Table 4. Chromosome number of regenerated plants from multiple embryos in undeveloped seeds from 2x 'Clementine' crossed with 4x 'Kawano Natsudaikai'.

No. embryos in examined seeds	No. regenerated plants	
	Chromosome number (2n)	
	27	Others
2	2	0
3	3	0
4	2	0
5	3	0
6	3	0
7	3	0
8	4	0
11	5	0

Fig. 2. Single (left) and multiple (right) embryos formed in undeveloped seed from 2x 'Clementine' x 4x 'Kawano Natsudaikai'.

Fig. 3. Isoelectric focusing profiles of peroxidase isozymes in triploid plants produced from one polyembryonic seed.

genetically identical and derived from a single fertilized egg cell.

The present study demonstrates that sexual polyembryony of citrus occurs at the triploid level. This sexual polyembryony seems to be a specific phenomenon related to abnormal development of triploid embryos in monoembryonic diploid x tetraploid crosses.

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HORTSCIENCE 25(10):1277-1279. 1990.

Growth and Fruiting of Short-internode Main Dwarf, Normal-internode Parent, and Hybrid

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Additional index words. *Cucumis melo*, leaf area, leaf and stem dry weight, leaf area ratio, chlorophyll, ribulose-1,5-bisphosphate carboxylase/oxygenase, net assimilation rate, elemental concentration, yield

Abstract. Plants of Main Dwarf, a short-internode mutant of the normal-internode 'Mainstream' muskmelon (*Cucumis melo* L.), have shorter internodes, fewer nodes, less total vine length, less total dry weight, smaller leaves, increased chlorophyll concentrations, increased specific leaf dry weight, and increased ribulose-1, 5-bisphosphate carboxylase/oxygenase (EC 4.1.1.39, rubisco) activity per unit leaf area than 'Mainstream' plants. Main Dwarf plants produce an equal number of fruit as 'Mainstream' plants but are only half their size. Many of the plant and fruit characteristics for F₁ (Main Dwarf x 'Mainstream') are similar to those of 'Mainstream', except for greater leaf chlorophyll and rubisco activity per unit leaf area. The F₁ ('Mainstream' x Main Dwarf) produced fewer and lower weight fruit than its reciprocal, F₁ (Main Dwarf x 'Mainstream').

Main Dwarf muskmelon is a short-internode (SI) single gene recessive mutant (*si-3*) of the normal-internode (NI) cultivar Mainstream (Knavel, 1990). SI mutants previously reported were of the *si-1* (Davis et al., 1976; Knavel, 1988a; Zink, 1978, 1979) and of the *si-2* gene type (Paris et al., 1984). Main Dwarf plants have more-branching, less-compact, and more-open vines and have smaller leaves than other SI genotypes such as Ky-P₇ (Knavel, 1988a) and Persia-202 plants that exhibit an upright growth habit

(Nerson et al., 1983). The prostrate spreading vine of Main Dwarf plants, which do not have brittle and twisted internodes as reported (Denna, 1962) for *si-1* plants, may be of value in the development of SI genotypes with the potential of higher yields on per unit area than now used for NI cultivars. The objective of this study was to document vegetative growth, fruiting, and leaf characteristics of SI Main Dwarf plants and compare these characteristics with those of the NI parent 'Mainstream' and their reciprocal hybrids.

Each year (1985, 1986, 1987) seed were sown in plastic pots (0.1 liter) containing a commercial peat moss and perlite mixture. The plants were grown for ≈30 days in a plastic greenhouse (from 10 to 15 Apr. to mid-May) before being transplanted to the field onto rows spaced 1.8 m apart, center

Received for publication 24 Aug. 1989. Published as 89-10-178 Agricultural Experiment Station Article. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.

Table 1. Plant characteristics of short-internode Main Dwarf, normal-internode 'Mainstream', and F₁ (Main Dwarf x 'Mainstream') for 58-day-old^a plants in 1985.

Genotype	Total vine length (mm)	Nodes (no./plant)	Internode length (mm)	Leaf area (m ² /plant)	Leaf dry wt (g/plant)	Vine dry wt (g/plant)
Main Dwarf	1570	54	29	0.21	11.9	5.4
Mainstream	3570	85	42	0.29	16.7	8.7
F ₁ (Main Dwarf x Mainstream)	3140	73	43	0.26	14.8	7.4
LSD, <i>P</i> = 0.05	590	12	4	NS	2.1	3.2

^a30 days after transplanting into field.

NSNonsignificant at *P* = 0.05.

Table 2. Plant characteristics and elemental concentration of short-internode Main Dwarf, normal-internode 'Mainstream', and F₁ (Main Dwarf x 'Mainstream') for 72-day-old^a plants in 1985.

Genotype	Leaf area (m ² /plant)	Leaf dry wt (g/plant)	Vine dry wt (g/plant)	Elemental concn (% dry wt)					
				Laminae			Stem and petiole		
				N	K	Ca	N	K	Ca
Main Dwarf	0.69	35.0	17.0	4.42	3.23	5.36	4.33	6.01	2.73
Mainstream	1.06	55.7	29.7	4.69	3.18	4.82	4.12	6.76	2.53
F ₁ (Main Dwarf x Mainstream)	1.13	62.7	37.3	4.33	3.10	5.21	4.08	6.52	2.39
LSD, <i>P</i> = 0.05	0.14	7.8	4.2	0.32	NS	0.39	NS	0.32	0.21

^a44 days after transplanting into field.

NSNonsignificant at *P* = 0.05.

Table 3. Chlorophyll, specific leaf weight, rubisco activity, and accumulated dry weight of short-internode Main Dwarf, normal internode 'Mainstream', and F₁ (Main Dwarf x 'Mainstream') plants.

Genotype	Chlorophyll ^a		Specific leaf dry wt ^b (mg·cm ⁻²)	Rubisco activity ^c		Accumulated dry wt (g·day ⁻¹) ^d
	(μg·cm ⁻²)	(a : b ratio)		(μmol CO ₂ /hr per cm ² leaf area)	(μmol CO ₂ /hr per mg chlorophyll)	
Main Dwarf	41.3	2.4	6.3	28.1	681	2.5
Mainstream	37.3	2.4	4.5	25.3	678	4.3
F ₁ (Main Dwarf x Mainstream)	41.6	2.4	5.6	28.7	690	5.3
LSD, <i>P</i> = 0.05	3.6	NS	1.0	2.1	NS	0.8

^aData recorded on 72-day-old plants in 1987.

^bData based on plant growth from 10–24 June 1985.

NSNonsignificant at *P* = 0.05.

to center, and covered with black polyethylene mulch. Plants were spaced 1 m apart in a single row. Each year all plots received 112 kg N/ha and P and K based on soil analysis and experiment station recommendations (Roberts et al., 1988) for muskmelon production on Maury silt loam soil (fine, mixed, mesic, typic Paleudalfs). All fertilizer materials were disked into the soil before the mulch was placed.

The experimental design was a randomized complete block with three replications. For growth measurements in 1985, three plants from each replication were harvested for each parent and hybrid at 58 and 72 days after seeding. At each harvest, plants were cut at the soil surface, the leaves cut at the junction of petiole and laminae, and leaf area measured with a LI-COR Model 3100 leaf area meter (LI-COR, Lincoln, Neb.). Stem and branch length were measured at 72 days. Leaf area ratios and net assimilation rates were determined according to procedures by Watson (1952) and Wallace and Munger (1965).

Leaves and stems were washed in deionized water before being oven-dried at 70°C for dry weight and elemental analyses. Nitrogen was determined by micro-Kjeldahl and K and Ca by atomic absorption spectrophotometry. Six plants per replication were left in the field for determination of fruit char-

acteristics and yield. All data were subjected to analysis of variance.

In 1987, chlorophyll density, chlorophyll a : b ratio, specific leaf weight, and rubisco activity were measured in leaf disks (1.55 mm²) void of vascular tissue, punched from mature leaves. Samples were taken at noon. Chlorophyll was determined as described by Inskeep and Bloom (1985). Specific leaf dry weights were recorded after desiccation at 75°C for 24 hr. Leaf disks used for measuring rubisco activity were frozen in liquid N₂ at the time of sampling and pulverized in liquid N₂ with a mortar and pestle before extraction with buffer (3 ml·g⁻¹ fresh weight) containing 100 mM Bicine -Na⁺(pH 8.2), 10 μM Leupeptin, and 5 mM 2-mercaptoethanol. After centrifugation at 12,000 × *g*, an aliquot of the supernatant (50 μl) was assayed for rubisco activity at 30°C (Pierce et al., 1982) without prior activation with Mg²⁺ and HCO₃⁻. (Preliminary experiments established that Mg²⁺ and HCO₃⁻ activation was not necessary for maximum rubisco activity.)

Main Dwarf plants have less total vine length, fewer nodes, shorter internodes, less leaf area, and less leaf and vine dry weight than plants of their NI parent 'Mainstream' (Tables 1 and 2). At each sampling time, F₁ (Main Dwarf x 'Mainstream') plants were similar to 'Mainstream' plants except for vine dry weight, which was greater than for

'Mainstream' plants at 72 days (Table 2). Other than this characteristic, there is no indication that hybrid vigor was expressed. Average mature leaf sizes of Main Dwarf, 'Mainstream', and the F₁ (Main Dwarf x 'Mainstream') were 960, 1450, and 1450 mm², respectively.

Main Dwarf plants absorbed N and K as well as the NI 'Mainstream' plants (Table 2). Potassium concentration for Main Dwarf, 'Mainstream', and the F₁ (Main Dwarf x 'Mainstream') was similar in the laminae, but Main Dwarf plants had significantly less K in stems and petioles. The levels in 'Mainstream' reported here are in agreement with a previous report (Knave, 1988b) for other experiments with 'Mainstream' plants. They are also within the ranges reported by Tyler and Lorenz (1964) and Bhella (1985) for muskmelon plants.

Chlorophyll concentrations were significantly higher in leaves of Main Dwarf and the F₁ (Main Dwarf x 'Mainstream') than in 'Mainstream' (Table 3). Specific leaf weight was 40% greater for Main Dwarf and 24% greater for the F₁ hybrid as compared to 'Mainstream'. All three genotypes had similar chlorophyll a : b ratios. Nerson et al. (1983) reported that leaves of Persia-202 plants had much less chlorophyll than leaves of SI and NI cultivars used in their study.

Total rubisco activity per unit leaf area

Table 4. Yield comparison of short-internode Main Dwarf, normal-internode 'Mainstream', and F₁ (Main Dwarf x 'Mainstream') for 1985, 1986, 1987, and the reciprocal hybrid F₁ ('Mainstream' x Main Dwarf) in 1987.

Genotype	Fruit yield		Mean fruit wt (kg)
	No./plant	Wt (kg/plant)	
		1985 and 1986	
Main Dwarf	7.6	5.0	0.64
Mainstream	8.6	10.5	1.20
F ₁ (Main Dwarf x Mainstream)	8.1	11.0	1.35
Significance			
Year	**	**	*
Genotype	NS	**	**
Year x genotype	NS	NS	NS
		1987	
Main Dwarf	7.0	4.8	0.69
Mainstream	7.5	9.3	1.24
F ₁ (Main Dwarf x Mainstream)	8.0	10.3	1.29
F ₁ (Mainstream x Main Dwarf)	6.8	8.3	1.22
LSD, P = 0.05	0.9	1.7	0.50

NS,*,**Nonsignificant or significant at P = 0.05 or 0.01, respectively.

Table 5. Comparison of fruit characteristics of short-internode Main Dwarf with normal-internode 'Mainstream' and F₁ (Main Dwarf x 'Mainstream') in 1985.

Genotype	External			Internal		
	Length (mm)	Diameter (mm)	Suture rating*	Seed cavity ratio (L : D) ^y	Flesh thickness (mm)	Flesh color ^x
Main Dwarf	104	112	1.2	1.35	30	2.5
Mainstream	147	138	2.0	1.52	40	3.0
F ₁ (Main Dwarf x Mainstream)	148	140	2.0	1.48	49	2.8
LSD, P = 0.05	6.0	7.8	0.3	0.13	2.3	0.5

*Ratings made on a scale of 1 to 5; 1 = no netting or suturing.

^yLength : diameter.

*Ratings made on a scale of 1 to 5; 1 = light orange, 5 = dark orange.

was ≈11% higher in extracts from the leaves of Main Dwarf and F₁ (Main Dwarf x 'Mainstream') than in 'Mainstream' (Table 3). However, on a chlorophyll basis, rubisco activity was equivalent among all three genotypes. Even though there were increases in the level of chlorophyll and activity of rubisco per unit leaf area in Main Dwarf, the reduced total leaf area at 44 days after transplanting resulted in a total amount of chlorophyll and rubisco activity per plant (285 mg and 194 mmol CO₂/hr, respectively) that would be less than that for 'Mainstream' (395 mg and 268 mmol CO₂/hr, respectively). However, the same was not true for the F₁ hybrid, which had levels of chlorophyll and rubisco activity similar to those of Main Dwarf but not reduced total leaf area. However, increased specific leaf weight, increased chlorophyll, and increased rubisco activity did not appear to be related to fruit yield.

Main Dwarf plants produced as many fruit but yielded only one-half the total weight of 'Mainstream' plants (Table 4). In 1985 and 1986, plants of 'Mainstream' and F₁ (Main

Dwarf x 'Mainstream') produced the same yield based on total number and weight of fruit. In 1987, the F₁ ('Mainstream' x Main Dwarf) produced about the same number of equal weight fruit as 'Mainstream', but total number and weight of fruit per plant were less than for the reciprocal hybrid, F₁ (Main Dwarf x 'Mainstream').

Net rating and stem scar diameter of Main Dwarf fruit were similar, but fruit were smaller than 'Mainstream' and F₁ (Main Dwarf x 'Mainstream') fruit (data not shown). 'Mainstream' and F₁ (Main Dwarf x 'Mainstream') fruit were similar for length, diameter, suture rating, seed cavity ratio, flesh thickness, and flesh color; and, except for flesh color rating, these dimensions or ratings were all greater than for Main Dwarf fruit (Table 5). Fruit characteristics of reciprocal hybrids appeared very similar in 1987.

The similarity of Main Dwarf, 'Mainstream', and F₁ (Main Dwarf x 'Mainstream') plants for fruiting characteristics suggests that Main Dwarf is isogenic to 'Mainstream' except for the recessive gene

for SI (Knavel, 1990).

It is commonly known that chlorophyll is maternally inherited. In this study, F₁ (Main Dwarf x 'Mainstream') plants had chlorophyll levels and rubisco activity similar to Main Dwarf plants. Thus, Main Dwarf plants may be of value for increasing these characteristics in other hybrid combinations. This conclusion is supported by the fact that the reciprocal F₁ in 1987 had fewer fruit and lower weight of fruit per plant than F₁ (Main Dwarf x 'Mainstream').

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