Reprinted from HortScience, Vol. 23(1), February 1988
A publication of the American Society for Horticultural Science, Alexandria, Virginia

HortScience 23(1):145–148. 1988.

Growth Analysis of Three Cucumber Lines Differing in Plant Habit

Denis R. Ramirez[1], Todd C. Wehner[2], and Conrad H. Miller[3]
Department of Horticultural Science, North Carolina State University, Raleigh, NC 27695–7609

Additional index words. *Cucumis sativus* var. *hardwickii*, growth analysis, leaf area, relative growth rate, dry matter partitioning, multiple branching, dwarf, determinate, vegetable breeding

Abstract. **Growth analyses were conducted in the greenhouse on two commercial lines, 'Calypso' and M 21 [of cultivated cucumber (*Cucumis sativus* L. var. *sativus*] differing in growth habit and one line, LJ 90430, of the wild cucumber *Cucumis sativus* L. var. *Hardwickii* (R.) Alef., to determine relationships between morphological characteristics and fruit yield. Multiple fruiting in LJ 90430 was associated with high leaf area and multiple branching. The standard commercial pickling cultivar, Calypso, which usually produces one to two fruit per plant per harvest, had less leaf area and fewer branches per plant than LJ 90430. Competition between early fruit development and vegetative growth was possible in 'Calypso' and M 21, but not in LJ 90430, which did not begin fruit development until vegetative growth was completed. Dry weight percentage in the fruit of LJ 90430 was low initially and increased steadily until the final harvest. Dry weight percentages in the fruit of 'Calypso' and M 21 were high initially and decreased generally thereafter. Relative growth rates of the whole plant followed similar trends in LJ 90430, 'Calypso', and M 21.**

The growth of a developing fruit on a cucumber plant inhibits the development of fruits that set later (4). It also affects the development of the roots and the main shoot apex (9, 13). The inhibitory effect ceases when the growing fruit is removed, allowing the production of several fruit per plant under multiple-harvest conditions. However, yields of only one to two fruit per plant are typical for crops harvested once-over (10).

McCollum (9) proposed that the mechanism of inhibition was the result of growth-regulating substances produced by fertilized ovaries. This possibility was investigated by Nienhuis (11), who made reciprocal grafts of *Cucumis sativus* var. *sativus* and *Cucumis sativus* var. *hardwickii* (referred to as sativus and hardwickii, respectively, hereafter). Hardwickii is a progenitor or feral cucumber that sets a large number of fruit, apparently lacking the inhibitory effect of one fruit on another (8). Nienhuis did not find any evidence for an inhibitory growth substance that could be translocated from developing sativus fruits across a grafted union and inhibit fruit setting on a hardwickii recipient scion (11).

Another explanation for the inhibitory effect of one fruit on another could be that fruit of the commercial cultivars of cucumber constitute strong sinks for assimilates, which draw heavily on plant supplies and inhibit the development of other fruit. Photosynthetic leaf area was found to be a limiting factor in cucumber yield (13).

The objective of this study was to determine if morphological characteristics or developmental features contribute to production of greater fruit weight and number in cucumbers. In addition, hardwickii was evaluated as a multiple-fruiting line for use in plant breeding programs as a source of genes for high yield.

Received for publication 14 Apr. 1986. Paper no. 10438 of the Journal Series of the North Carolina Agricultural Research Service, Raleigh, NC 27695–7601. The use of trade names in this publication does not imply endorsement by the NCARS of products named, nor criticism of similar ones not mentioned. Research funded in part by the North Carolina Pickle Producers Association. We gratefully acknowledge the assistance of R.R. Horton, Jr. 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.

[1]Graduate Assistant. Presently Research–Extension Specialist in Horticulture, Escuela Agricola Panamericana, Tegucigalpa, Honduras.
[2]Associate Professor.
[3]Professor.

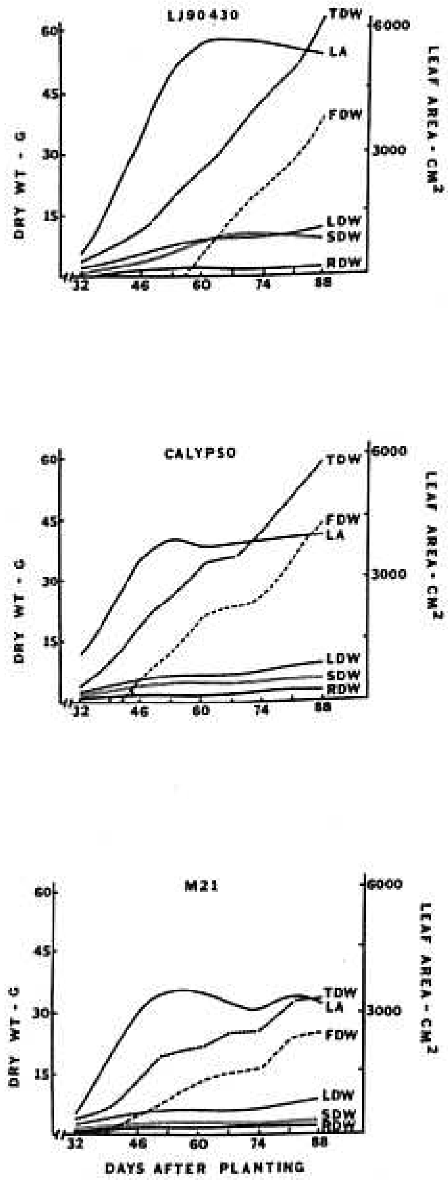

Fig. 1. Plant growth from pollination through mature seed stage (32 to 88 days after planting) in three cucumber lines (LJ 90430, 'Calypso', and M 21). Data shown are dry weights of the whole plant (TDW), fruit (FDW), leaves (LDW), stems (SDW) and roots (RDW), and leaf area (LA).

Table 1. Fruit number per plant and dry weight of leaves, stems, fruits, and roots of LJ 90430, 'Calypso', and M 21 at final harvest (88 days after planting) in the greenhouse.[z]

Cultivar or line	Fruit no.	Dry wt per plant (g)				
		Leaves	Stems	Fruit	Roots	Total
LJ 90430	26	12.4	9.9	40.8	2.6	65.7
Calypso	3	9.2	5.3	43.7	1.7	59.9
M 21	2	7.9	3.0	24.3	0.7	36.0
LSD (5%)	4	1.3	0.8	12.6	0.9	15.1
CV (%)	24	11	8	20	31	17

[z]Data are means over four replications.

Table 2. Stem length and fresh weight of leaves, stems, and fruit per plant of LJ 90430, 'Calypso', and M 21 at final harvest (88 days after planting) in the greenhouse.[z]

Cultivar or line	Stem length (cm)[y]	Fresh wt per plant (g)			
		Leaves	Stems	Fruit	Total
LJ 90430	1070	79	120	504	703
Calypso	195	76	86	769	931
M 21	86	74	43	468	585
LSD (5%)	60	16	13	108	123
CV (%)	8	12	9	11	10

[z]Data are means over four replications.
[y]The sum of main stem length plus length of all branches per plant.

The study was conducted in the Horticultural Science greenhouses in Raleigh, N.C. during Fall 1982. Three lines, LJ 90430 (a multiple-branching, late-maturing line from India), 'Calypso' (a tall, indeterminate, early-maturing cultivar), and M 21 (a dwarf, determinate, medium-maturity breeding line from North Carolina State Univ.) were used in the experiments. The experimental design was a split plot in a randomized complete block with four replications. Harvests were made 32, 39, 46, 53, 60, 67, 74, 81, and 88 days after planting, beginning 2 Nov. and ending 28 Dec.

Seeds were planted in 50-mm-diameter peat pots containing a 1 sand : 1 soil : 1 peat (by volume) mix. The soil medium was mixed after adding 833 g of finely ground dolomitic limestone and 142 g of 10N–1.8P–6.6K per m^3. Uniform plants were transplanted 20 days after seeding to 250-mm-diameter pots containing the same soil medium. Plants were given three 0.5-liter fertilizations containing 2 $g \cdot liter^{-1}$ 10N–4P–8K at 2-week intervals. Dinocap [2,4-dinitro-6-octyl-phenyl-crotonate; 2,6-dinitro-4-octyl-phenyl-crotonate; and nitrooctyl-phenols (principally dinitro)] was sprayed at flowering with 1.3 g a.i. in 4 liters of water to control powdery mildew and repeated later as necessary. All plants were hand-pollinated daily during a period lasting at least 16 days.

Seeds of LJ 90430 have a dormancy period lasting several months after harvest. To overcome that dormancy, seeds were soaked in acetone for 24 hr, air-dried for 4 hr, and incubated at 38° to 40°C and 100% RH for 48 hr. In order to induce flowering of LJ 90430, plants were placed under shadecloth beginning 2 days after germination and subjected to a photoperiod of 9.5 hr for 17 days before transplanting.

The following measurements were made at each harvest: fresh and dry weight of leaves, stems, fruits, and roots; number of leaves, fruits, and branches; stem length; and leaf area. Due to difficulty in separating the roots from the wet soil medium, fresh root weight was not used in any calculations. Total fresh weight was calculated as leaf + stem + fruit fresh weights. Total dry weight was calculated as leaf + stem + fruit + root dry weights. Leaf area was determined with an electronic leaf area meter (LI-COR LI-3100). Relative growth rates were estimated by use of the formula: $RGR = 1/W \times dW/dt$, as described by Beadle et al. (1), where RGR = relative growth rate ($g \cdot g^{-1}$ per week), W = initial total dry weight of the plant (g), dW = increment increase in dry weight (g) in time dt, and dt = 1 week.

At the end of the growing period (88 days), LJ 90430 and 'Calypso' had produced about the same amount of total (leaf + stem + fruit + root) dry weight and fruit dry weight (Table 1). M 21, however, had produced significantly less total dry weight than the others. LJ 90430 incorporated a greater proportion of dry weight into leaves, stems, and roots than the other two lines (9.3%, 6.4%, and 6.2% for LJ 90430, 'Calypso', and M 21, respectively), and the number of fruit per plant was significantly increased in LJ 90430.

'Calypso' had a significantly greater total fresh weight and fruit fresh weight than LJ 90430 and M 21. Stem length (which was related directly to branch number) was significantly higher in LJ 90430 than in 'Calypso' and M 21. 'Calypso' had a significantly higher stem length than M 21 (Table 2).

'Calypso' had a significantly higher leaf area than LJ 90430 and M 21 in the first two harvests (32 and 39 days after planting); however, LJ 90430 had the highest leaf area after 39 days (Table 3, Fig. 1). Fruits started developing on plants 37 days after planting in 'Calypso', 39 days after planting in M 21, and 53 days after planting in LJ 90430. At that time, their leaf area had developed 65%, 59%, and 93%, respectively, of their maximum leaf areas. In 'Calypso' and M 21, fruit set occurred ≈1 week before stems and leaves had reached maximum dry weight. In LJ 90430, fruit set coincided with the completion of maximum vegetative development.

Final root dry weight was significantly higher in LJ 90430 than in 'Calypso', which, in turn, had higher root weight than M 21 (Table 1). Differences among the three lines in root dry weights were greater on a percentage basis than differences in total weight. That difference resulted in a dry weight for roots representing 4% of the total dry weight in LJ 90430 but only 3% and 2% in 'Calypso' and M 21, respectively (Table 4).

At final harvest, fruit dry weight and fruit fresh weight as a percentage of total plant weight was significantly higher in 'Calypso' than in M 21, which, in turn, had a significantly higher percentage fruit weight than LJ 90430 (Table 4). That trend was evident

Table 3. Leaf area per plant at each of nine weekly samplings of LJ 90430, 'Calypso', and M 21 in the greenhouse.

Cultivar or line	Leaf area[z] (cm^2) Days after planting 32	39	46	53	60	67	74	81	88
LJ 90430	74	1928	3734	5152	5715	5744	5601	5583	5395
Calypso	123	2489	3604	4025	3770	3832	3980	4082	4086
M 21	105	1928	3106	3547	3473	3254	2958	3151	3252
LSD (5%)	15	560	806	717	885	906	759	995	1075
CV (%)	9	15	13	10	12	12	11	13	15

[z]Data are means over four replications. Analyses were performed separately for each of the nine harvests.

Table 4. Percentages of total fresh and total dry weight per plant partitioned into leaves, stems, fruits, and roots of LJ 90430, 'Calypso', and M 21 at final harvest (88 days after planting) in the greenhouse.

Cultivar or line	Partitioning into organ[z]: Fresh wt[y] Leaves	Fresh wt Stems	Fresh wt Fruit	Dry wt Leaves	Dry wt Stems	Dry wt Fruit	Dry wt Roots
LJ 90430	11	17	72	19	15	62	4
Calypso	8	9	83	15	9	73	3
M 21	13	7	80	22	8	68	2
LSD (5%)	1	2	3	2	2	3	1
CV (%)	7	11	2	4	8	3	28

[z]Data are means over four replications.
[y]Fresh weight calculated without roots due to difficulty in separating them from the wet soil medium.

as early as 1 week after fruit set. At that time, fruit dry weight in 'Calypso' represented ≈28% of the total dry weight, as compared to 13% and 21%, respectively, in LJ 90430 and M 21. On a fresh-weight basis, fruit weight in 'Calypso' 1 week after fruit set represented 38% of the total as compared to 30% and 22%, respectively, for M 21 and LJ 90430 (Fig. 1). LJ 90430 accumulated a significantly higher percentage of fresh and dry weight into its stems than 'Calypso' and M 21 (Table 4). M 21 produced a significantly higher percentage of leaf fresh weight and leaf dry weight than LJ 90430 and 'Calypso'.

Our results indicate that 'Calypso' had produced the same amount of total dry weight and fruit fresh weight as LJ 90430, in spite of having a smaller leaf area (Fig. 1). The increased production of dry weight relative to leaf area observed in 'Calypso' could be the result of an increase in leaf photosynthetic rates. The early presence of fruits might be a factor leading to enhanced photosynthetic rates. That factor has been shown for apple (*Malus domestica* Borkh.) (5), potato (*Solanum tuberosum* L.) (12), and other crops (2).

Fruit growth in 'Calypso', M 21, and other commercial cultivars usually begins before vegetative growth is completed. In LJ 90430, however, fruit growth did not start until vegetative growth was completed (Fig. 1). Early competition for assimilates between fruits and vegetative parts during the period of early development of fruit could be a factor influencing fruit set and development. This suggestion is in agreement with the high degree of inhibition of the first fruit on the development of other fruit found in 'Calypso' and M 21. On the other hand, LJ 90430 produced many fruit per plant and did not have any significant competition between vegetative and reproductive sinks.

The dry weight percentage in the fruit of 'Calypso' and M 21 was high initially but decreased rapidly later. That occurrence was probably a result of rapid fruit growth. In LJ 90430, where fruit growth was slower, the percentage of dry weight in the fruit was low at the beginning but increased steadily afterwards. It is possible that rapidly growing sinks in 'Calypso' and M 21 create a steep gradient in assimilate concentration. That development, in turn, results in the sink drawing assimilates from more distant source leaves than do weakly growing sinks (3). That demand could help explain, at least in part, the strong inhibitory effects of the first fruit on those developing later, as is common in 'Calypso' and other cultivars. Hewitt et al. (6) found that fruit of tomato (*Lycopersicon esculentum* Mill.) lines having higher solids content were also stronger sinks for assimilates than those of lines that had low solids content. Additional research is necessary to determine whether there is a relationship in cucumber between fruit solids content, stage, and rate of fruit development and sink strength.

Compared to cultivated lines of cucumber, the hardwickii line, LJ 90430, was distinctive in having strong vegetative sinks and weak reproductive sinks. Another characteristic feature was its multiple branching. Typically, plants were not single-stemmed as with 'Calypso', but produced about four main stems with short lateral branches at most nodes. Usually, one fruit set and developed at the end of each short branch. Fruit also set at the nodes where no short lateral branches had developed. The possibility of an association between branching habit and multiple fruiting is yet to be investigated.

A significantly higher leaf area was produced 53 days after planting and beyond by the multiple fruiting line, LJ 90430, as compared to 'Calypso' and M 21 (Table 3). That higher leaf area was due to many small leaves on LJ 90430 plants. Large leaf area has been associated with high solids content in tomato fruit (7), but not with high number of fruit. There is a need for further investigation on the relationships among leaf area, photosynthetic rate, and the time leaves remain photosynthetically active. Such information could help explain the role of source strength in determining fruit set and development in cucumber.

LJ 90430 is an important breeding line because of its delayed fruiting, multiple-branching, and high leaf area. However, it may not be useful as a source of germplasm for plant breeders interested in developing high-yielding lines because, in spite of the increased leaf area and delayed fruiting, fresh fruit weight was lower than that of 'Calypso' and dry fruit weight was the same.

Literature Cited

1. Beadle, C.L. 1982. Plant growth analysis. In: J. Coombs and D.O. Hall (eds.). Techniques in bioproductivity and photosynthesis. Pergamon, Elmsford, N.Y.
2. Burt, R.L. 1964. Carbohydrate utilization as a factor in plant growth. Austral. J. Biol. Sci. 17:876–877.
3. Cook, M.D. and L.T. Evans. 1978. Effect of relative size and distance of competing sinks on the distribution of photosynthetic assimilates in wheat. Austral. J. Plant Physiol. 5:495–509.
4. Denna, D.W. 1973. Effect of genetic parthenocarpy and gynoecious flowering habit on fruit production and growth of cucumber *Cucumis sativus* L. J. Amer. Soc. Hort. Sci. 98:602–604.
5. Hansen, P. 1970. ^{14}C studies on apple trees: IV. The influence of the fruit on the photosynthetic yields of fruits and leaves. Physiol. Plant. 23:805–810.
6. Hewitt, J.D., M. Dinar, and M.A. Stevens. 1982. Sink strength of fruits of two tomato genotypes differing in total fruit solids content. J. Amer. Soc. Hort. Sci. 107:896–900.
7. Hewitt, J.D. and M.A. Stevens. 1981. Growth analysis of two tomato genotypes differing in total fruit solids content. J. Amer. Soc. Hort. Sci. 106:723–727.
8. Horst, E.K. and R.L. Lower. 1978. *Cucumis hardwickii:* a source of germplasm for the cucumber breeder. Cucurbit Genet. Coop. Rpt. 1:5.
9. McCollum, J.P. 1934. Vegetative and reproductive responses associated with fruit development of the cucumber. Cornell Agr. Expt. Sta. Memoir 163:1–27.
10. Miller, C.H. and G.R. Hughes. 1969. Har-

vest indices for pickling cucumbers in once-over harvested systems. J. Amer. Soc. Hort. Sci. 94:485–487.

11. Nienhuis, J. 1981. The effects of various graft combinations between *Cucumis sativus* and *Cucumis hardwickii* on growth, flowering and fruit setting characteristics. MS Thesis, N.C. State Univ. Raleigh.

12. Nosberger, J. and E.C. Humphries. 1965. The influence of removing tubers on dry matter production and net assimilation rate of potato plants. Ann. Bot. (London) 29:579–588.

13. Pharr, D.M., S.C. Huber, and H.N. Sox. 1985. Leaf carbohydrate status and enzymes of translocate synthesis in fruiting and vegetative plants of *Cucumis sativus* L. Plant Physiol. 77:104–108.