exhibiting the most intense yellow-orange mesocarp pigmentation were prominent among those chosen. Selected half-sib families were planted in Summer 1989 and 1990, examined for intensity of color, and 26 selections were made among half-sibs.

To prepare plants for carotenoid evaluation, field production was at the Univ. of Wisconsin Agricultural Research Station in Madison (plano silt loam soil, 16-h photoperiod at summer solstice, 19 °C average summer temperature). Seeds were planted about May 20 into the greenhouse in flats containing a ratio of 1 field soil : 1 compost : 1 sand : 1 sphagnum peat and transplanted to the field between 5–10 June, depending on weather conditions. Plants were grown in 1.0 × 1.0-m hills, 3.0 m between hill centers, in a rectangular grid, with four to six plants per hill in 1991. In 1992 and 1993, plants were grown in single rows with 15 to 20 cm between plants and 1.8 m between rows.

LOM 404 (Late Orange Mass selection from cage 404) was developed from a Wis. SMR18-derived backcross, designated 104 in 1991, by continued half-sib family selection for dark orange mature fruit mesocarp color through 1994 (Fig. 1). In 1991, the internal color of immature fruit (size 2, 27 to 38 mm in diameter) was also evaluated and variation from white to dark orange observed. The F_1 hybrid 104 x 101 was noteworthy. Line 101 was a second generation half-sib family selection from an 'Addis'-derived backcross. This hybrid, produced in 1991, was the source of EOM (Early Orange Mass) families. EOM 400 and EOM 402 were derived from self-pollinations of plants with dark orange immature fruit mesocarp color, with further individual-plant selection in 1992 and 1993. In 1993, a second generation of individuals was selected from plants grown in the greenhouse. In 1994, a final seed increase of all populations was made by allowing 32 to 36 plants from each population to intermate in 3 × 6-m cages using bees for pollination.

Description

After seven cycles of phenotypic recurrent mass selection for orange flesh color beyond the BC_1 generation (BC_1M_7), fruits of LOM 404 contained total carotenoids (fresh weight basis) at 1 to 15 $mg{\cdot}kg^{-1}$ with a mean of 7 $mg{\cdot}kg^{-1}$ in replicated field trials from fruit produced in Madison, Wis., in 1991, 1992, and 1993 (for photo, see cover story).

EOM 400 and EOM 402 are the result of five generations of self-pollination and individual plant selection and one generation of mass selection (F_5M) for immature fruit color. Fruit contained 1 to 25 $mg{\cdot}kg^{-1}$ total carotenoids on a fresh weight basis with a mean of 5 $mg{\cdot}kg^{-1}$.

Samples for carotenoid analysis were lyophilized and analyzed as described by Simon and Wolff (1987). Carotenoids conditioning orange and yellow flesh color included a mixture of xanthophylls and beta-carotene. About 40% of the carotenoids was beta-carotene in immature fruit, 80% in mature fruit (Navazio, 1994). The balance at each maturity type was xanthophylls.

Internal (mature and immature) fruit color was orange in 70% to 90% of the plants in EOM 400 and EOM 402 in 1994, with the balance being yellow in the samples examined. The incidence of plants with dark orange mature fruit color was somewhat higher in EOM 402 (15%) than in EOM 400 (5%); the incidence of plants with yellow immature fruit color was also somewhat higher in EOM 402 (30%) than in EOM 400 (10%). Internal mature fruit color was dark orange in 20 % of the plants of LOM 404 with the balance being orange (60%) and yellow (20%). Immature fruit color of LOM 404 was usually white. Based on visual evaluation, variation in color occurred between years, with cool weather reducing intensity of color. In rare segregants (<5%), fruit at both stages of maturity were pale green internally. Fruit color was usually pale in hybrid combinations where parents lacked internal fruit pigment. Internal fruit color was stable after processing with refrigerated (fresh-pack) or traditional salt-brine preparation. Fruit of all populations were predominantly of the shape suitable for pickling, but longer-fruited segregants occurred that were suitable for fresh-market (slicing) use. Segregation for spine color and resistance to powdery mildew caused by *Sphaerotheca fuliginea*

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[1]Current address: Alf Christianson Seed Co., P.O. Box 1788, Mount Vernon, WA 98273.

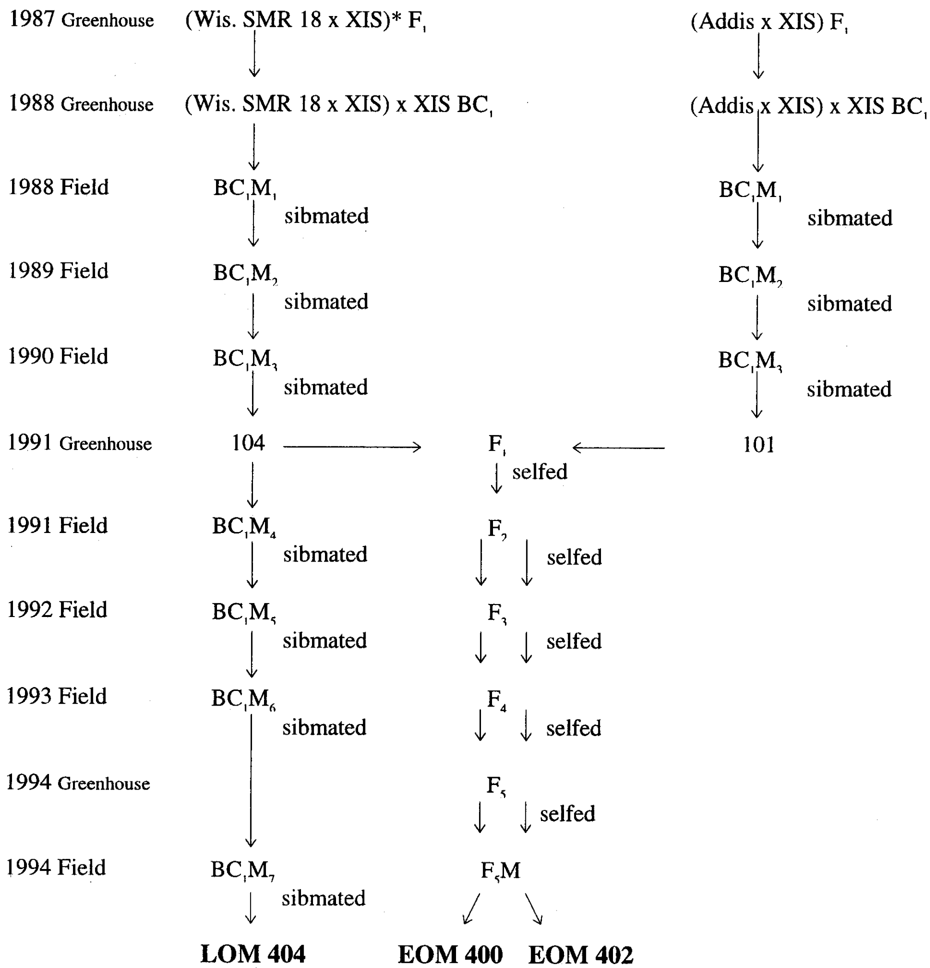

Fig. 1. Origin of Early Orange Mass 400, Early Orange Mass 402, and Late Orange Mass 404 cucumber populations (*XIS = *Cucumis sativus* L. var. *xishuangbannanesis* Qi et Yuan).

(Schl. ex Fr.) Poll. also was observed. No plants with delayed production of pistillate flowers were present in EOM 400, EOM 402, or LOM 404.

The carotenoid content of EOM 400, EOM 402, and LOM 404 represents a significant increase above the trace amounts occurring in typical cucumbers. The provitamin A carotene content of dark orange segregants in these releases is similar to other orange-fleshed cucurbits such as muskmelon (*Cucumis melo* L.), pumpkin (*Cucurbita pepo* L.), and squash (*Cucurbita* ssp.) (19, 10, and 1 to 47 $mg \cdot kg^{-1}$ beta-carotene equivalents, respectively, fresh weight basis; Gebhardt et al., 1982; Haytowitz and Matthews, 1984; Navazio, 1994). Although high-carotene cucumbers cannot be expected to contribute significantly to the vitamin A status of U.S. consumers, where vitamin A deficiency is rare, carotene-rich food intake is associated with reduced incidence of certain cancers and heart disease and thus they could contribute to U.S. health in this way. Furthermore, high-carotene cucumbers could be a useful addition to the diet of consumers in vitamin A-deficient regions of the world, which typically produce warm-season crops, like cucumbers.

Beyond the nutritional benefits of high-carotene cucumbers, the striking appearance of this commodity could attract consumer attention as a specialty crop, either processed or fresh. Furthermore, yellow-fleshed selections could also be useful as a "naturally" colored processed product, thus eliminating the need to use yellow dye.

Availability

Seed of EOM 400, EOM 402, and LOM 404 will be provided upon written request addressed to P.W. Simon. It is requested that appropriate recognition be made if this germplasm contributes to the development of a new breeding line or variety. Genetic material of this release is deposited in the U.S. National Plant Germplasm System where it is available for research purposes, including development and commercialization of new cultigens.

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