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# The causes of poor bearing of pear trees of the variety 'Doyenne du Comice'

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'Doyenne du Comice' is generally considered as a commercial pear variety with highly palatable fruits. A shortcoming of this variety is, however, that it starts bearing late in life and give but a small crop. The trees form a large number of flower buds and bloom profusely but set little fruit and easily drop the fruitlets. This may be due either to external factors or to some causes of genetic character.

Adequate mineral fertilization is an essential condition for normal development of flowers and fruits on apple and pear trees. Kłossowski (1964) established a significant correlation between the nitrogen, potassium, calcium and magnesium content in apple leaves and the yield. According to Childers (1954), increase in nitrogen content in the leaves from 2.0 to 2.2 percent of dry weight may increase the crop by about 25 percent.

The supply of organic matter to the plants has a marked effect of fruit set. Z. Zielińska (1953) found that ringing of branches may double the carbohydrate content in the leaves. By ringing the branches of 12-year-old apple trees Heinicke (1923) enhanced bearing by 10–30 percent as compared with the yield of unringed branches on the same trees.

An important factor influencing fruit set is adequate pollination, particularly of self-sterile varieties and those with a weak tendency to parthenocarpy to which 'Doyenne du Comice' belongs (Celichowski 1939; Crane and Lewis 1942; Bagenal 1942; Brzeziński 1949; Kobel 1960; Karnatz 1962, 1963).

According to Luckwill (1946, 1949, 1953), Teubner and Murneek (1955), Hartman and Howlett (1962), growth substances condition fruit set, and it is the seeds that are the source of these substances. On the other hand, for seed formation, normal development of the ouvles and embryo sacs is essential.

The aim of the present investigation was to establish the causes of mass fruit drop in 'Doyenne du Comice' on the trees growing in Natolin.

## MATERIAL AND METHODS

The studies were carried out in the years 1962, 1964 and 1965 (in 1963 the blossoms were demaged by frost) in Natolin near Warsaw in the orchard of the Agricultural Experimental Station of the Warsaw Agricultural University. 'Doyenne du Comice' trees 23-year-old growing on wild pear (*Pyrus communis*) rootstock at 10×10 m distances were utilized for the experiments. Nearby grew trees of the varieties: 'Clapp's Favourite', 'Williams', 'Bonne Luise d'Avranches' and 'Beurré Hardy'. The trees grew on light pseudopodsol formed from silt formations of alluvial origin on light boulder clay.

The orchard was maintained in clean cultivation until July when cover crops were sown. The tree rows grew in sod. Mineral fertilizers were applied in the orchard every year in spring in an amount of ca. 100 kg N, 70 kg $P_2O_5$, 120 kg $K_2O$ per hectare. Pest and disease control was conducted according to the timetable for the given year.

It was attempted to establish whether there is any relation between the bearing of the variety in point and the nitrogen fertilization level, ringing and pollination. The dynamics of fruit drop were followed to determine the relation between fruit growth and the number of seeds in them. The development of the embryo sac was investigated as well as the earliest stage of development of the embryo.

The dynamics of fruit drop was determined on six trees with similar growth intensity flowering profusely. One half of these trees were additionally fertilized with nitrogen in the amount of 1 kg/ha of the pure component. On three branches on diverse sides of the trees, flower clusters and fruit were counted at weekly intervals beginning with April and up to July-August in dependence on the vegetative season. The last determinations were made at the period of fruit harvest. The results are given as mean percentage of fruits as compared with the number of flower clusters.

The influence of the pollen of different varieties on fruit set was studies in 1962 and 1965. In the first year 400–600 flowers on six trees were pollinated with the pollen of the varieties: 'Bonne Louise d'Avranches', 'Beurré Hardy', 'Nouveau Poiteau', 'Josephine de Malines', 'Williams', 'Colorée de Juillet', 'André Desportes' and with own pollen. In 1965 the pollen of 'Josephine de Malines' and 'Nouveau Poiteau' was not available and could not be used, neither were the varieties 'Bonne Luise d'Avranches' and 'Beurré Hardy' used because the results obtained with them in the previous year had not been satisfactory. The pollen of each of the remaining varieties was used for pollinating 600–900 flowers. As controls served flowers from open pollination. The results are given as percentage of fruits in relation to the number of flower clusters.

The effect of ringing on fruit set drop was investigated for two years. In 1962 girdles 0.5 cm wide were cut on about 1,5 m branches on nine trees 15 days after their flowering, and in 1965 two, equal branches on six trees were ringed about 10 days before efflorescence, and the third was left intact as control. The flowers on one of the ringed branches were additionally hand-pollinated with a mixture of the pollens of the above enumerated varieties, whereas the other ringed branch and the control one were left to open pollination. The results are expressed as the percentage of fruits in relation to the number of fruits set in 1962 and to the number of flower clusters in 1965.

The supply of basic mineral components to the trees was determined on the basic of measurements and chemical analysis of leaves. In 1962 and 1965, 50 leaves were taken in August from each tree from spurs (2–3rd leaf from above in the rosette) of the bearing limb and a similar leaf sample was collected from a non bearing branch, 50 leaves were also taken from shoots (one leaf from the middle part of the shoot). The leaves were collected in 1962 and 1965 from 18 and 24 trees, respectively. One half of the trees received each year an additional dose of nitrogen fertilizer.

For leaf surface measurements ten leaves were randomly collected from each tree. The fresh weight of leaves was determined by weighing the whole 50-leaf sample immediately after their picking. The percentage of dry matter and the N, $P_2O_5$, $K_2O$, CaO and Mg contents were determined in two samples from spurs and one from shoots, consisting of 50 leaves each, from two untreated trees and 50 from two treated additionally with nitrogen fertilizer, and expressed as percentage of dry weight.

Nitrogen was determined by the Kjeldahl method, potassium and calcium – in a flame photometer, phosphorus – by the vanadium method, and magnesium – colorimetrically with the use of thiazole yellow.

The fruits were investigated in 1962, 1964 and 1965. In the first year fruits were collected randomly from six trees (three trees from each treatment with nitrogen fertilizer), 50 fruits from each. Then the percentage of fruits with fully developed seeds was established according to the following classification: number of developed seeds 0, 1–3, 4–7, 8–10. In 1964, 30 fruits were taken for these investigations from each tree: 10 large, 10 medium-sized and 10 small ones. In 1965 also only 30 fruits were collected from each tree but randomly as in 1962. In the latter year the percentual contribution of the particular seed classes on the ringed branches on which the flowers were pollinated with mixed pollen was, moreover, calculated. Besides full seeds, empty ones were counted in 1965 and the narrow empty seed sacs.

The relation between the fruit weight and the number of full seeds was investigated in 1964 and 1965; in the latter year also the relation between the fruit weight and the number of full seeds, of full seeds plus empty ones, and the weight and the number of full seeds, empty ones and narrow empty seed sacs taken as whole. For these studies the method of linear correlation was applied and the results are expressed by means of the coefficient $r$ of this correlation.

Investigations on the development of the embryo sac were performed in 1964 and 1965. In the former year 15 flower buds were taken from each of two profusely flowering trees not receiving additional nitrogen at 1–2 day intervals beginning with the period when the flower buds were still completely closed until their full development.

In 1965 flower buds, flowers and fruitlets were collected, 10 of each from each of three trees shortly before efflorescence, at the end of flowering, and 3 and 12 days after petal fall.

In 1964 well developed flower buds were taken without regard to their position in the inflorescence and from various parts of the crown. Well developed flower buds were also collected in 1965 but only the apical ones and always from the same selected branch, on each of the three trees. Twelve days after flowering only fruitlets inhibited in growth and those with a tendency to dropping were collected.

The avaries from the flower buds, and flowers, and the fruitlets were fixed in a modified Navashin fixing solution used in the Institute of Genetics in Lund. Composition: solution A – chromic acid, 1 g, glacial acetic acid, 10 ml, distilled water, 85 ml; solution B – 40% formalin, 30 ml, 95% ethanol 10 ml, distilled water 55 ml.

The material was kept in the fixing solution for 24–72 hrs. Then after passing through primary *n*-butyl alcohol, the specimens were embedded in paraffin after previous dehydration with 70, 96 percent and absolute ethanol. Microtome sections 12–20 μ thick were stained with haematoxylin after Erlich.

The microscopic observations are illustrated by photographs.

## Elaboration of data

Fruit drop is presented in graphs (Fig. 2). The remaining quantitative data were elaborated by means of analysis of variance after R.A. Fischer: cases of one-way and multi-way classification in independent and split-plot design, respectively. For evaluation of the significance level Student's $t$ test was used at two levels of probability $\alpha = 0.05$ and $\alpha = 0.01$.

The percentage of fruits in relation to the number of flowers or flower clusters exhibited, in dependence on the pollinizers used, treatment by ringing or not, a wide discrete variability. In this case statistical analysis was performed on values transformed according to the Bliss function and the significance of the difference was avaluated directly on the basis of the probability of the hazard corresponding to these differences; the value of the empirical $t_0$ ratio was calculated and its significance was determined by Student's $t$ test $[\alpha(t \geqslant t_0)]$. The corresponding mean values are listed in the text below.

The content of dry matter and of the mineral components in leaves was characterized on the basis of the arithmetic means. The differences between the trees were evaluated by Pearson's coefficient (V%).

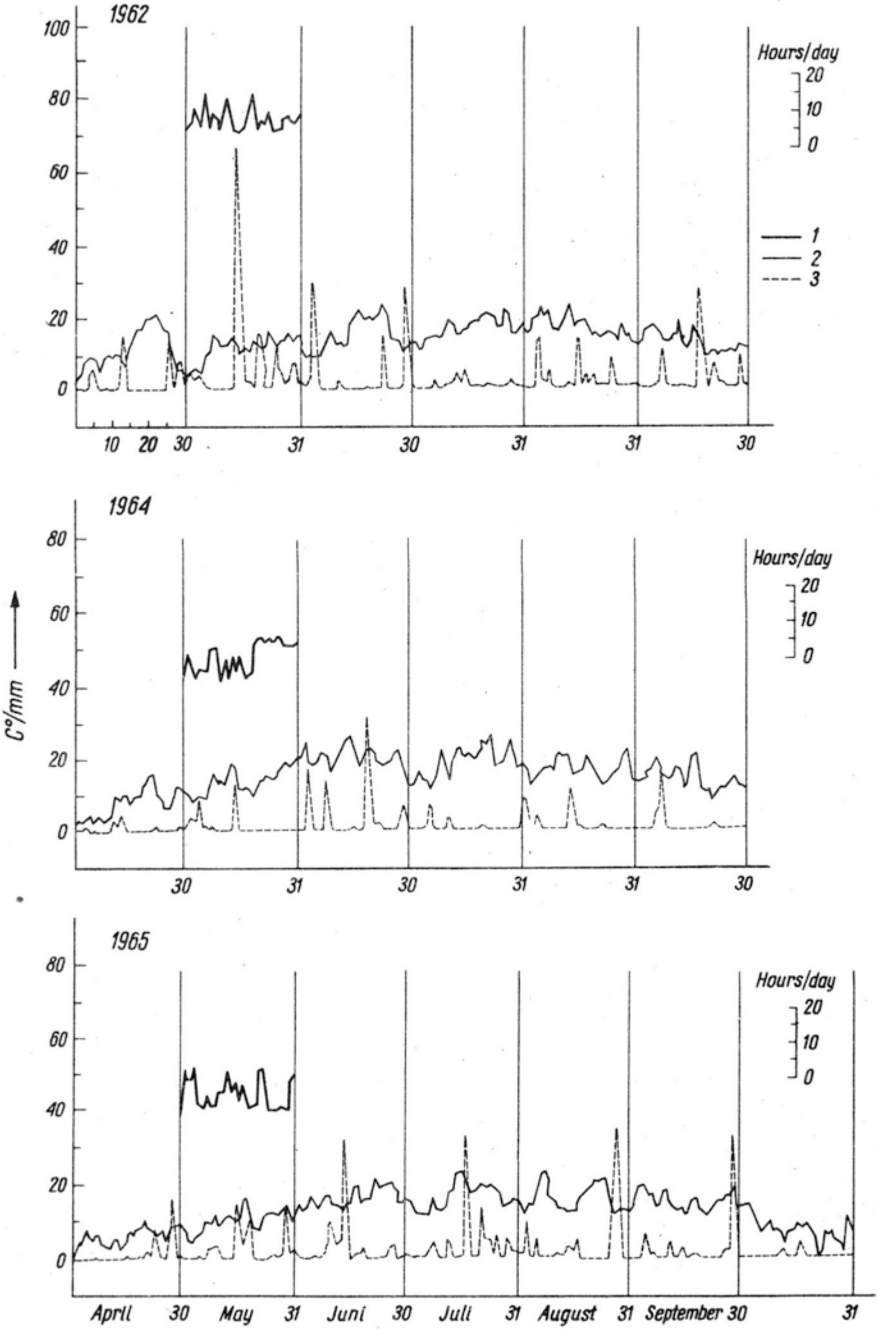



Fig. 1. Climatic conditions

1. Insolation; 2. Mean temperature; 3. Rainfall

## RESULTS

### 1. Atmospheric conditions and flower and fruit drop

The curves of mean temperatures, precipitation and insolation in the course of the experiments in 1962, 1964 and 1965 are given in Fig. 1.

Full flowering of the 'Doyenne du Comice' trees in Natolin occurred in 1962 around the 7th of May, in 1964 around the 18th, and in 1965 as late as the 27–30th.

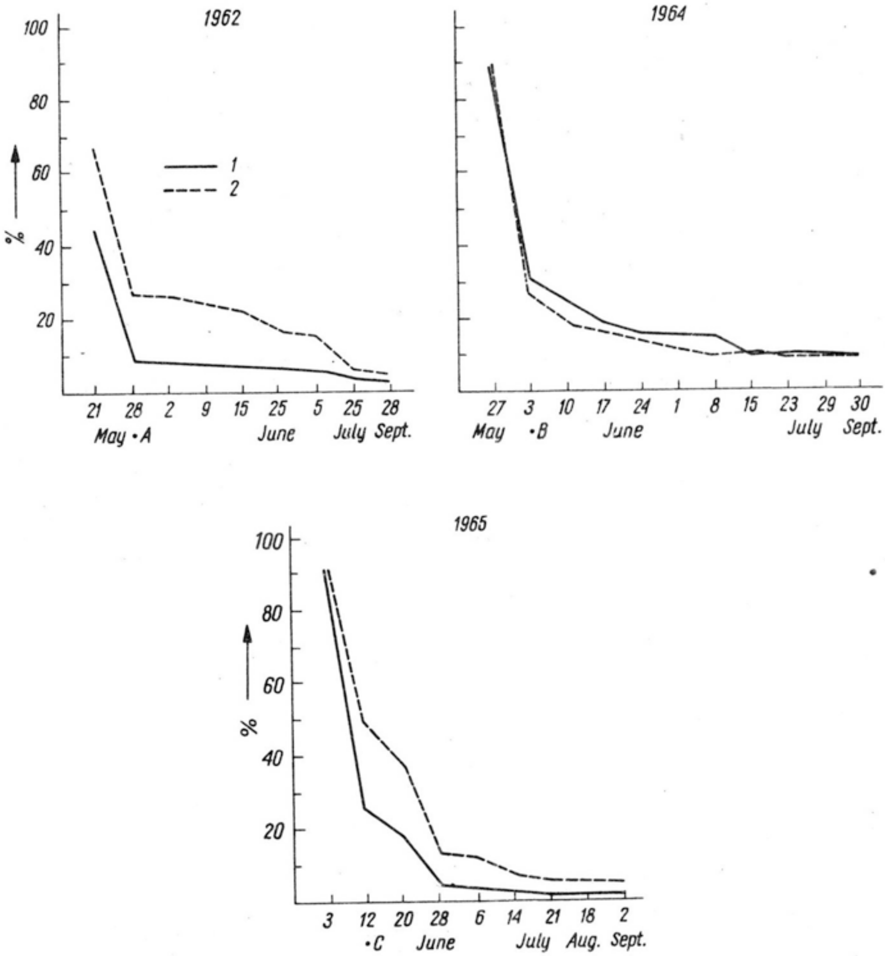



Fig. 2. Percentage of fruits as related to of the number of flower clusters
A – 16 days after bloom; B – 11 days after bloom; C – 12 days after bloom
1. additional nitrogen; 2. without additional nitrogen

On the basis of the studies performed in three years, (Fig. 2) three periods of flower and fruit drop may be distinguished for the 'Doyenne du Comice'. The first period of most abundant flower and fruit drop always occurred immediately after flowering and lasted for two weeks. After this period there still remained on the trees about 30–50 percent of the fruitlets as compared to the number of flower clusters.

The second fruit drop was observed every year in June, one week after the first drop. It lasted also about two weeks. The most intensive June drop occurred in 1965 (35%). However, its intensity was always much lower than in the earlier period. The third fruit drop was noted about 2–4 weeks before the harvest.

Ten to twenty days after petal fall, i.e. in the second period of fruit drop, a differentiation of the fruitlets could be observed as regards size. Most fruitlets were inhibited in growth and exhibited a lighter green colour, particularly of the fruit pedicle as compared with the colour of the small number of larger fruitlets. Some of these small fruitlets dropped under a light touch, others remained on the trees for some weeks longer. In 1965 about 28 days after petal fall the inhibited fruitlets were 11–16 mm in diameter, whereas the diameter of normally developing fruitlets was 24–27 mm. The seeds in these smaller fruitlets were generally shrivelled and did not completely fill the seed cavity.

The average percentage of fruits at the time of harvest as compared to the number of flower clusters did not exceed in all three years 5–10 percent. It we assume at least six flowers in the cluster, the average percentage of fruits in relation to the number of flowers would be 0.8–1.7 percent.

### 2. Influence of mineral fertilization on fruit set drop

Additional nitrogen fertilization did not diminish fruit drop as shown by the diagrams (Fig. 2), and even in 1962 and 1965 a rather marked tendency to more intensive fruit drop was observed.

In the analysis of leaves from the spurs with and without fruits a relation could be established between the size and chemical composition of the leaves, on one hand, and bearing on the other. The following eight characteristics were taken into account: weight of the leaves, surface area of the blade, dry weight and N, $P_2O_5$, $K_2O$, CaO and Mg content.

a) Leaf size

The size of the leaves was expressed in terms of fresh weight (dkg/50 leaves) and of the surface area of the blade ($cm^2$/10 leaves). Both features were subjected to the same statistical analysis and the same characteristics were adopted for them: average values and effect of the factors investigated corresponding to the differences arising owing to the action of the given factor. These effects indicate an increment in size due to additional nitrogen fertilization or to bearing (Table 1).

Table 1

Weight of leaves (dkg/50 leaves), surface area of leaf blade (sq.cm/10 leaves) as well as effect of bearing, $E_o$, and effect of nitrogen fertilization, $E_n$, expressed in the same units

| Characteristic | Kind of shoots | 1962 | | | 1965 | | |
|---|---|---|---|---|---|---|---|
| | | mean | $E_o$ | $E_n$ | mean | $E_o$ | $E_n$ |
| Weight | Spurs | 18.40 | 2,87** | – | 19.44 | – | 3.04* |
| | Shoots | 28.45 | – | – | 28.56 | – | 3.06* |
| Surface area | Spurs | 138.80 | 17,03** | – | 151.80 | 14.10* | – |
| | Shoots | 186.20 | – | – | 211.50 | – | – |

* – significant differences (at $\alpha = 0.05$ level)
** – significant differences (at $\alpha = 0.01$ level)

In 1962 no significant effect of fertilization on the leaf weight could be revealed. The influence of this factor was pronounced in 1965. Additional nitrogen fertilization significantly increased in that year leaf weight both on spurs and on shoots.

A significant correlation between leaf weight and bearing was established in 1962. It was manifested in that the leaves on the bearing spurs exhibited a greater weight than those on spurs without fruits. This relation could not be unequivocally established in 1965.

Additional nitrogen fertilization had no effect on the blade surface area either on spurs or on shoots (Table 1). On the other hand, the intensity of bearing of the branches proved to exert a significant effect: leaves from the spurs on profusely bearing branches had a significantly larger surface area than those on poorly bearing branches.

b) Dry weight and content of basic mineral components

Statistical analysis of the results demonstrated that both additional nitrogen fertilization and bearing of the branches examined had no significant influence on the dynamics of dry weight or on the content of basic mineral components in the leaves. It was thus assumed that all the trees were similar as regards the characteristics investigated. Therefore each feature was characterized by the mean, calculated as the average for all the trees, and by Pearson's coefficient as index of variability between the trees (Table 2).

In general the percentual mineral components content in the leaves in 1965 was distinctly smaller than that in 1962 (Table 2). The only exception in this respect was potassium in the spur leaves. If we compare the mineral components content in the leaves of spurs and of shoots, it is seen that the leaves of the shoots contained only more potassium and phosphorus. The other components, on the contrary, occurred in larger quantities in the spur leaves.

The numerical values of the coefficient of variance (V%) are relatively

Table 2

Dry weight (as percentage of air-dry leaf weight), basic mineral components content (as percentage of dry weight) and variations between trees expressed as Person's coefficient (V%)

| Characteristic | Kind of shoots | Mean | | Difference | Variation, V% | |
|---|---|---|---|---|---|---|
| | | 1962 | 1965 | | 1962 | 1965 |
| Dry weight | Spurs | 93.4 | 91.9 | 1.5 | 0.3 | 1.0 |
| | Shoots | 93.3 | 92.4 | 0.9 | 0.5 | 1.8 |
| | Difference | 0.1 | 0.5 | | | |
| N | Spurs | 2.17 | 1.77 | 0.40** | 4.1 | 4.2 |
| | Shoots | 1.98 | 1.63 | 0.35** | 4.0 | 7.4 |
| | Difference | 1.19** | 0.14** | | | |
| $P_2O_5$ | Spurs | 0.340 | 0.331 | 0.009 | 6.3 | 5.4 |
| | Shoots | 0.428 | 0.337 | 0.091** | 14.5 | 8.9 |
| | Difference | 0.088 | 0.006 | | | |
| $K_2O$ | Spurs | 1.45 | 1.81 | 0.36** | 10.7 | 10.6 |
| | Shoots | 2.01 | 1.99 | 0.02 | 20.9 | 13.5 |
| | Difference | 0.56** | 0.18 | | | |
| CaO | Spurs | 2.53 | 2.20 | 0.33* | 12.2 | 14.6 |
| | Shoots | 1.82 | 1.83 | 0.01 | 13.2 | 18.4 |
| | Difference | 0.71** | 0.37* | | | |
| Mg | Spurs | 0.468 | 0.328 | 0.140** | 9.7 | 22.1 |
| | Shoots | 0.415 | 0.315 | 0.100** | 8.9 | 21.8 |
| | Difference | 0.053 | 0.013 | | | |

* – significant differences (at $\alpha = 0.05$ level)
** – significant differences (at $\alpha = 0.01$ level)

low. This indicates that the selected trees constituted a uniform sample as regards the features investigated. It may, therefore, be assumed that they were also similar in respect to other features such as ability of taking up mineral components from the soil, growth intensity and bearing.

### 3. Influence of organic compounds on fruit drop

The influence of ringing reducing fruit drop in 1962 is presented as percentage of ripe fruits in relation to the number of fruitlets in the first 15-day period after flowering (time of ringing). The average values are 22.3 percent for nonringed and 53.4 percent for ringed branches. The difference is large and statistically highly significant $F_e = 17.71$, $F_{0.01} = 11.26$.

In 1965 the percentage of ripe fruits was calculated in respect to the number of flower clusters (ringing 10 days before flowering). Both in 1962 and 1965 ringing was found to reduce fruit drop. The difference in the means between the treatment with ringing and the control in 1965 was also very large, however, it proved to be statistically nonsignificant owing to the wide variability of the replicates. For instance in the control treatment the mean percentage of fruits varied within the limits of 0–16 percent and in the ringing treatment and open pollination from 0–27.7 percent. The values of 16 percent for the control and 0 percent for the ringing treatment were the extremes. In most replicates a distinct influence of ringing could, however, be discerned.

The highest mean percentage (12.7) in respect to the flower clusters was found on the ringed branches where the flowers had been additionally pollinated with the pollen mixture. A somewhat lower percentage of fruits (9.2) was noted on ringed branches on which the fruits originated from open pollination. The lowest mean percentage of fruits (3.9) was determined on nonringed branches and with open pollination. Additional pollination by the pollen mixture probably exerted a certain influence which, however, was not decisive.

Table 3

Mean percentage of fruits in relation to number of flower clusters and number of replicates in the particular percentage classes (1965)

| Treatment | up to 5% | up to 10% | above 10% | mean |
|---|---|---|---|---|
| Not ringed, open pollination | 5 | – | 1 | 3.9 |
| Ringed, open pollination | 3 | – | 3 | 9.2 |
| Ringed, mixed pollen | 2 | 1 | 3 | 12.7 |

## 4. Effect of pollination on fruit set

The results concerning the effect of pollen from different varieties on fruit set, obtained in two years proved that in all cases the selfpollinated flowers did not yield fruits. The influence of pollen from other varieties varied in the particular years.

The pollinizing varieties used in 1962 (Table 4) may be divided into three groups.

To the first belong varieties such as 'Bonne Louise d'Avranches', 'Beurré Bosc', 'Clapp's Favourite', 'Beurré Hardy'. The percentage of fruits in relation to the number of flowers was for these varieties similar as that obtained from the controls (no significant differences within the group).

To the second group belong the varieties: 'Nouveau Poiteau', 'Josephine de Malines', 'Williams' and 'Colorée de Juillet'. The mean percentage of fruits obtained with these varieties as pollinizers was significantly higher than that of fruits set in open pollination (controls).

Table 4

Percentage of fruits (in relation to flowers) obtained in dependence on the pollinizer and differences between means

| Treatment | Symbol of mean | 1962 | | 1965 | |
|---|---|---|---|---|---|
| | | Means % | Symbol of difference* | Means % | Symbol of difference* |
| Doyenne du Comice × Doyenne du Comice | $X_0$ | 0.0 | $X_1-X_6$<br>$X_1-X_7$ | 0.0 | $X_4-X_5$ |
| Doyenne du Comice × from open pollination | $X_1$ | 1.96 | $X_1-X_8$<br>$X_1-X_9$ | 1.7 | $X_4-X_9$ |
| Doyenne du Comice × Bonne Louise d'Avranches | $X_2$ | 1.75 | $X_1-X_{10}$<br>$X_2-X_5$ | – | $X_8-X_9$ |
| Doyenne du Comice × Beurré Bosc | $X_3$ | 2.12 | $X_2-X_6$<br>$X_2-X_7$ | – | $X_9-X_{10}$ |
| Doyenne du Comice × Clapp's Favourite | $X_4$ | 2.88 | $X_2-X_8$<br>$X_2-X_9$ | 3.0 | |
| Doyenne du Comice × Beurré Hardy | $X_5$ | 4.43 | $X_2-X_{10}$<br>$X_3-X_6$ | 1.3 | |
| Doyenne du Comice × Nouveau Poiteau | $X_6$ | 6.08 | $X_3-X_7$<br>$X_3-X_8$ | – | |
| Doyenne du Comice × Josephine de Malines | $X_7$ | 6.75 | $X_3-X_9$<br>$X_3-X_{10}$ | – | |
| Doyenne du Comice × Williams | $X_8$ | 6.77 | $X_4-X_6$<br>$X_4-X_7$ | 2.7 | |
| Doyenne du Comice × Colorée de Juillet | $X_9$ | 7.42 | $X_4-X_8$<br>$X_4-X_9$ | 0.9 | |
| Doyenne du Comice × André Desportes | $X_{10}$ | 10.33 | $X_4-X_{10}$<br>$X_5-X_{10}$ | 2.5 | |

× – significant difference (at $\alpha = 0.05$ level)
* – difference close to significant

The third group with the highest percentage of fruits (10.33) comprises only one variety – 'André Desportes'.

The results of 1965 were quite different from those of 1962. The mean percentage of fruits was lower in all groups than in 1962. Only pollen from 'Clapp's Favourite' afforded in this year a somewhat higher percentage of fruits. However, the differences between the percentage, percentage of fruits obtained on pollination with some other variety ('Beurré Hardy', 'Williams', 'Colorée de Juillet' and 'André Desportes') and percentage of fruits obtained from the controls were slight and statistically nonsignificant.

On the other hand, drastic significant differences were observed in the effect of the two varieties 'Williams' and 'Colorée de Juillet' (0.9 and 2.7%), which in 1962 were assigned to the same group and had shown a very similar mean value (6.8 and 7%).

The varieties which in 1962 had proved to be very good pollinizers for the 'Doyenne du Comice' as for instance 'Colorée de Juillet' and 'André Desportes' (7.42 and 10.33% of fruits, respectively) gave in 1965 very poor results (0.9 and 2.5% of fruits, respectively).

## 5. Seed content in the fruits

The number of seeds in the fruits was recorded over a 3-year period (Table 5). Notwithstanding the year and the nitrogen fertilization level, most fruits (ca. 50%) had 4–7 developed full seeds. Only about 30 percent of the fruits contained 1–3 such seeds, an exception being the fruits in 1965 from trees additionally treated with nitrogen from which about 43 percent of fruits had such a number of seeds. Only a small percentage of the fruits were seedless or had a larger number of seeds (8–10). The percentage of these seeds varied in the particular years. The highest number of seedless fruits was noted in 1962 (13%), it was similar in 1964 (10%) and lower in 1965 (4%). The highest percentage of fruits with 8–10 seeds was found in 1964 (16%), it was much lower in 1962 (9%) and lowest in 1965 (6%).

Table 5

Mean percentage of fruits with 0, 1–3, 4–7, 8–10 full seeds in dependence on nitrogen fertilization ($N_0$ – no fertilizer added, $N_1$ – nitrogen fertilizer added)

| No. of seeds | 1962 | | | 1964 | | | 1965 | | |
|---|---|---|---|---|---|---|---|---|---|
| | $N_0$ | $N_1$ | Mean | $N_0$ | $N_1$ | Mean | $N_0$ | $N_1$ | Mean |
| 0 | 14 | 12 | 13 | 10 | 10 | 10 | 4 | 3 | 4 |
| 1 – 3 | 23 | 37 | 30 | 33 | 17 | 25 | 37 | 43 | 40 |
| 4 – 7 | 50 | 45 | 47 | 50 | 47 | 48 | 57 | 44 | 50 |
| 8 – 10 | 13 | 6 | 9 | 6 | 27 | 16 | 2 | 10 | 6 |

Fruits from the trees receiving additional nitrogen fertilization mostly gave a higher contribution of fruits with 8–10 seeds. In 1964 it amounted to 27 percent, whereas untreated trees yielded only 6 percent. This percentage of fruits was much lower in 1965 in both treatments but the course of the differences between them was similar, whereas in 1962 it was quite exceptional. In that year more fruits with 8–10 seeds were found on trees not subjected to additional fertilization. A higher percentage of fruits fell to the class with 4–7 seeds in all years and a lower percentage to the class with 1–3 seeds in the fruit on normally treated trees as compared to the yield of trees additionally fertilized with nitrogen.

These wide differences between the particular years in the percentage of fruits of the particular seed classes might have been due to some degree to the method of fruit sampling in the investigations. Moreover, the classification of full seeds was burdened with a large error since the seeds of the 'Doyenne du Comice' greatly vary in the degree of fullness.

Ringing and additional pollination with a mixture of pollens did not change the percentage of the fruits of the particular classes. The same tendencies were observed as for the fruits from untreated branches.

About 60 percent of fruits both from the untreated branches with flowers exposed to open pollination and from the ringed branches with flowers additionally pollinated with the pollen mixture had 4–7 seeds, and only about 20 percent contained 1–3 seeds. Seedless fruits and those containing 8–10 seeds were very scarce.

The fruits originating from flowers pollinated by several varieties had markedly more seeds as compared with those from all other treatments. The high percentage of seedless fruits from the flowers pollinated by the varieties 'Beurré Hardy' and 'Colorée de Juillet' was probably accidental and due to the very small number of fruits examined (Table 6).

Table 6

Mean percentage of fruits with 0, 1–3, 4–7, 8–10 full seeds in dependence on ringing and pollinizers (1965)

| Treatment | No. of seeds | Class, number of seeds | | | |
|---|---|---|---|---|---|
| | | 0 | 1–3 | 4–7 | 9–10 |
| | | mean fruit percent | | | |
| Not ringed, open pollination | 14 | 7 | 22 | 64 | 7 |
| Ringed, open pollination | 27 | 7 | 22 | 67 | 4 |
| Ringed, pollen mixture used | 56 | 11 | 23 | 61 | 5 |
| Doyenne du Comice × Clapp's Favourite | 22 | – | 9 | 59 | 32 |
| Doyenne du Comice × Williams | 16 | – | 6 | 44 | 50 |
| Doyenne du Comice × André Desportes | 15 | – | 7 | 53 | 40 |
| Doyenne du Comice × Colorée de Juilliet | 7 | 14 | 14 | 43 | 29 |
| Doyenne du Comice × Beurré Hardy | 4 | 25 | – | 25 | 50 |

The mean number of full seeds in one fruit, irrespective of the nitrogen fertilization level, ringing or the pollinizer always remained within the limits of 4–7. From among the fruits from the above enumerated treatments, those originating from flowers pollinated with pollen from several varieties exhibited a higher mean (5–7). The mean number of developed but empty seeds was in all groups about 1–2 per fruit. In the cases where the full number of seeds could not be accounted for in terms of full and empty seeds, the remaining seed cavities of the fruit were occupied by empty narrow seeds (Table 7).

Table 7

Mean number of full, full + empty, full + empty + narrow empty seeds per 1 fruit in dependence on nitrogen fertilization, ringing and polinizers

| Treatment | No. of fruits | Full | Full + empty | Full + empty + narrow |
|---|---|---|---|---|
| | | mean no. of seeds per 1 fruit | | |
| Without additional nitrogen fertilization | 83 | 3.9 | 5.1 | 9,0 |
| With additional N-fertilization | 90 | 3.9 | 4.6 | 8.8 |
| Not ringed, open pollination | 14 | 4.5 | 5.3 | 9.1 |
| Ringed, open pollination | 27 | 4.3 | 5.1 | 7.5 |
| Ringed, pollen mixture used | 56 | 4.2 | 6.2 | 9.2 |
| Doyenne du Comice × Clapp's Favourite | 22 | 6.1 | 6.9 | 9.2 |
| Doyenne du Comice × Williams | 16 | 7.2 | 7.5 | 9.6 |
| Doyenne du Comice × André Desportes | 15 | 6.4 | 7.8 | 9.1 |
| Doyenne du Comice × Colorée de Juilliet | 7 | 5.3 | 7.7 | 10.0 |
| Doyenne du Comice × Beurré Hardy | 4 | 5.0 | 5.7 | 6.2 |

Table 8

Coefficient of linear correlation (*r*) between fruit weight (*q*) (g/1 fruit) and number of seeds in the fruit (a, b, c)

| Treatment | No. of tree | 1964 | | 1965 | |
|---|---|---|---|---|---|
| | | q × a | q × a | q × b | q × c |
| $N_0$ | 1 | 0.772* | 0.457* | 0.451* | -0.055 |
| | 2 | 0.641* | 0.046 | 0.160 | 0.223 |
| | 3 | 0.123 | -0.044 | -0.022 | 0.342 |
| $N_1$ | 1 | 0.801* | 0.537* | 0.356* | 0.078 |
| | 2 | 0.683* | 0.455* | 0.399* | 0.047 |
| | 3 | 0.602* | 0.391* | 0.463* | 0.094 |

Natation: $N_0$ – no additional N-fertilization
$N_1$ – additional N-fertilization
a – number of full seeds
b – number of full + empty seeds
c – number of full + empty + narrow empty seeds
* – significant value.

In most cases a significant correlation could be established between the weight of the fruits and the number of full seeds in them (q×a, Table 8) (in 9 of 12 cases). The correlation was more pronounced for the trees receiving additional nitrogen treatment. The taking into account of empty seeds (*b*) did not affect the correlation level: the results of correlations q×a and q×b were similar. When the number of narrow seeds ($c$) was taken into account, the relation between the fruit weight and the number of seeds ($q \times c$) could not be established. It may be inferred therefrom that in bigger fruits the number of full seeds is larger. It seems therefore that the size (weight) of the fruits depends on the number of full seeds.

### 6. Development of the embryo sac and of early stages of embryo

Observations made in 1964 and 1965 proved that the ovule in 'Doyenne du Comice' flowers is anatropous, crassinucellary and has two integuments (Photo 14). When the flower buds were still completely closed in the slightly bursting mixed buds, the integuments reached about mid way up the height of the nucellus. The latter expands considerably in its micropylar part owing to intensive division of the parietal cells as well as to numerous periclinal divisions of epidermal cells. The archaesporial cell originates from the subepidermal layer and gives rise to parietal cells and to a secondary archaesporial cell. Sporadically the occurrence of two archaesporial cells was observed in one ovule (Photo 1). At the moment of opening of the sepals of the flower bud when the crown petals could be seen between them, meiotic division was already at an end, having yielded four megaspores. The embryo sac always develops from the chalazal megaspore while the remaining ones degenerate, the two middle megaspores being the first to undergo degeneration (Photo 2).

Among the 120 ovules investigated one was found with two embryo sacs. The embryo sac in 'Doyenne du Comice' is monosporic eight-nucleate of the Polygonum type. The single-cell stage occurred before the sepals had opened completely (Photo 3). It is at this period that digestion of the nucellus by the developing embryo sac starts. The cells of the parietal tissue first undergo this process. The development of this tissue attains its maximum in the ovule with two-nucleate embryo sacs (Photo 4). Four-nucleate and eight-nucleate sacs were found in flower buds in which the sepals were already open but the petals of the crown still folded (Photo 5, 6).

The stage at which two polar nuclei move towards the middle of the central cell of the embryo sac and the stage when they lie next to each other close to the egg cell occurs in halfopened flowers (Photo 7, 8, 9). At this moment the embryo sacs are almost mature.

The ripe embryo sac is relatively large, elongated along the ovule's axis. The egg apparatus exhibits typical bisymmetry. The synergids are large and strongly vacuolized. The egg cell is pyriform and contains a large vacuole in the micropyle (Photo 15). The three antipodes are not large but normally developed. The polar nuclei remain in the central cell of the embryo sac next to each other for rather a long time without fusing. The fusing polar nuclei which form the primary endosperm nucleus were found as late as the stage of open flowers. Unfused polar nuclei lying next to each other could be observed even as late as three days after flowering.

In half-open flowers, frequently embryo sacs in various stages of development were observed in the same ovary. For instance one ovule contained a two-nucleate, another a fournucleate sac, and the remaining ones had eight-nucleate sacs. In another ovary two-nucleate and eight-nucleate embryo sacs were found.

At the time of full bloom the differences in the degree of development of the embryo sac in the particular ovules were still more frequent. Beside an eight-nucleate embryo sac immediately after the third division another with a young egg aparatus was found as well as one with a mature egg apparatus (egg cell and developed synergids with large vacuoles). One embryo sac had already developed a primary endosperm nucleus, whereas in neighbouring in a ovule the embryo sac contained unfused polar nuclei lying next to one another.

In the period of flowering both in 1964 and 1965, not only the development of the embryo sacs was not uniform, but so was the degeneration of the particular elements, and even of the whole sac. The synergids and polar nuclei degenerated most frequently, they were shrivelled, stained dark and their cytoplasm was in a state of disintegration (Photo 11, 10). The egg cells in these ovules were as a rule normal (Photo 11) or were beginning to degenerate (Photo 10). However, in both the years when observations were made, several embryo sacs were found in fully developed flowers in which the egg apparatus and polar nuclei were completely degenerated (Photo 12, 13). About 1 percent of such sacs was found among the 200 ovules examined. On the other hand, about 20 percent of the embryo sacs were in the initial stage of degeneration.

Three days after petal fall the embryo sac degeneration was far advanced. At this period more than 25 percent of the embryo sacs were degenerating (150 examined). In one ovary three kinds of degeneration of the embryo sacs could be distinguished: 1) degenerating synergids and the beginning of degeneration of the primary endosperm nucleus, whereas the egg cell was normal (Photo 15); 2) degeneration of the whole egg apparatus and a primary endosperm nucleus smaller than normal (Photo 16); 3) degenerating synergids with egg cell and primary endosperm nucleus unchanged. The antipodals were at this period already degenerated in all the ovules.

In another ovary, embryo sacs were found with a degenerated egg apparatus and primary endosperm nucleus. There also occurred embryo sacs with only the egg apparatus (Photo 18) and others with only synergids degenerated (Photo 17).

In some ovules the whole embryo sacs degenerated and in others only the egg apparatus, whereas the nuclei remained unfused. The only abnormality exhibited by some few embryo sacs were the polar nuclei not yet fused at this period.

Embryo sac degeneration was sometimes accompanied by ovule degeneration. The internal integuments degenerated first, while the nucellus shrivelled later (Photo 17, 18).

Three days after flowering no fertilized embryo sacs could yet be found in the entire material examined.

Of the 80 embryo sacs examined in fruitlets inhibited in growth 12 days after flowering, about 18 percent were fertilized and contained developing embryos.

The symptoms of degeneration observed in the ovules varied, only about 5 percent of the 80 ovules investigated showed no trace of degeneration. The embryos in these ovules developed normally and consisted at this period of about 10 cells (Photo 27). The second group of ovules had a normal nucellus but either only the inner or also the outer integument were degenerated (Photo 19, 25, 28). A part of these ovules were unfertilized and showed remains of the degenerating egg apparatus (Photo 19, 28). Others had a two or three-cellular degenerating embryo (Photo 25).

The largest group consisted of ovules in a more advanced stage of degeneration with embryos in various stages of development. Among these ovules there were some not numerous ones which had already completely degenerated and formed a compact dark-staining mass or a fimbriated body (Photo 20, 21, 26). Most ovules in this group had a degenerated inner integument and a degenerating laterally constricted nucleus. The nucellus was generally normal in the micropyle owing to which the ovule had the shape of a long club (Photo 22, 29).

The embryos of these degenerating ovules were in various stages of development. Some of them were inhibited in growth immediately after fertilization (Photo 24), others developed up to a 5–10-cell stage (Photo 22, 29). The structure of some of these embryos was disturbed (Photo 23), others were in an initial stage of degeneration or else developed normally (Photo 22, 29).

After twelve days similarly as three days after flowering, the degree of degeneration of the embryos in the same ovary varied widely. In one ovary, for instance, all the ovules had similarly degenerating nucelli, whereas the degree of degeneration of the embryos varied: some were inhibited in growth immediately after fertilization and others developed normally to a ten-cell size (Photo 22, 24). In another ovary beside a completely degenerated ovule, a degenerating nucellus but a normally developing embryo were found. In a further ovary there were ovules both with normal and with degenerating nucelli.

In the embryo sacs with 2–4-cell embryos, about 4–8 free endosperm nuclei were present, whereas the 10-cell embryo had about 16 such nuclei.

In both years of observation 20 percent of the flowers had ovaries containing 4 carpels with 8 ovules (Photo 30) and about 80 percent ovaries were composed of 5 carpels with 10 ovules.

## DISCUSSION

The trees 'Doyenne du Comice' observed in Natolin in years 1962, 1964 and 1965 flowered profusely but the crop was only about 0.8–1.7 percent as compared to the number of flowers. This confirms the opinion of numerous authors (Hrebnicki 1905; Brzeziński 1929; Brook 1956; Cauwenberghe 1958) that this pear sets but little fruit.

The course of natural fruit drop in 'Doyenne du Comice' in Natolin agreed in general with the descriptions of many authors concerning apple and pear trees (Heinicke 1923; Murneek 1933; Luckwill 1949; 1953 I). However, they all report that the first fruit drop lasts for 3–4 weeks from petal fall, whereas in the case of 'Doyenne du Comice' it lasted only 2 weeks.

The causes of intensive fruit drop may vary. Mineral nutrients supply, and particularly of nitrogen, and a sufficient amount of carbohydrates supplied by the leaves are decisive for, set, and growth of fruit (Heinicke 1923; Kobel 1960).

Insufficient fertilization could not, in all probability, have been the cause of poor bearing of the 'Doyenne du Comice' in Natolin. The trees grew on rather good soil and the dose of fertilizers applied corresponded to those recommended by Pieniążek (1956) for bearing pear orchards in Poland. The nitrogen, phosphorus, potassium, calcium and magnesium contents as percentage of leaf dry mass (Table 2) were close to, or lay within the limits of optimal values of these components as given by various authors (Smith and Taylor; Thomson et al.; Konworthy, Fiedler – quoted by Kłossowski). The leaves from shoots in 1965 contained only 1.63 percent of nitrogen in the dry weight which is less than the optimum values (2.01–2.68%) reported by the above mentioned authors for apple trees and by Pieniążek (1965) for pear trees (2.5%), it fits, however, within the limits of the values given by Fiedler (1.60–2.40%). This content does not seem to be deficient, since additional nitrogen fertilization did not raise its level. The rather wet spring of 1962 probably caused an increase in nitrogen content in the leaves as compared with that in 1965, the utilization of the mineral soil components being better in these conditions (Fig. 1).

The presence of fruits on the trees did not affect the nitrogen content in the leaves growing on the same shoots. The leaves on fruit-bearing and sterile branches (which had dropped almost all flowers and fruitlets) contained similar quantities of nitrogen.

Different results are obtained in alternately bearing varieties. In these cases an abundant crop is associated with an increased nitrogen content in the leaves (Godziejewska 1964; Kłossowski 1964). This leads to the conclusion that only the presence of flowers, and not of fruits, is associated with an increased nitrogen level in the leaves.

Additional nitrogen fertilization of a part of the experimental trees did not increase the percentage of fruits set, but on the contrary lowered it (Fig. 2).

This contradicts the results obtained by Heinicke (1923) who noted a 100 percent better fruit set after intensive nitrogen fertilization of 12-year-old apple trees. It is, however, in agreement with the observations of Kraus and Kraybill (quoted by Kobl 1960) that high nitrogen doses exert an unfavourable influence of fruit set in tomatoes.

In both years (1962, 1965) a quantity of fruits by 50 percent larger was observed on ringed branches than on untreated ones (Table 3). The effect of increase in the organic matter content on fruit set was pronounced in 1962, the differences proving statistically significant. In 1965 the percentage of fruits set on ringed shoots varied so widely that the differences as compared with the control shoots were nosignificant, although the arthmetic mean was distinctly higher. This experiment, however, is not sufficient evidence for the influence of increased organic matter content on fruit set in 'Doyenne du Comice'.

Experiments proved that the leaf size has a certain influence on fruit set. On the fruit-bearing branches the mean weight of fresh leaves and the surface area of the leaf blade were significantly larger than on those which had dropped most flowers and fruitlets (Table 1). The leaves on shoots were always larger than those on spurs, as already observed by Esajan (1963).

Similarly, in the experiment of Heinicke (1923) with apple trees, branches with large leaves set more fruits than those with smaller one. On the other hand, different results were obtained with alternately bearing apple trees (Karpov 1951; Fulga and Filipov 1961; Zaliwski 1962; Godziejewska 1964). The leaves of the nonfruiting trees were at least twice the size of those on the trees bearing fruit. Probably in this case the abundant yield reduced the size of the leaf blade, whereas in Henicke's (1923) and in the present experiments larger leaf dimensions were associated with better bearings.

Heavy rainfall in May and in the beginning of June 1962 and drought in the same period of 1964 (Fig. 1) may have been the cause of intensive fruit drop in the 'Doyenne du Comice' in Natolin immediately after flowering in these years, whereas in 1965 the distribution of precipitation was more uniform.

The observations of 1962 and 1965 proved that 'Doyenne du Comice' is self-sterile and requires cross-pollination as has been claimed earlier by Crane and Lewis (1942).

Many varieties proved to be good pollinizers for the 'Doyenne du Comice'. These varieties have also been recommended by some authors (Celichowski 1939; Crane and Lewis 1942; Brzeziński 1949; Cauwenberghe 1959). In 1962 about 4.43–10.33 percent of fruits were obtained in relation to the flowers pollinized with 'Beurré Hardy', 'Nouveau Poiteau', 'Josephine de Malines', 'Williams', 'Colorée de Juillet' and 'André Desportes' pollens (Table 4). This percentage was equal to or twice that (5%) obtained by Crane and Lewis (1942) after the best possible pollination and by Głowska (1954) when using a pollen mixture (2.2%).

## Plate I

Longitudinal sections through ovules (× 400)

1. Archaesporial cell in prophase stage of meiosis 2. Four megaspores 3. One-nucleate embryo sac 4. Two-nucleate embryo sac 5. Four-nucleate embryo sac 6. Eight-nucleate embryo sac

## Plate II

Longitudinal sections through ovules (× 400):

7. Eight-nucleate embryo sac, one nucleus from each pole is moving to the centre 8. Mature embryo sac, polar nuclei not fused 9. Mature embryo sac 10. Mature embryo sac, polar nuclei fused 11. Degenerating synergids and primary endosperm nucleus at the end of bloom 12. Degenerating whole egg apparatus and primary endosperm nucleus at the end of bloom

## Plate III

Longitudinal sections through ovules (× 400)

13. Degenerating whole embryo sac at the end of bloom 14. Ovule with eight-nucleate embryo sac (× 120)

Embryo sacs from one ovary 3 days after petal fall:

15. Degenerating synergids and primary endosperm nucleus, egg cell is normal 16. Degenerating egg apparatus

Embryo sacs from individual ovaries 3 days after petal fall:

17. Degenerated integuments, beginning of the nucellus degeneration and degenerating synergids 18. Degenerated integuments, beginning of the nucellus degeneration and degenerating egg apparatus

## Plate IV

Embryo sacs from individual ovaries 12 days after bloom:

19. Degenerating egg apparatus (× 400) 20, 21. Degenerating whole ovule (× 122)

Ovules from one ovary 12 days after bloom (× 124):

22. Normal embryo in degenerating ovule 23. Degenerated embryo sac in degenerating ovule 24. Retarded embryo development in degenerating ovule

## Plate V

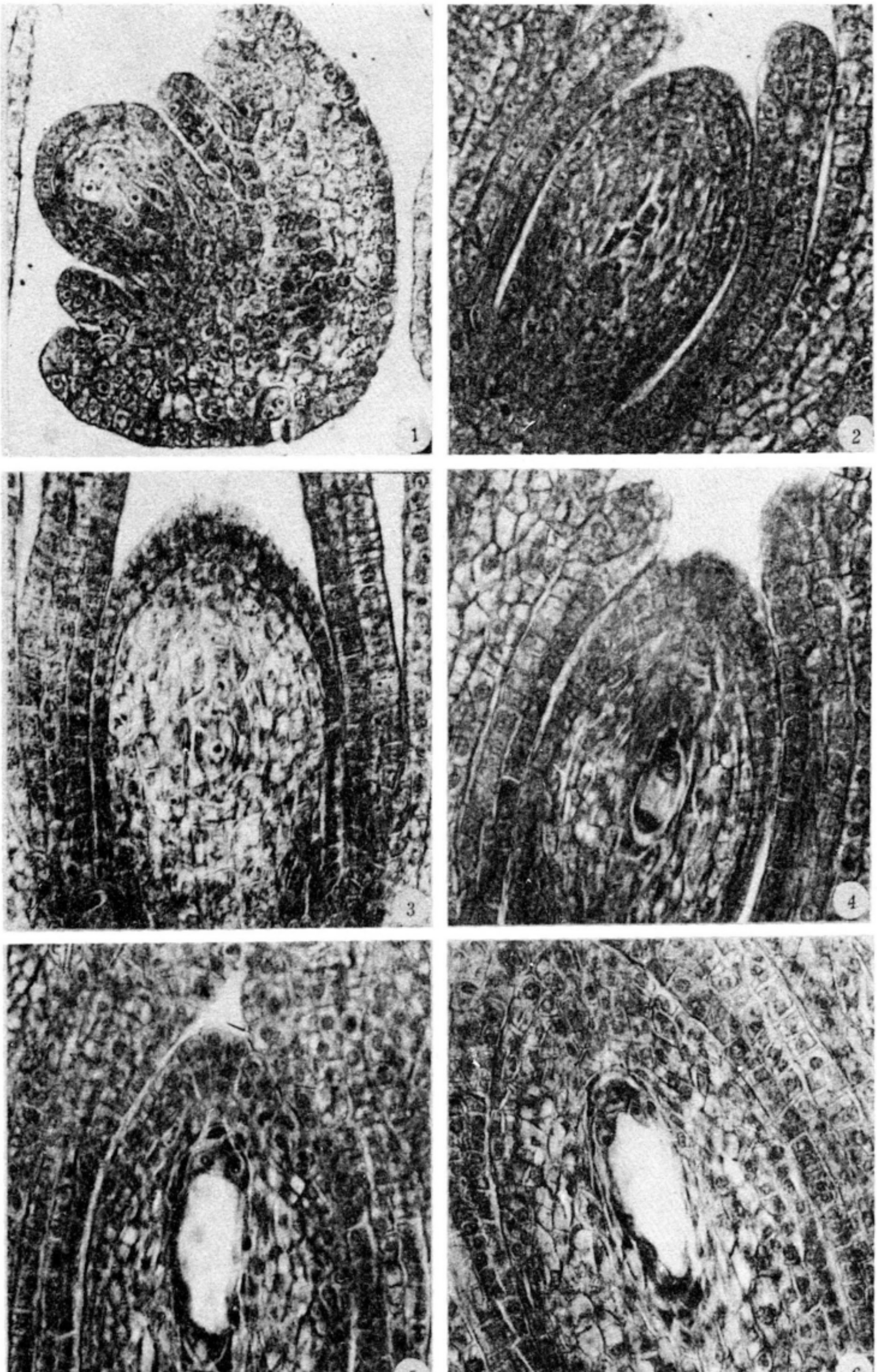
Ovules from one ovary 12 days after bloom:

25. Normal nucellus, degenerating several-cell embryo (× 124) 26. Completely degenerated ovule (× 124) 27. Normal nucellus and normally developing about ten-cell embryo (× 400)

Ovules from individual ovaries 12 days after bloom (× 124):

28. Degenerating egg apparatus and primary endosperm nucleus, nucellus normal 29. About eight-cell embryo in degenerating ovule 30. Cross section through four-carpellary ovary (× 40)

Plate I



# Plate II

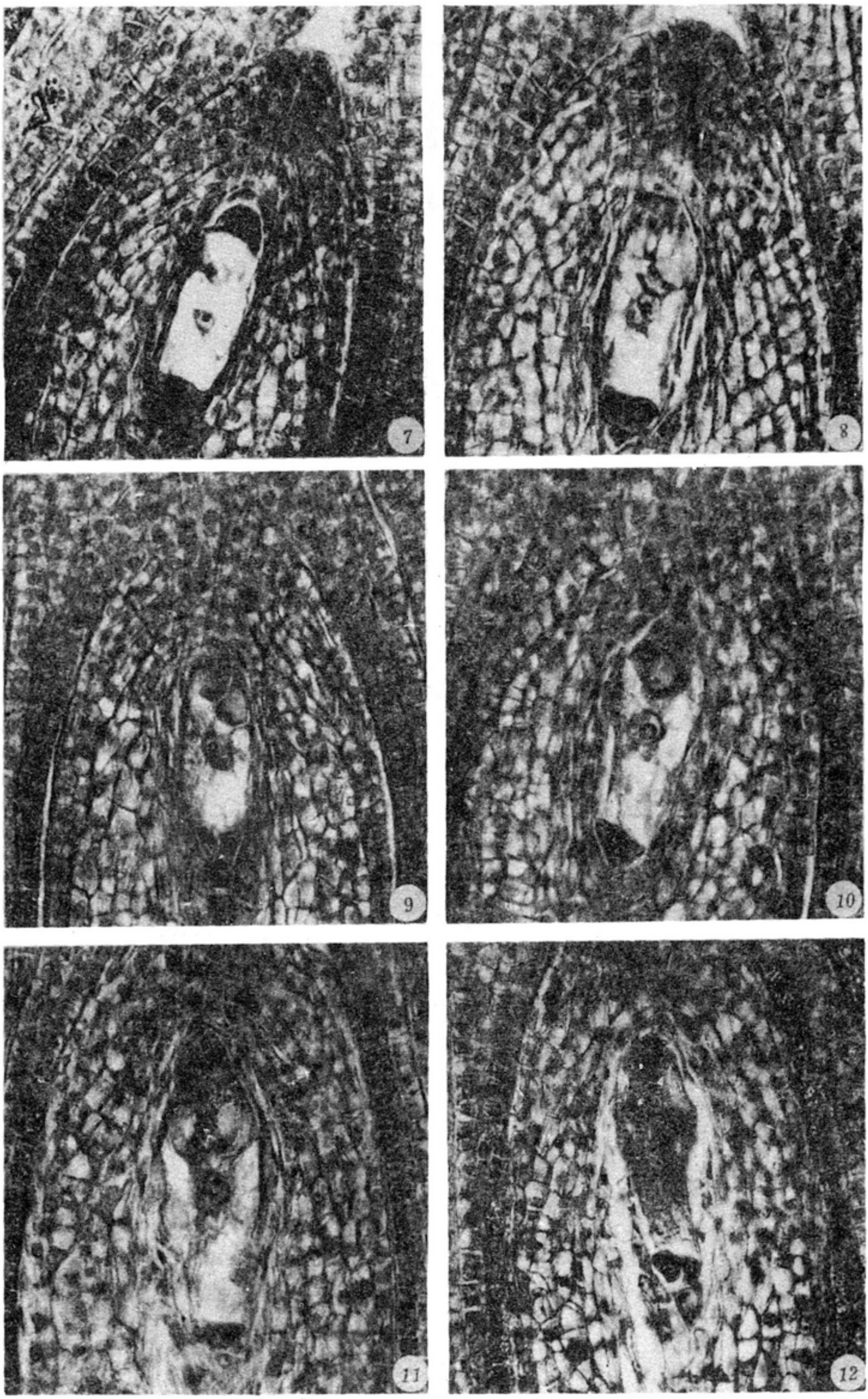


Plate III

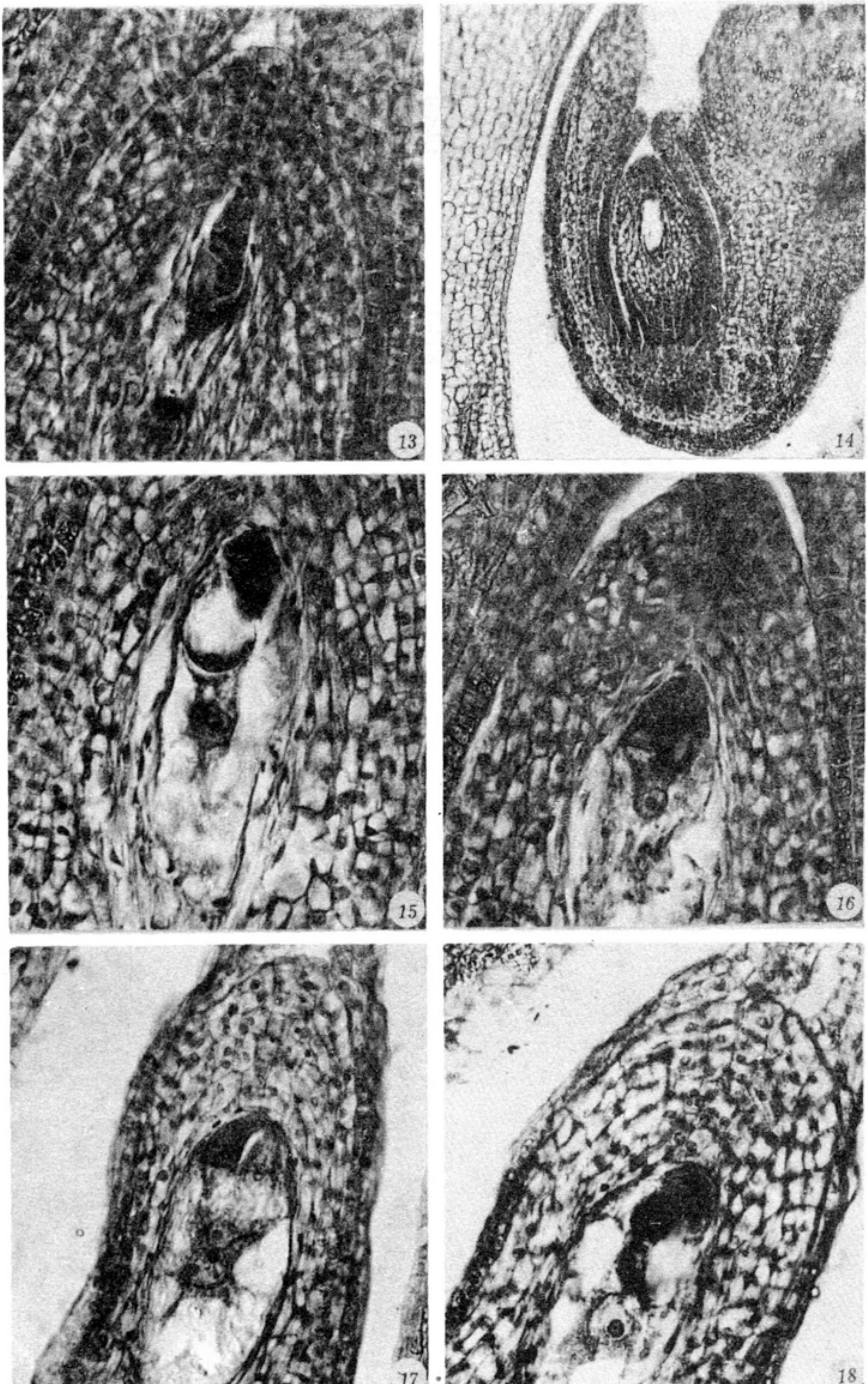


Plate IV

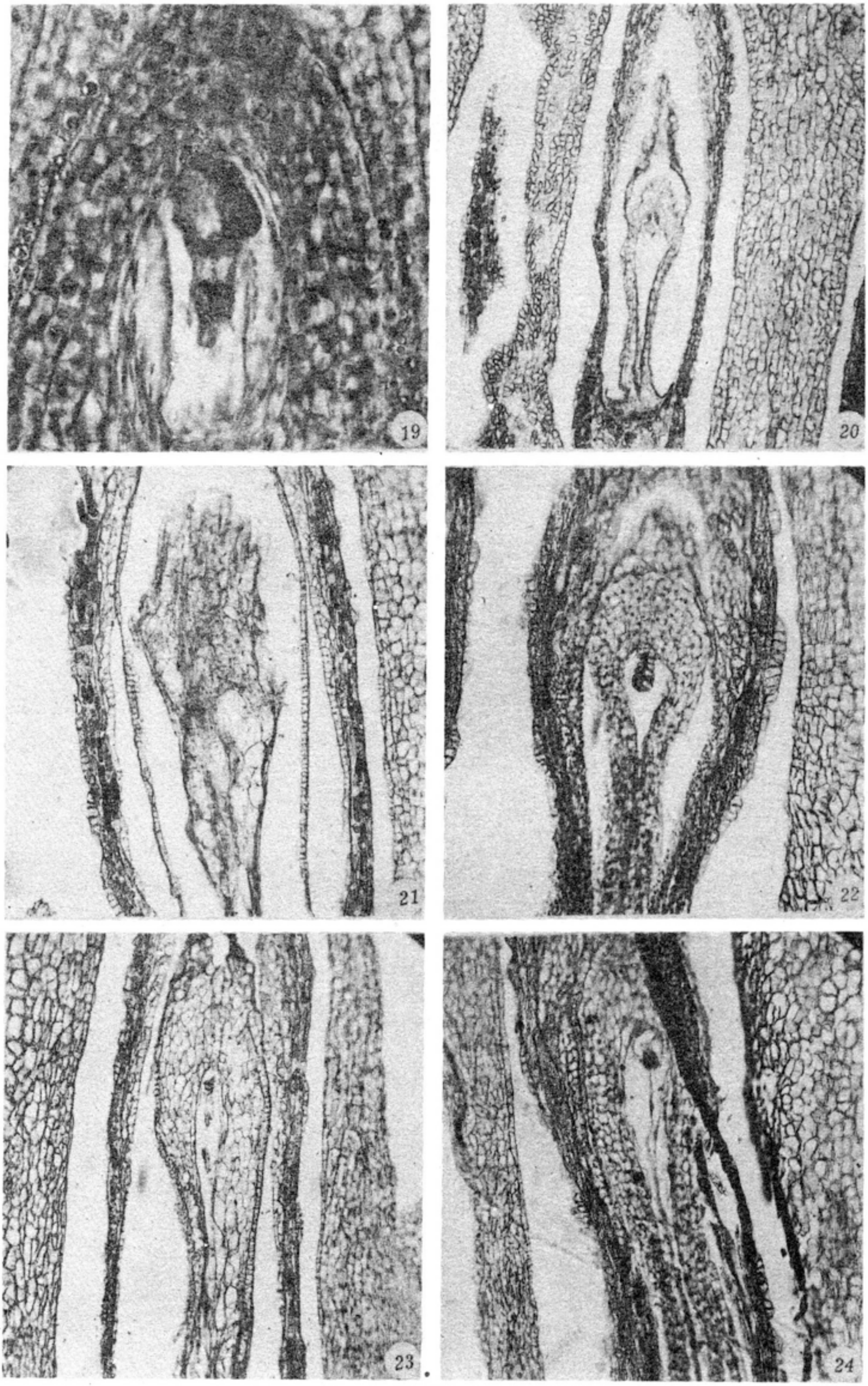
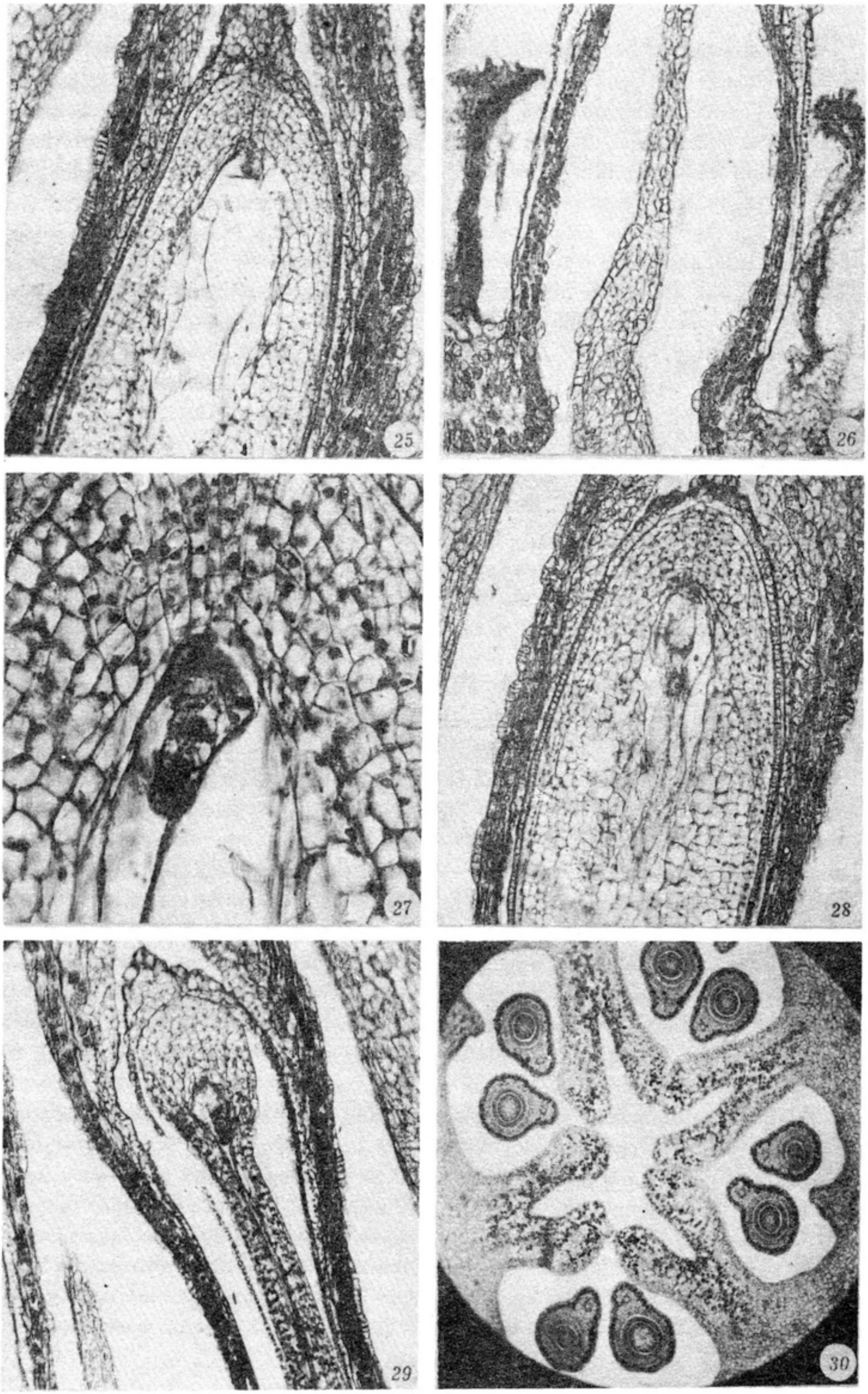


Plate V



As indicated by the present results, the varieties 'Williams' and 'Clapp's Favourite' may be considered as good pollinizers for 'Doyenne du Comice'. In both years treatments with pollen from these varieties yielded a rather high mean percentage (3%) of fruits. Moreover, the flowering time of these variaties is close to that of 'Doyenne du Comice', and they both belong to the best productive varieties in Poland as well as in other countries.

Although the same pollinizers were used in 1965, only 0.9–2.5 percent of fruits was obtained, whereas in 1962 it amounted to 1.7–10.3. Thus this experiment did not prove a significant effect of the pollinizer on fruit set.

Poor fruit setting in 1965 may have been due to the unfavourable atmospheric conditions at the period of flowering. The high percentage of fruits obtained in 1962 owing to pollination with pollen from such varieties as 'Nouveau Poiteau', 'Josephine de Malines', 'Williams', 'Colorée de Juillet' and 'André Desportes' may have been sporadic. The branches on which the flowers were pollinated with pollen from these varieties may have been better bearing ones. On the 'Doyenne du Comice' trees wide variations in fruit bearing of the particular branches are observed, even when the number of flowers is similar.

The extensive literature dealing with the ovule and embryo sac development furnishes no data concerning the 'Doyenne du Comice'.

The unnormal development of the ovule or the embryo sac may be one of the causes of poor fruit set.

In the flowers of 'Doyenne du Comice' sporadic occurrence of two archaesporal cells in one ovule has been observed, one ovule with two embryo sacs was found too.

A multicellular archaespore was found by Gorczyński (1934) on a triploidal and by Williams (1965) on a diploidal apple tree. Such spores are rather common in the *Rosaceae* family (Schnarf 1931). Twin embryo sacs were found by Aubertin and Dayton (1961) on the tetraploidal apple tree 'Giant Yellow Transparent' and two embryos in one seed were detected by Osterwalder (quoted by Kobl 1960).

In 'Doyenne du Comice' in fully open or overblown flowers, besides embryo sacs with mature egg apparatus, young eight-nucleate sacs having only passed the third division were found in the neighbouring ovules. These immature embryo sacs occurring at full bloom may not have been fertilized owing to their retarde development.

Unequal development of the embryo sacs in the same ovary indicating some kind of developmental anomaly had not been reported so far.

The egg cell in the mature embryo sac is pear-shaped and contains a large vacuole in the mycropyle (Photo 15). According to Dowrick (1958) the egg cell of the pear 'Beurré Bedford' is large spherical and deprived of vacuoles. The drawing given by author, however, does not correspond to this description. The polar nuclei lying next to each other in the central cell of the embryo sac do not fuse for rather a long time. Unfused polar nuclei were observed in the flowers of 'Doyenne du Comice' even three days after flowering. According to Gorczyński (1934) fusion of the polar nuclei in the embryo sacs of apple trees occurs very early. Dowrick (1958), on the contrary, observed in unfertilized embryo sacs of the pear variety 'Beurré Bedford' unfused polar nuclei 21 days ofter pollination. This author believes that a primary endosperm nucleus does not form at all and that the fusion of two polar nuclei with the pollen nucleus occurs during the first mitosis of the endosperm. In the 'Doyenne du Comice', on the other hand, the occurrence of primary endosperm nuclei in mature but unfertilized both normal and degenerating embryo sacs has been revealed beyond doubt, besides the occurrence, also established with certainty, in other embryo sacs of still unfused polar nuclei. On this basis it may be concluded that fusion of the polar nuclei occurs before fertilization.

In 'Doyenne du Comice' flowers the ovules were fertilized between the 3rd and 12th day after pollination. Numerous other authors also noted fertilization of the embryo sacs in apple and pear trees between the 6th and 12th day after pollination (Dowrick 1958; Aubertin and Dayton 1961; Williams 1965).

In the fertilized 'Doyenne du Comice' ovules endosperm and zygote divisions occurred almost simultaneously. Dowrick (1958) made the same observations on the variety 'Beurré Bedford'. This author believes that the embryo in the pear tree develops immediately after fertilization because the zygote does not pass to a resting stage. According to Osterwalder, Steinegger and Schanderl (quoted by Kobel 1960) and according to Aubertin and Dayton (1961) the early embryo in apple and pear trees is at first distinctly delayed in development as compared to the endosperm. Also Eaton (1962) established on the cherry and Czosnowski (1965) on the plum that the first division occurs much earlier in the endosperm than in the zygote.

Dowrick's view concerning the almost simultaneous division of the zygote and the endosperm, based on the results of investigations performed on the single pear variety, 'Beurré Bedford', cannot be generalized. It is possible that this phenomenon occurs only in certain pear varieties and among them in 'Doyenne du Comice'.

The present investigations nave demonstrated that the degeneration of embryo sacs in 'Doyenne du Comice' flowers occurred before fertilization in the period of flowering. At this time there were not many completely degenerated embryo sacs, however, as many as 20 percent of them had degenerating endosperm nuclei and synergids. This degeneration could not have been caused by a cytological factor, owing to an unnormal course of meiosis, as is the case in triploidal varieties. In forming flowers of 'Doyenne du Comice' neither pentads beside tetrads, nor deformed embryo sacs with a varying number of nuclei like those described by Kobel (1960) and ovules with several embryo sacs degenerating after a certain time as described by Gorczyński

(1934) were found. Neither can embryo sac degeneration starting so early be due to the lack of fertilization. Williams (1965) observed in nonfertilized ovules degeneration of the synergids, the egg cell and the secondary nucleus in apple flowers as late as 7–9 days after full bloom, and in stronger flowers even later. Degeneration of the embryo sac at the period of flowering was noted by Dorsey (1929) in trees growing in neglected orchards.

Both fertilization and the content of essential mineral components in the leaves indicate that the 'Doyenne du Comice' trees in Natolin had fairly good agrotechnical conditions which could not be the cause of degeneration of the embryo sacs at the period of flowering.

The degeneration, started at the period of flowering and progressed causing growth inhibition in a great number of fruitlets. This degeneration began not only in the embryo sac passing subsequently to the nucellus (Photo 16), but sometimes, on the contrary, the inetguments and the nucellus degenerated before the embryo (Photo 29). A normally formed embryo was also observed 12 days after flowering in the degenerating nucellus (Photo 22). It may be presumed that degeneration occurred independently in the gametophyte and the sporophyte. It radiated from the embryo sac towards the nucellus, whereas earlier degeneration of the integuments and nucellus caused the embryo sac to degenerate.

The degeneration observed in the ovules in flowers of 'Doyenne du Comice' in Natolin does not resemble the description of this process by other authors in fruit trees.

Gorczyński (1934) observed flower degeneration in the variety 'Belle de Boscoop' caused by lack of fertilization. The embryo sacs were always the first to degenerate causing subsequently degeneration of the nucellus, whereas the integuments resisted to this process.

Degeneration caused by a lack of equilibrium between the number of chromosomes in the nuclei of the parent gametes observed by Dowrick (1958) in diploidal and tetraploidal pear trees pollinated with 'Beurré Bedford' pollen involved only the embryo.

Dorsey (1929) and Williams (1963, 1965) observed degeneration due to insufficient nutrition, which attacked in the first place the embryo sac and only sometimes the embryo.

Degeneration induced by an external factor has been observed by Luckwill (1953 II). After spraying with α-naphthalene acetic acid the nucellus degenerated first and afterwards the embryo and the endosperm.

The degeneration processes described by the above quoted authors were initiated always at a definite site. The present observations on 'Doyenne du Comice' did not confirm this finding. Degeneration in the flowers of 'Doyenne du Comice' occurred at various periods and started in various tissues of the ovule. Only one observation agrees with those of Teubner and Murneek (1955) and of Hartman and Howlett (1962), namely, the varying sensitivity of the ovules in one and the same ovary.

It would seem that the tendency to ovule degeneration is a specific feature of 'Doyenne du Comice' conditioned by heredity. Its cause might lie in a low varietal stability and higher tendency to disturbances in developmental processes leading to degeneration of the ovules at various periods. In view of such a specific genetic lability, degeneration may be induced by various factors.

Owing to the degeneration of the embryo sac and ovule seeds are not formed, and according to many authors, it is they that are the source of growth substances conditioning fruit set (Luckwill 1946, 1949, 1953 I; Teubner and Murneek 1955; Hartman and Howlet 1962).

Investigations conducted over a three-year period concerning the characteristic of seeds in fruits proved that 'Doyenne du Comice', irrespective of nitrogen fertilization or branch ringing, forms only 3–14 percent of seedless fruits (Tables 5, 6). Neither has this pear variety, according to Karnatz (1962, 1963) a greater liability to parthenocarpy, and in the opinion of Crane and Lewis (1942) it does not produce any seedless fruits.

In the present experiments, in all the three years, most fruits contained 4–7 full seeds, and only a much smaller number had 1–3 seeds. A full number of seeds was found only in 2–27 percent of the fruits (Table 5). On the other hand, in the fruitlets inhibited in growth, which dropped, at most one undamaged ovule was found with a normally developing embryo. One may, therefore, conclude that in the 'Doyenne du Comice' only those fruits remain attached on the tree which contain at least three full seeds.

The establishment in most cases of a significant correlation between the fruit weight and the number of seeds in them (Table 8) is one more evidence to the fact that seeds exert an important influence on the growth of 'Doyenne du Comice' fruits.

No significant influence either of additional nitrogen fertilization or of ringing the branches on the number of seeds in the fruits could be established. In all treatments the mean number of seeds was 3.9–4.5 per fruit (Table 7). Only the use of pollen from the best pollinizing varieties increased the mean number of seeds to 5.0–7.2 per fruit.

Thus it seems that for normal growth of the fruits of 'Doyenne du Comice' the presence of four well filled seeds is sufficient.

The present investigations proved that the immediate cause of low fertility of the pear 'Doyenne du Comice' is excessive fruit drop due to the lack of formation of seeds and this in turn is the consequence of the degeneration of fertilized and nonfertilized ovules. The pronounced tendency to ovule degeneration in this variety is probably a specific genetically conditioned trait of this variety.

## CONCLUSIONS

1. The main cause of excessive fruit drop in 'Doyenne du Comice' is the

lack of seed formation which is a consequence of degeneration of the embryo sacs and ovules.

2. Ovules undergo degeneration at various stages of development both when immature before fertilization, and after fertilization when containing normally developing embryos.

3. The earliest symptom of developmental disturbances are drastic differences in the development of embryo sacs within one ovary.

4. The tendency to ovule degeneration seems to be a specific trait of the 'Doyenne du Comice' variety conditioned by heredity. Its origin may lie in lower than in other varieties stability and greater liability to disturbances of developmental processes leading to ovule degeneration at various stages. In view of such a specific genetic lability, degeneration may be induced by various factors.

5. 'Doyenne du Comice' is a self-sterile variety and has no tendency to parthenocarpy.

6. The presence of at least three completely developed full seeds ensures a normal growth of the fruits.

7. The varieties 'Williams' and 'Clapp's Favourite' are good pollinizers for 'Doyenne du Comice'.

8. High nitrogen doses do not increase the percentage of fruits set and even exert a negative effect.

9. An increased content of organic compounds in the branches (due to ringing) favours fruit setting.

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## PRZYCZYNY MAŁEJ PLENNOŚCI GRUSZY ODMIANY 'KOMISÓWKA' ('DOYENNE DU COMICE')

### Streszczenie

Badania przeprowadzono w latach 1962, 1964, 1965 w sadzie Rolniczego Zakładu Doświadczalnego SGGW Wilanów, w Gospodarstwie Wolica koło Natolina. Doświadczenie założono na 23-letnich drzewach 'Komisówki' na podkładce dzikiej gruszy (*Pyrus communis*) posadzonych w rozstawie 10 × 10. Badania prowadzone były w trzech głównych kierunkach i miały na celu:

1. Ustalenie zależności między zawartością składników odżywczych a owocowaniem drzewa. W związku z tym dokonano obserwacji nad dynamiką opadania zawiązków owocowych z drzew nawożonych azotem w dwóch poziomach. Przebadano stan drzew pod względem zaopatrzenia w podstawowe składniki mineralne i zanalizowano wpływ obrączkowania na opadanie zawiązków owocowych.

2. Zbadanie wpływu zapylania i rozwoju nasion na przebieg owocowania. W związku z tym zastosowano zapylenie kwiatów pyłkiem różnych odmian. Zbadano występowanie nasion w owocach oraz współzależność między ciężarem owocu a liczbą nasion.

3. Zbadanie rozwoju woreczka zalążkowego i wczesnych stadiów zarodka.

Na podstawie uzyskanych wyników wyciągnięto następujące wnioski:

1. Główną przyczyną nadmiernego opadania zawiązków owocowych 'Komisówki' jest niewytwarzanie nasion, będące następstwem degeneracji woreczków zalążkowych i zalążków.

2. Degeneracji podlegają zalążki w różnych stadiach rozwoju zarówno niedojrzałe przed zapłodnieniem, jak i zapłodnione z normalnie rozwijającymi zarodkami.

3. Najwcześniej występującym przejawem zakłóceń rozwojowych są duże różnice w rozwoju woreczków zalążkowych w obrębie jednej zalążni.

4. Można sądzić, że skłonność do degeneracji zalążków jest swoistą cechą 'Komisówki' uwarunkowaną dziedzicznie. Podłożem jej mogłaby być mniejsza niż u innych odmian stabilność i większa podatność na zakłócenia procesów rozwojowych, prowadząca do degeneracji zalążków w różnych okresach. Przy takiej szczególnej genetycznej labilności degenerację mogą wywołać różne czynniki.

5. 'Komisówka' należy do odmian samosterylnych i nie ma skłonności do partenokarpii.

6. Obecność co najmniej trzech wykształconych pełnych nasion zapewnia normalny wzrost owocu.

7. Odm. 'Williams' i 'Faworytka' są dobrymi zapylaczami dla 'Komisówki'.

8. Wysokie dawki azotu nie wpływają na zwiększenie procentu zawiązywania owoców, powodując nawet efekt ujemny.

9. Zwiększona zawartość związków organicznych w gałęzi (przez obrączkowanie) wpływa na lepsze zawiązywanie owoców.