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BREEDING PARTHENOCARPIC PICKLING CUCUMBERS (*CUCUMIS SATIVUS* L.): NECESSITY, GENETICAL POSSIBILITIES, ENVIRONMENTAL INFLUENCES AND SELECTION CRITERIA

O. M. B. DE PONTI

Institute for Horticultural Plant Breeding (IVT), Wageningen, the Netherlands

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SUMMARY

Parthenocarpic pickling cucumbers have been selected after crossing pickling and slicing cucumbers. On the best lines 90% of the female flowers set fruit (up to 75 fruits per plant within six weeks). At declining daylength productivity decreased, mainly because of a reduced flower initiation and partly by a reduced parthenocarpic potential.

The correlation between several selection criteria and the possibilities of preselection of young plants is discussed.

INTRODUCTION

Parthenocarpy within the species *Cucumis sativus* L. has long been known to occur (see STURTEVANT, 1890). NOLL (1902), who introduced the term parthenocarpy, was the first to study this phenomenon in cucumber. Other early reports are from EWERT-PROSKAU (1909), STRONG (1921, 1932), WELLINGTON & HAWTHORN (1928) and HAWTHORN & WELLINGTON (1930). It was not until the 1950's, however, that in glasshouses in the Netherlands and elsewhere in Europe parthenocarpic slicing cucumbers were grown on a large scale.

Pickling cucumbers still need pollination for fruit set. Until the 1960's they were grown only in the open, but subsequently Dutch growers found it profitable to grow them in glasshouses. Culture in glasshouses entails extra risks because of the necessary pollination, although in outdoor cultivation, too, pollination is far from guaranteed.

Pollination of cucumbers is mainly effected by honey-bees. To ensure maximum pollination bee colonies must be placed in the glasshouses and often also in the field, which requires special attention during chemical control of insects and diseases. Yet pollination may be insufficient, for honey-bee activity is influenced by different environmental conditions (COLLISON & MARTIN, 1973). Because cucumber is not a very attractive plant to honey-bees in comparison with many others, pollination may also be reduced when the bees prefer neighbouring crops or wild plants (COLLINSON & MARTIN, 1970; FREE, 1970). Also with abundant pollination, fertilization and fruit set are not always certain to take place, for instance at higher temperatures, when pollen tube growth is reduced (MATLOB & KELLY, 1973).

To maximize yield there has recently been a shift to predominantly female and all-female varieties. Until these varieties are parthenocarpic, 10% monoecious or androecious plants, which are less productive, have to be added for pollen supply, which reduces the yield per ha. Fruits with developing seeds inhibit the growth of later fruits; however, to a lesser extent if fruits grow parthenocarpiccaly (STRONG, 1921; TIEDJENS, 1928; MCCOLLUM, 1934; DENNA, 1973). Provided this is also true if immature fruits are harvested, it will increase and speed up multiple fruit set per plant, which is favourable for mechanical harvest.

From the above it might be clear that growing pickling cucumbers will be more profitable and less risky if pollination is no longer a prerequisite to fruit set. Since the beginning of the 1970's (ROBINSON et al., 1971) many papers have been published on the induction of parthenocarpy by growth regulators. Of these the morphactine chlorflurenol seems to be most promising (CANTLIFFE, 1974; WIEBOSCH & BERGHOEF, 1974). In the 1960's already breeders started the development of genetically parthenocarpic short-fruited and pickling cucumber lines (PIKE & PETERSON, 1969; KVASNIKOV et al., 1970; JULDASHEVA, 1971a, 1971b, 1973; BAKER et al., 1973; LASKAWY & REIMANN-PHILIPP, 1974; MESHCHEROV, 1974; MESHCHEROV & JULDASHEVA, 1974).

Our research was started in the 1960's. This paper deals with the development and selection of promising parthenocarpic lines. The correlation between different selection criteria and the influence of season is also discussed.

MATERIAL AND METHODS

At the beginning of the project no pickling cucumbers with a high tendency towards parthenocarpy were known. Therefore we used a slicing cucumber line (P1) as a progenitor for this character and crossed it with a gynoecious pickling cucumber line (P2). After a number of generations of line selection (see Fig. 1) a gradually increasing degree of parthenocarpy was combined with the short (8–12 cm) fruiting character.

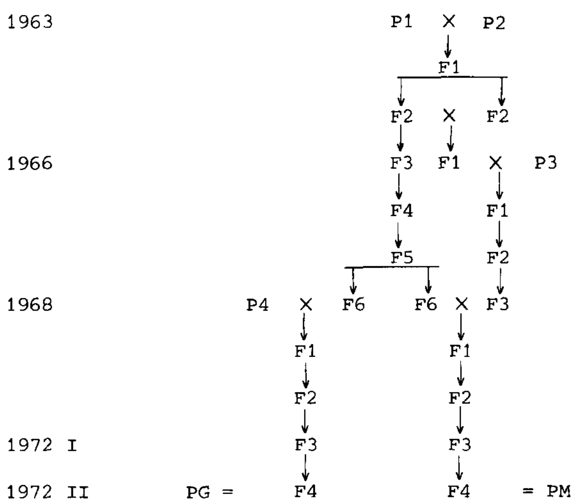

Fig. 1. Breeding programme applied to select the parthenocarpic pickling cucumber lines (P_1–P_4: see text).

In the course of selection crosses were made with two partly parthenocarpic short-fruited cucumber lines bred elsewhere, one (P3) at the Venlo Experimental Station in the Netherlands originating from a Porto Rican pickling cucumber variety, the other (P4) at Michigan State University, USA, originating from the slicing cucumber 'Spotresisting' (PIKE & PETERSON, 1969).

Thus two groups of parthenocarpic lines have been developed, one from the parents P1, P2 and P4, all lines being gynoecious (PG lines), the other from the parents P1, P2 and P3, all lines being monoecious (PM lines). The difference in sex expression is but accidental.

From the very first it appeared necessary to select rigorously against carpel separation, sponginess and different types of cavities, unfavourable characters frequently occurring in seedless fruits. This was done by cutting all fruits into halves and rating them.

The programme was carried out in glasshouses, which had been screened against honey-bees to prevent pollination. The temperature was kept at 20 °C during the night and at 23 °C minimum during the day. In sunny days the temperature sometimes rose above 30 °C. The plants were uniformly pruned by removing the laterals and ovaries of the first five nodes, the following laterals were pruned after the second node.

This paper presents the results of the final selection.

In the spring of 1972 (72 I) 10 F_3 PG lines and 3 F_3 PM lines were judged. Each line was planted in 3 replications of 10 plants. From 17 March to 27 April fruits of 8–12 cm length were harvested twice a week, counted and weighed.

In the autumn of 1972 (72 II) 14 F_4 PG lines and 11 F_4 PM lines were judged. The 7 parental F_3 lines were also included in this trial. Each line was planted in 3 replications of 5 plants. Harvest took place from 1 September to 9 October. Records were the same as for 72 I and cover again a six-week period from the date the first plant in the trial started producing.

In the spring of 1973 (73 I) 12 PG lines with a different degree of parthenocarpy, 2 PM lines and a non-parthenocarpic line were studied in detail. Each line was planted in 5 replications of 3 plants. Besides the number of parthenocarpic fruits the number of aborted ovaries was recorded. This enabled us to calculate the parthenocarpy percentage:

$$\% \text{ parthenocarpy} = \frac{\text{number of parthenocarpic fruits}}{\text{total number of female flowers}} \times 100.$$

These data were scored per plant part, for which purpose the plant was divided into 8 sections (see Fig. 2) up to the 25th node. Harvest took place from 12 March to 20 April.

In the autumn of 1973 (73 II) 39 F_1 populations, P_2 and 8 PG lines, also observed in 73 I, were judged again. The experimental design and the observations were the same as for 73 I, apart from the scoring per section. Harvest took place from 27 August to 5 October. In this trial the ovaries of the first five nodes were not removed.

All experiments were arranged in randomized blocks.

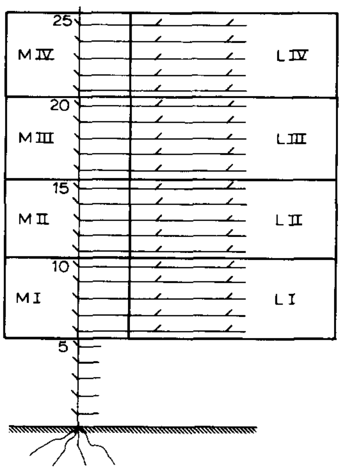

Fig. 2. Schematic representation of the cucumber plant (M = main stem; L = lateral shoot).

RESULTS AND DISCUSSION

Productivity of parthenocarpic lines. The production data of the best F_3 and F_4 lines (Fig. 3), as manifested in the 72 I, 72 II and 73 I trials, are recorded in Table 1. The less productive lines are not mentioned individually, but contributed to the mean figures. Significant differences exist between individual lines ($P > 0.95$). So selection between lines was still profitable. The selection within 7 F_3 lines resulted in 10 (out of 25) F_4 lines which outyielded their parental lines in the 72 II trial, but only two (72186 and 72211) differed significantly ($P > 0.95$) from their parents.

There are two reasons to doubt whether by further selection the parthenocarpic productivity would still markedly increase. First, the differences between lines are diminishing in later generations and second, the sharp decline in variance per line (Table 1) from F_3 to F_4 demonstrates the increased homozygosity for this character in all F_4 lines. Except for the productivity and the shortness of fruits this breeding material still needs improvement with respect to plant habit, fruit characters and resistances. Fig. 4 gives typical examples of fruits of PG and PM lines.

The above considerations led us to decide that there was little point in further selecting within these lines. Improvements should rather be reached through backcrosses and recombinations. Therefore we finished selection, released the best lines to Dutch breeding companies and devoted ourselves to a detailed study of the parthenocarpic character.

The number of parthenocarpic fruits depends on many factors like number of flowers, degree of parthenocarpy and different physiological processes governing the growth of fruits. In our opinion the criterion of fruit number was too rough to obtain a better insight in the parthenocarpic phenomenon. In 1973 we switched to scoring the parthenocarpy percentage.

The records on those PG lines which were present in both 1973 trials are summarized in Table 2. Data on a non-parthenocarpic line and 2 PM lines have been added. From

Fig. 3. Parthenocarpic fruit set on PG line 72175.

Table 1. Number of fruits (average per plant) and variance of the best lines in 72 I and 72 II after six weeks harvest. Each F_4 line is a progeny of one plant of the adjacent F_3 line.

F_3 line No	F_4 line No	Number of fruits				Variance	
		F_3		F_4		F_3	F_4
		72 I	72 II	72 II	73 I	72 II	72 II
PG lines							
71191	72181	54	25	32	47	185	69
71192	72175	51	26	37	74	134	54
71194	72186	47	25	51	63	224	135
71206	72192	49	30	38		257	104
71207	72201	55	26	26	35	169	41
PM lines							
71213	72211	55	43	53		276	110
71214	72206	52	25	39		151	171
mean of all lines		42	29	33	55	199	100

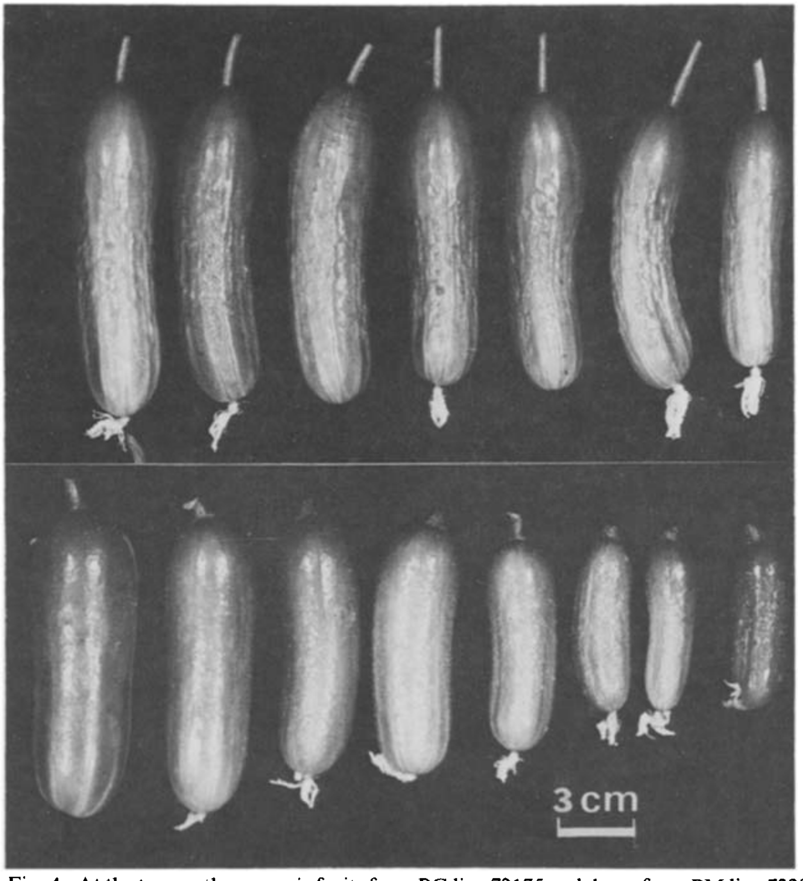

Fig. 4. At the top parthenocarpic fruits from PG line 72175 and down from PM line 72206.

this table it can be seen that lines with the same number of fruits (72190 and 72201, 72433 and 72436, 72175 and 72430) can differ substantially in their parthenocarpy percentage. By recording only the number of fruits, lines (such as 72433) could be discarded with a relatively high parthenocarpy percentage. PM lines, with a relatively low number of female flowers, can only be properly compared with PG lines by means of the parthenocarpy percentage. On the other hand, lines with such an excess of female flowers that even with pollination not all can grow into a fruit, may be discarded by only taking into account the parthenocarpy percentage.

From the above it appears that the choice of the right selection criterium is a delicate question. Whether the highest degree of parthenocarpy has been reached can best be checked by comparing rather pure lines, both pollinated and unpollinated (KVASNIKOV et al., 1970).

Influence of the season. The data in Table 1 show that the number of parthenocarpic fruits of all lines is markedly less in the autumn than in the spring. The same effect

Table 2. Records on different parthenocarpic lines and one non-parthenocarpic line (72421, progeny of P_2)in the 73 I and 73 II trials. The figures are the average per plant.

Line No	Number of flowers		Number of fruits		% parthenocarpy	
	73 I	73 II	73 I	73 II	73 I	73 II
PG lines						
72175	82	55	74	42	90	76
72186	85	67	63	40	76	60
72190	79	64	34	20	44	31
72201	54	41	35	22	63	53
73426	91	72	53	40	58	55
72430	118	79	76	48	64	60
72433	55	45	46	32	83	72
72436	76	56	49	27	64	49
Mean	80	60	54	34	67	58
PM lines						
72444	50		45		90	
72445	57		48		85	
72421	96	75	0	0	0	0

can be noticed in the data collected by STRONG (1932). Different environmental factors were investigated to explain this phenomenon. The mean values for temperature, hours of sunshine and radiation were the same in both seasons. The average daylength was also the same, but in spring daylength increased (12 → 15 h) whereas in autumn it decreased (14 → 11 h). Fig. 5 demonstrates that the differences occur mainly in the last two weeks of the harvest. In these weeks daylength changed in 72 I from 14 to 15 and in 72 II from 12 to 11 h. So daylengths below 12 h seem to influence (parthenocarpic) fruit set of cucumber. A negative influence of short day (7 h) on parthenocarpy has also been observed by KVASNIKOV et al. (1970) and by RYLSKI (1974) in summer squash. NITSCH et al. (1952), however, claim the contrary, although their figures are not convincing and partly contradict pronouncements of NITSCH (1952).

In 1973 the influence of the season was the same as in 1972 (Table 2). Now the detailed records enable us to analyse this phenomenon. On the basis of the mean figures of 8 PG lines we may ascribe the reduction in the number of parthenocarpic fruits in the autumn mainly to the reduction in number of female flowers and only to

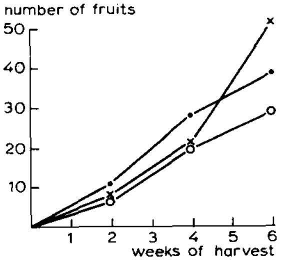

Fig. 5. Course of the parthenocarpic production in mean numbers of fruits per plant during six weeks of harvest in spring and autumn. x = F_3 lines in 72 I; ○ = F_3 lines in 72 II; ● = selected F_4 lines in 72 II. The lines are identical with those represented in Table 1.

Table 3. Correlation coefficients for individual plants between numbers of fruits over 6 weeks of harvest and several other criteria in 72 II. All coefficients are significant at the 1 % level.

Criterium	Correlation coefficients			
	PG-F_3	PG-F_4	PM-F_3	PM-F_4
Weight of fruits over 6 weeks	0.95	0.85	0.91	0.86
Number of fruits over 4 weeks	0.97	0.93	0.92	0.86
Number of fruits over 2 weeks	0.87	0.75	0.70	0.43

a small extent to a decreased parthenocarpic potential. Reduction of numbers of female flowers by short day has also been noticed by TIEDJENS (1928), but NITSCH et al. (1952) found the opposite effect.

Table 2 also shows that the sequence of the 8 PG lines for the different characters is the same in spring and autumn. This may indicate that in these lines the gene activities for flower initiation and parthenocarpy are equally influenced by seasonal factors. So far there are no reasons to breed parthenocarpic varieties for particular seasons. We have no experience with these parthenocarpic lines in the open. From phytotron experiments, however, we have some indications that lower temperatures stimulate parthenocarpy. This corresponds with the work of NITSCH (1952), NITSCH et al. (1952), BORGHI (1970) and RYLSKI (1974).

Correlation of selection criteria. Only after calculating the correlation coefficients between extensive and restricted observations can one decide if it is justified to limit the observations.

Provided fruits of the same grading are harvested, numbers give about the same information as weights, as is shown by the correlation coefficients in Table 3. In PG lines the counting of the numbers of fruits may be restricted to 4 or even 2 weeks. This is probably also justified for PM lines, if the harvest is reckoned from the first date of production on these lines themselves, which is 1–2 weeks later than on PG lines.

If observations are not limited to a specific period but to a section of the plant, they may be restricted to only the main stem up to the 20th node when judging lines (see Table 4). For a reliable selection of individual plants one should observe the main

Table 4. Correlation coefficients for lines and for individual plants between the parthenocarpy percentage over I-IV/M +L and several smaller sections of the plants (for explanation of symbols see Fig. 2).

Criterium	Correlation coefficients	
	for lines	for plants
I-III/M +L	0.98	0.89
I-II/M +L	0.95	0.78
I-III M +I-II L	0.95	0.81
I-IV M	0.92	0.75
I-III M	0.92	0.69

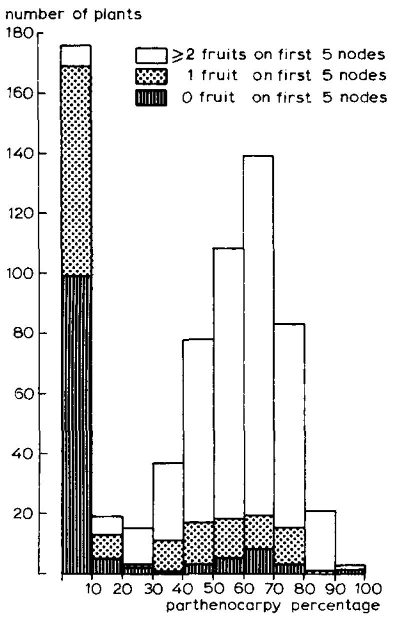

Fig. 6. Diagram showing the relation between the absolute number of fruits on the first five nodes and the parthenocarpy percentage (n = 689).

stem and laterals up to the 15th node. This corresponds rather well with a harvest period of 2–4 weeks.

Even if observations would be restricted to only 2 weeks they can only be made on full-grown plants. Selection could be further simplified if preselection of young plants were possible. To ascertain this we studied in 73 II the relation between the absolute number of parthenocarpic fruits on the first 5 nodes and the parthenocarpic percentage calculated at the end of the observations on all lines and F_1 populations of this trial. The diagram of Fig. 6 prove that by discarding plants with fewer than two parthenocarpic fruits on the first five nodes the frequency of plants with a high parthenocarpy percentage is markedly increased. Preselection of young plants can be carried out either by extra dense planting followed by a quick first selection or by keeping the plants in the (14 cm) pot longer than usual (Fig. 7). Both procedures appeared effective in our later experiments.

Since Beyer & Quebedaux (1974) and Cantliffe & Phatak (1975) proved the parthenocarpic mechanism to be located in the ovary, any earlier selection, on vegetative plant parts, will show little promise.

CONCLUSIONS

Pickling cucumber lines combining a rather high parthenocarpy percentage with a high production of parthenocarpic fruits have been developed.

Preselection by discarding young plants with no or only one fruit on the first five nodes will promote the efficiency of further breeding work.

For a reliable selection of individual plants harvest observations can be restricted

Fig. 7. Preselection in the pot-plant stage. Left a non-parthenocarpic and right a parthenocarpic plant.

to about three weeks or to main stem and laterals up to the 15th node. It is very useful to take into account not only the absolute number of parthenocarpic fruits but also the parthenocarpy percentage, especially as long as only partly parthenocarpic plants are found, which have to be intercrossed to improve the degree of parthenocarpy.

When daylength declines to below 12 h the production of (parthenocarpic) fruits decreases sharply. This is due mainly to a lower degree of flower initiation and only partly to a reduced parthenocarpic potential. It would be valuable to study the influence of a wider range of daylengths.

We are confident that parthenocarpic varieties of pickling cucumbers will prove their superiority in several characters.

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