THE YIELDING CAPACITY OF TETRAPLOID SUGAR AND FODDER BEETS

MET SAMENVATTING

HET OPBRENGSTVERMOGEN VAN TETRAPLOIDE SUIKER- EN VOEDERBIETEN

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ABSTRACT

Since the discovery of the use of colchicine in plant breeding, breeders have created tetraploid sugar and fodder beet. The results obtained were not very encouraging and therefore they soon proceeded to develop varieties containing triploids.

At the Foundation for Agricultural Plant Breeding, Wageningen, polyploidy breeding was started in 1950. The initial material comprised two sugar beet varieties and five fodder beet varieties. By cytological examination of the aberrant individuals in the first and the second year after colchicine treatment, seed was obtained which produced a high percentage of tetraploids. In total 793 C_2 families were tested on trial fields and from these 32 % appeared to be better than the original diploid material.

The breeders interested in the material were provided with seed and stecklings of all the families in the C_1, C_2 or C_3 stage. With the distribution of this material the building up of tetraploid families at the Foundation for Agricultural Plant Breeding has been closed.

INTRODUCTION

In 1938 it was discovered that colchicine influences cell division in such a way that no new cell-wall is produced, thus resulting in a cell with a double number of chromosomes. Beet research workers have soon utilized colchicine in the creation of tetraploid beets.

In the U.S.A. and Canada the first results were recorded in 1940 by ABEGG (1) and PETO & BOYES (8). In a one-year trial AMSTRONG (3) was not optimistic about the yielding capacity, but ABEGG (2) stated in 1946 that some tetraploid families made a favourable impression. PETO and HILL (9) also obtained good results with their tetraploid sugar beets, although good types were few and far between. In 1952 similar results were published by STEWART and GASKILL (13). This is the reason why polyploidy breeding in these countries has not been adopted on a large scale.

In Western Europe similar results were obtained by SCHLÖSSER (12), FRANDSEN (5) and ERNOULD (4). The only advantages mentioned were a better leaf-development, a lesser tendency to bolting, a better shape of fodder-sugar beet and fodder beet and a lesser tendency to produce fanged beets.

Thus, *tetraploid* beet have not yielded the results which had been expected. May be the initial material was not comprehensive enough, and limited the possibilities of obtaining better types. In addition it soon appeared that *triploids* offered better prospects and the tetraploid families were used only for crossing, in order to produce

triploids. However, the successes achieved with tetraploids in Japan have induced research workers in the U.S.A. and Canada to pay more attention to this work.

The Foundation for Agricultural Plant Breeding, Wageningen, started with polyploidy breeding in 1950. The aim was to create tetraploids from a number of diploid commercial varieties and to use the new material for intercrossing and the production of triploids. It was assumed that by using varieties of a quite different type heterosis would occur and that this would open new opportunities for the breeding work in general. Prospective crosses would be most effective when a start was made with valuable tetraploid material.

In recent years this procedure has been carried out with all the tetraploid families obtained in 1951, 1952 and 1953. Beet breeders have received seed and stecklings of these families in order to broaden their selection basis.

In this publication a report will be given of the way in which the tetraploid material can be compared with the initial diploid material.

THE COURSE OF THE INVESTIGATION

C_0 generation

The Foundation for Agricultural Plant Breeding has no beet varieties of its own. Therefore commercial seed of 7 diploid varieties was treated with colchicine in 1950, 1951 and 1953 (KLOEN and SPECKMANN, 6). In total 32,500 clusters were used and after the treatment 3,146 aberrant individuals were planted in the field. After cytological examination it was possible to store 780 "tetraploids" in a pit. In the second year they were all planted and again examined cytologically before flowering. The non-tetraploids were rejected.

The following table gives the number of C_0 beets of which seed was harvested.

TABLE 1. NUMBER OF C_0 BEETS OF WHICH SEED WAS HARVESTED

Group	Commercial varieties	Tetraploid varieties	Number of seed bearing C_0 beets
Sugar beet	Kuhn P	SX	75
	Kleinwanzleben E	SY	82
Fodder beet of very high dry matter content	Friso	VA	102
	Fodder sugar beet CB	VB	132
Fodder beet of high dry matter content	Alpha	VC	112
Fodder beet of low dry matter content	Barres Strynø X	VD	111
	Peragis	VE	107

The percentage of beets producing seed was small. On account of the work involved in the cytological examination it was aimed to harvest seed of some 100 tetraploid individuals per variety and this was successfully carried out. It should be ascertained whether this guaranteed sufficient possibilities for the breeding of tetraploids.

C_1 generation

The C_1 seed was sown in a glasshouse in the autumn; the tetraploids were selected after cytological examination in the four-leaf stage or on root-tips (fig. 1). An attempt was made to get at least 3 C_1 beet plants from every C_0 mother beet, but this was not always possible. In the material treated with colchicine in 1950, seed was harvested in

1951 also from stems which had not been examined cytologically. The result was that the percentage tetraploids in the C_1 was about 60 %. Among these there were mother beet plants which did not yield a single tetraploid on 10 and more offspring.

The next year, when only seed was harvested from cytologically checked stems, this occurred to a far lesser degree; now the percentage of tetraploids amounted to $\pm$ 85 %. An accurate examination of the C_0 generation has the advantage that in the C_1 a far smaller number of beet may be examined to select an equal number of tetraploids.

According to the procedure described above it is possible to restrict the cytological examination of the C_1 to a minimum. By vernalisation in the course of the winter the vegetative period of the plant was reduced to ten months so that already in the course of the following summer seed could be harvested.

C_2 generation

The C_2 seed was sown in a trial in order to obtain an impression of the characters displayed. The C_2 offspring of the same mother beets (C_0) were laid out in adjoining plots in order to facilitate comparison. In order to prevent degeneration by inbreeding as much as possible, the polycross method was used.

In assessing the value, special attention was paid to root weight, dry matter content (of all varieties) and the sugar content of the sugar beet varieties. On the basis of the results obtained the best families were separated from those which were less promising. The next year they were also propagated by separate isolation. This was possible because a reserve field had been laid out with all the families (fig. 2). One row was taken from each family, which was sufficient for a good comparison of leaf type. From the best families 10 roots were chosen (by sight) for seed production, while of the other families 3 roots were destined for seed production (fig. 3) with a view to maintenance.

In polyploidy breeding tetraploid forms are obtained which are physiologically different from the diploids in every respect. It has appeared that in the course of the first few generations after colchicine treatment a stabilization of the material takes place. During this process it becomes cytologically and physiologically adapted to the environment. This causes less valuable types to be eliminated which means that families that at first do not look very promising, later can make a better impression (RASMUSSON, 11). Therefore it is recommended not to select too strictly for yield in the first few generations so that the less promising types are given an opportunity to adapt themselves.

C_3 generation

Seed of the best families was sown on a trial field in order to compare them with the initial material and to ascertain the effects of selection.

The C_3 seed harvested from the remaining families was sown on the trial field as a mixture in order to gain an impression of the production capacity.

The building up of the tetraploid varieties is now completed. A number of good families has been chosen to ascertain the behaviour and purity of the tetraploids in later generations and to study the possibilities of using them for several purposes. In publications to follow the results of intercrossing the tetraploids will be given and also the production of triploids.

RESULTS OBTAINED

In 1953 and following years families of the sugar beet varieties were tested on the trial field (figs 4a and 4b). The fodder beet varieties were tested in the years 1954, 1955, 1956 and 1957. The results obtained have been included in tables 2 and 3.

TABLE 2. COMPARISON OF TETRAPLOID AND DIPLOID FAMILIES

Year	Variety	Number of tetraploid families	Number of families better than the diploid varieties
1953	SX and SY	44	18
1954	SX and SY; VA, VB, VC and VD	269	52
1955	SX and SY; VA, VB, VC and VE	131	37
1956	SX and SY; VA, VB, VC and VD	241	116
1957	SX and SY; VA, VB, and VE .	108	27

TABLE 3. COMPARISON OF TETRAPLOID FAMILIES AND THE DIPLOID VARIETIES FROM WHICH THEY WERE DERIVED

Variety	Number of families	Number of families better than the diploid varieties
SX	127	31
SY	116	46
VA	117	67
VB	156	37
VC	93	39
VD	90	27
VE	94	3
Total	793	250 (± 32%)

From the tables 1, 2 and 3 it follows that the number of C_0 families from which seed was harvested is smaller than the number which was sown on the trial field. This is due to the fact that of several families more components were sown out on the field. When sufficient seed of separate C_1 plants was obtained it was sown on the trial field. In table 2 the total number of families has been included.

Table 3 includes the number of families derived from C_0 beets and shows that a reasonable percentage (32 %) has given favourable results. The families have been compared with commercial varieties of which the seed was harvested in the previous year. In this connection it should be mentioned that breeders are continuously trying to improve their varieties and in general they will now be better than they were in 1950, 1951 and 1952, when the seed was treated with colchicine.

The variety VE is, relatively taken, the worst of all because of the occurrence of a high percentage of bolters. This is partly due to the fact that in 1953 the harvested seed had to be stored in a moist place. In later years the number of bolters was much lower.

Further it should be borne in mind that since 1950 much work has been done to improve the variety Peragis (personal communication). It could therefore be expected

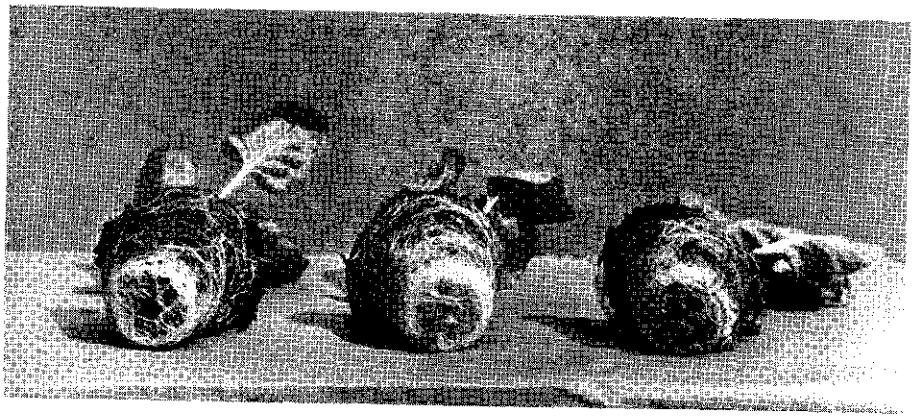

FIG. 1. C_1 PLANTS GROWN IN POTS FOR CYTOLOGICAL INVESTIGATION

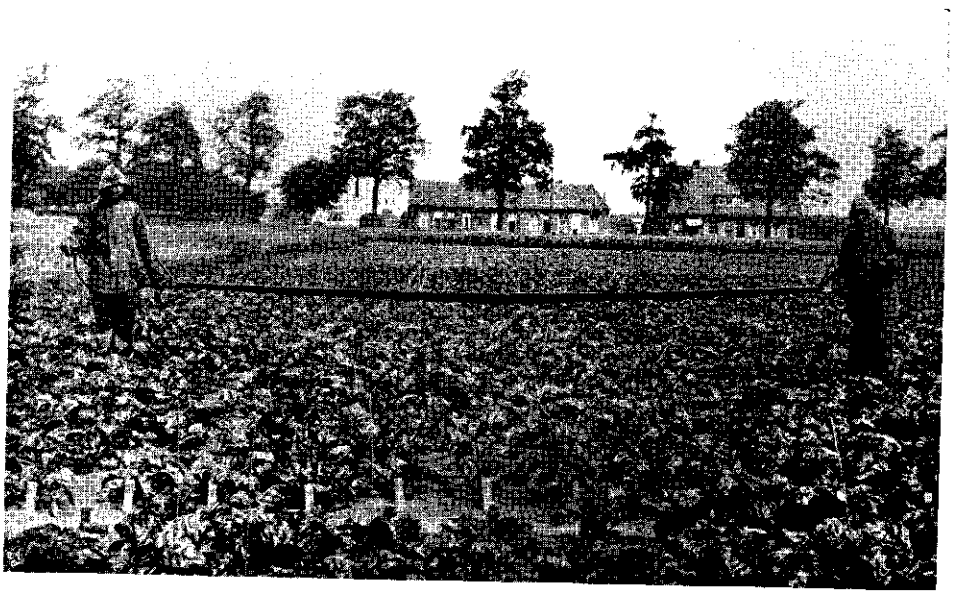

FIG. 2. SURVEY OF THE RESERVE FIELD SPRAYED WITH METASYSTOX AGAINST APHIDS

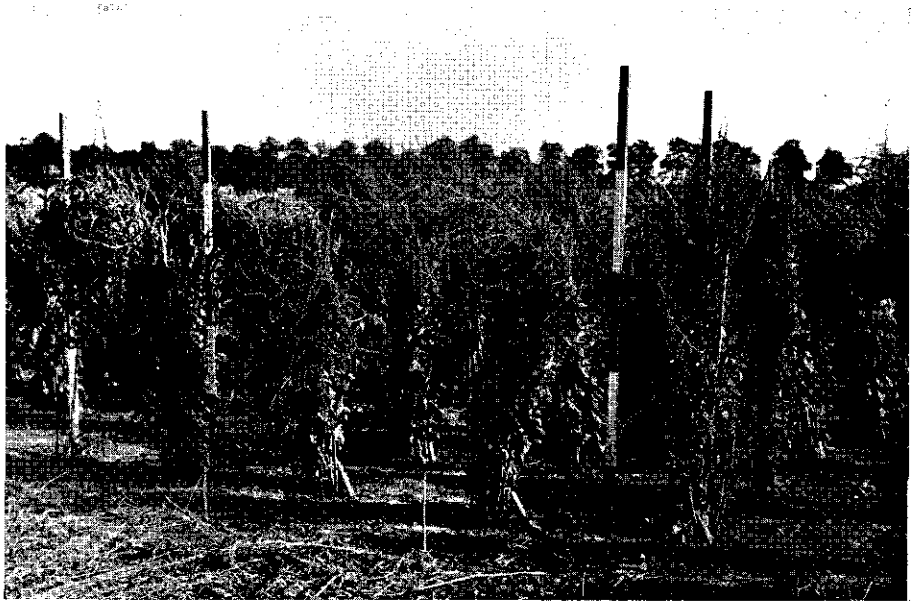

FIG. 3. SEED PRODUCTION OF TETRAPLOID FAMILIES

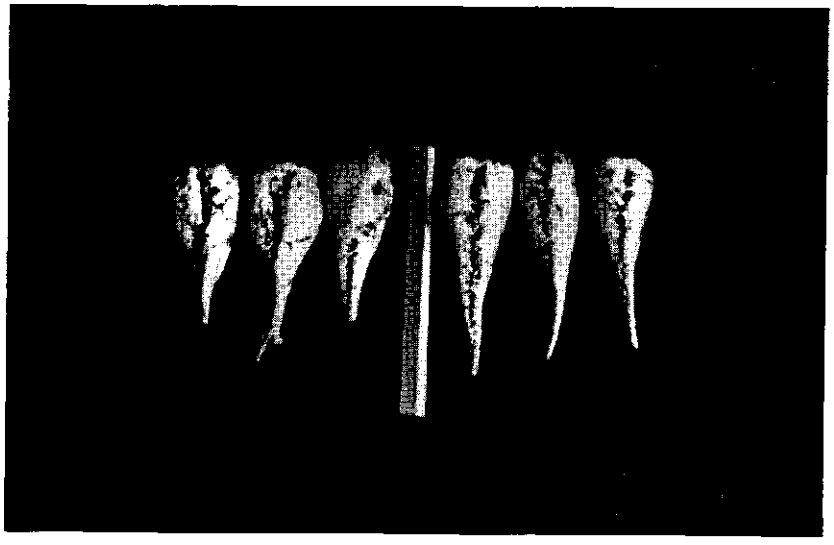

FIG. 4a. BEETS OF AN SY FAMILY

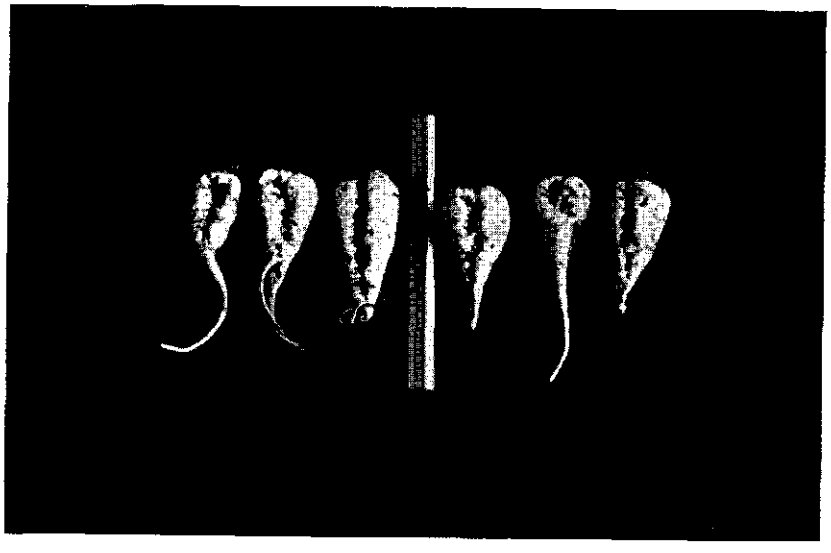

FIG. 4b. BEETS OF THE VARIETY KLEINWANZLEBEN FROM WHICH SY IS DERIVED

that a comparison with tetraploid material from commercial seed of some years ago would make a less favourable impression for this variety.

As was already mentioned, seed of the best tetraploid families derived from one year was sown (in the case of sugar beet varieties of two years). The following table gives the dry matter and sugar content as well as the dry matter and sugar yield, in order to give an impression of the variation in these characteristics. The seed was sown in six replications of 8 m^2 (60 plants) in 1956.

TABLE 4. THE SUGAR CONTENT AND SUGAR YIELD OF THE TETRAPLOID FAMILIES

No. SX	Sugar content	Sugar yield kg/plot	No. SY	Sugar content	Sugar yield kg/plot
47 . .	16.63	8.69	1441	15.49	8.13
108 . .	17.98	7.55	1037	15.60	8.07
1005 . .	17.03	7.36	420	16.33	7.91
1002 . .	17.55	7.30	1034	15.82	7.86
1023 . .	17.13	7.25	1007	16.12	7.79
118 . .	16.62	7.18	498	16.20	7.77
99 . .	17.63	7.14	1039	15.40	7.77
1012 . .	17.23	7.08	1040	14.75	7.75
1025 . .	16.75	7.03	1042	15.82	7.73
1016 . .	17.43	6.99	1030	15.85	7.70
127 . .	17.14	6.93	1033	16.08	7.65
1020 . .	17.25	6.81	1032	16.10	7.64
			1169	16.17	7.57
			1028	16.00	7.57
			416	16.15	7.49
			487	14.35	6.95
Kuhn P .	17.20	7.11	Kleinwanzleben E . .	16.60	7.14

The sugar content of SX compared with Kuhn P is more prominent than that of SY compared with Kleinwanzleben E. There is a considerable variation in content and weight, and this offers good prospects for selection. (Table 4.)

The dry matter content of VA approaches that of Friso more closely than that of VB when compared with fodder sugar beet CB which is somewhat better. This is also apparent when the varieties VA and VB are compared with one another. (Table 5.)

The dry matter content of VC and VD does not differ much from the original varieties but in this case there are valuable families as concerns dry matter weight. The variety VE cannot yet be included in this survey. (Table 6.)

From the tables (7 and 8) it is clear that the families make a favourable impression. Only the order of dry matter yield has undergone some change.

A seed mixture was also composed of the best families SX and SY. The results are given in table 8.

TABLE 5. FODDER BEET OF HIGH DRY MATTER CONTENT

No. VA	Dry matter content	Dry matter yield kg/plot	No. VB	Dry matter content	Dry matter yield kg/plot
1068 . .	21.33	9.96	1165	19.11	10.88
1047 . .	21.64	9.61	1149	19.16	10.42
1049 . .	21.68	9.46	1158	19.88	10.25
1046 . .	22.18	9.33	1140	18.85	10.07
1098 . .	21.87	9.31	1171	19.72	9.94
1105 . .	21.77	9.22	1130	19.52	9.91
1092 . .	21.50	9.20	1156	19.81	9.84
1063 . .	21.64	9.12	1181	19.44	9.76
1099 . .	21.29	9.01	1185	19.39	9.71
1080 . .	21.43	8.99	1182	19.07	9.52
1060 . .	21.34	8.96	1118	19.43	9.20
1069 . .	20.81	8.85			
1070 . .	21.58	8.83			
Friso . .	21.57	9.46	Fodder sugar beet CB	19.98	9.76

TABLE 6. FODDER BEET OF MEDIUM AND LOW DRY MATTER CONTENT

No. VC	Dry matter content	Dry matter yield kg/plot	No. VD	Dry matter content	Dry matter yield kg/plot
1235 . .	16.35	10.53	1280	11.79	9.48
1234 . .	16.42	10.23	1263	12.17	9.41
1230 . .	16.13	9.97	1264	12.26	9.39
1196 . .	16.82	9.96	1255	11.87	9.31
1210 . .	16.39	9.80	1277	12.03	9.07
1227 . .	16.53	9.72	1272	12.31	9.06
1211 . .	16.64	9.54	1273	11.90	9.06
1214 . .	16.42	9.48	1248	11.93	9.05
1237 . .	15.92	9.35	1240	11.84	9.03
1216 . .	16.23	9.26	1280	11.55	8.92
1229 . .	16.47	9.24	1282	12.11	8.91
1192 . .	16.22	9.15	1243	11.78	8.81
			1269	12.18	8.79
			1258	12.14	8.55
			1257	12.28	8.06
			1247	12.28	8.06
Alpha. .	16.36	9.56	Barres Strynø X . . .	12.08	8.85

TABLE 7. RESULTS OF SELECTION IN TWO CONSECUTIVE GENERATIONS

Variety	Selection in the C_2 stage		Examination in the C_3 stage Better than or equal to original variety
	Number of best families	Better than or equal to original variety	
SX	14	7	7
SY	16	14	15
VA	13	1	3
VB	14	4	8
VC	12	6	6
VD	15	10	11

TABLE 8. RESULT OF SEED MIXTURES OF BEST FAMILIES

	Sugar content	Sugar yield kg/plot
SX	17.07	7.13
SY	15.83	7.56

On comparison with the original material (table 4) SX has a good sugar content; SY has a good sugar yield, but the sugar content is not satisfactory.

As was already mentioned, seed was also harvested from the other families of which two yearly harvests flowered simultaneously. In 1956 seed was collected of the families isolated in 1954 and 1955 and this was sown in a trial as a mixture in 1957 (table 9).

TABLE 9. COMPARISON OF THE BEST FODDER BEET FAMILIES WITH THE OTHER FAMILIES

	Dry matter content		Dry matter yield kg/plot	
	Best families	Other families	Best families	Other families
VA				
1955	20.2	20.0	10.94	10.75
1956	19.2	20.4	11.14	11.06
VB				
1955	19.1	19.4	11.24	10.30
1956	19.0	19.8	10.82	10.20
VC				
1955	15.5	15.2	11.38	11.07
1956	15.6	15.5	11.13	11.08

It is apparent that there is only little difference in the contents compared. In connection with the dry matter content it should be stated that a seed mixture does not present an equally reliable picture as the average of the families. For technical reasons it was not possible to carry this out in the most reliable way. In the variety VC the gain in yield by the selection was not great and this also holds for the variety VA. From this the conclusion may be drawn that the other families have given a better impression in the following generation on account of the stabilization mentioned above. The variety VB showed a clear difference and in this variety the best families produced better figures than those of the other two families when compared with the diploid fodder sugar beet CB.

The results from the tetraploid families of 2 sugar beet and 5 fodder beet families show that in the C_2 stage a larger number of families were better than the diploid varieties from which they had been derived. It follows that breeding for tetraploidy offers better prospects than was assumed at first. If the observations and suggestions of RASMUSSON are correct the material will undoubtedly improve still further according to the adaptation of the material to the environment.

From the investigations described in this paper the conclusion may be drawn, in addition to KNAPP's (7) opinion, that tetraploidy-breeding in beet offers more possibilities than was hitherto assumed, provided that the breeding-programme is set up on a sufficiently broad basis at the outset.

SAMENVATTING

Het opbrengstvermogen van tetraploide suiker- en voederbieten

Sedert de ontdekking van de toepassingsmogelijkheden van colchicine in de plantenveredeling zijn de kwekers begonnen met het tetraploid maken van suiker- en voederbieten. De verkregen resultaten waren niet erg hoopvol en reeds spoedig is men daarom overgegaan tot het creëren van rassen, waarin triploiden voorkomen.

De S.V.P. is in 1950 begonnen met de polyploidieveredeling van 2 suikerbieten en 5 voederbietenrassen. Door de afwijkende bieten in hun eerste en tweede levensjaar nauwkeurig cytologisch te onderzoeken werd zaad verkregen, waarin een hoog percentage tetraploiden voorkwam. In een éénjarige zaadteelt werd van de C_1 bietenzaad geoogst, dat op het proefveld werd uitgezaaid.

In totaal werden 798 families in het C_2 stadium onderzocht en hiervan bleek 32 % beter te zijn dan de diploide uitgangsrassen. Van een jaargang werd van de beste families zaad op het proefveld uitgezaaid, het percentage van het aantal families, dat beter was dan het uitgangsmateriaal bleek iets groter.

Van de overige families werd ook zaad geoogst; zij kwamen in het stadium C_3 iets slechter naar voren dan de beste families.

Aan de daarvoor in aanmerking komende kwekers zijn van alle families in het C_1-, C_2- of C_3-stadium zaad en stekbieten afgestaan, waarmede de opbouw van de tetraploide rassen door de S.V.P. is afgesloten.

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