JARQ 27, 1-7 (1993)

Factors Influencing the Rooting of Cut-Sprouts in Sweet Potato

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Abstract
One of the limiting factors for dry matter production in sweet potato (*Ipomoea batatas Lam.*) is the establishment of cut-sprouts or cuttings. To improve the establishment of cut-sprouts, factors affecting the rooting of cut-sprouts were investigated. First, the effect of the soil temperature on rooting was investigated. The optimum soil temperature for rooting and varietal differences, varietal differences in rooting ability at a low soil temperature, and the effect of high soil temperature stress on the rooting were analyzed under controlled environment. The effect of vinyl mulching on rooting and the formation of tuberous roots was analyzed under field conditions. Second, the effect of holding (storage) of cut-sprouts on rooting was investigated. Beneficial effect of holding for 5 to 10 days on the rooting, formation of tuberous roots and yield was revealed. The physiological mechanisms of the beneficial effect of holding were also analyzed.

Discipline: Crop production
Additional key words: establishment of cut-sprouts, formation of tuberous roots, holding, *Ipomoea batatas*, soil temperature

Introduction

The main characteristics of dry matter production in sweet potato are as follows : (1) Maximum dry matter production rate is not very high. (2) Relatively high dry matter production rate persists for a long period of time. (3) Dry matter partitioning to tuberous roots is very high[9]. Based on these characteristics it is important for the improvement of the dry matter production and yield to accelerate the rooting and establishment of cut-sprouts after planting. However, information about the physiological factors affecting these developmental processes is still limited.

I have investigated the relationship between some environmental or endogenous factors and the rooting or establishment of cut-sprouts. The results of these studies have been published in several papers[1-7]. In the present paper, I summarize my studies on the effects of the soil temperature and of holding (storage) of cut-sprouts on the rooting of sweet potato.

Effect of soil temperature on rooting of cut-sprouts and formation of tuberous roots

The soil temperature is one of the major environmental factors influencing the rooting and tuberous root formation. The effect of the soil temperature on rooting, and some root characteristics of cut-sprouts were investigated under a controlled environment. The effect of polyethylene film mulching on rooting and tuberous root formation was also examined under field conditions.

(1) Using a cultivar (abbreviated as cv.) Okinawa 100, the critical and optimum soil temperatures for rooting were investigated at constant soil temperatures from 13 to 40 °C. The rooting of cut-sprouts occurred normally at soil temperatures ranging from 19 to 37 °C. At a soil temperature of about 30°C, maximum values were recorded for the root

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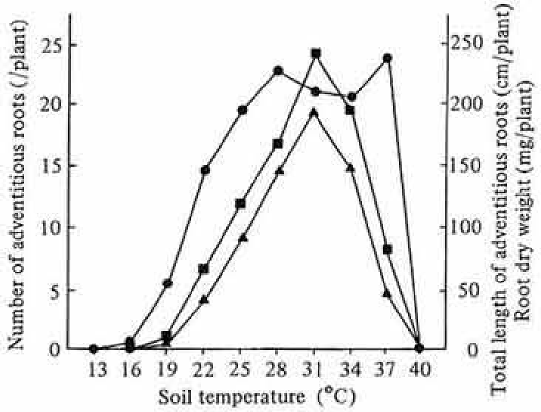

Fig. 1. Effect of soil temperature on number (●) and total length (■) of adventitious roots and root dry weight (▲) at 1 week after planting
Cultivar : Okinawa 100.

length and root weight at 1 week after planting (Fig. 1). The number of leaves that recovered from wilting and developed at 1 and 2 weeks after planting also reached maximum values at 30°C. Therefore, the optimum soil temperature for the rooting and establishment of cut-sprouts for the cv. Okinawa 100 was found to be 30°C.

(2) The varietal differences in the optimum soil temperature for the rooting of cut-sprouts among the 12 Japanese cultivars were investigated at soil temperatures ranging from 26 to 35°C. The optimum soil temperature for 8 cultivars, i. e. cvs. Koganesengan, Okinawa 100, Shiroyutaka, Shirosatsuma, Minamiyutaka, Beniaka, Beniazuma and Norin 1 was about 30°C. For the cvs. Kokei 14, Norin 2, Tamayutaka and Benikomachi, the temperature was higher than for the others, i. e. 32-35°C.

(3) The varietal differences in the rooting ability at low soil temperatures were also investigated. First, the ratio of the root length at 18°C to that at 28°C was determined. The ratio differed among the cultivars, and it was higher for the cvs. Norin 1, Minamiyutaka, Kokei 14 and Benikomachi. Next, the root length per unit weight of cut-sprouts after 4 weeks from planting at 15°C was measured. It also varied, and the values were higher for the cvs. Norin 1 and Minamiyutaka and lower for Benikomachi and Kokei 14, etc. (Table 1). Thus the rooting ability at low soil temperatures appeared to be higher for the cvs. Norin 1 and Minamiyutaka.

(4) To analyze the effect of high soil temperature stress on rooting and some root functions, cut-sprouts of 3 cultivars were exposed to soil temperatures of above 40°C for 0-24 hr per day during a period of 1 week after planting. Total root length decreased due to the high soil temperature treatments. However, in the treatment that lasted less than 2 hr, the extent of the decrease was small due to the compensatory increase in the number of roots, although the average root length apparently decreased. In spite of the decrease in the total root length, the number of leaves and transpiration rate did not decrease by the exposure to a high soil temperature for 2 hr, presumably due to the increase in the root activity based on the root respiration rate and total sugar content (Table 2). In the high soil temperature treatments there were a

Table 1. Total root length, root dry weight and number of leaves 5 weeks after planting at a soil temperature of 15°C

Cultivar	Fresh weight of cut-sprouts (A) (g)	Dry weight of cut-sprouts (B) (g)	Total root length (C) (cm)	C/A	C/B	Root dry weight (D) (mg)	D/A	D/B	C/D	No. of leaves
Koganesengan	39.0	3.55	708	18.2	199	248	6.36	69.9	2.85	4.6
Okinawa 100	32.8	2.99	682	20.8	228	259	7.90	86.6	2.63	5.4
Norin 1	31.2	3.74	984	31.5	263	423	13.55	113.1	2.33	6.9
Norin 2	23.5	2.15	409	17.4	190	214	9.11	99.5	1.91	2.6
Kokei 14	28.4	2.70	505	17.7	187	244	8.59	90.4	2.07	3.8
Tamayutaka	28.7	3.01	486	16.9	161	254	8.85	84.4	1.91	4.4
Minamiyutaka	36.6	3.51	1,092	29.8	311	450	12.30	128.2	2.43	4.7
Benikomachi	38.4	3.92	658	17.1	168	258	6.72	65.8	2.55	4.5
Beniazuma	30.5	3.39	699	22.9	206	291	9.54	85.8	2.40	4.6

Values are the average of 8 cut-sprouts except for the dry weight of cut-sprouts which is the product of the fresh weight and dry weight ratio of another 8 cut-sprouts.

Table 2. Effect of high soil temperature (40°C) treatment on rooting and some root characteristics at 1 week after planting

Cultivar	Duration of exposure to high soil temperature (hr/day)	Total root length (m)	Root dry weight (mg)	Root respiration rate (mg/g/hr)	Root total suger content (mg/g)	Root starch content (mg/g)	Root diameter (mm)	Root stele diameter (mm)	No. of leaves	No. of dead leaves	Transpiration rate ($\mu g/cm^2/s$)
Koganesengan	0	20.3	291	5.72	29.4	33.7	1.18	0.49	6.5	1.8	9.78
	3	16.1	266	6.16	32.4	33.2	1.16	0.44	7.5	0.5	8.17
	6	2.7	62	6.85	33.6	33.3	1.09	0.34	5.8	1.7	3.10
Kokei 14	0	18.6	366	4.16	27.7	26.6	1.12	0.41	7.3	1.2	6.99
	3	12.8	302	4.57	36.6	27.2	1.27	0.44	7.7	1.3	6.97
	6	3.3	85	7.35	49.8	30.3	1.29	0.38	7.2	1.0	3.44

a): Root respiration rate was measured at 25°C in the dark.
Values are the averages of 6 plants except for the root and root stele diameter which are the averages of the thickest 20 roots.

large number of roots with few cell layers in the primary cambium and the lignification of the stele cells was accelerated (Fig. 2). Thus a high soil temperature above 40°C that lasted less than 2 hr per day did not suppress the establishment of cut-sprouts apparently. From the anatomical point of view, however, it appeared difficult for the roots to develop to tuberous roots[8] when exposed to a high soil temperature even for only 2 hr per day.

(5) The effects of polyethylene film mulching and the planting time on the rooting of cut-sprouts and the formation of tuberous roots were examined under field conditions by using 3 cultivars. The average soil temperature when mulching was omitted was about 20°C at both planting times and it increased by about 6°C when clear film mulching was applied and by about 2°C in the case of silver film mulching. The average duration when the soil temperature exceeded 40°C was 1.4-2.4 hr per day

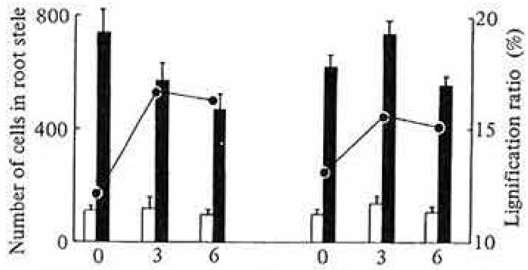

Fig. 2. Effect of high soil temperature (40 °C) treament on the number of lignified (A : □) and non-lignified (B : ■) cells and lignification ratio (A/A+B : ●) of root stele at 1 week after planting
Left: Koganesengan, Right: Kokei 14.

in the case of clear film mulching. Total root length at 1 week after planting was longer in the order of clear film>silver film>mulching omitted. Maximum root diameter at 4 weeks after planting was larger in the order of clear film>silver film>mulching omitted. The distance from the root base to the portion with a maximum root diameter increased by clear film mulching apparently. Thus the rooting and establishment of cut-sprouts were accelerated by polyethylene film mulching, and this promotive effect was also observed in the formation of tuberous roots. However, due to the high soil temperature associated with clear film mulching, the roots became tuberous in the deeper soil layers where the temperature was not very high. Therefore, the shape and joint part of the tuberous roots bacame longer.

Effect of holding (storage) of cut-sprouts on rooting and formation of tuberous roots

It is noteworthy that sweet potato growers often plant cut-sprouts a few days after cutting in Japan. The effect of holding of cut-sprouts on the rooting, the formation of tuberous roots and yield was investigated. In this study, the holding of cut-sprouts was carried out under a 13.5-18°C and 80-95% relative humidity regime and continuous weak light conditions.

(1) The effect of holding for 5 to 15 days on rooting was tested by using 2 cultivars under controlled environment (28°C/18°C, day/night temperature). The number of roots at 1 week after planting decreased in the cut-sprouts subjected to holding. On the other hand, the average root length

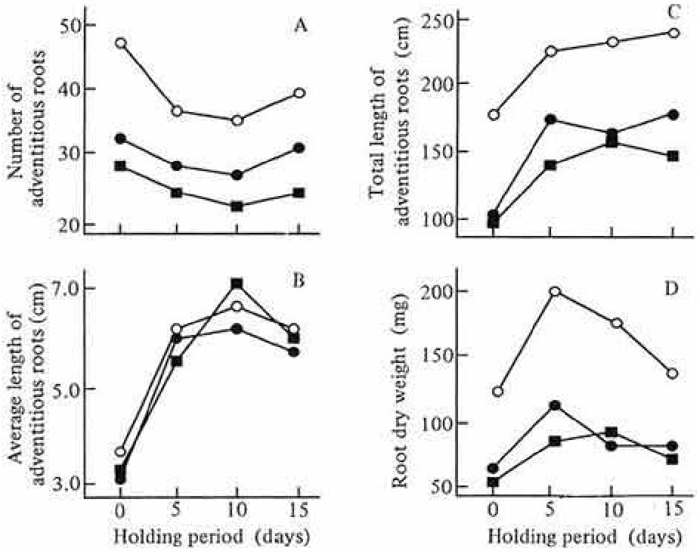

Fig. 3. Effect of holding on number (A), average length (B), total length (C) of adventitious roots and root dry weight (D) at 1 week after planting
○ : Koganesengan (1983), ● : Koganesengan (1985), ▲ : Kokei 14 (1985).

increased in the held ones. Consequently the total root length increased by the holding practice. The root dry weight increased by holding during 5–10 and after the 15-day holding period the root dry weight did not differ from that of the control without holding. The number of living leaves decreased markedly by the 15-day holding treatment (Fig. 3). Thus the holding of cut-sprouts for 5–10 days appeared to exert a beneficial effect on the rooting and establishment of cut-sprouts.

Anatomical observation of the thickest roots at 1 week after planting showed that the developmental stages of the roots were accelerated by holding. The primary cambium of the roots was also activated by holding. These facts indicate that holding promoted the formation of tuberous roots[8]. However, the lignification of the stele in the roots was accelerated by the 15-day holding treatment (Table 3). Since the stele lignification prevents the formation of tuberous roots[8], it appeared that holding for 5–10 days accelerated the formation of tuberous roots.

Table 3. Effect of holding on the anatomical characteristics of roots at 1 week after planting

Cultivar	Holding period (days)	Root diameter (mm)	Root stele diameter (mm)	No. of cell layers in primary cambial zone	No. of lignified cells in root stele (A)	No. of non-lignified cells in root stele (B)	Lignification ratio (A/A+B, %)
Koganesengan	0	1.16 a	0.32 b	2.5 b	83.1 b	465.5 b	15.1 b
	5	1.23 a	0.46 a	3.7 a	109.7 a	615.7 a	15.1 b
	10	1.15 a	0.39 ab	3.6 a	107.3 a	589.3 a	15.4 b
	15	1.10 a	0.38 ab	3.5 a	103.2 a	510.4 ab	16.8 a
Kokei 14	0	1.21 a	0.31 b	2.2 b	57.8 c	488.4 b	10.6 b
	5	1.21 a	0.37 ab	3.2 a	77.1 bc	616.1 a	11.1 b
	10	1.26 a	0.42 a	3.5 a	121.4 a	611.1 ab	16.6 a
	15	1.11 b	0.33 b	3.0 a	103.8 ab	478.0 b	17.8 a

Values are the averages of the thickest 15 roots.
The values followed by same letters are not significantly different according to 5% level Duncan's multiple range test.

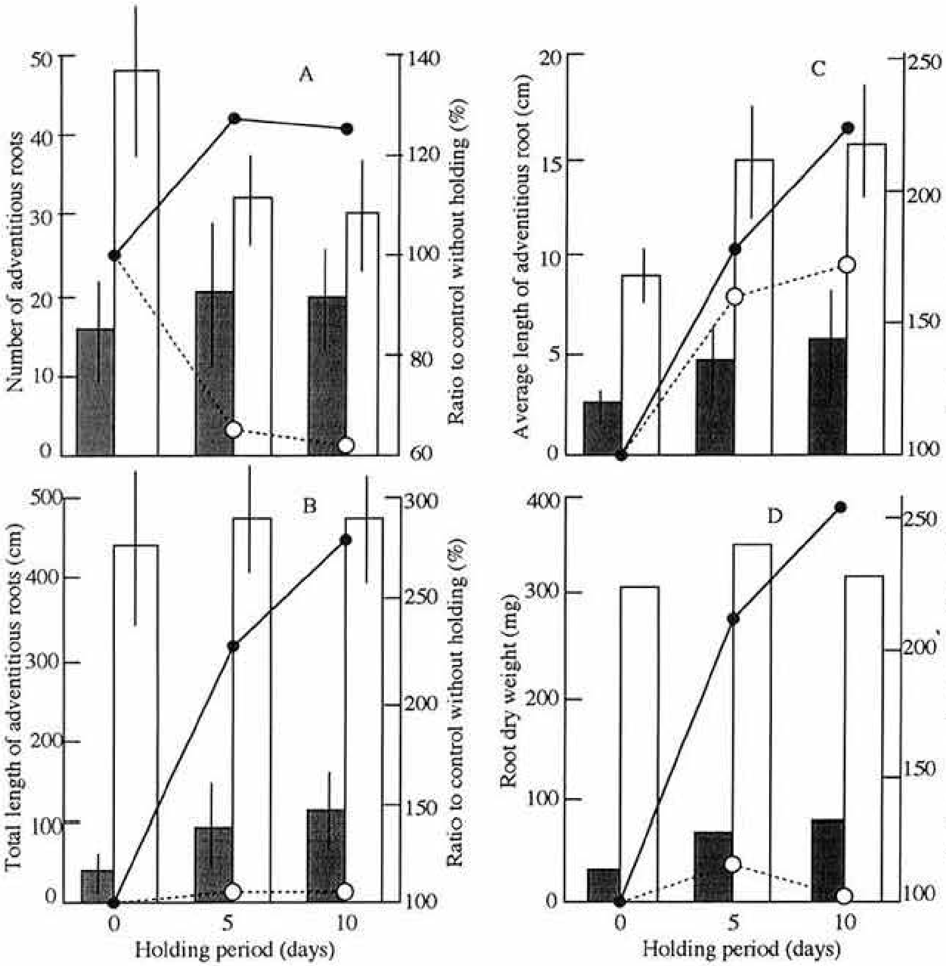

Fig. 4. Effect of holding on number (A), total length (B), average length (C) of adventitious roots and root dry weight (D) at 1 week after planting at different soil temperatures
■, □ : Average value per plant ± standard deviation, ●, ○ : Ratio to control without holding,
■, ● : Soil temperature 20°C, □, ○ : Soil temperature 30°C.

(2) The effect of holding was also tested under unfavorable environmental conditions. Under favorable conditions (soil temperature 30 °C or soil moisture 70% of field capacity) the total root length increased by about 10% by holding for 5-10 days. On the other hand, under a low soil temperature (20 °C, Fig. 4) or moisture (30% of field capacity) regime, the number of roots, total root length, average root length and root dry weight increased by holding for 5-10 days by about 30-50%, 3 times, 2 times and 2 times, respectively. Thus the beneficial effect of holding on rooting was more apparent under adverse environments.

(3) To analyze the physiological mechanisms of the beneficial effect of holding on rooting some physiological changes in the cut-sprouts during the holding period were investigated.

The fresh weight of the cut-sprouts decreased gradually with the increase in the duration of the holding period, whereas the dry weight ratio increased. The lower leaves of the cut-sprouts began to wither after 10 days of holding and on the 15th day about 3 basal leaves fell. Respiration rate in the cut-sprouts decreased on the 5th and 10th day of holding, but it increased again to the initial rate on the 15th day of holding (Fig. 5).

Nitrogen content in each organ of the cut-sprouts did not change during the holding period. Carbo-

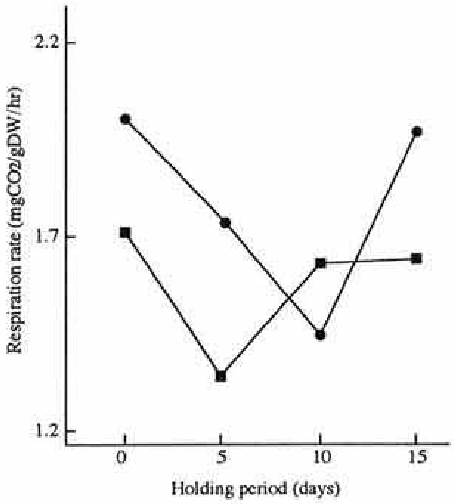

Fig. 5. Changes in respiration rate of cut-sprouts during holding period
●: Koganesengan, ■: Kokei 14.

hydrate content of the leaf blades and the upper stems decreased during the holding period. In the lower stems that corresponded to the rooting sites, the content did not change in one cultivar and it increased in another cultivar during the holding period. Indole acetic acid (IAA) and abscisic acid (ABA) levels in the lower stems were analyzed by high performance liquid chromatography (Table 4). The IAA level in the lower stems tended to decrease gradually with the increase of the duration of the holding period. On the other hand, the ABA level in the same part increased on the 5th and 10th day of holding, and ABA disappeared on the 15 th day of holding presumably due to the fall of the lower leaves. Based on the results obtained, it was suggested that the beneficial effect of holding for 5-10 days was associated with the translocation of carbohydrates to the rooting site, without conspicuous loss of nutrient reserves by the respiration and

Table 4. Changes in IAA and ABA contents of basal 3 nodes of stem (rooting site) during the holding period

Cultivar	Holding period (days)	IAA content (pmol/g fr. wt.)	ABA content (pmol/g fr. wt.)
Koganesengan	0	134.1	745
	5	48.5	1,067
	10	76.5	904
	15	36.5	trace
Kokei 14	0	66.2	511
	5	54.8	1,177
	10	64.5	628
	15	25.7	trace

IAA and ABA contents were determined by HPLC with fluorescent (Ex : 280, Em : 355 nm) and absorbance (280 nm) monitor, respectively.

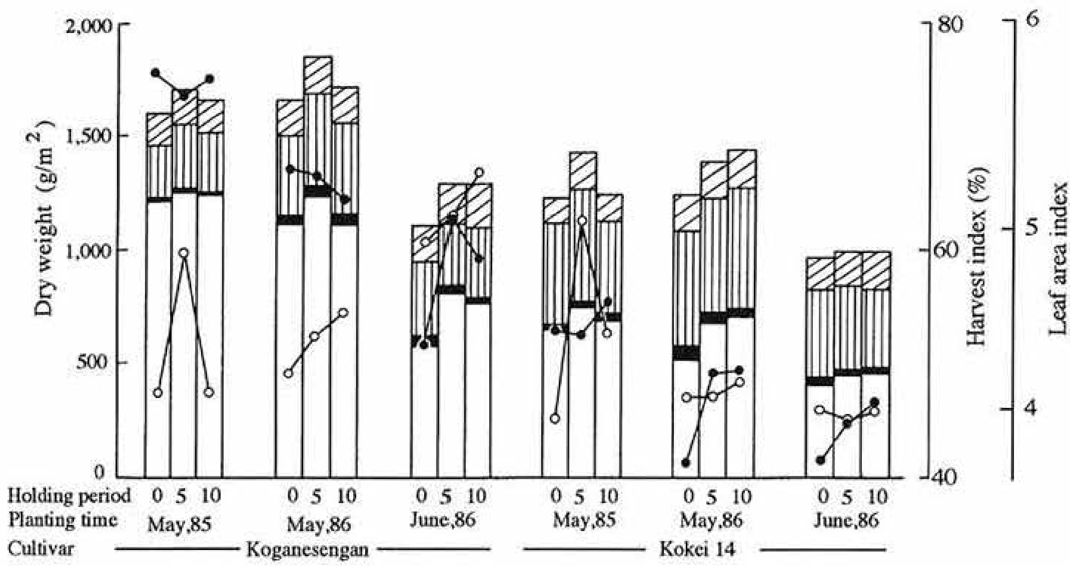

Fig. 6. Effect of holding of cut-sprouts on the dry weight of each organ at harvest (Oct.)
▨: Leaf blade, ▥: Petiole and stem, ■: Tuberous root (50 g>), □: Tuberous root (50 g<),
○: Leaf area index at harvest, ●: Harvest index.

defoliation. The decrease of the IAA level in the rooting site seemed to be related to the decrease of the root number and the promotion of root elongation. The increase of the ABA level may be related to the suppression of excessive transpiration after planting.

(4) Effect of holding on the field establishment of cut-sprouts, formation of tuberous roots and yield was examined under field conditions for 3 planting times in 1985 and 1986 by using 2 cultivars.

Although the survival ratio of the cut-sprouts was nearly 100% in every treatment, the number of leaves was larger and the transpiration rate was higher at 1 or 2 weeks after planting in the 5-10-day holding treatment than in the control without holding. At 5 weeks after planting, the number and dry weight of tuberous roots in the case of holding were larger than those in the absence of holding. The total dry weight and leaf area tended to increase with the holding practice at this stage. Although no significant difference was observed in the yield in terms of the duration of the holding period in 1985, higher yields at 1% significance level were obtained by holding in 1986. Also the total dry weight and harvest index increased in the case of holding (Fig. 6). Thus it is concluded that the holding practice promoted the establishment of cut-sprouts and the formation of tuberous roots, and that these effects were often related to the increase of yield.

Both in the experiments on the effects of the soil temperature and holding, a similar trend was observed as follows : the formation of tuberous roots was delayed when a larger number of roots and shorter roots were observed during the rooting of cut-sprouts. These results suggest that it is important to consider the balance of two functions of roots, i.e. absorption of water and nutrients and storage organ. It is also suggested that the root length is a more important characteristic than the root number for the optimum rooting form of cut-sprouts in sweet potato.

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(Received for publication, Feb. 3, 1993)