'Glockenapfel'	0,918
'Golden Delicious'	0,908
'Cox Orangen Renette'	0,885
'Ingrid Marie'	0,902.

Ein Vergleich mit den Sortenmittelwerten für den Fruchtformindex (Tab. 2) zeigt, daß bei 'Glockenapfel' und 'Golden Delicious' die Berechnung des Fruchtvolumens ohne Korrekturfaktor zu hohe, bei 'Cox Orangen Renette' und 'Ingrid Marie' zu niedrige Werte ergibt. Die sortencharakteristischen Unterschiede in der Fruchtgestalt kommen in den Werten für den Fruchtformindex der einzelnen Sorten, bei denen $K_v = 1{,}00$ wird, zum Ausdruck.

Zusammenfassung

Unter Berücksichtigung des Fruchtformindexes $h/\varnothing$ der einzelnen Frucht kann man den Volumzuwachs beliebig zusammengesetzter Gruppen von Früchten an verschiedenen Bäumen vergleichen. Bei der Berechnung der Zuwachsraten des Fruchtvolumens braucht man nur Durchmesser und Höhe der Früchte zu kennen, um das tatsächliche Volumen in guter Annäherung zu berechnen. Die Daten der Regression des Korrekturfaktors für das Volumen (K_v) auf den Fruchtformindex werden für vier Sorten stark unterschiedlicher Fruchtform angegeben. Das Volumen der Frucht wird nach folgender Formel berechnet: $V = \frac{4}{3} \cdot \pi \cdot r^3 \cdot K_v$. Vergleichende Untersuchungen über die Zuwachsrate verschiedener Sorten können bei Verwendung der sortentypischen Regressionen durchgeführt werden.

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Cytogenetics of autotetraploid sugar beets (*Beta vulgaris* L.)

Part II: The type of numerical chromosome reproduction

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Summary. Variety seed samples, samples of eutetraploid plant progenies and samples of aneutetraploid or tetraploid population progenies were investigated for chromosome numbers. Genomal and chromosomal deviations from the artificially induced 4x genome level were encountered. Though deviations from the genome level were found to be exceptional, their impact on the reproduction of chromosome numbers may not be underestimated because sugar beets cross readily between genome levels. In general eutetraploid plants remained stable at the 4x genome level, but produced a high percentage of aneutetraploid plants. The chromosomal deviations on the 4x genome level ranged from −2 to +3 chromosomes. In cytogenetic terms chromosome reproduction of eutetraploid plants is characterized by incomplete selection pressure for euploidy. The type of chromosome reproduction differs from the diploid type in as much as eutetraploid plants do not precisely reproduce the chromosome number and gene content, fundamentals on which are based the Mendelian laws of inheritance. In propagation and selection of tetraploid sugar beets the mode of reproduction of chromosome numbers described has to be taken into account.

Introduction

Meiotic regularity, which results in progeny plants with the parental chromosome number is one of the fundamental characteristics of cytogenetics of diploid plants. As a result of the chromosome doubling in induced tetraploids the meiotic configurations necessarily will be different, but besides that may follow a regular pattern. Cytological studies of meiosis in several induced autotetraploids such as sugar beet (SAVITZKY 1952, MOCHIZUKI 1953, FELTZ 1953, LINDE-LAURSEN 1964, BOSEMARK 1965), corn (RANDOLPH 1935), rye (O'MARA 1943, MÜNTZING 1951) or barley (ROSENDAHL 1944) demonstrated that this is not the case. Chromosome configurations and chromosome divisions were found to proceed in a highly unpredictable way, which results in the formation of gametes with deviating chromosome numbers. It depends from the viability or non-viability of these gametes if euploid chromosome reproduction will be complete or not.

In plant breeding, conservation and propagation of commercialised varieties are based upon the fact that seed parents reproduce themselves with respect to chromosome number, thus permitting to predict their qualities within the limits of Mendelian laws. These essentials will not come through as soon as plants produce progenies with deviating chromosome or genome numbers. In autotetraploid sugar beets, which are used already for commercialised seed production, and where meiotic instability is known to exist (ROMMEL 1965), little was known about the mode of numerical chromosome reproduction. After the number of aneuploids in some tetraploid varieties was found to be rather high (ROMMEL 1963) euploid and aneuploid plants were selected and their progenies investigated for chromosome numbers.

Material and Methods

In 1962 and 1963 randomized seed samples of five colchicine induced tetraploid varieties were studied for chromosome number. All samples represented a C_4 generation but the varieties varied considerably in their genetic background and origin (Table 1). Besides that they had been grown in different years and in various parts of the country, which means that the seed was produced under very different environmental conditions.

Table 1. *Tetraploid varieties investigated.*

Year of investigation	Tetraploid variety	Diploid origin
1962–64	B 742 – MM	MLR
	Ebro 646	Ebro 229
1963–65	B 742 – IM	MLR
	Ebro 645	Ebro 194
	J 8413	AJ-1

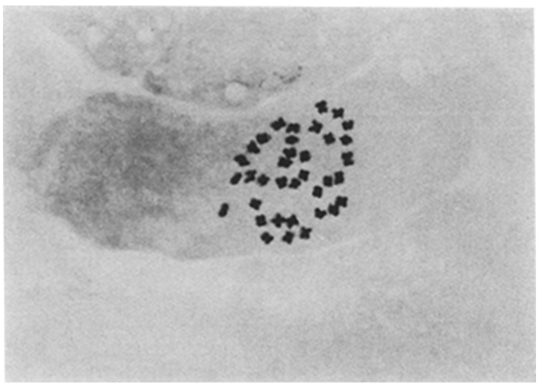

Fig. 1. 2 n = 36

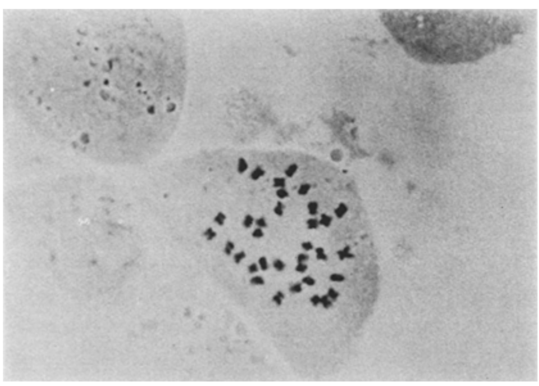

Fig. 2. 2 n = 34

Figures 1–5. Chromosome numbers in autotetraploid sugar beet.

In 1963 and 1964 plants selected from these seed samples and with determined chromosome numbers, were grown to maturity in hemp isolation. The layout of the test has been described in Part I (ROMMEL 1965). Each variety was represented by a eutetraploid plot (36×36 chromosome plants), a tetraploid population plot (34×35×36×37×38 chromosome plants) and an aneuploid plot (34×35×37×38 chromosome plants). Small euploid stecklings were discarded to ensure complete euploidy. The proportion of euploid to aneuploid plants in the tetraploid populations was about 2:1. In 1964 and 1965 randomized seed samples from each plot were germinated and cytologically controlled for chromosome number.

For germinating the seeds a standard procedure was adopted: Germination was carried out in the greenhouse, using soil filled wooden boxes. The seedlings were kept under optimum light and water supply at a temperature of 20–24 °C. Care was taken to have growing conditions always the same for all seed samples tested.

To count the chromosomes young leaves were collected, pretreated, fixed and stained as described by TJIO and LEVAN (1950), and modified by ROMMEL (1963). The chromosome number counted in one plant was assured in at least four to five cells, the quality of which is demonstrated in Figures 1–5.

Experimental Results

The results of chromosome counts applied to autotetraploid variety samples and subsequent generation

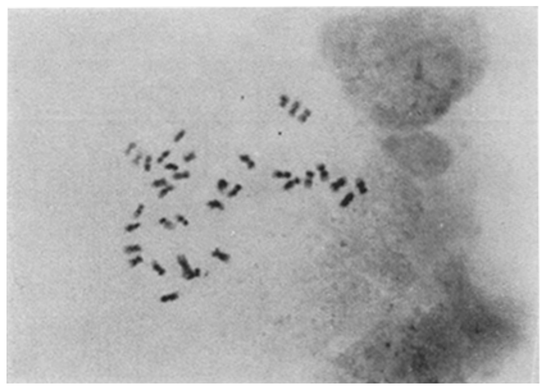

Fig. 3. 2 n = 35

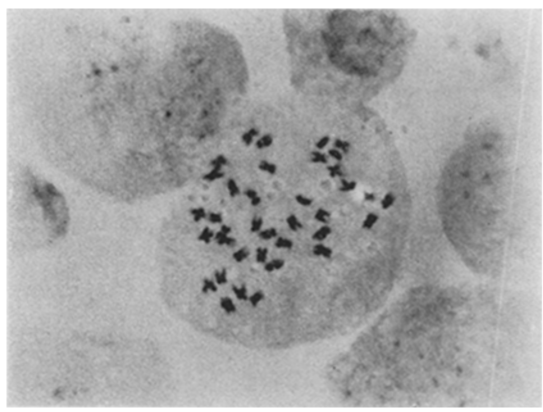

Fig. 4. 2 n = 37

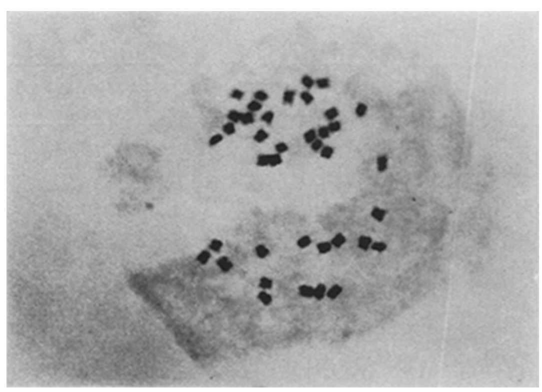

Fig. 5. 2 n = 39

Table 2. *Chromosome numbers in autotetraploid variety samples.*

Variety	Total no. of plants	Chromosome number 2 n = **18**	19	20	25	26	**27**	28	29	30	31	32	33	34	35	**36**	37	38	39	**54**
742–MM	550	—	1	1	1	—	4	—	1	2	—	1	—	10	70	319	117	22	1	—
4x in %												0.2		1.9	12.9	59.0	21.7	4.1	0.2	
Ebro 646	520	1	—	—	—	—	—	—	—	—	—	—	1	11	85	312	100	9	1	—
4x in %													0.1	2.1	16.4	60.1	19.3	1.9	0.1	
742–IM	367	—	—	—	—	—	—	—	—	—	—	—	1	4	30	242	74	11	3	2
4x in %													0.3	1.1	8.2	66.3	20.3	3.0	0.8	
8413	313	—	—	—	—	—	1	—	—	—	—	—	1	4	34	213	56	3	1	—
4x in %													0.3	1.3	10.9	68.3	17.9	1.0	0.3	
Ebro 645	316	—	—	—	—	2	8	—	—	—	1	—	—	5	35	205	51	9	—	—
4x in %														1.6	11.5	67.2	16.7	3.0		

are presented in Tables 2—5. Numerical chromosome variation was found in all samples investigated and included changes in genome number and aneuploidy around the diploid, triploid and tetraploid chromosome level.

Table 3. *Numerical chromosome reproduction of eutetraploid plants.*

Variety	Chromosome number 2 n = **18**	26	**27**	28	34	35	**36**	37	38	39	No. of 4x plants	Total n. of plants
742–MM	—	—	—	—	1	18	74	25	2	—	120	120
4x in %					0.8	15.0	61.7	20.8	1.7		100	
Ebro 646	—	—	2	—	—	16	78	22	1	—	117	119
4x in %						13.7	66.7	18.8	0.8		100	
742–IM	—	—	3	—	3	9	70	20	5	—	107	110
4x in %					2.8	8.4	65.4	18.7	4.7		100	
8413	1	—	3	—	1	10	87	15	8	1	122	126
4x in %					0.8	8.2	71.3	12.3	6.6	0.8	100	
Ebro 645	—	—	3	—	2	11	69	14	4	—	100	103
4x in %					2	11	69.0	14.0	4.0		100	

Genome number

Twice diploid or aneudiploid plants appeared in variety samples (Table 2), and once a diploid plant was found in the progeny of eutetraploid plants. Whereas in the case of the variety samples the origin of the diploid or near- diploid plants cannot be traced back and mechanical admixture may not be excluded (Ebro 646), it is safe to state that the diploid plant from J 8413 (Table 3) is a polyhaploid. It remains to investigate if this plant had undergone genetic changes as reported from another polyhaploid sugar beet plant (ROMMEL 1966).

The two hexaploid plants found among the variety seed sample of B 742-MM (Table 2) represent another change on the genome level. ELLERTON and HENDRIKSEN (1959) have reported on the occurrence of unreduced eggcells in diploid plants, and probably the same will happen in the tetraploids. As a result of the fertilization of an unreduced tetraploid eggcell by a diploid pollen hexaploid plants arise (FISCHER 1962).

Almost all seed samples contained triploid plants, especially the aneuploid progeny plots, which were growing next to a diploid-tetraploid plot. According to LEVAN (1942) sugar beets cross easily between diploid and tetraploid plants thus producing viable triploid seeds. In tetraploid varieties which were not controlled cytologically in the preceding generation triploid seeds can arise by outcrossing, from diploid or triploid plant admixture in previous generations or from aneutetraploid plants. In progenies from controlled eutetraploid plants triploids can be produced only by outcrossing or by aneuploidy.

Aneuploidy

The results of the cytological examinations of the original variety samples show a high percentage of aneuploids among the germinating seeds (Table 2). But even after the most carefull selection for euploidy none of the euploid groups produced a progeny fully stabilized on the euploid chromosome level (Table 3). With little differences between varieties or between years in euploid plant progenies aneuploidy ranged from 28.7 to 38.2% with chromosome deviations from the tetraploid level of −2 to +3 and with hypoploids always lesser in number than hyperploids. Very similar results in range of chromosome numbers and percent of aneuploidy were encountered

Table 4. *Numerical chromosome reproduction of tetraploid populations.*

Variety	Chromosome number 2 n = **18**	26	**27**	28	33	34	35	**36**	37	38	39	No. of 4x plants	Total no. of plants
742–MM	—	—	—	—	—	1	15	64	22	4	—	106	106
4x in %						0.9	14.2	60.4	20.8	3.7		100	
Ebro 646	—	1	3	—	—	2	13	90	20	4	—	129	133
4x in %						1.6	10.1	69.7	15.5	3.1		100	
742–IM	—	2	6	1	—	7	12	53	18	7	1	98	107
4x in %						7.1	12.3	54.1	18.3	7.1	1.1	100	
8413	—	1	2	—	—	—	9	48	15	5	1	78	81
4x in %							11.5	61.6	19.2	6.4	1.3	100	
Ebro 645	—	—	5	1	1	3	16	60	23	1	—	104	110
4x in %					0.9	2.9	15.4	57.7	22.2	0.9		100	

Table 5. *Numerical chromosome reproduction of aneutetraploid populations.*

Variety	Chromosome number 2n =												No. of 4x plants	Total no. of plants
	18	26	**27**	28	29	33	34	35	**36**	37	38	39		
742-MM	—	—	6	2	—	—	4	17	44	23	3	—	91	99
4x in %							4.4	18.7	48.3	25.3	3.3		100	
Ebro 646	—	—	3	1	1	—	2	8	24	25	3	1	63	68
4x in %							3.1	12.7	38.1	39.7	4.8	1.6	100	
8413	—	1	10	7	2	1	—	7	19	13	5	2	47	67
4x in %						2.1		14.9	40.4	27.6	10.7	4.3	100	
Ebro 645	—	—	5	4	—	—	—	11	21	18	6	1	57	66
4x in %								19.3	36.8	31.7	10.5	1.7	100	

in tetraploid population progenies (Table 4). Less percentage of euploids were found in the aneuploid progeny groups, but here, too, chromosome numbers were centered around the eutetraploid chromosome number. Plants with chromosome numbers between the near-tetraploid and near triploid level were not found. This makes it unlikely that triploid plants in pure tetraploid plant progenies arise from aneuploid plants producing a gradually falling down chromosome number offspring.

Discussion

Eutetraploid plants ($2n = 36$) when followed up to the next generation for the mode of their numerical chromosome reproduction revealed a picture not unexpected in induced tetraploid plants (ROMMEL 1961). Stabilization on the genome level was found to be high with most of the plants belonging to the eutetraploid or near-eutetraploid chromosome level. Nevertheless, even few exception from this genome stabilization like the presence of one polyhaploid plant has other consequences as a haploid in a diploid crop, where haploids are eliminated by sterility (ROMMEL 1966). Many reports deal with the cytogenetic properties of triploid beets (LEVAN 1942, MOCHIZUKI 1953, LINDE-LAURSEN 1964) and their influence on tetraploid populations (SCHNEIDER 1964, BOSEMARK 1965, THOENES 1965). The ease with which occurs pollinisation between the different genome levels makes it very difficult to keep autotetraploid sugar beets on the tetraploid level without repeated cytological controls.

Aneuploidy within certain limits of chromosome numbers was found to be the rule and not to be the exception in euploid and aneuploid progeny populations. The limitations in chromosome number apparently arise because viable off-number gametes are not functional in all possible combination. Reciprocal crosses between 2x and 4x sugar beets have demonstrated, that -1 and -2 or $+1$ and $+2$ gametes are viable and functional (MOCHIZUKI 1953). Combinations of -2×-2 (32 chromosomes) or $+2 \times +2$ (40 chromosomes) were not among the seeds from tetraploid plants, which leads to the assumption that these gametes though viable may only produce viable seeds in combination with euploid gametes. The fact, that in euploid and mixed euploid and aneuploid progenies percentage of euploids is almost identical but that the yield is significantly different (Part I) indicates that selection pressure for euploidy acts as well in fertilisation and germination as in the growing crop. Eliminating many aneuploids the selection pressure for euploidy at the same time creates sterility, lowered germination and lowered yield.

Though the type of gametophytic reproduction in autotetraploid sugar beet differs greatly from the diploid one it maintains its course as well as the diploid one is maintained through the generations. Complete selection pressure at meiosis is replaced by a slow selection process during the time of gamete formation, fertilisation, germination and plant development. There is little indication that this type of reproduction will be changed within a few generations and that the autotetraploid varieties represent what has been referred to as "raw polyploids".

Cytogenetics of autotetraploids must be considered as to be something different from the diploid type. Selection and breeding of diploid plants are carried out on the assumption of perfect numerical and gene content reproduction of the parental population. But it is evident that these assumptions are invalid in induced autotetraploid beets, where only about two thirds of the surviving progeny represent the parental population in chromosome number. What type of gene assortment has taken place in these plants can be calculated only on theoretical grounds. For any type of breeding work with tetraploid sugar beets it is very important to treat them with consideration of their cytogenetics which follow rules so different from those on which are based the rules of Mendelian inheritance.

Zusammenfassung

Samenproben von Sorten, von eutetraploiden Pflanzennachkommenschaften und von aneutetraploiden oder tetraploiden Populationsnachkommenschaften wurden auf Chromosomenzahlen untersucht. Es wurden genomale und chromosomale Abweichungen von der künstlich induzierten 4x Genomzahl festgestellt. Obwohl nur wenige Abweichungen von der Genomstufe gefunden wurden, darf ihr Einfluß auf die Chromosomenzahlreproduktion wegen der leichten Kreuzbarkeit der Rüben zwischen den Genomstufen nicht unterschätzt werden. Eutetraploide Pflanzen zeigten im allgemeinen eine Stabilisierung auf der 4x Genomstufe, produzierten aber einen hohen Prozentsatz von aneuploiden Pflanzen. Die chromosomalen Abweichungen von der 4x Genomstufe betrugen bis zu -2 und $+3$ Chromosomen. In cytogenetischem Sinne ist die zahlenmäßige Chromosomenproduktion tetraploider Pflanzen durch unvollständigen Selektionsdruck für Euploidie gekennzeichnet. Die Art der zahlenmäßigen Chromosomenreproduktion unterscheidet sich von der diploiden insofern, als eutetraploide Pflanzen sich in Chromo-

somenzahl und Geninhalt nicht genau reproduzieren, Voraussetzungen, auf denen die Regeln der Mendelvererbung beruhen. Bei der Vermehrung und Auslese tetraploider Zuckerrüben muß die beschriebene Art der zahlenmäßigen Chromosomenreproduktion berücksichtigt werden.

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Der Futterwert von diploidem und tetraploidem Rotklee und einige Möglichkeiten zu seiner Verbesserung durch die Züchtung

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Food value of diploid and tetraploid red clover and some possibilities of improvement through breeding

Summary. 1. In field and pot experiments the quality of diploid and tetraploid red clover (4 *n* synthetic and two 4 *n* breeding stocks) was evaluated. In comparisons with the diploid standard variety 'Marino' the following statements can be made for the tetraploid material:

a) The advantage of higher proportion of leaves in dry matter is reduced by their slightly smaller content of protein and the slightly increased content of crude fibre.

b) The proportion of stems was lower because of their reduced number. However, the quality of the stem dry matter was better (more protein, less crude fibre).

c) During the whole growth period, a unit of green matter contained the same amount of protein and crude fibre, but more water and fewer carbohydrates.

d) During the entire vegetative phase, the yield of crude protein was increased at the rate of 1 dt/ha and was maximal at the onset of flowering.

e) During development, the yield of crude fibre increased only gradually and remained comparatively lower. A slowed progress of wood formation in the stems could not be demonstrated. The rise of dry matter content in the stem was distinctly slower.

f) The amount of the mineral substances nitrogen, calcium and phosphorus was tested. Given sufficient water content in the soil, the content of phosphorus, especially in the leaves and roots, was distinctly higher. In both, diploid and polyploids, the amount of mineral substances in the dry matter rose with increased water content in the soil. The degree of the rise was the same in diploids and polyploids. Improvement in yield of dry matter led simultaneously to a rise in yield of mineral substances (N, CaO, P_2O_5), but only up to 50—75 per cent.

g) The relation between uptake of mineral substances and water loss (transpiration), and between uptake of mineral substances and production of dry matter was nearly the same in diploids and tetraploids.

2. A further increase in the protein yield is possible by increasing the comparatively low number of leaves of the tetraploid clover. It is advisable to reduce the amount of leaf stalks by selection; the total content of dry matter and the content of protein in the total dry matter would thus be increased.

3. 36 tetraploid strains of the old breeding material from the Institute of Plant Breeding, Groß-Lüsewitz were compared with the diploid variety 'Marino'. In this comparison it was found, that more than 80 per cent of all 4 *n* strains had a higher content of crude and pure protein, that more than 74 per cent possessed less crude fibre, that about 50 per cent of all strains had more calcium, and that all breeding stocks contained distinctly more phosphorus in the total dry matter than the diploid variety 'Marino'. Unfortunately, in no case was the dry matter content found to be higher than in the diploid variety.

Nachdem früher über die Unterschiede in der Stoffproduktion zwischen der diploiden Rotkleesorte 'Marino' und einigen tetraploiden Stämmen des älteren Groß-Lüsewitzer Zuchtmaterials berichtet worden ist (BELLMANN 1958, 1961, 1962a, b; BELLMANN und MEINL, 1961), soll nunmehr das Ergebnis von Untersuchungen über den Gehalt an futterwert-