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BRASSICA

CONFERENCE

1981

INTERNATIONAL CLUBROOT WORKING GROUP

EUCARPIA, VEGETABLE CROP SECTION

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WELLCOME TO BRASSICA CONFERENCE 1981

On behalf of the Department of Vegetable Crops at the Agricultural University of Norway it is a great pleasure for me to wellcome all the participants to this conference.

Our department is hounoured being called upon to organize these meetings as we are rather insignificant on the international scene. But over the years we have used part of our limited resources to cabbage breeding, particular in relation to clubroot resistance, and we hope that some of our findings and experiences can be of more general interest. Altogether we like to express the anticipation that the conference will be a vehicle to further international exchange of information and cooperation.

Many of the participants are coming from countries far away. As information for those visiting Norway for the first time, some tourist material is at hand. You are probably aware of that Norway is a versatile industrialized country where the oil sector recently is occupying a prominent place. As for agriculture, it has for years been political will to make it viable through price and import regulation. But at the same time there is a call for advanced production technology.

Our department is a part of the Agricultural University of Norway which has existed since the turn of century. The full study course with us is 5 years including a propaedeutic year. The number of students is close to 1000, in addition about 150

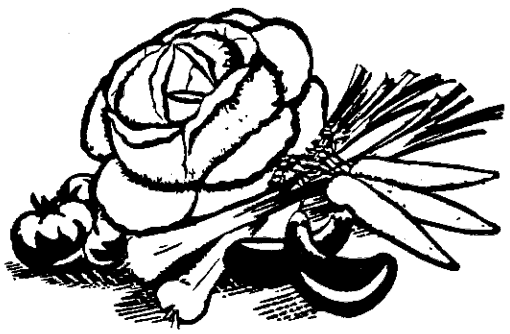
graduate students. The university offers specialized studies in 11 basic subjects. Department of Vegetable Crops belongs to the faculty of Plant Production and has a staff of 20, academic and none-academic in equal portions.

With reference to the stimulating acceptance of this conference, our department likes to express gratitude to the participants for interest and active parttaking. As for the planning of the meetings a special thank goes to Gunnar Weisæth and Jakob Apeland for their great efforts, but also to many others who so willingly have been helping in the preparations.

Finally we like to extend our thanks to organizations and firms which have given the conference financial support, and in this way made our days brighter.

To all: Thanks and good luck!

A.R. Persson
Chairman of the Dep. of Veg. Crops



CLUBROOT IN CALIFORNIA

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Plasmodiophora brassicae is of relatively recent occurrence in California. It apparently was introduced a few years before the first disease was observed by a grower in 1931. Its subsequent dissemination in the Half Moon Bay area was rapid due to the use of infected Brussels sprouts transplants. Further spread has been slowed by geographic barriers and interior quarantines of the State of California. Clubroot was confined to small vegetable-growing areas until 1978 when the first infestation was found in the Salinas Valley. This is a major production area with >26,000 ha of crucifers grown in 1980, mostly broccoli and cauliflower. The disease is now known in 10 fields and doubtless has been introduced into many more. In 1981 it was found in the Central Valley of California.

The pathotype of 3 collections from the Salinas Valley was 16-3-31 with the ECD differentials (cut-off point 11). Two collections from the Half Moon Bay area were more variable and were 16-7-31 and 16-23-31. All collections were race 7 by the Williams system. In a field trial in 1981 in the Salinas Valley, Badger Shipper had disease ratings varying from healthy to resistant type galls to the susceptible, large clubs. Cauliflower breeding lines from R. Gabrielson (Washington State University) and P. H. Williams (University of Wisconsin) were almost free of clubs.

Control measures were evaluated in field trials in 1980 and 1981. Soil solarization was not effective because lethal temperatures were not generated. Although there was full sun for much of the day, the ambient air temperature was too cool. Dry fallow for 3 months did not reduce disease incidence. Bed application of pentachloronitrobenzene and metham-sodium gave some control. Other fungicides gave no control.

The application of lime was the most promising control measure in both years. Highly significant reductions in clubroot were obtained at rates from 3400-5600 kg/ha and the control was no better at rates as high as 36,800 kg/ha. The pH of non-limed soils ranged from 5.5 to 6.3. The minimum effective lime applications often did not increase the pH to 7. It is suggested that pH alone is not an adequate predictor of the success of control by liming. Glasshouse tests of 21 different soil types that were limed in the field and infested in the glasshouse showed that soils in the Salinas Valley differ in responsiveness to lime. Eleven soils were responsive, i.e. little or no clubroot developed when 10^4 resting spores/gm were added to soil that received as little as 2800 kg/ha lime. In such soils the pH ranged from 6.4 to 8.0. Nonresponsive soils in similar conditions gave significant clubroot even though the pH was 7.0 to 7.5 in some samples.

Lime of soil for clubroot control thus is confirmed as an effective measure which has the advantage of being environmentally innocuous. In the Salinas Valley it also is readily available from the spent lime pile of a sugar beet factory.

Clubroot Populations in SE Scotland

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INTRODUCTION

Clubroot, caused by *Plasmodiophora brassicae* Wor., is the most important disease of brassicas in Scotland and is a major limiting factor in successful brassica production. The large area of susceptible forage brassicas, particularly swedes and rape, has created this disease situation. Chemical disease control in the forage crop is uneconomic. The advisory testing of soils in SE Scotland has helped to reduce the number of crop failures due to clubroot but good brassica land is out of production for many years because of soil contamination. The use of resistant varieties appears to be the only effective means of clubroot control.

The object of the present study was to provide basic information to the plant breeders on the range of pathogenic variation in *P. brassicae* together with a selection of suitable isolates for screening purposes. The data would also be of use to the advisory pathologists.

A survey of this kind has only been possible since the setting up of the ECD set. Despite the adoption of this differential set by European workers, comparatively few detailed investigations on variation in *P. brassicae* have been carried out.

In this survey samples of inoculum from 80 sites known to be contaminated with *P. brassicae* were collected and tested. A selected number of populations were also used to assess the clubroot reaction of common commercial swede and turnip varieties with the aim of producing a set of differential varieties.

MATERIALS AND METHODS

Conditions for plant growth: Test plants were raised in gravel-filled glasshouse benches (140 mm deep) where the soil temperature was maintained at 20-25°C by means of soil warming cables. Fluorescent lamps were used as supplementary lighting to maintain a 16 h day.

All plants were grown in 'John Innes no 3' compost. Thirty seedlings were arranged in 220 x 160 mm seed trays and each tray was placed in a 360 x 230 mm gravel tray positioned in the bench gravel. Plants were watered from below to avoid the splashing of soil to adjacent trays. The compost was kept at field capacity for 2 wks after inoculation to allow spore germination and infection and thereafter watered only as required.

Inoculum production: Samples of naturally infected soil collected from randomly distributed points with a 230 mm auger were used as the original source of inoculum. Soils were sieved and mixed with one third of their volume with JI no 3 compost and 'baited' with 10-day-old seedlings of Chinese Cabbage cv. Granaat. Resting spores were extracted after 6-7 wks. Generally galls were used immediately,

however, when storage was required the samples were placed in a deep freeze at -18°C.

Preparation of resting spore suspensions: Galls were thawed under cold running water, homogenised in tap water for 3-4 minutes at full speed in an 'MSE Ato Mix' laboratory blender and then filtered twice through muslin. The spore concentration in the filtrate was determined using a haemocytometer. Dilute suspensions were stored for up to 24 h in a dark refrigerator.

Modified slurry inoculation technique: For each seed tray of compost, the components of the slurry medium were 100 ml moist sieved (6.35 mm) peat, 50 ml JI no 1 compost, spore suspension and tap water to make up to 200 ml of medium. A 20 ml aliquot of a stock suspension containing 10 times the desired final spore suspension was dispersed by pipette to attain the final spore concentration of 10^5 spores/ml.

The slurry medium containing the spores were mixed thoroughly before being placed in 10 mm furrows in the compost (4 furrows to a seed tray). The seeds were placed directly on the medium and covered with JI no 1 compost.

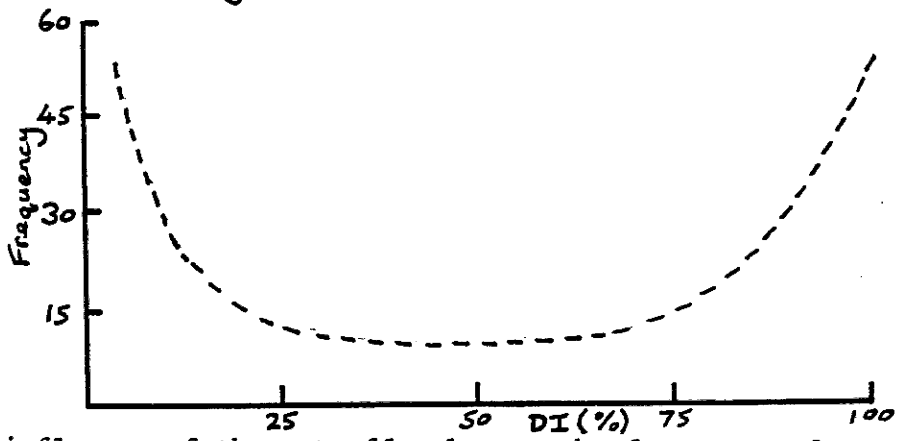
The same method was used to evaluate the reaction of the commercial varieties to 9 clubroot populations.

RESULTS AND DISCUSSION

The results of the survey are presented in appendix 1a and b of the handout. The results indicate that *B. napus* and *B. oleracea* differentials are heavily infected by most populations whereas *B. campestris* differentials are generally highly resistant.

The results were used to determine the most appropriate cut-off point for the distribution of the data. Two DI ranges occurred with greatest overall frequency, namely, 0-20% and 80-100% (fig 1). The lower peak of this bimodial distribution originated from the *B. campestris* and *B. napus* groups and the upper one from the *B. napus* and *B. oleracea* groups. Low disease indices for the first two species groups were usually derived from small proportions of severely diseased plants with the remainder showing no clubroot symptoms. The first cut-off point (10%) was selected in the middle of this lower peak and the second point (20%) at the end of the lower peak. The second point was selected in an attempt to avoid giving significance to responses which were uncharacteristic of the large proportion of the host or pathogen population. The 35% cut-off point was selected especially for the *B. campestris* group.

Figure 1.



The influence of the cut-off value on the frequency of occurrence of the ECD codes is shown in appendix 2 (see handout). The results indicate a wide range of pathogenic variation with 31 different populations identified at the 35% cut-off point. Population 16.31.31 was the most frequent population identified followed by 21.31.31, 20.31.31, 17.31.31, 16.22.31 and 16.30.31.

The frequency of susceptible reactions decreased as the cut-off point was raised (Table 1). Hosts 05 and 07 remained totally susceptible for each value.

Table 1. Influence of cut-off value on frequency of susceptible reactions on ECD set with 80 *P. brassicae* populations

Cut-off Point	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
10%	32	6	32	4	80	55	80	79	65	74	74	74	78	80	76
20%	17	3	15	2	80	48	80	77	64	68	71	74	77	79	70
35%	9	0	7	0	80	45	80	77	64	65	65	71	75	77	64

Table 2 shows the distribution of susceptible reactions recorded on the three groups of the ECD set. The *B. napus* data obtained with the highest cut-off point showed statistically significant regional differences ($P < 0.05$). This could mainly be attributed to the high level of virulence to this species carried by the *P. brassicae* populations collected in the Borders.

Table 2. Incidence (%) of susceptible reaction recorded on differential species groups in ECD set (06 + 07 omitted) for *P. brassicae* populations from 4 regions in SE Scotland

	No of tests	Cut-off value (%)	*B. camp.*	*B. napus*	*B. oler.*
Perth and Angus	11	10	20.5	86.4	92.7
		35	0	72.7	89.1
Fife	21	10	25.0	84.5	97.1
		35	4.8	75.0	91.4
Lothians	18	10	16.7	77.8	93.3
		35	2.8	72.2	80.0
Borders	30	10	26.7	90.0	96.7
		35	8.3	86.7	90.0

The reaction of a selection of commercial swede and turnip varieties to 9 selected clubroot populations is shown in Table 3. A 50% cut-off point was used. Varieties could be grouped according to their reaction to the populations.

Table 3. Reaction of commercial swede varieties to 9 clubroot populations

	1	2	3	4	5	6	7	8	9
Acme	S	S	S	S	S	S	S	S	S
Criffel	S	S	S	S	S	S	S	S	S
Doon Major	S	S	S	S	S	S	S	S	S
Magnificent	S	S	S	S	S	S	S	S	S
Scotia	S	S	S	S	S	S	S	S	S
Merrick	S	S	S	S	R	S	S	S	S
Monkwood	R	S	R	S	R	R	R	S	R
Resfingtoe	R	S	R	S	R	R	R	S	R
Ruta Otofte	R	S	R	S	R	R	R	S	R
Sator Otofte	R	S	R	S	R	R	R	S	R
Seefelder	R	S	R	S	R	R	R	S	R
Wilhelmsburger	R	S	R	S	R	R	R	S	R
W Prima	R	S	R	S	-	R	R	S	R
Doon Spartan	R	S	R	S	R	R	R	R	S

	1	2	3	4	5	6	7	8	9
Chignecto	R	S	R	-	R	R	-	S	S
Marian	R	R	R	S	R	R	R	S	R
Askgarde	R	S	R	S	R	R	R	R	R

POINTS TO BE DISCUSSED AT THE MEETING.

1. The range of pathogenic variation in *P. brassicae* in SE Scotland.
2. The suitability of the *B. napus* and *B. oleracea* differentials.
3. The use of commercial swede varieties as additional differentials.
4. Regional variation of the clubroot populations.
5. Cut-off points.
6. Value of such a survey.

APPENDIX 1(a)

Location of sites in S.E.Scotland from which inocula of P.brassicae populations were collected

Population number	Site	Region*	Inoculum source (if other than soil)
C1	Galalaw, Roxburgh	D	swede (cv.Victory)
C2	Oakwood Mill, Selkirk	D	swede (cv.Doon Major)
C3	House o' Rule, Roxburgh	D	swede (cv.Victory)
C4	Campend, Midlothian	C	swede (cv.unknown)
C7	Whitelee, Selkirk	D	
C8	Old Cambus, Berwick	D	
C10	Monktonhall, Midlothian	C	
C11	Monktonhall, Midlothian	C	
C13	Lochton, Berwick	D	
C18	Byrewalls, Berwick	D	
C23	Castlehill Manor, Peebles	D	
C24	Glenrath, Peebles	D	
C25	Woodhall, E. Lothian	C	Brussels sprout (cv.unknown)
C26	Elmwood College Farm, Fife	B	turnip/swede (cv.Acme)
C36	Kettle Farm, Fife	B	
C37	Kettle Farm, Fife	B	
C38	Kettle Farm, Fife	B	
C39	Kettle Farm, Fife	B	
C40	Kettle Farm, Fife	B	
C50	Seton Gardens, E.Lothian	C	
C51	Lochhill, E.Lothian	C	
C52	Tranent Mains, E.Lothian	C	
C53	Ferrygate, E.Lothian	C	
C54	Saltcoates, E.Lothian	C	
C55	Upper Keith, E.Lothian	C	
C56	Boghall, Midlothian	C	
C57	Peathill, Angus	A	
C58	Borlick, Perth	A	
C59	Taymount, Perth	A	
C60	Tealing House, Angus	A	
C61	Millhouse, Perth	B	
C62	Clentrie, Fife	B	
C63	Fleurs, Berwick	D	
C64	East Nisbet, Roxburgh	D	
C65	Swinwood Mill, Berwick	D	
C66	Prenderguest, Berwick	D	
C67	Littleton, Perth	A	
C68	Easter Lathrisk, Fife	B	
C69	South Cobbinshaw, Midlothian	C	
C70	Newark, Fife	B	
C71	Ballinbreich, Fife	B	
C72	Coldstream Mains, Berwick	D	
C73	Pusk, Fife	B	

Population number	Site	Region*	Inoculum source (if other than soil)
C74	Dryden Mains, Midlothian	C	
C75	Lacesston, Fife	B	
C76	Devonside, Fife	B	
C77	Edenwood, Fife	B	
C78	Meikle Obney, Perth	A	
C79	Auchindorie, Angus	A	
C80	Luffness Mains, E.Lothian	C	
C81	Kemphill, Perth	A	
C82	Kirktonhill, Berwick	D	
C83	Corsbie, Berwick	D	
C84	Lees, Berwick	D	
C85	Kersquarter, Roxburgh	D	
C86	Airdrie, Fife	B	
C87	Easter Softlaw, Roxburgh	D	
C88	Kirktonhill, Berwick	D	
C89	Gilston, Fife	B	
C90	Burnbrae, Berwick	D	
C91	Pitcruvie, Fife	B	
C92	Little Kenny, Angus	A	
C93	Smailholm Mains, Roxburgh	D	
C94	Riddleton Hill, Roxburgh	D	
C95	Blairfield, Fife	B	
C96	Old Jeddart, Roxburgh	D	
C97	Longnewton Forest, Roxburgh	D	
C98	Letham, Roxburgh	D	
C99	East Middleton, Midlothian	C	
C100	Linton Mill, Roxburgh	D	
C101	Middleton of Panbride, Angus	A	
C102	Wester Gospetry, Kinross	B	
C103	Woodhouse, Peebles	D	
C104	South Baldutho, Fife	B	
C105	Aberbothrie, Perth	A	
C106	Manderston, Berwick	D	
C107	Corstorphine, Midlothian	C	
C108	Whisgills, Roxburgh	D	
C109	Easter Howgate, Midlothian	C	
C110	Damhead, Midlothian	C	

* Regions

A, north of the R.Tay
B, between the R.Tay and the R.Forth
C, the Lothians
D, the Borders

APPENDIX 1(b)

Disease indices (%) recorded on ECD set following inoculation with P.brassicae populations from sites in S.E. Scotland

Population number	Differential														
	B.campestris					B.napus						B.oleracea			
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
C1	1	0	1	0	100	1	100	93	0	83	82	71	100	93	62
C2	0	0	0	0	100	18	100	100	72	100	7	68	72	100	16
C3	0	0	0	0	100	3	100	100	1	93	11	82	93	100	57
C4	0	0	3	0	81	2	100	83	6	82	2	21	40	100	10
C7	0	0	3	0	100	91	100	100	100	100	6	5	61	64	18
C8	10	0	17	0	100	0	100	91	0	90	0	100	93	100	85
C10	0	0	0	0	95	47	97	0	3	0	29	100	100	100	90
C11	0	0	0	0	88	100	100	100	100	95	100	100	100	100	100
C13	0	0	0	0	100	84	100	100	69	67	100	71	87	10	23
C18	0	0	14	0	96	0	100	100	2	80	24	24	82	96	46
C23	0	0	0	0	100	54	100	100	100	100	84	100	89	100	100
C24	1	0	7	0	100	0	100	97	0	82	19	51	50	76	26
C25	2	1	6	0	100	75	100	100	93	40	100	98	100	100	77
C26	0	0	6	0	97	0	100	90	0	90	24	73	55	83	21
C36	0	0	0	0	100	7	100	100	100	32	100	90	100	97	52
C37	3	0	0	0	100	0	100	100	100	3	100	83	100	100	68
C38	13	0	0	0	97	10	100	97	100	8	87	67	93	93	52
C39	9	2	2	0	97	3	100	100	100	59	94	59	93	100	52
C40	15	0	3	0	77	0	90	64	0	11	36	2	0	26	0
C50	0	0	0	0	87	46	93	68	100	42	55	40	97	90	41
C51	0	0	0	0	93	3	87	89	72	0	44	53	13	46	33
C52	7	7	3	0	83	0	40	47	53	10	31	9	30	28	1
C53	0	0	10	0	100	3	90	93	93	18	100	22	92	79	30
C54	0	0	2	0	98	0	70	77	87	1	41	7	70	67	10
C55	0	3	13	0	75	0	100	77	7	80	9	37	28	43	0
C56	2	3	19	0	100	100	100	100	100	100	100	98	100	100	90
C57	0	0	0	0	70	0	71	74	46	13	5	6	7	51	2
C58	0	0	21	0	100	100	100	100	100	100	100	76	100	100	54
C59	0	0	0	0	100	0	100	100	100	15	100	98	87	100	36
C60	24	4	0	0	100	4	100	100	59	0	94	56	100	98	49
C61	33	0	6	2	100	18	100	100	2	100	62	95	100	100	53
C62	9	1	15	0	100	25	92	100	46	100	28	54	94	100	43
C63	0	0	5	0	100	60	100	100	100	96	51	100	100	100	95
C64	16	0	5	0	100	100	100	100	81	100	92	91	100	100	94
C65	0	0	5	0	100	38	100	100	100	100	100	100	100	100	91
C66	4	0	1	0	86	46	95	100	100	100	95	90	100	100	68
C67	6	9	0	10	100	35	85	100	90	96	71	100	79	55	43
C68	0	0	4	0	100	10	100	99	100	88	100	100	100	100	88
C69	5	0	50	0	100	9	100	100	93	100	100	100	100	94	81
C70	0	0	5	0	100	100	100	100	38	100	57	87	100	100	37
C71	10	0	0	0	100	13	100	100	91	100	100	96	100	100	82
C72	10	0	4	0	100	29	100	100	100	100	58	81	100	100	79

Population number	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
C73	28	3	5	25	100	100	88	100	100	100	14	100	97	100	90
C74	0	5	13	2	100	100	100	100	100	100	100	100	100	100	100
C75	0	0	0	0	100	100	100	100	2	100	41	73	98	100	82
C76	0	0	13	0	100	100	100	100	92	99	53	83	100	100	56
C77	0	0	0	0	98	100	100	100	93	100	95	95	100	100	78
C78	2	0	3	0	100	100	100	100	100	100	100	95	100	100	58
C79	0	0	7	0	100	100	100	100	0	100	66	77	94	100	15
C80	3	0	15	0	100	100	95	100	100	41	100	100	100	100	60
C81	14	0	10	0	100	100	100	93	43	100	77	76	95	92	63
C82	10	0	0	0	100	100	94	100	100	100	100	88	100	86	80
C83	17	0	70	0	100	100	100	100	100	100	100	91	100	100	82
C84	16	5	33	0	100	100	100	100	100	78	100	96	100	100	96
C85	53	25	65	0	100	100	100	100	100	100	100	100	100	100	90
C86	0	2	0	0	100	96	100	100	100	100	95	91	100	100	33
C87	12	0	28	0	100	100	100	100	100	74	56	56	93	100	50
C88	5	0	24	0	100	83	100	100	67	100	94	62	88	100	80
C89	73	16	39	8	100	82	100	100	100	100	100	100	100	100	88
C90	96	22	65	0	100	100	100	100	100	100	100	96	100	100	77
C91	65	32	15	28	100	61	100	100	100	100	89	100	100	100	100
C92	17	7	6	0	100	83	100	90	100	100	25	88	100	100	95
C93	15	0	21	0	100	50	100	68	100	92	100	100	100	100	98
C94	8	4	52	0	100	37	100	100	100	91	100	81	100	100	90
C95	39	0	13	0	100	6	100	100	53	100	59	86	100	100	67
C96	61	0	0	0	100	7	100	79	5	100	91	94	100	100	79
C97	27	7	21	0	100	39	100	100	100	100	100	100	100	100	74
C98	49	11	34	0	100	93	100	75	81	100	100	100	100	100	60
C99	22	0	39	0	100	100	100	100	100	100	96	100	100	100	80
C100	44	10	10	0	100	10	100	96	100	100	100	100	100	100	49
C101	28	4	11	7	100	30	100	75	100	100	100	100	100	100	100
C102	24	8	13	0	100	100	100	88	100	100	100	100	100	100	100
C103	40	0	7	1	100	54	100	76	97	100	62	100	100	100	100
C104	11	2	21	0	100	8	100	43	100	25	100	100	100	100	100
C105	8	0	7	11	100	4	100	15	12	13	61	52	100	89	93
C106	0	0	4	0	100	90	100	96	100	100	100	69	86	96	19
C107	5	0	7	0	100	5	100	18	3	24	100	100	100	100	100
C108	8	0	3	0	100	15	100	52	89	100	100	8	83	95	56
C109	17	0	16	0	100	80	100	93	100	100	96	86	100	100	79
C110	25	4	11	0	100	93	100	83	81	100	100	83	100	100	51

APPENDIX 2

Influence of cut-off value on frequency of occurrence of ECD codes

Array of recorded reactions — Differential															ECD code	Frequency with cut-off value:		
B.campestris					B.napus					B.oleracea								
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15		10%	20%	35%
1*	1	1	1	1	1	1	1	1	1	1	1	1	1	1	31-31-31	1	0	0
1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	27-31-31	0	1	0
1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	23-31-31	5	2	0
1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	25-31-31	1	0	0
1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	21-31-31	11	4	3
0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	24-31-31	1	0	0
0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	20-31-31	8	7	3
1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	17-31-31	6	4	3
0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	16-31-31	14	23	27
1	0	1	0	1	0	1	1	1	1	1	1	1	1	1	21-30-31	2	0	0
0	0	0	1	1	0	1	1	1	1	1	1	1	1	1	24-30-31	1	0	0
0	0	1	0	1	0	1	1	1	1	1	1	1	1	1	20-30-31	2	2	1
1	0	0	0	1	0	1	1	1	1	1	1	1	1	1	17-30-31	0	2	2
0	0	0	0	1	0	1	1	1	1	1	1	1	1	1	16-30-31	3	4	5
1	0	0	0	1	1	1	1	0	1	1	1	1	1	1	17-23-31	1	0	0
0	0	1	0	1	0	1	1	0	1	1	1	1	1	1	20-22-31	1	0	0
1	0	0	0	1	0	1	1	0	1	1	1	1	1	1	17-22-31	1	2	1
1	0	0	0	1	1	1	1	1	0	1	1	1	1	1	17-15-31	1	0	0
1	0	0	0	1	0	1	1	1	0	1	1	1	1	1	17-14-31	1	1	0
0	0	0	0	1	1	1	1	0	1	1	1	1	1	1	16-23-31	2	1	1
0	0	0	0	1	0	1	1	0	1	1	1	1	1	1	16-22-31	5	3	2
0	0	0	0	1	0	1	1	1	0	1	1	1	1	1	16-14-31	2	4	6
0	0	0	0	1	0	1	0	0	1	1	1	1	1	1	16-18-31	0	1	0
0	0	0	0	1	1	1	0	0	0	1	1	1	1	1	16- 3-31	1	1	0
0	0	0	0	1	0	1	0	0	0	1	1	1	1	1	16- 2-31	0	1	2
1	0	0	1	1	1	1	1	1	1	0	1	1	1	1	25-31-30	0	1	0
0	0	0	0	1	1	1	1	1	1	0	1	1	1	1	16-31-30	1	0	2
0	0	0	0	1	1	1	1	1	1	1	0	1	1	1	16-31-29	1	0	0
0	0	0	0	1	1	1	1	1	1	1	1	1	0	1	16-31-23	0	1	0
0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	16-31-15	0	1	2
0	0	0	0	1	1	1	1	1	1	0	0	1	1	1	16-31-28	1	0	0
0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	16-31- 7	0	0	1
0	0	0	0	1	1	1	1	1	1	0	0	1	1	0	16-31-12	0	1	1
0	0	0	0	1	0	1	1	1	1	0	1	1	1	1	16-30-30	0	1	1
0	0	0	0	1	0	1	1	1	1	1	0	1	1	1	16-30-29	0	1	1
0	0	0	0	1	0	1	1	1	1	0	1	1	1	0	16-30-14	0	1	1
0	0	0	0	1	0	1	1	1	1	1	0	1	1	0	16-30-13	1	0	0
0	0	0	0	1	0	1	1	1	1	0	0	0	1	0	16-30- 8	1	0	0
0	0	0	0	1	1	1	1	0	1	1	1	1	1	0	16-23-15	0	1	0
1	0	1	0	1	0	1	1	0	1	0	1	1	1	1	21-22-30	1	0	0
0	0	0	0	1	0	1	1	0	1	0	1	1	1	1	16-22-30	1	3	2
0	0	1	0	1	0	1	1	0	1	0	1	1	1	0	20-22-14	1	0	0

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	ECD code	10%	20%	35%
1	0	0	0	1	0	1	1	0	1	1	0	0	1	0	17-22- 9	1	0	0
0	0	0	0	1	0	1	1	0	1	0	0	1	1	1	16-22-28	0	0	1
0	0	0	0	1	0	1	1	0	1	0	1	1	1	0	16-22-14	0	2	2
0	0	0	0	1	0	1	1	0	1	0	0	1	1	0	16-22-12	0	0	1
0	0	0	0	1	0	1	1	0	1	0	1	0	1	0	16-22-10	0	0	1
0	0	0	0	1	0	1	1	1	0	1	0	1	1	1	16-14-29	1	0	0
0	0	0	0	1	0	1	1	1	0	1	1	0	1	1	16-14-27	0	1	0
0	0	0	0	1	0	1	1	1	0	1	0	1	1	0	16-14-13	0	2	2
0	0	0	0	1	0	1	1	1	0	1	1	0	1	0	16-14-11	0	0	1
0	0	0	0	1	0	1	1	1	0	0	0	0	1	0	16-14- 8	0	1	1
0	0	0	0	1	0	1	1	1	0	0	0	0	0	0	16-14- 0	0	0	1
0	0	0	0	1	0	1	1	0	0	1	0	0	1	0	16- 6- 9	0	1	0
0	0	0	0	1	0	1	1	0	0	1	0	0	0	0	16- 6- 1	0	0	1
0	0	0	0	1	1	1	0	0	0	0	1	1	1	1	16- 3-30	0	0	1

[a] 0, resistance
1, susceptibility

The reaction of forage brassica varieties to nine populations of *P. brassicae* found in S.E. Scotland

	Population								
	1	2	3	4	5	6	7	8	9
a) Swedes									
Acme, Doon Major, Magnificent, Scotia, Criffel	S	S	S	S	S	S	S	S	S
Merrick	S	S	S	S	R	S	S	S	S
Monkwood, Resfingtoe, Ruta Otofte, Sator Otofte, Seefelder, Wilhelmsburger, W. Prima	R	S	R	S	R	R	R	S	R
Chignecto	R	S	R	-	R	R	-	S	S
Marian	R	R	R	S	R	R	R	S	R
Askgarde	R	S	R	S	R	R	R	R	R
Doon Spartan	R	S	R	S	R	R	R	R	S
b) Turnips									
Invincible, Green Top Scotch	S	S	S	S	S	S	S	S	S
The Wallace	R	S	R	S	S	R	R	S	R
The Bruce	R	R	S	S	S	R	R	S	S
Brimmond	R	R	R	R	R	R	R	S	R
Findlay	R	R	R	R	R	R	R	R	R
Appin	R	R	R	R	R	S	R	S	S
Civasto	R	R	R	R	R	R	R	R	R
Gelria R	R	R	R	R	R	R	S	R	R
Tigra	R	R	R	R	R	R	R	R	R
Barkant	R	R	R	R	R	R	R	R	R
c) Fodder Rape									
Canard, Lair	S	S	S	S	S	S	S	S	S

R = resistant; S = susceptible (50% cut-off level).

Population	ECD code 20% cut-off	35% cut-off	Origin
1	16.14.31	16.14.31	B. sprouts
2	16.22.30	16.22.14	Swede
3	16.14.8	16.14.8	Soil
4	16.30.14	16.30.14	Swede
5	16.31.23	16.31.7	B. sprouts
6	16.31.31	16.31.31	B. sprouts
7	17.14.31	16.14.31	Cauliflower
8	16.31.31	16.31.31	Rape
9	20.31.31	16.31.31	Soil

Races of Plasmodiophora brassicae Wor. in Finland

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At the begin of the 1970ies a study on the occurrence of Plasmodiophora brassicae races in Finland was started at the Institute of Plant Pathology (Linnasalmi and Palonen 1973). Within the Nordic clubroot project 1974-1977 (NJK-project 27) the main attention was focused on the races occurring in cabbage, cauliflower and swede cultivars.

Altogether 247 root samples infected with clubroot were obtained from 81 communes; race analyses were carried out on 90 samples.

For the determination and classification of the races the system of Williams (1966) was used. In our opinion this system is a reliable and convenient method for separating and identifying the main Plasmodiophora brassicae race types known at present in club root populations.

In the material race 2 was the most common, it was found in 32 communes. Races 3, 4, 6 and 7 were found in about ten communes each, while race 1 was met with in only one commune. No clear differences in the distribution of the races in various parts of the country could be noticed.

The methods of isolation and identification of the races have been briefly described in Linnasalmi and Weisaeth 1978. A more detailed description of the methods, containing tables and maps of the distribution of the races is in preparation and will be published soon.

In connection with the Nordic clubroot project samples of Plasmodiophora brassicae from Norway (38) and Iceland (2) (gathered by G. Weisaeth) were analysed in Finland. From the Norwegian samples races 1, 2, 4, 7 and 9, and from the Icelandic samples race 7 were isolated (Linnasalmi and Weisaeth 1978).

Within the frame of the project purified race material was distributed to the Scandinavian members of the project. From 1980, however, the type isolate material is deposited as race bank at The Swedish University of Agricultural Sciences, Department of Resistance Biology (Alnarp, Sweden), from where the race material is available for clubroot investigators on request.

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STUDIES ON POPULATIONS OF PLASMODIOPHORA BRASSICAE

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INTRODUCTION

Development of the European Clubroot Differential Series (ECD) (Buczacki, Toxopeus, Mattusch, Johnston, Dixon and Hobolth, 1975) provided a tool whereby studies on populations of *Plasmodiophora brassicae* by several workers might more easily be related to each other. Results of studies using the ECD series have been published in Clubroot Group Newsletters and by Dixon, (1977 a, b), Dixon (1980), Jones (1980) and Tinggal (1980). From the outset it was however recognised that the ECD series itself needed study and this might lead to the development of an improved differential series. The research reported in outline here, and to be published in detail elsewhere, aimed to look at three aspects: i) whether a uniform representative collection could be produced from a population ii) the effects of mixtures of pathotypes within a population and iii) the effects of inoculum concentration on disease expression by ECD hosts.

In the work described use has primarily been made of the *Brassica napus* hosts within the ECD series because only small effects can be obtained on the *B. campestris* group due to their high level of resistance and it is already well recognised that the *B. oleracea* differentials are extremely variable in their reaction. The *B. napus* differential series is set out in Table 1.

Table 1 *Brassica napus* differentials which form part of the European Clubroot Differential Series

06	Dc	101	(Nevin)
07	Dc	119	(Commercial Giant Rape)
08	Dc	128	(Selection of Giant Rape)
09	Dc	129	(New Zealand Resistant Rape)
10	Dc	130	(Wilhelmsburger)

RESULTS

1. Production of a representative collection from one population of P. brassicae

A *P. brassicae* population was obtained from the National Institute of Agricultural Botany (NIAB) cultivar trial sited at the Ministry of Agriculture, Fisheries and Food Experimental Husbandry Farm (MAFF/EHF) at Trawsgoed, Wales. Inoculum prepared from many field clubs on swede cv. Acme was passed through Acme in a glasshouse. Results from five ECD tests with the resulting clubs are given in Table 2.

Table 2 ECD codes obtained with a collection of the Trawsgoed population of *P. brassicae*

Test No.	ECD Code
1	17/31/31
2	16/15/31
3	20/14/31
4	20/14/15
5	16/14/31

In four tests, there was little or no disease on hosts 06 and 10, but in test 1 all plants of these two hosts were clubbed. These results were disturbing because one collection, produced by inoculation with one spore suspension, did not give consistent results. This implies that variation in the results of ECD tests may be due to variation within the collections. The Trawsgoed population of *P. brassicae* contains a minimum of two pathotypes, only one of which could infect hosts 06 and 10. Further tests with this population consistently gave either of the two reactions with the ECD *B. napus* hosts listed in Table 1.

2. Population heterogeneity

Inoculum for these studies was obtained from Trawsgoed and from further NIAB cultivar trials at an outcentre of MAFF/ EHS Rosemaund, Herefordshire. The range of differentials was reduced to 06 (Nevin), 10 (Wilhelmsburger) and 05 (Granaat).

Single clubs taken from specified cvs in the field and glasshouse were used to inoculate these differentials and the results shown in Table 3.

Table 3 Variation in pathogenicity between single clubs taken from field and glasshouse grown *Brassica* cvs infected with *Plasmodiophora brassicae*

Differential	Club no.	Disease index 1	2	3	4	5	6	7	8	9	10	11	12	13
inoculum source: Acme field grown clubs (Trawsgoed)														
Granaat		100	100	100	100	78	100	97						
Nevin		87	0	0	0	3	3	0						
Wilhelmsburger		77	5	3	0	10	0	0						
inoculum source: Acme glasshouse grown clubs (Trawsgoed)														
Granaat		100	100	100	100	100	100	100	100	100	100			
Nevin		0	0	2	0	0	36	3	0	3	0			
Wilhemsburger		4	0	10	6	3	22	0	0	6	9			
inoculum source: Wilhelmsburger field grown clubs (Trawsgoed)														
Granaat		100	100	45										
Nevin		73	94	0										
Wilhelmsburger		63	69	0										
inoculum source: Marian field grown clubs (Trawsgoed)														
Granaat		100	27	93										
Nevin		98	0	41										
Wilhelmsburger		100	2	9										
inoculum source: Bangholm field grown clubs (Trawsgoed)														
Granaat		34	64	39										
Nevin		0	0	0										
Wilhelmsburger		0	0	0										
inoculum source: Bangholm glasshouse grown clubs (Trawsgoed)														
Granaat		100	100	100										
Nevin		22	3	0										
Wilhelmsburger		6	7	0										
inoculum source: Acme glasshouse grown clubs (Rosemaund)														
Granaat		100	100	100	100	100	100	100	100	100	100	100	100	100
Nevin		0	20	100	0	72	60	96	89	54	0	39	5	0

a) Trawsgoed inocula

Five inocula (all three field grown clubs on Bangholm and one each on Wilhelmsburger and Marian) caused little disease on the universally susceptible Granaat. This was probably an effect of low spore viability. Nine of ten inocula from glasshouse grown clubs on Acme gave little or no disease on either Nevin or Wilhelmsburger but the other gave disease indices of 36 and 22, respectively. But inoculum from one field grown club (Acme club 1) produced disease indices of 87 and 77 on Nevin and Wilhelmsburger. Inocula from field and glasshouse clubs on Bangholm caused little disease on either Nevin or Wilhelmsburger. Inocula from two Wilhelmsburger and one Marian gall however infected the majority of differential plants.

b) Rosemaund inocula

Results obtained with material from Rosemaund showed even greater variability from club to club in ability to infect Nevin although all Granaat plants were diseased.

These effects were investigated further by cutting field grown clubs from Acme and Wilhelmsburger into quarters and using these to inoculate Granaat and Nevin, the results are shown in Table 4.

Table 4 Variation in pathogenicity between quarters of the same club when used as sources of inoculum of *P. brassicae*

Differential	Club portion	Disease index a	b	c	d
inoculum source: Acme field grown clubs (Rosemaund)					
Granaat		100	100	100	100
Nevin		54	94	100	35
inoculum source: Wilhelmsburger field grown clubs (Rosem'd)					
Granaat		100	100	100	100
Nevin		68	58	100	0

Evidence from these experiments demonstrated the existence of at least two pathotypes at both Trawsgoed and Rosemaund and that the relative proportions varied from club to club and even within portions of the same club determining whether or not Nevin became infected.

3. Spore concentration

In these experiments the source of inoculum was from NIAB trials at the Lancashire College of Agriculture Myerscough. In replicated tests at least 50 plants of each of the ECD hosts 05 to 10 were inoculated with concentrations of *P. brassicae* spores at 10^3, 10^4, 10^5, 10^6 and 10^7 ml^{-1}. Results are presented in Figure 1. Analyses of variance showed that the differences between disease incidence on different hosts at each spore concentration were highly significant ($P < 0.001$) as were the differences in disease incidence at different concentrations ($P < 0.001$) but the interaction between hosts and concentration was not significant which means that hosts showed similar reactions to differences in spore concentration. For each host there is a linear relationship between the percentage of diseased plants and spore concentration. Additionally at each concentration the incidence of disease was highest on ECD hosts 05 and 07 followed by host 08 while disease incidence was lowest on hosts 06, 09 and 10. Since the overall difference between disease incidence on different hosts was highly significant it can be concluded that a higher concentration of spores is required with ECD hosts 06, 09 and 10 than with hosts 05 and 07 to produce a similar incidence of disease.

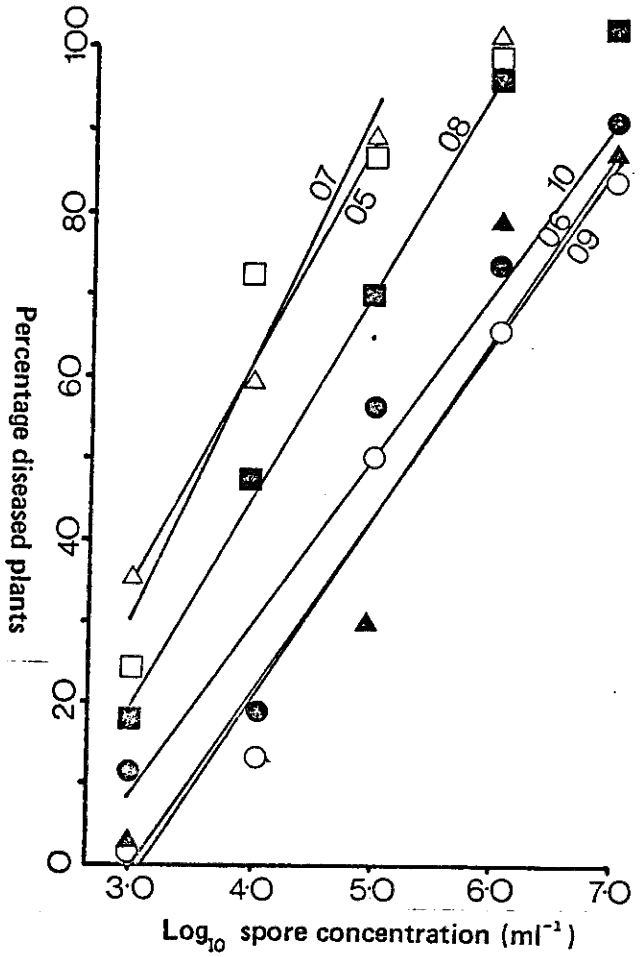
CONCLUSIONS

1. The use of highly susceptible hosts with which to passage *P. brassicae* inoculum prior to making differential tests for pathogenicity does not necessarily mean that a more uniform inoculum will be obtained.

2. Inoculum is likely to contain more than one pathotype of *P. brassicae* and the effects of these on ECD tests cannot be circumvented by taking single galls or even parts of the same gall from a specified host cultivar.

3. Some ECD hosts require greater concentrations of *P. brassicae* spores to produce a specified level of disease expression than others.

Figure 1. Relationship between concentration of P. brassicae spores and symptom expression



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STUDIES ON CLUBROOT POPULATIONS

Fritjof W. Heyn

The fungus Plasmodiophora brassicae passes meiosis during its life cycle which causes recombination and the appearance of new pathotypes in the populations, which are to be found in infected fields. The numerous data published in the Clubroot Newsletters clearly show that normally one is dealing with populations and not with races. In some rare cases the variation in one site may be stabilized to such an extent for one host species by the latter's permanent presence, that it can be justified to speak of a race. In order to find out about the variability of the virulence of the pathogen and the dynamic of the frequency of the different pathotypes within a population, a differential host set is needed derived from inheritance studies producing clear cut segregation ratios with purified races. Up to now only the ECD-test set is the first step towards this aim.

ECD-test results show that the virulence pattern alters fairly independently between the three species groups.

My own ECD-test results from different locations show a strong influence of the tradition of cultivationg certain cruciferae crops and the frequency of the appearance of the host plants in the field rotation.

The Wisconsin Pb 6 accession from Bear Creek is a 16/02/30 (tab. 1). The reaction in the B. campestris and B. napus group is very clear and shows a low virulence level because in that region only B. oleracea is grown intensely, resulting in a -/-/30-reaction. The German accessions tested also reflect clearly the farmer's use of Cruciferae crops. In Schleswig-Holstein in Lundsgaard and in Altenhof a 16/31/30 reaction is typical (tab. 2). Here in North Germany stubble turnips are unknown, but there is an old tradition of growing swedes and oil seed rape. The disease index of the B. oleracea hosts is partly higher in Lundsgaard because that field

Table 1

0	1	2	3		index
Pb 6 host: Bronowski					
16/02/30					9.77
20	.	.	.	-	0
18	.	.	.	-	0
18	.	.	.	-	0
19	.	.	.	-	0
.	.	.	7	+	100
5	.	.	.	-	0
.	.	.	47	+	100
10	.	.	.	-	0
8	.	.	.	-	0
10	.	.	.	-	0
18	4	2	.	-	11
.	2	5	5	+	75
.	.	.	18	+	100
.	.	.	14	+	100
3	2	2	8	+	67

Table 2

0	1	2	3		index
Lundsgaard, Kr. Flensburg Host: Weerape					
16/31/30			28.12.77		
6	.	3	.	-	22
8	.	2	.	-	13
9	.	.	1	-	10
11	.	.	.	-	0
.	.	.	5	+	100
.	.	.	12	+	100
.	.	.	5	+	100
.	.	.	10	+	100
.	.	2	7	+	93
.	.	.	11	+	100
7	.	1	.	-	17
.	3	2	.	+	47
.	.	.	2	+	100
.	.	.	11	+	100
3	2	2	1	+	37

0	1	2	3		index
Altenhof, Kr. Eckern Förde soil Bronowski as host					
16/31/30			28.12.77		
9	.	.	.	-	0
11	.	.	.	-	0
10	.	.	.	-	0
10	.	.	.	-	0
.	.	.	3	+	100
.	.	.	11	+	100
.	.	.	5	+	100
.	.	.	10	+	100
.	.	.	10	+	100
.	.	.	11	+	100
5	2	1	.	-	17
4	4	2	.	+	27
.	2	2	4	+	75
.	.	5	3	+	79
5	2	2	2	+	36

belongs to a breeder of narrow stem kale.

Marbeck in Nordrheim-Westfalen is a region with sandy soil and a milder climate than Schleswig-Holstein. Here stubble turnips and oil seed rape are grown as second crop after the cereal harvest: 23/31/31 (tab. 3). Klausheide (tab. 4), not far from Marbeck, is a place with sandy soil too, and with much oil seed rape breeding plots and multiplication fields. So the virulence pattern has extended to all B. napus hosta, due to the latter's frequent appearance in the field rotation. The same phenomenon can be shown for the stubble turnips in some places in the Netherlands with the "race" X, giving a 31-reaction for the B. campestris group (table 5).

Table 3

Marbeck host: Akela

23/31/31 28.12.77

B. campestris	01	2	8	2	20	+	73
	02	11	12	6	.	+	27
	03	8	23	9	.	+	34
	04	21	16	4	.	-	19
B. napus	05	.	.	.	7	+	100
	06	.	.	.	2	+	100
	07	.	.	.	17	+	100
	08	.	.	.	16	+	100
	09	.	.	.	20	+	100
	10	.	.	.	21	+	100
B. oleracea	11	.	.	.	12	+	100
	12	8	15	20	3	+	41
	13	.	.	.	14	+	100
	14	.	.	.	15	+	100
	15	17	16	10	.	+	36

Table 4

Klausheide host: Petranova

17/31/13 9.77

B. campestris	01	10	1	3	8	+	47
	02	23	.	2	.	-	5
	03	17	5	.	1	-	12
	04	20	5	.	1	-	10
B. napus	05	.	.	.	10	+	100
	06	.	.	.	40	+	100
	07	.	.	.	25	+	100
	08	.	.	.	25	+	100
	09	.	.	.	21	+	100
	10	.	.	.	20	+	100
B. oleracea	11	.	.	.	17	+	100
	12	12	4	4	.	-	20
	13	.	.	.	20	+	100
	14	.	.	.	11	+	100
	15	15	4	.	.	-	7

Table 5.

Race X Host: ECD 5

31/31/14				28.12.77		
01	.	.	.	8	+	100
02	.	.	.	8	+	100
03	.	.	.	10	+	100
04	.	.	2	8	+	33
05	.	.	.	9	+	100
06	.	.	.	12	+	100
07	.	.	.	12	+	100
08	.	.	3	6	+	89
09	.	.	1	11	+	97
10	.	.	3	9	+	92
11	7	.	1	.	-	8
12	.	1	9	1	+	67
13	.	2	8	.	+	60
14	.	.	6	5	+	82
15	8	3	.	.	-	9

Table 6.

Hasselt, Kr. Kleve Host: Su. rape

20/23/31				28.12.77		
01	9	1	.	.	-	3
02	9	.	.	.	-	0
03	5	.	2	2	+	37
04	2	.	.	.	-	0
05	.	.	.	3	+	100
06	.	.	.	11	+	100
07	.	.	.	5	+	100
08	.	.	4	2	+	58
09	2	.	.	.	-	0
10	2	6	2	1	+	39
11	.	.	4	5	+	85
12	1	1	7	2	+	64
13	.	.	.	2	+	100
14	.	.	.	10	+	100
15	.	4	5	.	+	52

Corresponding results are to be found in cabbage cultivation areas: in Hasselt in the Rheinland the ECD-code is -/-/31 (table 6). In Harpe (Niedersachsen, a village near Gorleben) a certain home garden frustrates its owner with total failure of the cabbage every year; this accession also is 31 for B. oleracea (table 7). The disease indices of the two latter locations show higher values for Harpe, reflecting a higher concentration of more virulent pathotypes in that clubroot population. The conclusion to be drawn from this is: by repeated cultivation of the hosts the ECD-code can be raised to 31 in nearly every place. The narrower the crop rotation is, the quicker raises the virulence in the population.

Table 7.

Harpe, Kr. Lückow-Dannenberg
Host: curly kale

16/06/31			28.12.77		
10	.	.	.	-	0
11	.	.	.	-	0
10	.	.	.	-	0
11	.	.	.	-	0
2	.	.	3	+	60
10	.	.	.	-	0
.	.	.	5	+	100
.	.	.	8	+	100
4	5	1	.	-	23
10	.	.	.	-	0
.	.	.	7	+	100
.	.	.	8	+	100
.	.	.	10	+	100
.	.	.	10	+	100
1	2	1	5	+	70

Clubroot accessions giving a clear reaction are good for finding out the number of resistance genes in the hosts. For this purpose I used the Wisconsin accession Pb 6 from Bear Creek (supplied by P.H. WILLIAMS) and cytoplasmically male sterile plants for producing numerous progeny from single plants.

Several susceptible heterozygous oms-plant were pollinated with a Pb 6-resistant plant, which was supposed to be homozygous recessive for the B. oleracea resistance genes. Two backcross progenies segregated for 1 resistant: 3 susceptible plants, and two other BC progenies segregated for 1 resistant: 7 susceptable ones. These results are to say that resistance to Pb 6 is due to homozygosity in three recessive loci. Just one dominant allele suffices to render a plant susceptable. When Badger Shipper (ECD 11) plants are tested, many susceptible plants are to be found. A cleaning up would be useful to build up lines out of the populations used as ECD 11, 12, 13, 14 and 15.

Oms-plants of all three ECD-species are available; also for Raphanus sativus, which would be a useful addition to the test set, because Raphanus has stronger resistance genes, than all the three other species.

It does not bring any progress to use computer programs for evaluation of the ECD-test data, when the tester lines are impure.

Quantitative studies on inheritance of resistance to race 2 of *Plasmodiophora brassicae* in rutabaga

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Resistance to the clubroot pathogen, *Plasmodiophora brassicae* Wor. in cabbage (*Brassica oleracea* L. ssp. *capitata* L.) is a recessive character (Walker and Larson, 1951), but in swede or rutabaga (*Brassica napus* L.), Wit (1964), Lammerink (1967), Johnston (1970) and Ayers and Lelacheur (1972) found that resistance to the disease was dominant over susceptibility. Furthermore, they found that the number of genes involved depended on the material used. However, many studies on inheritance of resistance in clubroot disease were over simplified because investigators often grouped the low infected plants as resistant categories. Strictly speaking, plants with small nodules are still susceptible to the pathogen genetically. This report presents the results of quantitative study on the inheritance to race 2 of *P. brassicae* in rutabaga by means of a 4 x 4 complete diallel cross. A diallel study would provide more information on the nature of inheritance of resistance and elucidate the data more appropriately.

Materials and Methods

Most rutabaga cultivars or lines tested are resistant to the clubroot pathogen, *P. brassicae* race 2 except the cultivar "Laurentian". Rutabaga cultivars "Wilhelmsburger" and "York", and line "Ditmars S-2" were used as resistant parents and "Laurentian" as a susceptible one in this study.

F_1 seeds of twelve cross combinations (including reciprocals) and F_2 seeds were obtained in the greenhouse during 1977 and 1978, respectively. A complete 4 x 4 diallel cross experiment was carried out in 1979. Plastic pots 10 cm in diameter were filled with pasteurized organic soil inoculated with a spore suspension of *P. brassicae* race 2 (ECD 16/02/31, Buczacki *et al.* 1975) at a concentration of 5×10^8 spores/100 g of soil at 50% moisture. Sixteen pots containing five seed each were used for each of the parental cultivars and F_1 crosses and 44 pots for the F_2 populations. During the first three weeks the pots were kept in growth chambers at a day/night temperature of 22°/18°C. From the fourth week, plants were moved into a greenhouse where the temperature was kept at 20° ± 2°C. Disease evaluation was made seven weeks after planting. Disease rating was based on that proposed for clubroot by Crête *et al.* (1963) with slight modification, namely: 1, no infection; 2, 1-29%; 3, 30-59%; 4, 60-100% root infection.

Statistical analysis of infection rating was performed according to the methods of Hayman (1954a, 1954b). The genetic components of variation, D (additive effects of genes), H_1 (dominance effects of genes), h^2 (dominance effects over all loci), F (covariation of additive and dominance effects) and H_2 (dominance indicating asymmetry of positive and negative effect of genes) were also estimated.

The narrow sense of heritability was estimated by the formula $(1/4\ D)/(1/4\ D + 1/4\ H_1 - 1/4\ F + E)$ (Crumpaker and Allard, 1962).

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Results and Discussion

Since the diallel analysis of Hayman (1954b) is based on certain assumptions, therefore the validity of the assumptions was tested by the equation (Hayman, 1954b).

$$t^2 = \frac{n-2}{4} \times \frac{(\text{Var Vr} - \text{Var Wr})^2}{\text{Var Vr. Var Wr} - \text{Cov}^2 (\text{Vr Wr})}$$

where n = number of parents used; Vr = variance of rth array; Wr = covariance between the parents and their offspring in rth array.

The value of t obtained in this study was 0.1604 [< 4.303 = to (df = 2)] indicating probable fulfilment of the postulated assumptions.

The mean infection ratings of the four parents and their F_1 and F_2 populations are given in Table 1, the analysis of variance of the diallel table and the genetic components of variation are presented in Tables 2 and 3, respectively.

Table 1. Infection rating† of four rutabaga parents and their F_1's and F_2's (in parentheses) to race 2 of P. brassicae.

	Laurentian	Wilhelmsburger	York	Ditmas S-2
Laurentian	4.000	1.027 (1.101)	1.000 (1.460)	1.328 (2.093)
Wilhelmsburger	1.029 (1.392)	1.044	1.088 (1.077)	1.023 (1.410)
York	1.000 (1.517)	1.000 (1.075)	1.000	1.000 (1.320)
Ditmas S-2	1.518 (2.300)	1.000 (1.321)	1.000 (1.405)	1.000

† Infection rating of 1-4 with 4 indicating greatest root infection or susceptibility.

Table 2. Analysis of variance of diallel table.

Sources	df	Mean square	
		F_1	F_2
a	3	5.3388**	7.5373**
b	6	2.8857**	1.8869**
b_1	1	5.4939**	1.1081*
b_2	3	3.7724**	3.0980**
b_3	2	0.2516**	0.4596
c	3	0.0194	0.0494
d	3	0.0015	0.0082
Error	48	0.0435	0.1784
Total	63		

* Significant at P = 0.05
** Significant at P = 0.01

Table 3. Genetic and environmental components with standard errors and various ratios between components for resistance to P. brassicae in rutabaga.

Symbol	Components estimation ± SE		Component ratios		
			Expression	Estimation	
	F_1	F_2		F_1	F_2
D	2.2181 ± 0.0688**	2.2097 ± 0.1365**	$(H_1/D)^{1/2}$	1.5447	0.6877
F	2.0230 ± 0.2585**	1.6550 ± 0.3506**	$(H_2/(4H_1)$	0.0672	0.1618
H_1	5.2928 ± 0.2926**	1.0451 ± 0.3967*	h^2/H_2	1.2928	0.5214
H_2	1.4219 ± 0.0729**	0.6764 ± 0.1341**	KD/KR†	1.8377	3.3911
h^2	1.8382 ± 0.1830**	0.3527 ± 0.2484			
E	0.0105 ± 0.0450	0.0212 ± 0.0610			

* Significant at P = 0.05
** Significant at P = 0.01
† $KD/KR = [(4\ DH_1)^{1/2} + F]/[(4\ DH_1)^{1/2} - F]$

The high significance of a in both F_1 and F_2 generations suggests that the parents were genetically variable, a is also the magnitude of general combining ability which is primarily recognized as a measure of additive gene action. This significance of a is in agreement with that of the additive genetic component D. The significance of b indicates that some of the loci responsible for the resistance to P. brassicae race 2 showed dominance. This is also in agreement with the significance of the genetic component H_2. Component b measures the specific combining ability which is regarded as an estimate of the effect of non-additive gene action. However, the mean square ratio of a/b are 1.85 and 4.00 in F_1 and F_2, respectively, indicating that additive gene action is relatively more important in this set of diallel cross. The significance of b_1 suggests that the partial dominance effects are largely unidirectional towards resistance. This can also be noted from the significance of h^2. There is discrepancy in reciprocals due to dominance since b_3 is significant in F_1 population. However, maternal effect is not present in the material used in this study because components c and d are non-significant. The non-significance of environmental effect, E, suggests that the materials used are stable in the experimental environment.

The quantity of $\sqrt{(H_1/D)}$ measures the degree of dominance over all loci. The value of these estimates are respectively 1.5447 and 0.6877 in F_1 and F_2 generations (note that the degree of dominance of F_2 is expected to be half of the F_1 value, thus 0.6877 x 2 = 1.3754, which is close to that of F_1). These values are greater than one, it suggesting that overdominance may be present. However, as Allard (1956) pointed out, the overdominance shown by the ratio $\sqrt{(H_1/D)}$ may be confounded with the complementary type of gene action; he pointed out that this will increase Vr in relation to Wr. The ratios of Vr/Wr in this study are 0.8716 and 0.6764 for F_1 and F_2, respectively. Both values are relatively small, the overdominance detected in this study therefore is unlikely to be attributed to the above mentioned reason. Wigan (1944) used potence to determine the degree of dominance. He defined potence as the degree to which a hybrid deviates from the additive expectation. A hybrid having the value of either parents would show a potence $(= P_1 + P_2 - 2F_1)/(P_2 - P_1)$ of 1.0. The deviation from the additive expectation must result from dominance at one or more loci, assuming possible epistatic interaction and sampling variation to be nigligible. The estimate of overall potence obtained in the present study is -0.3943 indicating partial dominance of resistance over susceptibility.

The ratio h^2/H_2 estimates the number of groups of genes controlling a character exhibiting some dominance, the estimate is 1.2928 from F_1 generation suggesting that at least two major gene groups controlling resistance to race 2 exhibit some degree of dominance.

The order of dominance of the parents determined by the value of (Wr + Vr) is "York", "Ditmars S-2", "Wilhelmsburger" and "Laurentian", and the order of

parental resistance performance, Yr, is exactly the same. The correlation coefficient, r between (Wr + Vr) and Yr is 0.7044 from which it appears that "York" carries the most dominants. The value of heritability in the narrow sense was estimated as 40.09% which is reasonably high.

Since resistance to race 2 of P. brassicae in rutabaga is controlled by only relatively small number of genes and its heritability is reasonably high, therefore, either backcross or simple recurrent selection can be used to create new resistant lines.

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CLUBROOT RESISTANCE IN FODDER RAPE.

by

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Among farmers the leafy type of Brassica napus ssp. oleifera (biennis), fodder rape, has become a popular crop in Norway. The acreage is approx. 6000 hectars. The crop is used for grazing, for silage or fed as fresh fodder to cattle and sheep.

Clubroot disease caused by the soil borne fungus Plasmodiophora brassicae WOR. is the most widespread and persistant disease on cruciferous crops in this country. Resistant varieties would offer the only economic means to overcome the pathogen. However, up to now little efforts have been made by brassica plant breaders to introduce clubroot resistant varieties of fodder rape. The lack of resistance in commersial varieties is clearly demonstrated by observations made on heavy clubroot infected soil at the Dep. of Farm Crops, Agricultural University of Norway (AUN), table 1.

There is no doubt, most of the varieties offered for the farmers use are very susceptible to the pathogen. Only the varieties Nevin and CIV-Bladcool have shown some resistance. Dixons and Doodsons (1969) also found that Nevin had less gall development than Early Giant at Trawscoed in Wales.
At Rosemaund, Hereford, both varieties were heavily infected. They explained the different reactions at the two centres in the occurence of different physiological races of P. brassicae.

The Norwegian selection called FRM is found to have much better resistance in our test field than all the others tried, including the very resistant marrow stem kale variety Grüner Angeliter. FRM descend from selections of healthy plants among different fodder rape varieties made on heavily infected P. brassicae soil at AUN in the early sixties. Its agronomical values, such as resistance to bolting, the proportion of stem to leaves and its low digestibility cannot be accepted. In our small scale breeding programme we

are trying to improve the plant materials in these charachters. Results are given in table 2.

The crossings between CIV-Bladcool and Ringot A or Ringot B have given acceptable proportions of leaves to stems, high dry matter yields with normal dry matter contents and high digestibility. However, both numbers were susceptible to clubroot disease. The two next combinations, Nevin crossed to Ringot A or Ringot B, have better clubroot resistance, but still many plants were attacted. In other charachters they seemed to be of less value than the two previous crossings. The two following numbers, FR 22/80 and FR 53/80, both with the common mother plant FRM, have quite good resistance to P. brassicae. FRM is susceptible to bolting, but combined with bolting resistant varieties, such as Ringot A and in particular Ringot B, the offsprings were improved in this charachter. The last crossing, Sharpes Early Giant x Ringot A, did not seem to give any improvement. Its scores for bolting is high, and the leaves to stem proportion is unfavourable, which leads to low digestibility.

Of various reasons we have not made much attention to the problems of physiological races of P. brassicae. It is obvious, however, that in future breeding programmes tests of resistance for different races should be included as a routine work. From The Nordic Clubroot Research Operation Programme, where they already are testing breeding materials on pure races, we certainly would get great help in connection to these problems. Figure 1 presents a test of breeding materials of fodder rape on race 4 which is supposed to be an aggressive one. The test was arranged in co-operation with dr. R. Jönsson and M. Gröntoft at Svaløf. This test demonstrates very clearly that there is a long way to go for obtaining full clubroot resistance in fodder rape. On the other hand, the results from the observations at AUN indicate that plants will survive to a much greater extend than the race test indicates due to the fact that gall development may be reduced or stopped, or that plants after a light infection are able to establish a new system of roots for further growth. Despite these arguments the aim for brassica plant breeders should be to provide varieties of fodder rape with exelent resistance against pests and diseases including race specific resistance to Plasmodiophora brassicae WOR.

Table 1. Observations on clubroot resistance in fodder rape varieties, AUN, Norway 1972.

Variety	Per cent		
	Healthy plants	Slightly infected	Heavily infected
CIV-Bladcool	20	40	40
Elsoms Giant Broadleaf Rape	0	20	80
Emerald Giant	0	0	100
English Giant Forage Rape	0	20	80
English Giant Rape Seed no. 2963	0	40	60
English Giant Rape Seed no. 11114	0	20	80
Escofar Certified Early Giant	0	30	70
Fora	0	0	100
Gartons Early Giant Rape	0	30	70
Giant Essex Rape	0	30	70
Giant Rape Seed	0	30	70
Hurst Giant Reselected Winter Rape	0	10	90
FRM	70	20	10
Nevin Rape	10	20	70
Ringot 68-A	0	30	70
Silona	0	40	60
Sharpes Early Giant	0	10	90
Sharpes Extra Tall	0	30	70
Tantal	0	30	70
Grüner Angeliter, kale	60	20	20

Table 2. Agronomical characters of breedings of fodder rape in trials on healthy soil, and observations on resistance at clubroot infected soil, AUN, 1980.

Breeding no.	Bolters [1]	Per cent leaves [2]	D.M. Yield t/ha	D.M. %	Digest-ibility in vitro	Club root test [3]
FR 2/80, CIV-Bladcool x Ringot A	1	56	9.02	12.5	73.1	sus
FR 4/80, Ringot B x CIV-Bladcool	2	59	10.08	13.0	73.0	sus
FR 17/80, Nevin x Ringot B	1	54	8.21	12.8	72.9	res/sus
FR 56/80, Nevin x Ringot	1	50	8.50	12.3	73.0	res/sus
FR 22/80 , FRM x Ringot B	2	55	8.41	13.3	72.8	res
FR 53/80, FRM x Ringot A	3	49	9.20	13.3	72.8	res
FR 31/80, Sharpes Early Giant x Ringot A	4	46	8.92	13.4	72.9	res/sus
CIV-Bladcool	2	51	8.63	13.4	-	sus
Ringot A	2	54	6.06	10.9	73.1	sus
Ringot B	1	54	6.89	13.0	72.9	sus
Nevin	3	51	9.40	13.6	-	sus/res
FRM	4	49	7.72	13.7	-	res

1) Bolter score, 1-5, 1=nil bolters. 5=100% bolters.

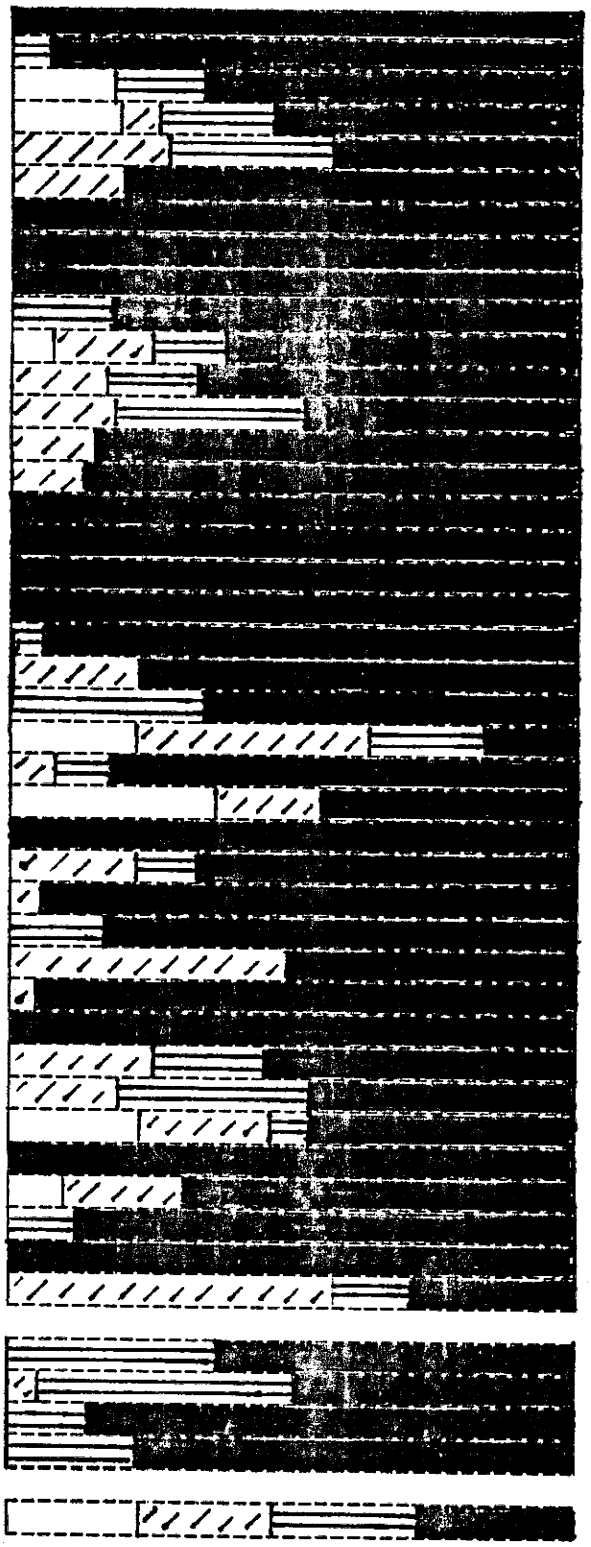
2) Per cent leaves at silage stage.

3) Clubroot test, visual judgement

sus = susceptible res/sus > 50% healthy plants
res = resistant

Fodder rape Breeding no.	n=number plants tested	Results at field obs. at AUN 1980.
3/80*	n=6	res.
6/80	n=13	res.
8/80*	n=22	-
9/80*	n=15	res.
21/80*	n=10	res.
22/80*	n=10	res.
Ringot B	n=14	sus.
Ringot A	n= 8	sus.
31/80	n=20	res./sus.
51/80*	n=17	res./sus.
52/80*	n=18	res.
53/80*	n=14	res.
54/80*	n=6	res.
55/80*	n-15	res.
57/80*	n=16	res.
58/80	n=18	res./sus.
59/80	n=16	sus./res.
61/80*	n=15	res.
64/80	n=23	res./sus.
93/80	n=18	res./sus.
94/80	n=20	res.
FRM-77	n=10	res.
FRM-76	n=15	res.
FRM-73	n=14	res.
FRM-72	n=6	res.
110/80*	n=21	res./sus.
112/80*	n=10	res.
113/80*	n=24	res./sus.
116/80	n=20	res.
118/80*	n=11	res.
161/80*	n=24	res.
167/80*	n=25	sus./res.
175/80	n=25	res.
105/80	n=19	res.
186/80*	n=18	res.
187/80	n=25	sus./res.
203/80*	n=20	res.
204/80	n=17	sus./res.
205/80	n=21	res./sus.
207/80	n=21	res.
J. Queen	n=17	
B. Shipper	n=25	
Laurentian	n=19	
Wilhelmsb.	n=13	

* FRM-crossing



resistant 1-2 mm 2-5 mm > 5 mm

Gall size and distribution in percent

res. = resistant res./sus. = > 50% healthy plants

sus. = susceptible sus./res. = < 50% healthy plants

Figure 1. Results from a test on Plasmodiophora brassicae WOR., race 4, in fodder rape, Svalöf 1981. Compared with field observations at AUN 1980.

BREEDING FOR IMPROVED RESISTANCE TO CLUBROOT IN OIL RAPE

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In Sweden clubroot earlier was a problem in swedes and turnips but today the acreage of these crops is very small. However, with increasing cultivation of cruciferous oil crops after the Second World War clubroot again has become a problem in some areas. Breeding for improved resistance to clubroot in oil rape was started at Svalöf more than twenty years ago.

Very limited variation in clubroot resistance has been found within oil rape. Therefore genes for clubroot resistance have been transferred from other Brassica species or subspecies. The fodder rape varieties Clubroot Resistant Rape from New Zealand and Nevin from Wales have been used as gene sources and by repeated selection at Svalöf the resistance in these varieties has been further improved. Also Gry, a Norwegian swede variety, has been used as a gene source for resistance. Besides, artificial oil rape has been produced by crossing clubroot resistant cabbages from Norway and clubroot resistant oil turnip rape. Breeding work aiming in transfer of genes for clubroot resistance from Raphanus to Brassica napus is going on. Turnips have been the main gene sources in the breeding for improved resistance in oil turnip rape. Among others the varieties Bortfelder, Dales Hybrid, Mainepe, Vobra and Debra have been used.

Repeated selection for clubroot resistance in heavily infected fields has been tried at Svalöf but this method resulted in very limited progresses only. From 1965 a greenhouse method for selection is used. Tests are carried out in small pots, placed in a sand bed, heated electrically to +23 centigrades. F_2 and F_3 plants with good resistance are selected and then backcrossed to varieties with high cultivation value. When these breeding programs were started high yielding varieties with high erucic acid content in the oil were used as backcross parents. Later on they have been replaced by varieties with improved oil and meal quality.

Clubroot races are denominated due to differences in their ability to attack certain host plants. Many different systems for race determination exist. At Svalöf Williams' (1966) system is still used. By use of four differentials, Jersey Queen, Badger Shipper (cabbages), Laurentian and Wilhelmsburger (swedes), theoretically 16 races can be determined. Other systems have been tested but have been abandoned for certain reasons.

In nature clubroot races mostly exist in mixture. A certain separation of races can be obtained by growing the parasite on the same variety for many generations. The callus technique developed by Ingram (1969) has been used for purification of races by members of The Scandinavian Clubroot Working Group. Race identifications are carried out by growing the purified races on the differential set and are considered safe when the test results from at least two successive callus cultivations are in agreement. By use of this technique the clubroot races 1-4, 6 and 7 have been purified so far. At Svalöf today most clubroot tests are carried out with spores from purified races.

Spore suspensions used for greenhouse tests were earlier prepared from clubs collected in many fields, meaning that many races were present in the suspensions. This method has its limitations. In most fields the race situation is unknown and unstable. Therefore very big variations in the race composition of the used spore suspensions can occur between tests. Differences in resistance between lines and plants can be discovered as long as the breeding materials own genes for resistance to all in the suspension existing races. However, problems arise when an additional race occurs. Then all the breeding materials, previously considered as resistant, suddenly are susceptible. This situation occurred at Svalöf some years ago. However, it would have been a mistake to discard these breeding materials, which it has taken many years work to build and which, no doubt by judgement from previous tests, contained resistance to the in field most common races. Obviously the use of spore suspensions with unknown race composition is hazardous. For further progresses in the breeding work a better knowledge about the race composition in used suspensions is necessary. Pure races are needed.

When spore material from fields are used for clubroot tests the breeder is given very limited and unsafe information about the resistance in his breeding materials. The results are not reproducible. When purified races are used the test results are more distinct and in most cases an either or reaction is observed. The results are reproducible. Obviously the callus technique is very useful for puri-

Plasmodiophora. Comparison between clubroot tests with spores from fields and from purified races.

Differential	Attacked plants, %							
	Spores from field			Spores from purified race				
	A	B	C	1	2	3	4	7
Jersey Queen	55	50	100	100	94	100	100	97
Badger Shipper	33	90	86	6	82	5	100	100
Laurentian	71	79	100	100	100	100	100	0
Wilhelmsburger	0	56	100	100	0	0	92	0

Plasmodiophora. Results from tests with purified races.

Material		Attacked plants, %				
		Race				
		1	2	3	4	7
Winter rape	Brink	100	100	100	100	100
Winter rape	Breeding material	100	3	0	100	0
Summer rape	Breeding material	53	0	0	100	0
Winter turnip rape	Breeding material	13	9	3	5	0
Artificial rape		-	-	-	6	-
Swede	Kiri	87	15	10	8	0
Swede	Gry	0	0	0	-	0
Turnip	Debra	0	0	0	0	0
Radish	Saxa	0	0	0	0	0
Radish	Nery	0	0	0	5	0

fication of clubroot races. With such races the breeder is given a more detailed and safer information about the race specific resistance in the breeding materials. Gene sources for resistance to specific races can easier be found and the breeder is given increased possibilities to build up materials with resistance to more races step by step. At Svalöf an artificial rape with good resistance to race 4 has been produced by crossing resistant cabbage from Norway and resistant winter turnip rape. Interspecific crosses between Raphanus and Brassica have been made in intention to build up a more general resistance. However, these efforts have not been successful so far.

Pure races means a big advantage in the breeding work for improved clubroot resistance. The callus technique has been useful for purifying such races, but the method is rather labourious. In the future pure races can probably be produced easier from single spore cultivations. Various differential sets for race determinations have been used, but none of them without disadvantages. More homozygous differentials are needed. Today, homozygous lines can be produced from pollen cultivations. By testing such lines against pure races of the parasite it will be possible to build up a more perfect differential set.

Plasmodiophora. ECD-set tested against purified races.

Differential		Attacked plants, %				
		Race				
		1	2	3	4	7
B. campestris						
01	aaBBCC	0	0	0	11	0
02	AAbbCC	0	0	0	0	0
03	AABBcc	0	0	0	0	0
04	AABBCC	0	0	0	0	0
05	aabbcc	100	100	100	100	100
B. napus						
06	Dc 101	8	87	70	10	0
07	Dc 119	100	100	100	100	4
08	Dc 128	89	40	48	68	0
09	Dc 129	0	0	5	29	0
10	Dc 130	100	0	45	92	0
B. oleracea						
11	Badger Shipper	0	100	8	95	100
12	Bindsachsener	74	100	100	100	95
13	Jersey Queen	100	100	100	100	100
14	Septa	100	100	100	100	100
15	Verheul	53	87	100	69	100

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Problems encountered in breeding for resistance to Plasmodiophora brassicae through interspecific hybridization

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In our breeding program the purpose of interspecific hybridization between Brassica napus and B.oleracea ssp. capitata is to transfer race 2 resistance to cabbage from rutabaga. Since resistance to race 2 of Plasmodiophora brassicae in B. napus is a dominant character, thus the dominance of resistance to the pathogen should be advantageous in future F_1 hybrid cultivar production in cabbage. However, there were certain problems we experienced during the past few years. I shall discuss them briefly.

Male sterility. Male sterility is a common phenomena in most interspecific hybrids and their backcross progenies. In our triploid and tetraploid F_1 hybrids the degree of male sterility (in terms of pollen stainability) are varied (Chiang et al. 1979). The triploid hybrids (2n=28, a_1c_1c) has the lowest pollen stainability (1.99-9.71%). The triploid hybrids practically produce no pollen grain. Within the tetraploid hybrids (2n=37, a_1c_1cc) the pollen stainability varied from 24.77 to 53.19%. Nevertheless, we have two plants in this group produce abundant pollens constantly but the majority of the tetraploid hybrids are highly male sterile. The only hexaploid hybrid (2n=55, a_1c_1cccc) produces good amount of pollen grains and set seeds when selfed. This lends further support for our observation that the genetic unbalance brought on in the species hybrids between B. napus and B. oleracea can be better tolerated if more sets of c-genomes are present, at least as far as pollen fertility is concerned (Chiang et al. 1978). Because of the relative low number of chromosomes in the triploid and tetraploid hybrids they are used in backcross breeding extensively. It should be pointed out that all hybrids will set some seeds when they are pollinated by cabbage pollens (as well as by broccoli and cauliflower pollens) but male sterility is persistent in backcross progenies. So far all the triploid and tetraploid hybrids and their backcross progenies have their cytoplasm derived from B. napus thus, the cause of male sterility seems cytoplasmic origin. However, two plants among our selected progenies produced some pollen grains in the end of season (when plants grow older). We collected the pollens and they were backcrossed to cabbage plants (as female parent), unfortunately, we failed to restore the male fertility in the resulting progenies. Therefore, male sterility in our species hybrids is not simply due to cytoplasm alone.

Lack of recombinations in backcross progenies. One of the first backcross progenies designated as B_1-A-1 derived from one of the triploid hybrids is not only resistant to race 2 but also has a desirable low chromosome number (2n=18) and resembles to cabbage closely. Studies on the karyotype comparison and the meiotic chromosome behavior, we concluded that in B_1-A-1 cabbage chromosomes no.1 and no.7 each had a shorter counter part apparently contributed by B. napus (Chiang et al. 1980). It is considered that the genes for resistance to race 2 of P. brassicae is carried by one of these two B. napus chromosomes.

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Although B_1-A-1 is highly male sterile but backcross seed were easily obtained when it was used as female parent. Results of disease reaction to race 2 of P. brassicae in backcross progenies derived from B_1-A-1, were relatively low. For example, percentages of resistant plants in B_2, B_3 and B_4 generations were 2.78, 8.04 and 1.01, respectively. Ayers and Lelacheur (1972) reported that resistance to race 2 in Ditmars-S2, the B. napus parent involved in the origin of B_1-A-1, is controlled by single major dominant gene, and this would indicate that resistance was not the result of recombination because one should expect to find more resistant plants than the above mentioned figures. At this stage we consider that resistance is the result of limited transmission of a B. napus chromosome which is either successfully transmited to the progenies or not at all.

Screening tests. We often asked ourselves should we conduct our screening tests in greenhouse or in field? The answer of this question is heavily depended on the purposes of the test. For horticultural character evaluation such as head size, head shape, firmness, etc., as in the case of cabbage, should be made only on matured plants grown in clubroot pathogen infected fields. Since the number of resistant plants with desirable characters are relatively low, a large population of progenies should be screened in the field. Therefore, field space may become as a limiting factor for screening test. In addition, a mixture of races of P. brassicae in the experimental plots is almost unavoidable. This will create more problems especially in genetic stueids on inheritance of resistance to a given race. If it is possible we should screen large number of seedlings against a specific pure race in greenhouse in spring, so that resistant seedlings can be transplanted into clubroot infected fields immediately. By doing this, we can observe further in disease resistance and also be able to evaluate the horticultural characters.

In spite of the difficulties mentioned above, we already selected some multi-race resistant cabbage plants with good quality. In addition, from the preliminary analysis of thiocyanate (SCN^-) content in our segregating progenies, it showed that there was a positive correlation between clubroot resistance and the concentration of SCN^- suggesting that when we select resistant plants we also simultaneously select the low SCN^- content individuals (Chong et al. 1981). Homozygous resistant plants will be selected once we restored the male fertility, and we hope this problem will be solved in the near future.

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Studies on the interaction between *Plasmodiophora brassicae* collections and *Brassica oleracea* genotypes in relation to breeding for resistance to clubroot.

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Introduction

Breeding for resistance to a parasite is essentially a matter of exploiting genetic variation for reaction to the organism within the host population. Resistance breeding can only proceed where such variation exists and can be readily recognised and selected. In contrast to breeding for other characters however, the parasite population is equally likely to exhibit genetic variation for propensity to attack the host. It is therefore essential to study the form of and genetic basis for variation in both partners as observed in the association between host and parasite.

Theory and practice suggest that hosts and parasites of different genotype interact to produce patterns of response which may broadly be divided into two types, although it is probable that in all host-parasite combinations both types occur together to differing degrees:

1. Differential interactions with inversions in ranking. This type of relationship is illustrated in the theoretical example given in Table 1 and corresponds to vertical resistance/pathogenicity (Robinson, 1969). Such a relationship may need to be considered quantitatively as in Table 1 but frequently may be considered qualitatively where the differences between host genotype/parasite genotype combinations are very marked (Table 2).

Table 1

Host genotypes	Parasite genotypes A	B	C
X	2.4	2.5	1.7
Y	2.8	1.9	2.9
Z	1.5	1.6	2.3

(Parasite development measured on a 1-3 scale)

Table 2

Parasite genotypes A	B	C
S	S	R
S	R	S
R	R	S

(R = Resistant; S = Susceptible)

The essential feature of this relationship is that one host genotype (e.g. Z) may be more resistant to one pathogen genotype (e.g. A) than another (e.g. C) yet the opposite is true for a different host genotype (e.g. X). This results in inversions when genotypes are ranked according to performance and to describe this it is necessary to include an interaction term in a linear model, such as analysis of variance. This type of interaction is frequently explicable in terms of a gene-for-gene relationship (Person, 1959).

2. Non-differential interactions with constant ranking. This type of relationship is illustrated in Table 3 and corresponds to horizontal resistance/pathogenicity (Robinson, 1969). While such a relationship usually has to be considered quantitatively (Table 3), this is not necessarily so. If threshold values for parasite

development determine whether a disease is observed or if a value is selected by the observer below which the host is considered to be resistant (e.g. $\leqslant 1.5$ in Table 3) then this may, after re-arrangement, result in the pattern shown in Table 4. This results in apparent race-specific effects but with no inversions in ranking.

Table 3

Host genotypes	Parasite genotypes A	B	C
X	1.0	1.5	2.0
Y	1.5	2.0	2.5
Z	2.0	2.5	3.0

(Parasite development measured on a 1-3 scale)

Table 4

	Parasite genotypes C	B	A
Y	S	S	R
Z	S	S	S
X	S	R	R

(R = Resistant; S = Susceptible)

Parasite genotype C is always the most virulent regardless of host genotype while host genotype X is always the most resistant regardless of parasite genotype. This type of data can be described by a simple model with additive effects of parasites and hosts so that following an analysis of variance there would be no significant genotype x genotype interaction provided the data had, if necessary, been appropriately transformed.

The establishment of the major type of relationship involved in the host parasite association is clearly of primary importance to a successful breeding strategy. The study of variation for parasitic behaviour is of interest, regardless of the host genotype considered, but it only assumes practical relevance when variation for parasitic capability on sources of resistance likely to be used commercially are employed. This may not be the case at present with the B. oleracea/P. brassicae Woronin association.

The effectiveness and durability of a source of resistance (and hence its value for breeding) depends upon (a) the extent of the parasite's attack; (b) the initial frequency within the parasite population and relative fitness of variants causing most damage; (c) the response of the parasite population to the selection pressure imposed by growing genotypes carrying the resistance and (d) the ease with which successful parasite variants are disseminated.

With this in mind and as a prelude to embarking upon a breeding programme for resistance to clubroot in Brassica oleracea, the nature of the relationship between Brassica genotypes and Plasmodiophora brassicae has been investigated.

Information obtained from reported tests using the European Clubroot Differential Set (ECD)

The investigations of ECD data reported below have been carried out using all the reported tests. However, the figures quoted and conclusions drawn refer only to data reported by the following workers whose permission to refer to their results is gratefully acknowledged: Dr R. Crête, Drs S Lewis and T. Brokenshire, Dr M. Waring, Mr H. Yoshikawa, Dr I. McNaughton and Dr H. Toxopeus. We are also grateful to Dr D. Jones for access to unpublished data.

Brassica napus

Whilst non-differential (or horizontal effects) may probably be observed in the association between P. brassicae collections and B. napus L. cultivars, the major effects are differential (or vertical). This is illustrated in Table 5 where two genotypes used by Johnston (1968) and now included in the ECD set (Buczacki et al., 1975) react differentially to two races of P. brassicae (N1 and N2, sensu Johnston, 1968).

Table 5

Host genotype			*P. brassicae* race	
			N1	N2
Dc 129	(09)	cv. Clubroot Resistant	S	R
Dc 130	(10)	cv. Wilhelmsburger	R	S

Crute *et al.* (1980) after considering published genetic and pathogenicity data, concluded that resistance in the *B. napus* genotypes included in the ECD set was controlled by either 3 or 5 genes (additional genes may exist in genotypes, such as cv. Chignecto, not included in the ECD set). Recently, data reported in Clubroot Newsletters have been used to test these hypotheses. Working only with data from collections which gave a disease index of $\geqslant$ 80% on ECD 07, the fit to each model was tested after the data had been converted to binomial form by applying a range of different 'cut-off' points. Table 6 shows the proportion of tests fitting each model at a 'cut-off' point of 25%. The choice of different 'cut-off' points made little difference to the overall proportion of tests which fitted the models, as would be expected if the data were discontinuous. The 5 gene model was a marked improvement over the 3 gene model in its fit to the data. The heterogeneity of the seed stocks of certain differentials may account for some of the apparent disagreement. The high frequency of occurrence of all differential pathogenicity determinants and their combinations to match resistance in the *B. napus* ECD differentials, in Europe at least, suggests that such resistance may be of little practical value for future breeding.

Table 6

Relative fit to genetic models of ECD data on *B. napus* genotypes (25% cut-off)

Worker	Number of tests	% accepted	% fit to model	
			3 gene	5 gene
NVRS	23	83	95(91)	100(100)
Jones	34	89	97(93)	100(100)
Lewis	59	81	96(93)	98(97)
Crête	48	94	93(73)	96(82)
McNaughton	10	90	100(100)	100(100)
Waring	20	100	65(22)	70(33)
Yoshikawa	58	28	69(62)	88(85)
Toxopeus	41	66	96(75)	93(50)
All	293	73	90(78)	94(86)

(Figures in brackets are the % fit to models when collections which were either virulent or avirulent on all host genotypes were excluded from the calculation.)

Brassica campestris

Resistance to *P. brassicae* in *B. campestris* L. also appears to be most differential and the available data closely fit a 3 gene model (Crute *et al.*, 1980) based on the suggestions of Wit (1964) and Toxopeus & Janssen (1975). A strong association between differential pathogenicity on *B. campestris* and that on *B. napus* exists in that > 95% of all collections exhibiting pathogenicity on at least one of differentials 01-04 (*B. campestris*) were pathogenic on all of 06-10 (*B. napus*).

Brassica oleracea

In contrast to *B. napus* and *B. campestris*, resistance to *P. brassicae* in *B. oleracea* appears mostly to be non-differential. The probable exception is the resistance in cv. Badger Shipper (ECD 11). The other ECD hosts do not appear to exert major differential effects and are therefore inappropriate for a "differential series". Data reported in Clubroot Newsletters support this hypothesis. These data were converted to binomial form by choosing a range of particular 'cut-off' points for

the disease index (25%, 50%, 80%, 90% and 95%). Only tests with an index of $\geq$ 80% on cv. Septa (ECD 14) were considered. Two by two contingency tables were constructed for each pair of genotypes. These recorded the numbers of tests which fell into each of four categories: both genotypes susceptible, both resistant and the two genotypes reacting differently. These tables made it possible to identify rare classifications when one out of the four categories occurred relatively infrequently. From this information it was observed that certain genotypes were rarely recorded as resistant if others were susceptible and a hierarchy of relative resistance could be constructed to account for this. Table 7 shows two hierarchical patterns. More than 95% of the ECD data considered (at a 'cut-off' point of 80%) were consistent with one or other of these patterns. The 'cut-off' point chosen for the classification procedure made little difference to the conclusions. The differences in ranking between Tables 7a and 7b reflect the differential resistance of cv. Badger Shipper (ECD 11) which could either be more or less susceptible than ECD 12 and 15.

Table 7

Hierarchy of susceptibility in B. oleracea genotypes

(a)			(b)		
1 =	(14)	Septa	1 =	(14)	Septa
	(13)	Jersey Queen		(13)	Jersey Queen
3	(12)	Bindsachsener	3	(11)	Badger Shipper
4	(15)	Verheul	4	(12)	Bindsachsener
5	(11)	Badger Shipper	5	(15)	Verheul

Further evidence of this type of relationship came from an experiment in which several lines of B. oleracea, with and without reported resistance to clubroot, were inoculated with four different collections of P. brassicae under glasshouse conditions. The resulting galls were weighed and it was possible to rank genotypes relative to one another on this basis for each collection (Table 8).

Table 8

Host genotypes ranked according to mean gall weight

	Collection				Rank of mean weight
	A	B	C	D	
Jersey Queen	3.5	1	1	1	1
Shetland Cabbage	1	2	4.5	2.5	2
Septa	3.5	3	4.5	2.5	3.5
Oregon CR1	2	4.5	2	4	3.5
Badger Shipper	5.5	4.5	3	5	5
Verheul	5.5	6	6.5	6.5	6
Bindsachsener	8	7.5	6.5	6.5	7
Böhmerwaldkohl	7	7.5	8	8	8
Ranking of collection	1	2	3	4	

(1 = Heaviest; 8 = Lightest)

Table 8 cont.

Correlation matrix of rankings of host genotypes attacked by different P. brassicae collections

	A	B	C	D	Mean
A		0.79*	0.64	0.79*	0.86**
B			0.80*	0.97***	0.98***
C				0.81*	0.83*
D					0.98***
Mean					

*P = 0.05; **P = 0.01; ***P = 0.001. (6 degrees of freedom)

A nearly consistent relationship across collections is apparent. There were also marked quantitative differences between pathogen collections in terms of horizontal pathogenicity as determined by the size of gall produced. This may prove to be an important feature of the Brassica/P. brassicae relationship.

This and other experiments have confirmed the findings of others (Nieuwhof & Wiering, 1962; Weisaeth, 1961; Ashizawa et al., 1978) that Böhmerwaldkohl is probably the best source of resistance available in B. oleracea. However, under optimum conditions, highly pathogenic collections will still cause severe galling. No other purported source of resistance has performed better than Böhmerwaldkohl in our experiments.

Prior to a full commitment to the utilisation of Böhmerwaldkohl in a large scale breeding progamme, further questions need answers. Work is now concentrating upon determining how commonly the level of pathogenicity needed to gall Böhmerwaldkohl severely is encountered in P. brassicae populations; what result selection pressure imposed by this sort of resistance will have on P. brassicae populations; whether there is a good relationship between glasshouse and field responses, and the mode of inheritance of the resistance. In addition, a search for more effective sources of resistance is being continued.

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The Evolution of Chemical Control Methods of Clubroot in Czechoslovakia

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Clubroot is a very destructive disease alsé in Czechoslovakia because every year the losses it causes represent 10 to 15% of the yields of brassica crops. In some years, especially in weather conditions favourable for the development of this disease they are even much higher, and sometimes the infection is so great that all cultures got destructed.

In Czechoslovakia, the scientific research of chemical control method of Plasmodiophora brassicae began 50 years ago when prof. Baudyš /1930/ from the Agricultural University in Brno published the first report on the positive influence of calciumcyanamid on clubroot. Later on, prof. Baudyš again, established that liming of highly acid soils had a good effect on this disease. The development of chemical control methods of Plamodiophora brassicae which substanttially represent soil desinfection, has been very intensive in these last years. At the beginning. and in many cases even at the present time, soil has been desinfected before planting brassica crops as follows : formaldehyd (from 1 to 5 litres of 5% solution . m^2) , methylbromid (200g.m^3) , borax (30 kg. ha^{-1}) , boron acid /Baudyš 1930; Lužný,Polach 1961/. Later on, especially before planting seedlings, prepared pits for

them were desinfected by using 0,25% solution of Heryl (80% thiuram), by dusting them with Hermal (70% thiuram), or Hermal L (35% thiuram and 50% lindan). Relatively successful was also the preventive treatment of pits before planting with Agronal (2,8% fenylmercurychlorid), or with Agrostan N (1,75% methylmercury acetate)-/Peiker 1964/. There was some danger in applying these preparations containing an organic form of mercury and so toxic not only for plants but also for animals. From this point of view these mercury organic praparations must not be used for soil desinfection because hygienic regulations do not permit it.

Very good results in the chemical control of clubroot, as said before, were attaind with calciumcyanamid in doses from 0,6 to 1,2 $t.ha^{-1}$. Calciumcyanamid must be applied two or three weeks before planting seedlings. The good effectiveness of calciumcyanamid was demosnstrated in large number of experiments /Duchoň,Hampl 1959; Zvára, Rod 1967/, and therefore in that time it was applied in cooperative farms specialized in brassica crops. However, changes coming about in the technology of steel production where calciumcyanamid was got as a by-product, caused that it is no longer at disposal.

After the second world war, first in other countries, but later also in Czechoslovakia, fungicides on the basis of chlornitrobenzenes showed to be very useful in the control of clubroot. Very effective were Brassisan (trichlornitrobenzene), Bulbosan(tetrachlornitrobenzene), Brassicol (tetrachlornitrobenzene)-/Našinec, Rokos 1969/. Most of these fungicides have not found their use in farming practice because their effectiveness depends on hight soil humidity, and they are relatively

expensive. Their application as well brings about some hygienic problems in most countries.

According to our experiments /Zvára, Voženílková 1978/, some systemic fingicides containing benomyl (Benlate, Fundazol), thiophanat- methyl(Topsin M) or carbendazim (Bavistin) show very good results in the chemical control of clubroot. These fungicides used in doses 130 to 250 $mg.kg^{-1}$ of soil reduced the infection of brassica crops with Plasmodiophora brassicae down to 60-100%. The best form of applying sastemic fungicides is to prepare a mixture of peat substrate, soil, fungicides, water and dip in it seedlings before palnting them. It is also possible to incorporate these systemic fungicides directly in soil, about 15 cm deep. In this case, however, the quantity of used fungicides is too high and therefore it is too costly.

In other analogically carried out experiments, fungicides usually used against other diseases were used in the chemical control of Plasmodiophora brassicae with very good results. They were, for example, ethylendirhodanid (Agrovit) applied to soil before planting seedlings in the dose of $8g.m^2$ with 100% results. On the other hand dazomet (Basamid granulate) incorporated into soil in doses up to $40g.m^2$ was effective only in 40 - 60%, which depended on host plants, soil types and application methods.

New ways and principles are therefore being sought to extend the assortment of fungicides effectively applicable in the control of clubroot. Some possibilities may be seen in the new systemic fungicides effective against downy mildew. According to a working hypotheses a pot experiment in glasshouse was conducted in order to determine on its basis the effect

of the following preparations on clubroot : Ridomil 25WP (metalaxyl) in 0,05 and 0,1% concentrations; Cursate (DPX 3717) combined with Dithane M-45 (mancozeb) in 0,01% concentration, and 0,15% Cursate + 0,3% Dithane M-45; Previcur S-70 (protiocarb) in 0,2% and 0,4% concentrations ; Fademorf 20EC (trimorfamid) in 0,125% and 0,25% concentrations. These preparations were incorporated into soil by means of watering, or sprayed on leaves. Cauliflower(Brassica oleracea var. botrytis) - cultivar Bravo, planted in uniformly infected soil was used as the experimental crop. The preparations were applied in two terms : the first - one week after planting the test plants, the second - 30 days after the planting. The whole experiment which lasted 82 days showed that the highest effectiveness as compared with untreated control, was that of Ridomil 25WP in 0,1% concentration (90%), and of Cursate 50WP in 0,15% concentration with combination of Dithane M-45 in 0,3% concentration (89,3%). Fademorf 20EC in 0,125% concentration and Previcur S-70 in 0,4% concentration gave satisfactory results. The results got when using the other fungicides were much worse.

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Clubroot and liming

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On many small farms in different area of Norway cole crops are grown on the same soil year after year and limed heavily to reduce the incidence of clubroot.

At the horticultural school Gjennestad, Stokke in Vestfold, a steady liming experiment was started in the spring 1974 for studying the effect of two liming materials and amounts of lime on clubroot. Calcium hydroxide and limestone were miced into the soil before transplanting the late cabbage 'Toten Amager Fodstad' (table 1). The soil is as well drained moraine, sandy loam with about 6% organic matter. The average precipitation in a year is 1000-1100 mm.

Due to a dry season, clubroot was not observed before autumn in 1974. Also in the dry and warm summers 1975-76 the plants did not suffer much of the disease before autumn. In 1977 and later the field was irrigated in dry periods. The irrigation clearly increased the incidence of clubroot early in the season, especially on control plots.

The content of CaO in hydrated lime was somewhat lower than expected (table 1). In 1980 the rate was increased to obtain the same pH on plots calculated to receive the same dose of CaO of limestone and hydrated lime.

The difference in pH clearly resulted in different incidence og clubroot and yield. The two liming materials seems to have the same effect on clubroot. The soil in the experiment can be kept close to pH by adding 100-150 g CaO/m^2 - year. To obtain alkaline soil the amount has to be increased to 150-200 g CaO/m^2 - year. In such a soil, with precipitated calsium carbonate, the pH will be dependent on the CO_2 - concentration and the Ca^{++} -activity according to the equation:

$$pH = 4,93 - \tfrac{1}{2} \log (Ca) - \tfrac{1}{2} \log P_{CO_2}$$

After liming in spring, we therefore in autumn will find pH between 7,0 and 7,5 in heavily limed soil.

Except in 1976-77 the incidence of clubroot was low in treatment 4 and 5 (table 2 and 3). The results in 1980 show that under

good growing condition cabbage can give a high yield also in heavily infected fields. But practical experience indicate that if the soil is kept rather wet during a warm summer, the attack of clubroot can be serious also on heavily limed soil with precipitated calsium carbonate, especially on cauliflower, chinese cabbage and swedes.

Due to the acid-forming complete fertilizer used, and high precipitation, agricultural soil in southern part of Norway in average has to be added about 40 g CaO/m^2 - year (in Rogaland more than 50 g CaO/m^2 - year) to keep the pH around 6,0 - 6,5. Accordingly, the clubroot liming increases the cost tremendously. In addition the heavy liming often result in serious attack of Rhizoctonia (wire-stem) in the field, in manganese deficiency and may be zinc deficiency. In 1979 and 1980 half of the plants in each plot was added 100 g ZnO per m^2 peat block surface before transplanting. In early August 1979 we observed higher plants and larger leaves in the rows of plant added zinc-oxide in all plots. Also at harvesting the difference in hight could be observed, but the yield was equal. In 1980 the addition of zinc-oxide redused yield (1421 g compared to 1583 g).

Table 1. Liming rate and pH in water suspencioun (Autumn)

Treatment	g CaO/m^2 - year			pH				
	1974	1975-76	1977-80	1974	1975	1977	1978	1980
1. Control	0	0	0	5,2	6,3	6,0	5,8	5,7
2. Limestone	500	100	100	6,4	6,7	7,1	6,9	6,6
3. Hydrated lime	500	100	100	6,1	6,6	6,8	6,3	6,6
4. Limestone	1000	200	250	6,7	7,2	7,4	7,2	7,1
5. Hydrated lime	1000	200	250	6,5	7,2	7,4	7,3	7,5

Table 2. Average head weight in grams

Treatment	1974	1975	1976	1977	1978	1979	1980
1. Control	1830	1260	455	500	837	777	1344
2. Limestone, low	1810	1260	726	1093	1155	1222	1220
3. Hydrated lime, low	1850	1450	798	1080	1124	1131	1457
4. Limestone, high	1950	1370	717	1542	1364	1323	1737
5. Hydrated lime, high	1770	1430	648	1502	1264	1240	1653

Table 3. Grading of clubroot at harvesting in percent of plants

Treatment	1976		1979		1980		
	Moderate	Low	Heavy	Low	Heavy	Moderate	Low
1. Control	96	0	83	17	100	0	0
2. Limestone, low	17	25	3	37	73	10	7
3. Hydrated lime, low	58	25	27	50	53	3	27
4. Limestone, high	21	17	3	7	10	0	33
5. Hydrated lime, high	17	8	0	10	0	3	3

BRASSICA CROPS IN NORWAY

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Vegetables within the genus Brassica

In Norway Brassica is the most important genus of the vegetable crops judged from the area of production and the quantity of products produced. The reason for this prominence is that the brassicas are for the most cool season crops fitting the Norwegian growing season. But also the versatility of the genus as far as cultivated types are concerned and the great variation within the cultivated types explain its popularity. There are Brassica cultivars to be planted whereever there are potentials of growing vegetables in Norway, even high in the mountains and in the outmost north, far beyond the artic circle. Furthermore, the variability of the products coming from the brassicas matches the variability of consumers' taste. Roughly estimated, about 50% of the area cultivated with vegetables in Norway is occupied with brassicas, and this has been the situation for several decades.

Looking back at old times, crops like turnip and cabbage were some of the cultivated crops first mentioned in our literature. How they entered this country are somewhat obscure. We know that foreign munks bringing Christianity to Norway (from around year 1000) introduced many foodplants and herbs, but even before Christianity Norwegians were sailing to coasts and countries far off, and probably picked up whatever happened to be in their way, even seed and plants and brought their home.

Especially growing of turnips became so important that it was used as one of the chosen basic items for taxation.

First in the end of the 16. century we find a broader interest for vegetable crops and different brassicas are mentioned like red cabbage, savoy and cauliflower.

Before entering into a description and discussion of the different Brassica crops, I may mention that a considerable part of our vegetable research work has been dealing with brassicas, especially with reference to their climatic reactions and the selection of varieties for the different areas.

If we look at the diseases attacking Brassica, the clubroot is the most important one. The following crops experience the most severe attacks: Rutabaga, turnip, cauliflower and Chinese cabbage. As for pests in Brassica, there are great many, as the cabbage root fly (Hylemyia brassica and Hylemyia floralis) Diamond-back moth (Plutella maculipennis) and types of White Butterflies (Pieris) are among the most frequent ones.

In table 1 some statistical figures on Brassica production in Norway are presented.

The turnip (Brassica campestris L. var. rapifera Sinsk.) is probably the oldest cultivated Brassica in Norway and it seems to have dual role as a crop for

human consumption and feed for domestic animals. Before the Irish potatoes was introduced, turnip was in many families more a basic food source, represented for centuries and important food segment for poorer classes on the country side. The growing method was partly the same as we find still remains of in Scandinavia to-day, on land cleared by burning. Now a days the turnip plays a rather insignificant role as a source for food. Although in Northern Norway, the turnips is still popular and can easily be grown and fine quality obtained. For the rest there is a good demand for early turnip, which is partly from production in plastic tunnels. There are quite a few cultivars of turnips of Norwegian origin, and one of the most popular ones has been the clubroot tolerant 'Sola' which is a rather flat red-violet-topped early one. Lately the Japanese hybrid cultivars have attracted considerable attention as they are extremely early and well suited for forcing. Rutabaga (Brassica napus L. var. rapifera Metzg) appeared much later on our vegetable scene, probably introduced to us from Germany since parts of Norway maintined for a long period a considerable trade with the Hanseatic cities of Germany. It is also an interesting observation that later it was a certain export of rutabaga seed from Norway to Germany. Rutabaga has been gaining ground as vegetable. A doubling of comsumption has taken place in the last 10 years, and the area occupied by this crop is now about the same as for white cabbage. Rutabaga can be grown with a good result in most parts of the country, but in order to obtain a satisfactory yield in places with adverse climate, it is necessary to use transplants. Even in the southern Norway many growers use transplants (often based on soilblocks and peatpots) with the purpose of serving the early profitable market, and for this reason even grow the plants under plastic tunnels. As for selection of varieties, cultivars within the Bangholm group with red-violet tops are the most popular. The cultivars 'Gry' and 'Seefelder' have some resistance to clubroot, but since both have green tops they are not well accepted on the market. A new early North-Norwegian cultivar resistant to bolting is 'Vige'. It has a good shape and a nice violet skin colour. 'Vige' is also useful as an early cropper in the best climatic parts of the country. Apart from the general cabbage disorders mentioned before, boron defiency occurs in various degrees and cracking is a quality disorder which seems be difficult to solve.

Cabbage (Brassica oleracea L. var. capitata L.). We donnot know how the first cabbage grown in this country looked like. It is really through the first written trade transactions as for instance on custom duty levies and seed facturas we get more presice information. When importing cabbage heads in the year 1611 the duty was 6 shillings for 60, the same duty was levied on a barrel of "sauerkraut". On a factura for seed purchases to the garden of Akershus Castle (in Oslo) in 1667 white and red cabbage were itemnized as well as savoy cabbage, cauliflower, rutabaga and possibly turnip (Weisse Räber). The cabbage got general acceptance in the previous century, and varieties of different types and growing periods were introduced. Farmers were stimulated to grow their own seed, and with local seedproduction selection for the localities became an intrinsic part. Soon there were many Norwegian varieties and strains at hand in various groups, from summer cabbage to the late storing type. There were special types selected for southern, middle and northern Norway. Apart from cultivars in the very early type (Pointed cabbage and Ditmarsker) Norway was for several decades nearly self-supported with own seeds of cabbage. The seeds were produced by farmers by the mass selection methods. Recently F_1-hybrids mainly from the Netherlands seem to outyield and replace many of the local cultivars.

On the other hand, more recently Norwegian breeding programme on the governmental level has resulted in some very promising introductions of early cabbage.

Our university has also undertaken a long term work on the nature of resistance to the clubroot disease and in incorporating this resistance into some of the cultivated groups of cabbage.

Parts of these works will be reported at this conference.

As for the consumption of white cabbage there is a good market the year around. Since the early sixties there has been an increasing demand for the processing industry which may take around 15% of the crop for making the Norwegian type of "sauerkraut", a rather sweet and spiced product not fermented. The production of red cabbage and savoy is rather insignificant in this country.

Brussels sprouts (Brassica oleracea L. gemmifera CD.) is a crop gaining in popularity for two reasons. The new hybrid cultivars are clearly better producers than the old true varieties, and for this crop also the processing industry has shown an increasing interest. In addition the private comsumers have taken advantages of their deepfreezers for crops like brussels sprouts and sprouting broccoli.

Cauliflower (Brassica oleracea L. var. botrytis L.) has traditionally had a favoured place among our Brassicas. The popularity of the crop is increasing.

Cauliflower of the early production appears on the market in the latter half of June, although there may be productions before from plastic tunnels. The cropping lasts to the month of October when the frost puts an and to the production. Usually it is a peak on the market in July and another in September. The processing industry absorbs about 20% of the production for freezing and acts in this way also as a market regulator. As for the varieties the medium late Dutch varieties have gained the greatest share of the market.

Green Sprouting Broccoli (Brassica oleracea L. var. italica Plenck.). In spite of a campaign for green broccoli on account of taste and great nutritional values, the production has never got off the ground. One reason is quality problem when marketing and also the rather high cost of production.

Curled kitchen kale (Brassica oleracea L. var acephala DC.) has a rather moderate position in Norway with some production with market gardeners and in the home gardens.

Kohlrabi (Brassica oleracea L. var. gongylodes L.) has been an anonymous crop in Norway so far. But due to new and improved cultivars from the continent kohlrabi is deserving a second look especially in relation to the processing industry.

Chinese cabbage (Brassica pekinensis Rupr.) is an example of a vegetable making a remarkable quick career as a commercial crop. For years Chinese cabbage was known as an odd exotic vegetable with a typical bolting problem at our long summer days. With new cultivars and a by acquiring an understanding of the physiological mechanism behind induction of the reproductive cycle, the commercialization of the crop was stimulated. In addition the consumers appetite on the product has grown. It is fancied both for fresh salads and in cooking. To day, Chinese cabbage enjoy a long production season with us, starting in the spring from greenhouses and ending with late fall field

production for storage up to January-February. Varieties: 'Tip Top' and 'Nagaoka 50 days'.

The Fodder and Industrial Brassicas

Table 1 reveals considerable ups and downs in the production of Brassica for fodder. This is the case for turnip and rutabaga, marrow stem kale and oil crops for mature seed, whereas rapes for none-seed have remained rather high since 1969. The figures show a total increase in Brassica production which stems from a campaign for a better rotation while maintaining a relatively large grain production.

Rather as an spectator I have observed the oil crop Brassicas entering the Norwegian agricultural scenery, enjoying the beautiful yellow carpets spread out in the early summer.

The data I can present on these crops are in the first place from Lars Sogn at Statens kornforretning (Norwegian Grain Corporation).

During the second world war growing of oil crops was tried in a small scale with the hope of establishing a new source of fat and protein supply (Feste, 1944) but the crop did not get a foothold. The first real trial of these crops in practical scale started in 1955. There are many reasons for the slow Norwegian motion with respect to oil crops. One is the rather abundant supply of marine fatty oils, and furthermore the plant husbandry did not call for any new crops. But with the increase of cropped area of small grain the crop rotation became important for solving weedproblems and in order to avoid foot diseases. From 1975 to 1977 a practical trials covering 1000-1500 daa each year were conducted in the 7 South-East-Norwegian counties around the Oslofjord. These trials were organized and conducted by the Norwegian Grain Corporation. The following crops were included in the trials: Rapes of the campestris and napus types and White mustard (Sinapis alba L.). The performance of the latter did not merit practical application. To day, 95% of the area of the oilseedcrop is of the campestris-type since cultivars in this group are earlier and safer than the varieties of the napus type (100-110 days versus 120-130 days under good climatic conditions). Concerning the seed quality of the campestris-type the data indicate that the fat content is of the order of 42-44% and the free fatty acids usually far less than 1%. The protein content is of the 20-22% level. As for the napus type, the chlorophyll content tended to be to high. The basic price for 1980/81 was kr 345 pr. 100 kg with water content of 10%. The yield has been of order 1800 to 2000 kg pr. hectare. The seed is so far solely used in feed mixture for fat enrichment. So far we donnot have great pestproblems in the oil crops in Norway, but we have to control Phyllotreta spp and Melighetes aeneus. Rather narrow row distance, 13 and 26,cm has given the highest yield, best quality and most uniform ripening of the seed. Proper irrigation of the crop has resulted in an yield increase of something above 10%, but high amount of fertilizers has not paid off (no yield increase beyond 500 kg/hectare of a complete fertilizer D, 20 N, 5 P, 9 K).

There is no breeding of oil crops in Norway, and the cultivars used are mostly Swedish. 'Bele' has been the main turnip rape variety for many years, and also 'Torpe' has gained some merits and furthermore the new 'Torkel' which is low in erucic acid. These three are from Sweden, but also the Canadian 'Span' is met with some interest.

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TAB. 1. STATISTICAL FIGURES ON BRASSICA CROPS IN NORWAY, TOTAL AREA AND TOTAL YIELD. AREA BASED ON DECARES (daa) = 1000 m^2.

	1929 Production		1939 Production		1949 Production		1959 Production		1969 Production		1974 Production		1979 Production	
	daa	tonn	daa	tonn	daa	tonn	daa	tonn	daa	tonn	daa	tonn	daa	tonn
White cabbage	–	–	–	–	10049	–	14242	–	12750	33492	11593	47368	11993	36170
Cauliflower	–	–	–	–	4362	–	5430	–	4926	4974	5149	6979	6050	8624
Brussels sprouts	–	–	–	–	} 910		} 822		747	} 633	593	} 1071	1039	} 1322
Other	–	–	–	–					246		474		613	
Total	12414	–	14122	38184	15321	40508	20494	–	18669	–	17809	–	19695	–
Turnip and Rutabaga as vegetables and feed	170761	713458	181739	623447	119255	476441	116603	–	67895	342571	46760	298958	38748	–
Oilcrops for fodder	–	–	–	–	–	–	–	–	48314	–	60499	294482	63192	209704
Oilcrops for mature seed	–	–	–	–	–	–	–	–	77645	9400	36362	–	53313	9153
Marrow stem kale	253	–	12912	67863	11263	56496	21095	103000	20543	110000	18533	115612	13809	58754
Sum Brassica	183428	–	208773	–	145839	–	158192	–	233066	–	179963	–	188757	–
Area of tilled agric.land and hort.c. in Norway	2726760	–	2945668	–	2701013	–	3266671	–	3383931	–	–	–	4107433	–

(From the Agricult. Cencus of Norway)

AN OVERVIEW OF CALIFORNIA CRUCIFER PRODUCTION PRESENT AND FUTURE CONCERNS

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In California, the cole crops, Brassica oleracea, in particular broccoli and cauliflower, whether measured by volume or value, are the most important crucifers produced. Cabbage and Brussels sprouts, although significant, are of lesser importance; kale, collards and kohlrabi are relatively insignificant. Other crucifers, such as summer and winter-type radishes, rutabagas, Chinese cabbage, turnips, mustard greens, rapini and various oriental crucifers are also of relatively minor significance. Production of crucifers for oil seed or for animal forage and feeding is essentially nil. Although the potential for such production occupies considerable discussion, very little as yet has occurred.

Much of the growing climate and area of California is beneficial for crucifer production. Coastal valley climates that provide a cool, moist environment with relatively good sunlight are available almost year around and thereby permit almost continuous production throughout the year. Interior valley areas have favorable growing conditions from the autumn through the spring, with mild winter temperatures. These areas generally do not produce crucifer crops during the summer.

Rainfall is usually inadequate for production in nearly all of these areas, but irrigation is available and extensively used. This capability gives the advantage of controlling crop moisture needs while considerably reducing the incidence of foliage disease problems and other problems of excessive or untimely moisture.

Fertile, well drained soils, both coarse and fine textured, are a contributing advantage. The pH level of many soils used for crucifers is higher than ideal. This has not been a production disadvantage and in some locations is helpful in limiting the incidence of clubroot.

The above characteristics, along with good cultural practices and management combine to make California the major United States crucifer production area.

Production Statistics (1979)

Broccoli (Green Sprouting)

		Area (ha)	Yield (T/ha)	Production (Tons)	Value ($U.S.) (millions)	Value/Ton ($U.S.)
California	(total)	27,500	9.27	255,000	106	416
	fresh			131,000		
	processed			124,000		
U.S.	(total)	28,800	9.17	264,000	111	420
	fresh			136,000		
	processed			128,000		

California produced 96% of the U.S. total, and slightly more than half was used as a fresh product.

Cauliflower

		Area (ha)	Yield (T/ha)	Production (Tons)	Value ($U.S.) (millions)	Value/Ton ($U.S.)
California	(total)	13,400	10.97	147,000	71	483
	fresh			83,000		
	processed			64,000		
U.S.	(total)	17,200	10.99	189,000	89	471
	fresh			112,000		
	processed			77,000		

California produced about 78% of the U.S. total, and about 56% was used as a fresh vegetable. The U.S. production was about 4% of the world's supply, using about 5% of the surface area.

Cabbage

		Area (ha)	Yield (T/ha)	Production (Tons)	Value ($U.S.) (millions)	Value/Ton ($U.S.)
California	(total)	3,400	26.18	89,000	16	180
U.S.	(total)	37,300	29.44	1,098,000	172	157
	fresh	33,400	26.41	882,000	165	187
	processed	3,900	55.38	216,000	7	32

California produced 8% of the U.S. total, nearly all of which was for fresh market use. About 80% of the U.S. production is consumed as a fresh vegetable. On a world-wide basis, U.S. production was only 3%, utilizing 2% of the surface area.

Brussels Sprouts

	Area (ha)	Yield (T/ha)	Production (Tons)	Value ($U.S.) (millions)	Value/Ton ($U.S.)
California (total)	2,225	15.8	35,250	16.5	468

California produced nearly 100% of the U.S. Brussels Sprouts crop, with more than 80-85% of the crop processed by freezing.

Complete production statistics are not available from USDA sources for many other crucifer crops which, because of their limited volume, are considered as minor vegetables. Some parts of the U.S., particularly the southeast, does grow substantial quantities of kale, collards, turnips, mustard greens, and radishes. A significant amount of Chinese cabbage, other brassicas collectively known as oriental vegetables, and radishes are grown in California. Except for small regional areas, these crucifers--even if their total is combined--are still considered minor compared to many other vegetables.

However, the home garden production of many of these minor crucifers readily exceeds the total of the commercial scale production. These quantities are not included in the computation for USDA reports of production statistics. The American Frozen Food Institute reports on the quantities of frozen processed minor crucifers; and for reference purposes, in 1979, these were: collards (7,600 tons), kale (1,700 tons), mustard greens (7,300 tons), and turnips and turnip greens (17,900 tons). This does not include the quantities (probably close to these volumes) that were processed by canning. It would be relatively accurate to consider that two-to-three times this tonnage would not overestimate the tonnage of these minor vegetables that were used in the fresh form.

During the past ten years, a slight but perceptible decline in the per capita use of cabbage and Brussels sprouts has occurred, in contrast to a marked increase in both cauliflower and broccoli. Slight increases have been noted with the oriental type crucifers; and slight decreases with kale, collards, mustard greens, and turnips.

BROCCOLI

About 50 years ago, broccoli was essentially unknown in California; and in the last 10-15 years, this crop has rapidly increased in popularity and is now a vegetable of considerable importance. California dominates U.S. production and provides year-round availability. Broccoli's excellent processing characteristics is very contributory to its wide utilization.

Major California production areas are the coastal valleys of Salinas and Santa Maria. Considerable volume is also produced in some of the interior valleys. Planting and harvest periods in the coastal valley is continuous throughout the year. Production in the interior valley is limited during the hot summer period. Planting in these areas generally occurs during July-September, with harvest from October through June.

Nearly all plantings are direct field seeding because this procedure is less costly than the use of transplants, and accurate thinning of broccoli stands is not so critical as with cauliflower or cabbage. Seed is sown in two rows (30 cm. apart) near the edges of the flat surface (45-50 cm. width) of raised beds. The distance between beds is one meter, and the in-row plant spacing is about 20 cm. Plant population is 10 plants per square meter.

The use of size-graded seed with a high germination percentage, precision placement seed drills, and good bed preparation can allow for seeding to final stand. However, the majority of growers plant seed at 5 cm. distances, and excess plants are thinned.

This type of seed bed and planting procedure is widely used in California for the majority of crucifers grown. At times, convenience and compatibility with other crops and equipment favors these practices, even when unjustified as far as efficient land utilization is concerned. It is efficient for broccoli; it is not for cauliflower. In some areas, narrow beds (75-80 cm.) and single-row plantings are used for broccoli.

When necessary, conventional mechanical cultivation, including hand-hoeing, is used, although very good weed control is usually provided from several selective herbicides such as Treflan (trifluralin), Prefar (bensulide), Dacthal (DCPA), and Vegadex (CDEC). Tok (nitrofen) is no longer registered for use.

Generally practiced fertilizer usage provides about 200 Kg of N, 50 Kg of P, and 50 Kg of K. Most California vegetable soils usually have high levels of available K and often good P availability. Where this is not the situation, applications of both P and K should be raised to 100 Kg/ha.

Irrigation applied by furrow or with overhead sprinkler systems is provided as dictated by crop need. Usually a total of 50-70 cm. applied at 2-3 week intervals meets most requirements.

Rotations practiced are less than ideal. Because of economic pressure, a lower-value crop such as grain is not used; but broccoli is most often rotated with lettuce, celery, and other non-crucifer vegetables with a 3- or 4-crop period.

Varieties presently in relatively wide use are hybrids such as Green Duke, Premium Crop, Emperor, Corvette, Gem,Futura, Green Comet, and several others. Topper 430 and Packer are the more popular open-pollinated varieties used. Additionally, varieties such as Medium Late 423 and Medium Late 145 are used as overwintering types. These require about 120-150 days or more to mature, whereas most other varieties mature in 65-100 days from seeding.

Crop characteristics, whether for fresh or processed purposes, are nearly similar. Uniform, long-standing, large, compact, dome-shaped, shallow, well-branched heads free of defects with small dark green tightly-closed beads (flower buds) without protruding leaf bracts are preferred. Stems should be smooth with relatively few attached leaves, and solid. Stem thickness and head size is not as important for fresh market usage. Processors prefer thick heavy stems obtained from the larger, slower-growing cultivars such as Medium Late 145, but this cultivar has shorter stem internodes and therefore many more leaves attached to the main stem; accordingly, the stem is not smooth.

There is little interest in varieties that readily produce suckers (axillary floral stems) once the terminal stem is harvested, since the value of the additional product often is less than its harvesting costs. Thus the harvest of the terminal stems is the principle objective. Seldom are fields left long enough to capture the potential axillary growth production. The wide use of hybrids and improved cultural practices has reduced the number of harvests needed to clear a field. Fields are harvested three to four times, occasionally less; and sometimes in winter growing periods, five or more times. Previously, harvest frequency was greater.

Harvesting in most production districts is done by workers cutting the stems by hand, followed by tossing the product into bulk trailers or containers pulled through the field. In the Salinas area, self-propelled large conveyors (13-20 m. in length) are used as a labor aid to reduce the effort of transferring the product to the bulk containers. Experimental mechanical harvesters have been tested, but no mechanical harvesting is currently done.

Only a limited amount of broccoli is packed in the field. The majority is taken to packing sheds, where the broccoli (2-4 stems) is tied into bunches (700 or 800 gm.) and placed into wet-proof paper containers (14 or 18 bunches) weighing about 10-12 Kg. The product's field heat is quickly removed by hydro-cooling or iceing and refrigeration at 0-1°C. Kept at this temperature, a 10-14 day retention of quality is expected. Higher temperatures result in weight loss due to moisture loss and yellowing because of the high respiration rate. Product for processing is delivered to the processing facility, graded, washed, and prepared for freezing usually within hours of harvest.

The most troublesome field disease is downy mildew, Peronospora parasitica. Occasionally ring spot, Mycosphaerella brassicicola, black spot, Alternaria spp., and Rhizoctonia solani are problems. Seldom is yellows, Fusarium oxysporum, black leg, Phoma lingam, or black rot, Xanthomonas campestris, a problem. Club root, Phasmodiophora brassicae, has recently become a localized concern.

Viruses are generally not of serious economic significance. Post-harvest

diseases are Botrytis cinera, Erwinia carotovora, Pseudomonas spp., Sclerotinia sclerotiorum and Rhizopus nigricans. These are avoidable or of little significance if careful handling and cooling of the product is practiced.

The use of nematicides for the control of sugar beet/cabbage root nematode, Heterodera schachtii and root knot, Meloidogyne spp. is widely practiced.

The most serious insect pests are aphids, cabbage looper, and imported cabbage worm. Cabbage fly root maggot and cutworms are generally well-controlled.

Considerations for improved broccoli production might include: varietal improvement for greater yield and improved product characteristics. Varieties that provide a better concentration of harvest maturity along with the ability to retain market quality until harvested would--in addition to improving yield--reduce the number and frequency of harvest operations. Varieties that will perform better under cold temperature conditions and with better predictability of performance are needed. The identification and management of factors responsible for some physiological disorders, e.g., premature flower bud desication and abscission, needs attention.

It would also be beneficial to have terminal heads develop uniformly and at equal height on extruded stems well above the stem foliage, to facilitate mechanical harvesting and stem foliage trimming. Of possible merit would be an investigation of how to develop the growth of several uniformly-sized stems simultaneously on the same plant. Plant growth regulating materials might be involved in this effort. Similarly, it would be useful to determine how to utilize the plant more fully, such as hastening the development of many larger and uniform axillary stems. When mechanical harvesting becomes a reality, it may be economically justified to harvest this source of product. The development and adoption of mechanical harvesters and trimmers is a certainty; therefore, the adaption of plant characteristics to increase equipment efficiency is important.

Improvement in the methods and mechanics of hybrid seed production should facilitate varietal developments. Additionally, it is important to continue to improve upon the arsenal of effective and permissible herbicides and pesticides and integrated pest management practices.

CAULIFLOWER

Like broccoli, cauliflower also is very important to California's vegetable economy. Excellent climatic conditions exist for this commodity, for which more exacting growth requirements are needed. This is one advantage that makes California the major production area.

The major production areas are similar to those for broccoli, although within these areas the crop is usually placed on the better soils and where temperature variability is least. Planting and harvest periods vary with location and season. In the interior valleys, direct seeding will begin in July and continue through October; transplants are field-planted during August through October. Harvesting in these areas begins in October and continues through December. Infrequently are over-wintering crops produced in the interior valleys. In the south coastal areas of Orange and Ventura counties, transplants are commonly used; and field planting begins in December and continues through March. Harvesting begins in March and continues into June. The Santa Maria and Salinas Valley areas

generally seed directly into the field, and planting and harvesting is continuous throughout the year. This situation, and the overlapping with interior valley production results in a fairly uniform supply. However, the largest portion of the total production is obtained during the autumn. The mid-winter period is when supplies are lowest.

In contrast to broccoli, a sizeable volume of cauliflower is produced using transplants. Transplants are both grower-produced or purchased from transplant raisers. Transplants are used principally to shorten the time period the crop occupies the land and to permit a better adaption to existing climatic limitations to growth.

Direct seeding is performed as discussed for broccoli, except that more space is allotted per plant. Final plant populations vary from 13,000 to 30,000 per hectare. Many vegetable growers have adapted a uniform row width to standardize their equipment needs for the wide range of different vegetables grown. Thus, while double row beds, one meter apart are efficient for lettuce, celery or broccoli, they are not for cauliflower. Only one not two rows per bed can be grown. Two rows results in crowding and one is wasteful of space. Nevertheless, in the major coastal production areas growers use the one meter wide bed distance for cauliflower. In other areas, more appropriate bed distances of 75-85 cm are used. Within rows, spacing tends to be more uniform, generally 45-50 cm between plants, except for winter types which because of their size require 60-75 cm distances. Wide beds of two meters width with multiple row plantings are used by a few growers. Transplants are placed at these distances with multiple row transplanting equipment. Directly drilled plants are thinned to the desired spacings.

Most of the other cultural operations, such as cultivation, irrigation, weed and pest control, and rotation are similar to those mentioned for broccoli.

Cauliflower requires and utilizes greater quantities of fertilizers. Commonly, 200 Kg N, 50 Kg P and 50 Kg K is provided. This compliments the generally good availability of soil supplied P and K.

The predominant varieties used are improved selections of the Snowball Y type. These open-pollinated varieties are increasingly being supplemented by several hybrid varieties such as Snowflower, Snowpeak, Olympus and several others. Varieties of the St. Valentine type, e.g., February, Early March, etc., are used for the winter period when the Snowball types generally do not grow well. The winter types require exposure to cold temperatures in order to initiate curding, whereas the Snowball types do not. The winter types are a small proportion of the California crop. The winter types require 120-150 days or more from seeding to achieve maturity, whereas Snowball types mature within a 80-100 day period; and some early hybrid varieties will mature in 60-70 days. There is an overall market resistance to the winter type varieties because the curd surfaces are more coarse. Over-wintering varieties are much more variable as to uniformity of maturity than the Snowball types.

Crop characteristics wanted for fresh market purposes are large (18-20 cm diameter) white compact spherically rounded heads free of defects that are tightly branched with a smooth textured surface free of riciness or leaf bracts. The stems should be solid. For processing, larger head sizes (25 cm plus) are preferred and heads must be free of any discoloration. Discoloration is avoided by tieing outer foliage to cover the head and to exclude light.

It is important that plant growth provide good inner foliage cover as the curd enlarges and that the outer foliage be large enough to facilitate tieing together to exclude light from the curd. Preceeding harvest, field workers tie the foliage of plants approaching maturity. This is most often done with rubber bands. Due to variable maturities, the process may be done two, three, or more times. By using different colored bands, harvest workers can selectively harvest plants of the same relative maturity. The procedure is an expensive operation. Machinery that can selectively determine maturity and automatically tie the leaves of selected plants is in the advanced developmental stages.

Self-blanching varieties such as, Self Blanche produce large upright leaf growth intended to intercept light that would otherwise reach the curd, and therefore need not to be tied. These varietal types as yet have not performed well enough for acceptance in California conditions. In other US production areas, these varieties have found some acceptance.

Summer and autumn grown cauliflower attains relatively good uniformity of harvestable maturity and 2-4 harvests usually clear a field. With winter and spring harvests, five, six, or more harvests are often necessary to finish a crop.

Field workers selectively harvest by hand cutting heads that have attained sufficient size and/or maturity. The usual practice is to do the minimum amount of trimming. This is to protect the crud when it is transferred through the subsequent handling practices. The cut heads are tossed into bulk containers or transferred via conveyor belt equipment. An experimental selective mechanical harvester has been developed but has not proceeded beyond limited testing.

The harvested cauliflower is taken to packing sheds where it is closely timmed (nearly all leaves removed), washed, graded for size and quality, and individually overwrapped with plastic film. Very little is packed without overwrapping. Most commonly, the heads are placed (single layer) into fiber board containers and the product temperature is reduced by vacuum cooling or forced air refrigeration to 0-2°C. The packed container has about 10 Kg of product, which may include 9, 12, 16, or 20 heads. The 12 count is the preferred market size.

Recently several producers are completing the entire packing operation directly in the field. Others are performing closer field trimming to eliminate the transport of product waste to packing sheds and to reduce the amount of the more costly shed labor. The closely trimmed curds must receive careful handling to avoid damage and therefore are not as readily handled in bulk.

Cauliflower for processing is delivered to processing facilities where much of the trimming and coreing (stem removal) is performed with machinery. Physical damage usually does not become evident because the product is processed within a very short time.

Cauliflower unfortunately shares the same disease and pest problems that affect broccoli. Occasionally, marketability is harmed by the post-harvest occurrence of curd surface infection by Pseudomonas spp., Erwinia, Botrytis, and Alternaria. The incidence of these problems is more frequently observed during warmer temperature shipping periods.

Production improvements would be obtained through greater yield, uniformity of maturity and product quality features by the improvement of either open-pollinated or hybrid varieties. Especially important is the development of varieties with better and more reliable winter performance characteristics. Other plant characteristics that might provide for better foliage cover of the curd and strong (non-lodging) stems would assist in reducing or eliminating the need for tieing and facilitate harvest, whether manually or with machinery. A noticeable marketing development is the interest in smaller curd sizes. Should this continue, field spacings will be reduced and plant growth would be more upright and thereby may not require tieing. Another on-going area of investigation is to improve the effectiveness of pest control with an intergration of pesticides and biological controls.

BRUSSELS SPROUTS

Within a fairly restricted coastal area of central California essentially 100% of the U.S. Brussels sprouts production occurs. A long seasonal period of sunny mild days and cool humid foggy nights provides an ideal habitat for Brussels sprouts growth. Approximately 85% of the crop is processed by freezing, the remainder is for fresh market. Per capita consumption is stable at about 50 gm.

Bare-rooted field grown transplants exclusively are used in growing the crop. Seed, at a high seedage rate are sown during March through May into beds fumigated for disease prevention. These plants are usually 45-60 days old when pulled from seedbeds and mechanically transplanted. In areas where clubroot is a problem, the fungicide Terriclor (PCNB) is incorporated into the planted area prior to or as part of the transplanting procedure. Plantings are not made in raised beds, row widths are 80-90 cm apart, and plants are 40-50 cm apart in the row. Plant populations range from 22,000-31,000 per hectare. The higher plant densities used in northwestern Europe have not been adopted by California growers.

Transplanting begins in April and continues until late June. Harvest of early varieties starts in mid-August and the harvest of later varieties continues into March. The peak harvest activity occurs in October-November.

Mechanical cultivation is commonplace for weed control; sprout growers generally do not use herbicides. Since monoculture with Brussels sprouts is commonly practiced, weed populations through continued cultivations are sufficiently reduced so that herbicide usage is not significantly beneficial. Rotations with other crops is infrequent because in the sprout production area no other vegetable crops are as remunerative. Many farms have grown sprouts year after year for many years without interruption.

Fertilizer usage for Brussels sprouts is relatively high, particularly since soils in much of the production areas are not fertile. Commonly, 225 Kg N,60-75 Kg P and 75 Kg K are supplied. Liming for pH adjustment and clubroot suppression is done when appropriate.

Irrigations of 5-8 cm at 2-week intervals by overhead sprinkler irrigation provide the 40-50 cm of water needed to produce the crop. Irrigation is especially important during the crop's early development, when rainfall does not occur.

Later in the season rainfall usually relieves the need for further irrigation. In some years, rain interfers with harvesting operations. This is one of the reasons for initiating early harvesting.

About 15 years ago, the introduction of hybrid varieties very rapidly almost totally displaced the open-pollinated varieties then used. The open-pollinated varieties were very adapted to the area and existing circumstances of production. These varieties were selected by growers who produced their own seed supplies. The hybrid Jade Cross met rapid acceptance because it coincided with the significant loss of labor availability for hand harvesting of the open-pollinated varieties. The strongly determinate-like maturity characteristics provided by Jade Cross permitted mechanically aided single harvest of plants, in contrast to the frequent serial (8-10) hand harvest of the variable and indeterminate maturity of the open-pollinated varieties.

Jade Cross E, an improved cultivar similar to Jade Cross, is now the predominant variety. Several other hybrids are used, among which Craton, Valient, Lunet and Citadel are the more popular. Jade Cross E is harvested about 90-100 days after transplanting and is about 7-10 days later than Jade Cross. Craton and Valient require about 120-125 days, Lunet, 140-160, and Citadel, 150 days or more. The variety choices available permits the scheduling of a continuing harvest period. Harvesting of the processing crop is usually completed by mid-December.

Jade Cross E is difficult to hand harvest, the other hybrids if necessary can readily be hand harvested. Although greater emphasis is given to the processed crop, fresh market supplies are available throughout the season. Until recently much of the fresh market supply was from that portion of the crop which was oversized or otherwise unsuited for processing. Fresh market production has been given greater attention, and product quality has been improved through production tailored specifically for fresh market use. It remains a common practice during the winter period, after processing quotes have been met, to direct production to fresh market purposes. Much of the fresh market production is still hand harvested and varieties allowing for easy hand harvest are used.

The usual harvesting operation first involves foliage removal. Laborers using large knives cut off the leaves as close to the plant stem as possible, the stem remains intact. Mechanical leaf cutters are available, but their use is limited to short upright varieties. Following leaf removal, the plant stems are either cut and windrowed by hand, or a tractor-mounted cutting blade is used. Mechanical strippers mounted on towable trailers are pulled to windrowed piles of stems, and the devices shear off the sprouts from the plant stems. Several variations of mechanical strippers are in use. The detached sprouts are then conveyed into bulk trailers. Some preliminary grading and removal of leaves and leaf petioles occurs on the stripper unit but additional grading is done in the farm grading sheds. The sprouts are passed over spaced roller conveyors to release trash and damaged or diseased sprouts are removed. The product is delivered to the processor(in one ton bulk containers)where size grading and mechanical trimming is performed. The product is frozen, usually in less than 24 hours from harvest.

The fresh market product is handled about the same, except that precise trimming of the sprout stem base is not usual. The product after size grading is hydrocooled and packaged in 10 Kg wetproof fiberboard containers. The product may be iced and will be maintained at low temperatures, 0-1°C. Higher temp-

eratures rapidly increase respiration and yellowing and the development of objectionable odors. Some product is place packed into small waxed paper cups containing about 350 or 450 gm. These packages are overwrapped with plastic film and placed in a larger master container for market handling.

Crop characteristics are similar for the fresh or processed product. One noticeable exception is that of sprout size. Processors exercise a size preference for relatively round individual sprouts ranging in diameter from 19-30 mm. For fresh market, sprouts are usually larger and range from 25-40 mm. diameter, and shape is less restrictive. To accommodate automatic trimmers, processors prefer round-shaped sprouts, as these are easier to accurately size grade and thereby reduce trimming losses. For either purpose, the sprouts should be clean, free of damage or disease, firm, dark green, with few loose outer leaves, and with short stems. Plants should be tall, erect, with relatively wide internodes, easily deleafed, long-standing, resistant to disease; and of course, high-yielding.

Insect control is very important because of the severe restriction regarding insect presence within the processed product for which most of the crop is destined. Aphids, particularly the cabbage aphid, are most troublesome, since they are difficult to wash from the sprouts. Loopers are mainly a field problem. Generally good control of cabbage fly root maggot is usually achieved. It is common for growers to apply pesticides at two-week intervals for prevention and/or control of insect pests.

Diseases of most concern are botrytis and sclerotinia, especially with the early crop which is harvested during the warmer weather period. Downy mildew, so far, is not an industry-wide problem. Ring rot will occasionally cause losses. Clubroot can be a serious problem where infected soils are farmed. Soil pH adjustment with lime, fungicides, and transplant sanitation help to alleviate the seriousness. Verticillium infection is endemic; and although economically productive yields are achieved, potential yield is decreased.

Objectives to improve production would include the development of earlier, uniform varieties with better quality characteristics and with longer maturity quality-holding ability. Harvesting efficiency can be improved with the development of more effective machinery. The production of transplants could readily be improved through the use of recently developed technology and with the use of automatic transplanter equipment.

CABBAGE

Although the most important crucifer crop in the U.S., cabbage is of considerably lesser importance in Califoria. Since cabbage has relatively wide climatic adaptability, it can be grown in many areas of the U.S.; and thus California has no particular advantage. Additionally, production costs are higher in California and therefore are a competitive disadvantage to California producers. Nonetheless, production mostly during the winter and early spring fits into the U.S. supply situation, even though facing strong competition with Texas and Florida. Summer and fall production is largely marketed within California and the western U.S. Production of cabbage for processing in California is negligible, due to limited demand and the inability to compete with central and eastern U.S. producers. Per capita consumption has been decreasing slightly but steadily each year and is presently about 4 kg. Consumption of sauerkraut remains relatively uniform at about 1 kg./year. Coleslaw consump-

tion has increased, but the volume is very small and is simply displacing some of the otherwise conventional fresh usage of cabbage.

Important production areas in California are Ventura, Monterey, Santa Barbara, and Imperial counties. Emphasis is given to winter and early spring production, although supply is continuous. In the interior districts of Imperial and Kern county, planting occurs from August to October, with harvest continuing from October into June. Coastal areas plant and harvest throughout the year.

Since seasonal constraints as to time of planting or earliness of harvest are not a concern, there is no particular advantage for transplanting cabbage. Essentially, all of the commercial production is directly seeded. The standard cultural procedure is to plant two rows on raised beds (one meter from center to center). Overplanting is thinned to single plants. The majority of the crop is for fresh market purpose, for which small head sizes (1.5-2.0kg.) are preferred. Consequently, distances between plants in the row are usually 50-60 cm. Field populations range from 40-50,000 plants/ha.

Wide use is made of appropriate herbicides, and conventional cultivation is provided as needed. On the average, cabbage growers provide 150 kg. N, 50 kg. P, and 40 kg. K/ha to support crop growth. Most cabbage crops can be grown with 45-60 cm. of water, with furrow irrigation the usual application method. It is a general practice not to use overhead irrigation at the later period of crop maturity. Cabbage, not usually a main crop, is therefore more amendable to rotations--these are scheduled so as to avoid crucifer crops for 3-4 cropping periods.

Hybrid variety use has become well-entrenched, and among California growers, the use of open-pollinated varieties is becoming a rarity. Uniformity of maturity is perhaps the strongest feature provided by hybrids, which in turn improves the probability for single-harvest operations. Open-pollinated varieties still in use include Copenhagen Market, Golden Acre, Greenback, Danish Ballhead, and Early Jersey Wakefield. Among the more widely used hybrid varieties are Headstart, Market Prize, Market Topper, Roundup, King Cole, Stonehead, and a multitude of other hybrids. Several red cabbage varieties such as Red Acre, Ruby Ball, and Red Head (F_1) are grown on a limited scale, as are savoy cabbage types such as Chieftain Savoy and Savoy King (F_1). Usually varieties with early-to-midseason maturity characteristics, 90-120 days from seeding, are grown. Since large head sizes are not a principle objective, there is little interest to use later varieties capable of large head size development.

Preferred crop characteristics include high yield of uniform, relatively small, generally spherical heads free of defects that are solid with well-formed cap leaves and are short-stemed. Dark green or bluish green outer foliage with a heavy bloom is preferred over lighter green foliage. Individual head weight of 1.5-2.0 kg. is preferred. Within the past 10 years, market preference for larger heads that changed and has dictated that smaller head sizes be produced. Crop characteristics for the processed crop differ somewhat in that larger (5 kg. or more) heads are produced which must be very solid, long-standing without bursting, and having short stems with lighter green foliage. These characteristics are obtained with the use of later-maturing varieties and wider plant spacings that produce larger heads.

Harvesting is performed by hand cutting. Economic conditions often do not favor multiple harvesting, and most fields usually are cleared during the first harvest. Although harvesting equipment is widely used for the processing crop in other U.S. production areas, such equipment is not satisfactory for the fresh product. Similarly, since most of California cabbage is packed directly in the field, labor aid conveyors are seldom used. Occasionally some field-side or shed packing is done, in which case the harvested heads are transported from the field to the packing site in bulk containers.

After packing the cabbage is vacuum cooled or cooled with forced cold air. Refrigeration maintainance at 0-2°C is a standard procedure throughout the marketing process or if storage is required. With good handling and temperature management considerable keeping quality is possible. Most of the cabbage is packed and marketed in fiberboard containers holding about 20 Kg. Occasionally open mesh bags are used, also containing about 20 Kg of cabbage.

Production difficulties are presented by several diseases, notably downy mildew, sclerotinia and mycosphaerella. Fortunately clean seed and field sanitation make the incidence of black rot or black leg rare. Clubroot is not a problem in the present cabbage production districts. Yellows also is an infrequent problem since most varieties used are resistant to fusarium and/or growing temperatures are low. It is rather typical to treat for root knot and sugar beet nematodes in infected fields. Post-harvest losses occasionally result from infections of gray mold, Botrytis cinerea, soft rot, Erwinia carotovora or Rhizopus spp. Black leaf speck is also occasionally observed. The inciting agent and circumstances favoring the development of this disorder is still unresolved. Tip burn, a physiological disorder periodically causes some crop loss.

Insect problems are typical of those faced by most crucifer growers and include the cabbage looper, imported cabbageworm, diamond back caterpillar, armyworm, aphids, cabbage maggot and cutworms. In general, pesticides do provide adequate control.

Researchable areas for crop improvement include the development of harvest equipment that can selectively harvest, trim and perhaps pack the crop. Varietal improvements that increase plant resistance to disease, nematodes and insects would be a valuable contribution. Further improvement in herbicide and pesticide effectiveness coupled with and effective IPM program would likewise be a valuable contribution.

CHINESE CABBAGE

Chinese cabbage of either form, Brassica pekinensis or B. chinensis is of minor importance. The production area of all oriental vegetables in California is probably less than 2,000 ha. Even though the Chinese cabbage area may be half of this, it still is relatively little. Estimated production in California is about 15,000 tons, about one half of the U.S. volume. Recently, heightened demand for the crop has developed, but it is unlikely that this crop will escape the minor vegetable category for some time. As consumers, other than those of oriental background, become familiar with the crop, it is not reckless to expect that within a 10-15 year period it will compete against and exceed the volume of cabbage produced in California.

Production practices and problems are similar to those for head cabbage. Planting, fertilization and irrigation procedures are essentially the same. Plant spacings for B. chinensis, because of smaller plant size, is closer, averaging about 25-30 cm in the row versus about twice the space for B. pekinensis. B. chinensis is often marketed as oriental greens as well as a form of Chinese cabbage.

However, the climatic adaption range for Chinese cabbage is considerably narrower than that for head cabbage. Exposure to low temperature (less than

6-7°C) and long day length encourage premature bolting, and high temperatures (greater than 28-20°C) reduce crop quality and encourage tipburn. Favorable growing conditions are a temperature range of 10-20°C, with short or medium day length (10-12 hours). Accordingly, summer production is quite restricted, although cool coastal areas occasionally risk growing a crop. Late autumn through early spring is the principle harvest period with the production areas generally close to the larger California cities.

A significant breakthrough has occurred with the introduction and wide acceptance of varieties of B. pekinensis superior to the variety Michihli. Michihli is a loose-heading tall cylindical type (chihli), whereas the Wong Bok types which are now more popular are shorter, squat or drum-shaped and considerably more dense and heavier than the Chihli types. The Wong Bok types (retail sale name is napa cabbage) are available as loose, semi- or tight headed varieties. Varieties of the Wong Bok types such as Kyoto are rapidly being replaced by hybrid varieties such as Nagaoka and several others. In addition to providing excellent uniformity of market maturity, these varieties help to insure single harvest feasibilities and also provide a range of maturity periods which expands their climatic adaption to slightly warmer growing temperatures.

Although Chinese cabbage incurs most of the same diseases and insect problems of other crucifers, appropriate pesticides sometimes cannot be used because registered use for minor crops is not available.

Improvement of variety disease resistance is an important goal. Similarly, varieties with slower bolting characteristics would expand the adaptability of this crop to more California areas. Because of the limited volume of production, it is unlikely that mechanical harvesting equipment will be developed. However, in incorporation of characteristics favorable for crop harvest mechanization and handling should be considered.

RADISH

Although garden radishes are a minor U.S. crop (52,000 tons), California provided about 25% of the nation's supply and thus is of some importance. Winter and Oriental-type radish production in the U.S. amounts to less than 10% of the garden radish production. California produces a major portion of that crop. The small production areas for garden radishes are scattered throughout California, but most of the production occurs in the southern part of the state, principally in the Coachella Valley. Production occurs during the late autumn through early spring. Being limited to short-day, cool growing conditions, very little summer production is attempted. Winter and Oriental types of radish have a slightly broader climatic adaption; thus in addition to production in Southern California, some production occurs in the central coastal valleys. Home garden production, although difficult to measure, makes a significant contribution to the total produced.

Garden radish production is usually relegated to lighter sandy soils; the winter types prefer lighter-texture soils but are also grown on some of the medium to fine textured soils. Seeding is done on the flat or on slightly raised wide (1.5-2.0 meter) beds. Multiple-row planters (7-9 or more rows) using sized,

graded seed achieve good precision. Commonly, rows are spaced 20-25 cm. apart; and seed is planted about 2-3 cm. apart within the rows. No thinning is attempted. Plant populations range from 1.0-2.0 million/ha. Winter and Oriental types are given more space because of the considerably larger root size, with spacing dependent on the radish variety being grown.

Cultivation is principally with mechanical implements. Since most commercial radish growers have achieved and use relatively weed-free fields, herbicides are seldom used. Irrigation is by sprinkler, although some winter type radishes are furrow-irrigated. Three to four weekly irrigations amounting to 20-30 cm. is usually adequate for the short-term crop. Winter radishes require slightly more irrigation.

Fertilizer applied provides 50-70 Kg N. 50 Kg P, and 50 Kg K. It is common to have two to three, sometimes even four, croppings of garden radish on the same field furing rhe same growing season. Rotations with non-crucifer crops, i.e., spinach, parsley, onions, etc., in alternative years is generally practiced.

Cherry Belle and Scarlet Globe are the principal varieties. Other similar red globe varieties grown include Red Prince, Comet, Scarlet Knight, and Crimson Giant. Some Sparkler, a globe-shaped red/white variety, and French Breakfast, an oblong-shaped half red/white variety, are grown in small volume, as is the cylindrical white variety, White Icicle. The maturity range of these garden radishes is somewhat less than 30 days, and up to 50-60 days during cooler temperatures.

The winter radishes, such as the black-skinned Long Black Spanish and Round Black Spanish, and the Oriental types, require 60 to 90 days for maturity. The Oriental radishes are shape- and size-variable, depending on variety. Daikon or Chinese White have long and thick roots. Others which are large and round and with shorter length (15-20 cm) roots of 2-3 cm. diameter are also popular. The introduction of hybrid varieties has greatly increased the appearance of these shorter more slender radishes. Nonetheless, all the winter radishes combined are only 10% of the total California radish crop volume.

Radish characteristics sought are high-yielding rapidly-growing uniform roots that are solid, free of pithiness or other defects (cracks or splits), with small short tap roots and true-to-varietal shape. The preferred size range for the red globe-shaped roots is 20-30 mm.

Plant tops are important for those radishes marketed in bunches, and such tops should be clean, free of defects, green, and relatively short.

The Black Spanish winter radishes should also be uniform and true-to-variety shape. Typical root weights are 1-2 Kg. These are not marketed with tops. Some of the smaller-root Oriental radishes are bunched, and thus top appearance is important. The larger-sized Oriental radishes are topped, but uniformity of length and diameter is important. Such radishes easily weigh 1-3 Kg., and sometimes more.

Garden radishes are harvested by hand and by machinery. Bunched radishes are hand-harvested. For this purpose, the plants are undercut; workers then lift, grade, and tie together the tops of a number of radish plants. Such bunches usually weigh 300 gm. Four dozen of such bunches are placed into a master container(about 15 Kg). The ability to produce attractive healthy plant tops gives California an advantage in marketing bunched radishes. Topped radishes are mechanically harvested. The machinery undercuts the plants,lifts and tops them during the same operation, and deposits the roots into bulk containers which are transported to packing sheds. The radishes are washed, size- and quality-graded, the tap roots mechanically snipped, and packaged into film bags. The bags are of varying sizes and for marketing may

contain from 150-1000 gm. These individual bags are packed into master containers. Some larger individual containers (10-20 Kg.) are used for subsequent repackers.

Whether topped or untopped, the radishes are hydrocooled; and thereafter temperatures are maintained near 0°C under high relative humidity conditions. Under ideal storage conditions, radishes will retain good quality for 6-8 weeks; topped radishes for 3-4 weeks. The larger winter radishes have considerably longer storage life.

The very small production of winter radishes precludes mechanical harvesting investment. These are undercut, lifted and topped and other operations are manually performed. These are no standardized containers for the winter-type radishes. The majority are marketed relatively near the production areas. Some of the large sized roots such as Daikon are sometimes marketed as portions rather than as the intact root.

Disease problems are presented by downy mildew, Peronospora parasitica, bacterial black spot, Xanthomonas vesicatoria, and Rhizoctonia root rot, Rhizoctonia solani. Occasionally white rust, Albugo candida is troublesome.

Principle insect pests are flea beetles, aphids and cabbage root maggot.

Improvement can be achieved with improved uniformity at maturity. Often, larger roots may split or crack while the grower delays harvest in order to increase the size of slower developing plants. Varieties with resistance to the several serious diseases would improve both yield and quality. Greater bolting resistance of garden radishes is needed as is greater resistance to the development of pithy interiors.

TURNIPS

Turnips are a minor U.S. crop and of little significance in California. In the U.S. southeast and south, they are considerably more popular. The estimated U.S. production area is about 5,000-6,000 ha. Accurate crop statistics are not available, although in 1979 it was reported that approximately 18,000 tons were processed by freezing and over 6,000 tons were marketed fresh. The considerable volumn marketed locally and produced in home gardens is not reported, nor is the volumn processed by canning or fed to livestock. The aggregate would probably be 70,000 tons. Interest in turnips continues to steadily diminish. Its past popularity is attributable to its long storage feature. With other fresh vegetables now readily available year around, it has lost this advantage and does not compete well.

Turnips have a fairly broad adaptability, although summer or warm season production is inferior to that under cool growing conditions. Shape retention and foliage quality are better in cool conditions. Since turnip tops (greens) often are equal to or in some cases more important than roots, it becomes important to produce the crop under more favorable temperatures where foliage growth and appearance are enhanced.

In California, direct seeding is done, planting two rows per raised bed. Beds are one meter from center to center, and field populations range between 15-20 plants per square meter. Field populations are somewhat higher if the

crop is to be marketed as bunched turnips or as greens. Lighter-textured soils are preferred to avoid the possibility of misshapened roots.

A usual fertilization program is to provide 75 Kg N, 50 Kg P, and 50 Kg K. Irrigation needs are usually met with 30-50 cm. of water. Other cultural operations such as cultivation, weed, disease, and pest control, and crop rotation, are similar to those for other crucifer crops. Cabbage root maggot can be, for obvious reasons, a severe problem, and special concern is given to its control.

Harvesting is accomplished in several ways. If grown for topped roots (fresh or processed), the roots are allowed to enlarge somewhat; they are mechanically topped in the field, undercut,lifted by hand, bulked together, and taken to the packing facility. Turnips which are to be bunched together by their leaves are undercut and bunched in the field, followed by further subsequent shed packing. Except for very small operations, tops for turnip greens are mechanically cut, bulked, and shed packed.

The product is washed, whether roots and/or tops, and hydrocooled. High relative humidity and low temperature (0°C) conditions are maintained for handling or holding. Currently, topped turnips are packaged in large plastic film or open mesh cloth bags containing 23-23 Kg. These have a shelf like expectancy of 3-4 months. Bunched turnips or greens are packed in fiberboard containers. There is not a standardized container; but those which are wet-proof are used, since topicing is often given to this product. Shelf life of bunched turnip and greens is about 2 weeks under proper temperature management.

The principal white-fleshed variety is Purple Top White Globe; Yellow Globe and Golden Ball are the main yellow-fleshed varieties. Either will provide acceptable greens, but varieties such as Seven-Top and Shogoin are preferred for production of greens because of their higher foliage-yielding capabilities. Purple Top Milan is a widely-used variety for processing turnip roots. A number of excellent hybrids are available, but their acceptance so far has been slow.

Favorable crop characteristics, in addition to high yield of root uniformity in shape and size, include defect-free roots with small top attachment. If topped, they should be well-trimmed. For greens, the foliage should be clean, fresh in appearance, and absent of yellow leaves.

Crop improvement can be partly achieved with the increased use of hybrid varieties that provide greater uniformity and disease resistance. Unless crop production increases, it appeares unlikely that crop improvement research will develop.

RUTABAGA

Rutabaga (Swedes) is a very minor U.S. crop. The U.S. production area is only about 400-500 ha, and probably not more than 100 ha are grown in California. U.S. usage is estimated at 50,000 tons, which is chiefly supplied by imports from Canada. Market availability is considerably expanded by the crop's excellent storage (3-4 months) capacity.

Rutabagas have a relatively broad climatic adaption, but unless obtained from fall and winter harvests, quality is not good. The crop in California is planted

in the late summer or early fall and matures in 90-120 days. If grown under high temperatures, the principal root is poorly shaped (elongated), and the stem end is both thickened and elongated.

The crop is seeded directly either in single rows, 75-80 cm. apart, with final in-row spacing of 20-25 cm., or in double rows on raised beds, one meter apart from bed center to bed center, with spacing within rows of 25-30 cm. Lighter-textured soils are preferred to avoid misshapened roots and for ease of soil removal from roots at harvest.

Commonly-used fertilizer regimens apply 90-100 Kg. N and 50 Kg each of P and K. About 40 cm. of irrigation is used to produce the crop.

Harvest is principally by hand. Machinery is used to mow off the tops and to undercut or plow-out the roots. These are picked up and placed in bulk containers by hand. At the packing facility, the roots are trimmed so as to have smooth, rounded stem end; and the larger lateral roots are cut flush to the surface of the main globe-shaped root. Graded roots are washed and cooled by refrigeration and maintained during transport or storage at high relative humidities and low (0°C) temperatures. To prolong storage and to reduce shriveling, the roots are often lightly coated with paraffin or a similar wax. Containers are not standardized; most often, sacks containing 23-25 Kg. are used.

American Purple Top and Laurentian are the principal varieties used. Both are yellow-fleshed. White-fleshed varieties such as Macomber are not popular. The overall lack of popularity of rutabagas in California possibly explains why the use of other varietal sources has not been exploited.

Rutabagas characteristically are round, smooth, free of blemishes or other defects, well-trimmed, and with few lateral roots. Preferred market weight ranges between 1.5-2.0 Kg.

Rutabagas are attacked by the same diseases and insect pests affecting other crucifers. Cabbage root maggot is one of the more damaging pests.

Obtaining roots with fewer lateral roots, a pronounced stubbing of the tap root, and with a smaller stem and leaf attachment would be a benefit in reducing the trimming required. Disease-resistant cultivars are a worthy objective.

KOHLRABI

Kohlrabi, Brassica gongylodes, is another relatively unknown and underutilized vegetable in the U.S. No production area or volume statistics are reported. However, an increased interest has recently developed. More kohlrabi is being eaten uncooked in salad and used as a substitute for chinese chestnut in some dishes.

Kohlrabi is relatively broadly adapted to a wider range of growing climate than many other cool season vegetables. Although somewhat tolerant of warmer termperatures and frost, the crop's growth and quality is best achieved at 15-25°C. At these temperatures, growth is rapid; and rapid growth results in much more tender stem tissues.

Planting periods in California conditions are from August through March, with harvesting from October through June. Lengthy periods of cold temperatures will promote bolting, and areas where this might occur should not produce kohlrabi. Most soil types are suitable if well drained. Kohlrabi responds favorably to high fertility and commonly 75-100 Kg N is supplied with 40 Kg each of P and K. Forty cm of irrigation is usually sufficient to grow the crop, which generally is marketable in 55-70 days after seeding.

Seed is drilled directly in the field, either in single rows 75-80 cm apart with final in row spacing of 12-15 cm., or in double rows on raised beds (one meter apart from center to center) also at 12-15 cm in row spacings.

Plants are hand harvested by cutting the stem below the swollen portion. The plants may be bunched together in the field for later marketing, or they may be topped. The tops are marketable, but no significant market has developed for them. For market presentation, bunched kohlrabi should be smaller, the 3-5 kohlrabi making up the bunch should not exceed 6-8 cm in diameter. The foliage should be healthy, fresh, clean and neatly tied together. The lower stem ends should be well trimmed. The lower stem is rather fiberous and tough and requires care in trimming. Topped kohlrabi should be round or slightly flattened, with foliage and the lower stem closely trimmed. Kohlrabi that are badly misshapened, cracked or having other defects are discarded.

Post-harvest handling is similar to other root type crucifers, requiring high relative humidities and temperatures close to 0°C. Well maintained topped kohlrabi can easily have a storage life of several months. Containers for marketing are not standardized.

Early White Vienna and Early Purple Vienna are the dominant varieties. Both have white flesh, the outer skin color being green or purple; the green type is preferred. The excellent productivity of the hybrid Grand Duke and similar hybrids may soon displace the use of the Early Vienna varieties.

Black rot, black leg, yellows, clubroot, damping off and bacterial soft rot are occasional disease concerns. Insect problems are caused by cabbage maggot, cutworms, aphids, imported cabbage worm and the cabbage looper. Nematodes when present must be controlled or serious plant root damage will result.

Future improvement will occur from hybrids that increase yields and crop uniformity. The inclusion of disease and pest resistance would be useful. Kohlrabi with fewer and smaller leaf attachments would reduce trimming effort and improve product appearance.

CRUCIFER GREENS - MUSTARDS, KALE AND COLLARDS

All three types of crucifer greens are of minor significance in the U.S. and accordingly their production is quite limited. Even in the southeastern and southern U.S. where these vegetables are more popular, they remain minor crops.

Three kinds of leafy mustards are grown: *Brassica juneca* (in the largest volume, *Brassica rapa* var. *perviridus* (also known as spinach mustard) and celery

mustard, Brassica rapa var. chinensis (also known as pak choi). The mustards, kale and collards (both Brassica oleracea var. acephala) are cool season vegetables. They are produced during the autumn, with production continuing through the winter and spring. Kale has fair adaption, being reasonably tolerant of both warmer and cold temperatures. Collards and the mustards are not as hardy and growth is damaged by either higher or lower temperatures.

Crop production statistics are not available for these minor vegetables. A reasonable estimate based on information from various sources indicates that about 5,000 ha of various mustards are produced, mostly B. juneca; of which 4,500 tons were processed by freezing, and fresh volume was about 45-50,000 tons. About 1,000 ha of kale is grown; 1,600 tons were reported processed by freezing, and about 10,000 tons marketed fresh. About 7,000 ha of collards are produced; 8,000 tons for freezing and 70,000 tons marketed fresh. California production in all cases is negligible.

In California, supplies of kale and mustards are available from October through June; collards from November through May. From seeding to market maturity, the mustards require 45-60 days, kale 60-70 days and collards 75-90 days.

In many ways plant requirements and cultural operations are similar. Fertile well drained medium textured soils are preferred but finely textured soils are used if drainage is good. Fertilizer applications are in the general range of 75-100 Kg N and 40-50 Kg each of P and K. Irrigation needs are usually accommodated with 25-50 cm of water, the longer to mature crop (collards) using the higher amounts.

Planting is by direct seeding, either in single rows about 75-80 cm apart or in the standard double row raised bed. In row spacings are somewhat different; the final spacing for the mustards and kale is about 25-30 cm and collards are slightly wider at 40-50 cm. Cultivation and weed control practices are the same.

Hand cutting is the usual method of harvesting these commodities; the foliage is cut so that it either remains attached to the main stem or as separate leaves. The practice of leaf stripping, harvest of mature leaves while the plant is allowed to continue growth, is seldom done because it is too labor intensive. Either way, the leaves are usually bunched together. The pak choi (Chinese mustards) are cut at the soil line so that the plant remains intact and these are packed individually. Greens that will be processed are cut with a mower type harvester and the foliage is bulked together for subsequent handling. Whether packaged in the field or in a packing shed, the product will be graded, washed and hydro-cooled. Refrigeration or icing is used during transport to market or during storage. Market life, if high relative humidity and low temperatures (0°C) is provided is 10-14 days. Containers for marketing these crops are not standardized, most frequently wire-bound wooden containers are used.

Principle varieties of mustards include; Florida Broad Leaf, Southern Giant Curled and Fordhook. Tendergreen is the principle variety of B. rapa var. perviridus. The varieties of B. rapa var. chinensis often are not specifically identified but grouped as pak choi. Kale varieties include; Vates, Dwarf Green Curled Scotch and Siberian. Dwarf and tall types exist within these varietal types. Varieties of collards include: Georgia, Morris Heading and Vates.

The foliage is the principle plant part for marketing, although the upper succulent stem is also important for kale and collards. The foliage should be clean, dark green, fresh and without broken leaf ribs, torn blades or any other damage. The best leaves are those not yet fully expanded with relatively wide leaf blades and shorter petioles. Leaf blades should be neatly bunched and tied together.

Disease concerns for these crops include: downy mildew and cabbage yellows which can damage foliage and render the plants unmarketable. These crops are susceptible to the other commonly occurring crucifer diseases and to the insect pests also commonly attacking crucifers.

The possible development of hybrids might increase productivity and some needed disease resistance. Improvement in mechanical harvesters could reduce the present effort required for harvesting. Equipment for this purpose is in an advanced stage of development.

This lengthy narrative highlights some of the aspects of California's crucifer production. Some observers might comment that there are relatively few outstanding concerns. This is far from true. The California industry, although very dynamic, chronically faces new problems.

Although production continues and in many cases improves, there is a need for even more rapid and extensive improvement. Much has been and will continue to be gained through plant breeding improvement of the crop's yield and cultural characteristics. These gains cannot be fully appreciated without further improvement in production, harvesting, handling and marketing practices.

The use of energy, now considered a crisis, has always been an important concern. Producers must shepherd their available energy resources through every available practice. Greater efficiency in land preparation, cultivation and harvesting is mandatory. Wise use of energy intensive fertilizer and pesticide products is needed to reduce production cost inputs. Further exploration of slow release fertilizers, better placement and more appropriate application rates is needed. More efficient use of irrigation, both its application method and volume is being explored. Drip irrigation to provide moisture and to apply fertilizer and pesticides is being considered.

Improvements in cheaper and better transplant production methods may become a greater factor in reducing production costs and in particular by providing the advantage of greater land utilization. Growing more crops per year on a given field can greatly reduce production costs.

The reliance upon relatively few herbicides and pesticide products has been shown to be faulty. Therefore, further investigations on intergrated pest or bio-control management must proceed.

Harvesting and packing efficiences must be improved to reduce these costly production inputs. Container standardization, better storage and shipping procedures will also reduce the costs of making these crops available to U.S. consumers. Because California is essentially a net exporter of vegetables, the cost of long distance transportation is a vital concern. Unless these costs and those associated with the production of the crop are reduced the vegetable economy of California's agriculture will be seriously threatened. The effects of research and its application will determine how California fares in the future.

THE GENETIC RESOURCES OF CRUCIFEROUS CROPS

- a global plan of action -

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Paper to be presented at the EUCARPIA "Cruciferae 1981" Conference, Ås, Norway, 15-18 September 1981.

1. INTRODUCTION

The conglomerate of crops and wild relatives that belong to the family Cruciferae is large and complex. Centres of diversity of crops span the Eurazian continent (see Fig. 1), being products of the many ancient civilizations of this vast area. To some extent this diversity is reflected in the total of present day research and development activity on the genetic improvement of these crops.
A great number of plant breeders/geneticists of different cultural background and language, scattered all over the world, are active on many of these crops and all are concerned about the genetic resources of their crops.

The above explains to a large extent why concerted action had to await intitiatives by the International Board for Plant Genetic Resources (IBPGR). Once the right platform was made, developments were rapid due to the alert and vigorous response by the communities of breeders/geneticists; a signal of the deep concern.

On the basis of advice and a considerable amount of groundwork carried out by a small group of cruciferous crop breeders, strongly backed up by their colleagues, IBPGR formulated the internationally acceptable framework for the conservation and general description of the genetic variation of cruciferous crops and wild relatives.

The major part of the work was undertaken in 1980 resulting in the IBPGR report "Genetic Resources of Cruciferous Crops" which is just published (IBPGR, 1981). The following provides some additional background to this report, highlights a few important issues and provides some indications of future action since this is just the start of a large operation to physically save the genetic variation of our crops still present.

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2. HISTORICAL

1977, November: publication of the IBPGR report on the genetic resources of vegetables with special reference to those grown in the tropics (Grubben, 1977).

1979, 24-25 January: IBPGR expert consultation on the genetic resources of vegetables for the tropics at the National Vegetable Research Station (NVRS), Wellesbourne, U.K. (Anon., 1979). The Asian Vegetable Research and Development Centre (AVRDC), Taiwan, was appointed to coordinate and prepare a plan of action for priority Brassica spp. in cooperation with NVRS and the Vegetable and Ornamental Crops Research Station (VOCRS), Tsu, Japan.

1979, 3 October: creation of EUCARPIA Crucifer Genetic Conservation Group (CGCG) during the "Cruciferae 1979" Conference, Wageningen, the Netherlands. An appeal for global action on the integral conservation of the genetic resources of cruciferous crops was addressed to the IBPGR. In the following eight months a survey aimed to collate information on collections in Europe was completed (Toxopeus and Crisp, 1980).

1980, March: The CGCG proposal to include all cruciferous crops and wild relatives was accepted by the IBPGR. In this connection the IBPGR contracted specialists to produce status report of the genetic resources of cruciferous crops for specific regions.

1980, 17-19 November: IBPGR Secretariat consultation on the basis of status reports mentioned above. The report of this meeting provided the basis for the IBPGR publication on the Genetic Resources of Cruciferous Crops (IBPGR, 1981).

3. CROPS AND WILD RELATIVES

The crops and wild relatives considered in the IBPGR report on the "Genetic Resources of Cruciferous Crops" (IBPGR, 1981), are listed in Table 1.

4. DESIGNATED GENEBANKS

Genebanks which have been designated by the IBPGR to hold collections of specific cruciferous crops and wild relatives for longterm storage are presented in Table 2.

5. THE IMMEDIATE FUTURE

5.1 Existing collections

A summary of existing genetic resources collections is provided in the IBPGR report (IBPGR, 1981; Appendix IV). Further details on curator, nature of samples, source of collection, storage facilities, documentation, evaluation, etc. will be published at a later date in the IBPGR Directory of Vegetable Germplasm Collections.

Details of the accessions held by members of the EUCARPIA CGCG have been provided by Toxopeus and Crisp (1980). The degree of duplication needs to be sorted out.

5.2 Collecting expeditions

The IBPGR report (IBPGR, 1981) gives a detailed priority list for collecting cruciferous crops. An action plan for first priority crucifers has been established and is presented in Table 3.

The European Community Standing Committee on Agricultural Research is supporting a project for the collection of landrace material of Brassica spp. in the Common Market. The main contract was signed in July, just before the main holiday season; it provides for about 15 collecting missions in the years 1981, 1982 and 1983. The coordinating committee consists of Dr. P. Crisp, Dr. Mcfarlane Smith, Ir. H. ROelofsen, Ir. H. Toxopeus (all CGCG members). Plans to collect landrace material in Scotland, England and the Netherlands this fall and winter are nearly ready.

5.3 Descriptor lists

Passport and collectors information check lists have been drawn up (IBPGR, 1981; Appendix V, VI). and these should be used during collecting and conservation of crucifer germplasm.

Separate descriptor lists for the characterization and evaluation are needed for each crop with emphasis on the first priority crucifers. The IBPGR already commisioned specialists to produce descriptor lists for Brassica campestris subsp. rapa, Brassica carinata, Brassica juncea, Brassica oleracea and Raphanus spp. Descriptor lists still need to be commissioned for Brassica campestris subsp. chinensis, pekinensis and oleifera.

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Table 1. Crops and wild relatives considered in the IBPGR report on the "Genetic Resources of Cruciferous Crops"

Taxonomic name	Common name	Main use
Brassica campestris		
B. campestris subsp. *chinensis*	Pak choi	Vegetable
B. campestris subsp. *japonica*		Vegetable
B. campestris subsp. *narinosa*		Vegetable
B. campestris subsp. *oleifera*	Turnip rape	Oilseed
B. campestris subsp. *pekinensis*	Chinese cabbage	Vegetable
B. campestris subsp. *rapa*	Turnip	Vegetable/Fodder
Brassica carinata	Ethiopian mustard	Vegetable/Oilseed
Brassica juncea	Indian mustard	Vegetable/Oilseed
	Chinese mustard	Vegetable/Oilseed
Brassica napus		
B. napus var. *biennis*	Rapekale	Fodder
B. napus var. *napobrassica*	Swede turnip	Fodder/Food
B. napus var. *oleifera*	Oilseed rape	Oilseed
Brassica nigra	Black mustard	Condiment
Brassica oleracea	Wild relatives	
B. bourgaei (syn. *Sinapidendron bourgaei*) Canary Islands		
B. oleracea wild in England, Brittany (and northern Spain?); coastal		
B. robertiana northeastern Spain, Mediterranean, France, (Italy?); coastal		
B. insularis Corsica, Sardinia, Tunisia; mostly coastal		
B. macrocarpa Egadi Islands near Sicily		
B. villosa-incana (complex) Sicily, mainland Italy, northwestern Yugoslavia; coastal		
B. cretica (complex) Greece and Aegean Islands, Crete		
B. hillarionis Cyprus		
B. oleracea var. *acephala*	Kale	Vegetable/Fodder
B. oleracea var. *alboglabra*	Chinese kale	Vegetable
B. oleracea var. *botrytis*	Cauliflower	Vegetable
B. oleracea var. *capitata*	Cabbage	Vegetable/Fodder
B. oleracea var. *gemmifera*	Brussels sprout	Vegetable
B. oleracea var. *gongylodes*	Kohl rabi	Vegetable/Fodder
B. oleracea var. *italica*	Broccoli	Vegetable
Raphanus sativus	Radish	Vegetable/Fodder Oilseed/Green Manure
Raphanus spp.	Wild relatives	
Sinapis alba	White mustard	Oilseed/Green manure

Table 2. IBPGR designated centres for base collections of cruciferous crops

Base collection centres	Cruciferous crops
Plant Gene Resources of Canada (PGRC), Ottawa, Canada	Global collection oilseeds and green manure crucifers: B. campestris, B. napus, Sinapis alba, B. juncea,
National Vegetable Research Station (NVRS), Wellesbourne, U.K.	Global collection B. oleracea. Global collection vegetable and fodder types: B. campestris*, B. juncea, B. napus. Global collection Raphanus spp.
Institute for Horticultural Plant Breeding (IVT), Wageningen, the Netherlands	Global collection B. oleracea.
Institut für Pflanzenbau und Pflanzenzüchtung der FAL, Braunschweig, F.R.Germany	Global collection vegetable and fodder types: B. napus. Global collection oilseeds and green manure crucifers: B. campestris, B. juncea, B. napus, Sinapis alba. Global collection B. carinata.
Universidad Politecnica Madrid (UPM), Madrid, Spain	Global collection wild relatives.
Plant Genetic Resources Center (PGRC), Addis Ababa, Ethiopia	Global collection B. carinata.
National Bureau of Plant Genetic Resources (NBPGR), New Delhi, India	Asian collection oilseed crucifers: B. campestris, B. juncea. Global collection Raphanus spp.
Chinese Academy of Agricultural Sciences (CAAS), Beijing, China	Global collection B. oleracea. Global collection vegetable types of: B. campestris, B. juncea. Global collection Raphanus spp.
Seed Storage Laboratory, National Institute of Agricultural Sciences (NIAS), Tsukuba, Japan.	East Asian collection of all cruciferous crops.

* includes the turnip

Table 3. Action plan for first priority crucifers

Region	Crop	Type of support
China (as a country)	*Raphanus sativus* *Brassica campestris* subsp. *chinensis* *Brassica campestris* subsp. *pekinensis* *Brassica campestris* subsp. *rapa* *Brassica campestris* subsp. *oleifera* *Brassica juncea* oilseeds *Brassica juncea* oilseeds	Seed storage technology
Indian subcontinent	*Brassica juncea* oilseeds *Brassica campestris* subsp. *oleifera* *Brassica juncea* vegetables *Brassica campestris* subsp. *rapa* *Raphanus sativus*	Seed storage technology and collecting missions
Mediterranean	*Brassica oleracea* (wild relatives) *Brassica oleracea* var. *acephala* *Brassica oleracea* var. *botrytis* *Brassica oleracea* var. *capitata* *Brassica oleracea* var. *italica* *Raphanus sativus* *Brassica campestris* subsp. *rapa*	Collecting missions

Calculation of minimum germination temperature in cruciferous species

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I. SUMMARY

The effect of temperature on the rate of growth during germination has been determined for 13 vegetable crops in the cruciferous family.

The length of the root and the hypocotyl was measured together, and the time taken for it to grow from 10-30 mm was noted. Consequently, the rate of growth in mm/day was calculated.

Only low temperatures near the minimum temperature have been used in the determination of the minimum germination temperature.

On average, the minimum germination temperature was minus 0.6°C. The lowest average germination temperature in the trial was 0.1°C.

A close relationship was found between the minimum germination temperature and the recommended storage temperature of a crop. The recommended storage temperature for a number of these crops is about 0°C.

II. INTRODUCTION

The results described here are a part of the results of a larger investigation to find out the influence of temperature on germination. The calcultaion of the minimum germination temperature is an important part of the investigation.

Different methods for deducing the minimum germination temperature have, however, given different results (RØEGGEN 1981).

The only method that has given the lowest minimum temperature has been derived from trials with low temperatures down to the minimum temperature.

III. MATERIALS AND METHODS

The seeds were sown in Petri dishes on moistened filter papers, and then covered with black plastic so that germination could occur in the dark.

Fifty seeds were sown for each test, and four dishes were sown for each temperature. Each dish was examined once and then discarded.

The length of the root and hypocotyl was measured together as the measurement was taken from the root tip up to the cotyledons. The average length was calculated from 25 of the longest measurements.

To determine the length of time the root and the hypocotyl required to grow from 10 to 30 millimeters (mm), the results were plotted on a graph. Then the growth rate in mm/day was calculated.

Temperatures were measured at germination level to an accuracy of 0.1°C. The variation in temperature could be described as being very small.

The regression coefficient for "balanced linear regression" can be written as:

$$b_{ye} = \frac{\Sigma y(x/|x|)}{\Sigma |x|}$$

where $x = X - \bar{X}$ and $y = Y - \bar{Y}$ (RØEGGEN 1979).

The regression lines are prolongated to zero, where the minimum temperatures are read off.

IV. DEFINITION

The minimum temperature is defined as that temperature which lies in the transition between the lowest temperature that gives registrable growth and the nearest temperature that does not give registrable growth.

V. RESULTS

The results of the trials and calculations are given in table 1 and in figures 1 and 2. The curves in figures 1 and 2 are drawn using the least squares procedure.

In the trials, one has tried to use as low temperatures as possible. Thus, there is a difference of only 0.7°C between the average minimum temperature and the average of the lowest temperature tested. Using the method described, a lower minimum temperature is reached than the method, e.g. of BIERHUIZEN et al. (1974).

The calculation methods have given, on the whole, the same results, but there are a number of differences in individual trials. This difference gives some idea of how difficult it is to determine the minimum germination temperature accurately. The smallest correlation coefficients give the same results. This is especially the case with cauliflower where the minimum temperature is considered insufficiently defined due to bad germination.

VI. DISCUSSION

One assumes that the growth rate is linearly dependent on temperature near the minimum temperature. There is no evidence to show that the graph is linear near the minimum temperature. However, most of the trials show that the growth rate is linearly dependent on the temperature in the temperature scales shown in table 1.

Uncertainity in the lowest temperatures can arise sometimes. Theoretically one can have variations between growth-promoting temperature and temperature which does not give registrable growth. Here lies the danger in that one risks registering growth when one has already reached the minimum temperature. But the probability is small that this could have happened in the experiments.

The lowest temperatures gave the longest experimental periods. One reckons that the danger for unregistered rises in temperature increases with the length of the

trial period. At low temperatures, an unregistered temperature increase will result in comparatively larger errors. If this happens, for example at the lowes temperature under trial, the regression coefficient can be too small, resulting i that the minimum temperature calculated is too low.

Experiments that the author has carried out with peas, show that the respiration rate decreases with decreasing temperature down to the minimum germination tempe-rature. It is therefore possible to compare the minimum germination temperature to the recommended storage temperature (RØEGGEN 1975). Comparisons made with the recommended storage temperatures for a number of vegetable crops (APELAND 1969) show a close relation between the minimum germination temperature and the recom-mended storage temperature.

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Table 1. The minimum germination temperature for some vegetable crops in the cruciferous family.

Latin name	Vegetable crop	Variety	Temperature scale °C	Number of investigations	Minimum temperature: Using least squares procedure	Minimum temperature: Using balanced linear regression	Correlation coefficient
Brassica napus rapifera	Swede	Altasweet	0.2-4.9	7	-0.3	-0.3	0.956
" oleracea acephala	Kale	Westlandse Winter	0.1-3.7	4	-0.3	-0.3	0.994
" " botrytis	Cauliflower	Delira	0.1-3.2	11	0.5	0.5	0.845
" " capitata	Cabbage	Respla	0.1-2.9	7	-0.7	-0.9	0.954
" " " rubra	Red cabbage	Holdbar Vinter	0.2-2.9	6	-0.9	-0.8	0.986
" " gemmifera	Brussels sprouts	Focus	0.1-4.9	8	-0.8	-0.8	0.989
" " gongylodes	Kohlrabi	Lanro	0.2-2.9	7	-0.5	-0.6	0.936
" " italica	Sprouting broccoli	Grande	0.1-2.9	8	-0.8	-0.3	0.866
" " sabauda	Savoy cabbage	Vertus	0.1-3.4	7	-0.6	-0.8	0.961
" pekinensis	Chinese cabbage	Hiratsuka No. 1	0.2-4.9	4	-1.2	-0.8	0.963
" campestris rapifera	Turnip	Petrowski	0.0-3.7	8	-0.8	-0.7	0.969
Lepidium sativum	Garden cress	-	0.0-3.2	7	-0.9	-0.8	0.994
Raphanus sativus	Radish	Cherry Belle	-0.1-3.2	8	-0.5	-0.6	0.994
Average			0.10-3.35		-0.60	-0.55	0.954

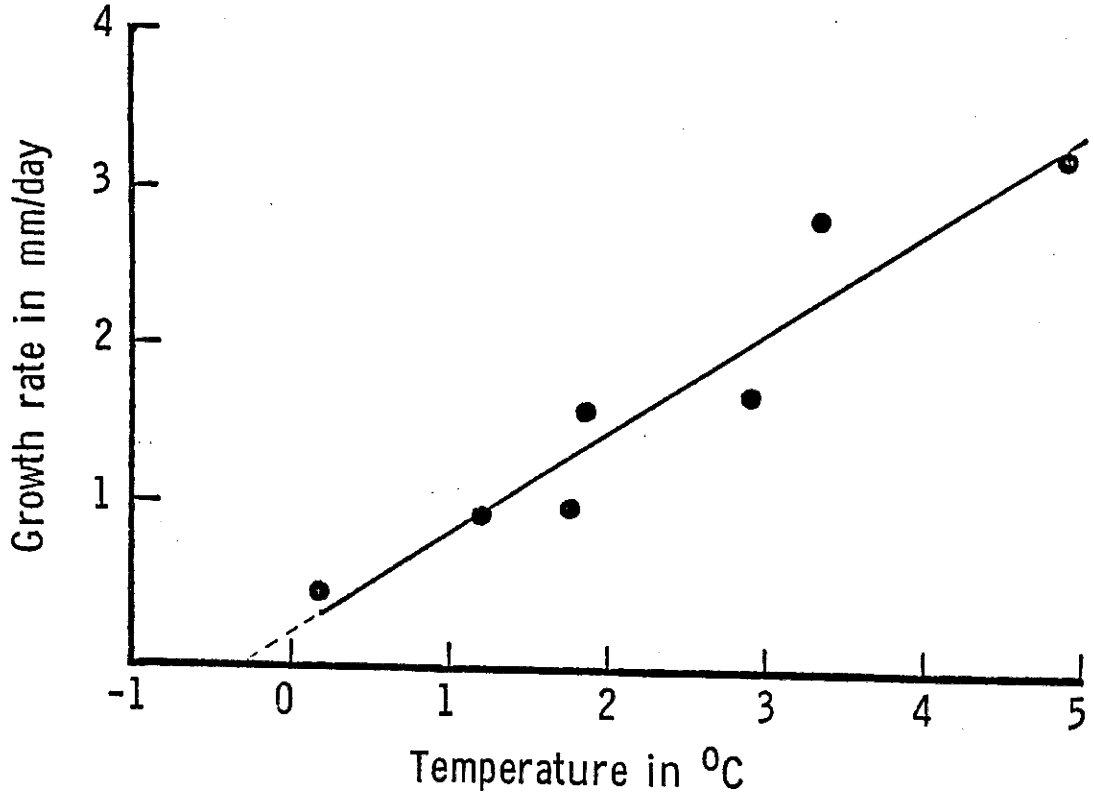

Fig. 1. Effect of temperature on the growth of the combined root and hypocotyl of swede within the range of 10 to 30 mm. Variety: 'Altasweet'.

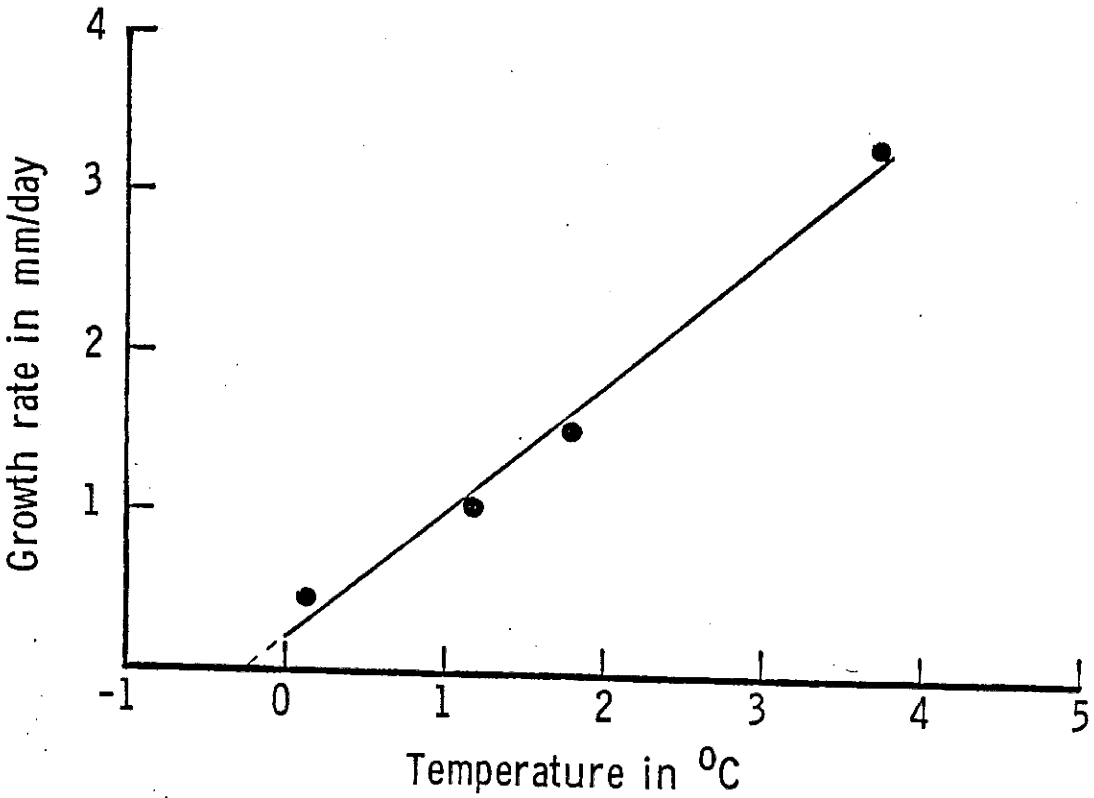

Fig. 2. Effect of temperature on the growth of the combined root and hypocotyl of kale within the range of 10 to 30 mm. Variety: 'Westlandse Winter'.

RUTABAGAS - B. napus as a Vegetable Crop

by

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Rutabagas, or swedes, the vegetable form of Brassica napus, is one of the popular vegetables grown in the short season, cooler regions of North America and northern Europe. The history of this species, resulting from a cross between forms of B. campestris and B. oleracea has been documented by Toxopeus (1979), and the recreation of this amphidiploid and other brassica species has been described by McNaughton (1976).

Although formerly used for fodder in North America, rutabagas are now only grown for use as a table vegetable. It is for this purpose that I want to discuss improvements that can be made by the breeder in producing an acceptable product for both producer and consumer. Reviews by McNaughton and Thow (1972) and Pivovarova (1979) provide much useful information on many aspects of rutabaga production.

About 4,000 ha of rutabagas are planted annually in Canada with some 1,500 ha being planted in each of the provinces of Quebec and Ontario. The remaining area planted is principally in the Atlantic provinces, with a very small area in British Columbia. Except for garden production, rutabagas are seldom grown in the prairie provinces.

Much of the crop is stored after harvest, which starts in August and continues through to November. In parts of Quebec and Ontario, plant leaves are removed prior to harvesting and the roots are mechanically harvested. In other areas, harvesting is done by hand; leaves are removed and roots are lightly trimmed before storing.

The present demand is for a smaller root about 10-15 cms and weighing 500-750 g. Some larger roots are marketed and in some areas a local demand exists for roots below 10 cm, which are sold in 5 kg lots. Roots are normally washed before sale and some are waxed, especially in Ontario.

To the Canadian consumer, three criteria appear to be of major importance in regard to the acceptability of rutabagas: 1) color of flesh - only yellow is acceptable; 2) color of skin - purple is preferred; 3) shape of roots - roots should be globe or spherical, free from side roots, cracks, etc. In addition, the flavor should be pronounced, but should not be excessively strong.

Bearing in mind that the breeder must develop a product that meets these criteria, let us turn to the producer and examine some of his problems. He is interested in obtaining the maximum yield of saleable product, either sold directly out of the field, or from storage after a period of several months. There are numerous limiting factors preventing him from reaching this goal, and they are not all amenable to a plant breeding solution. Additionally, the production of rutabagas has had to change from being highly labor intensive, to one where minimum labor inputs are used.

Two major advances in technology have helped in reducing labor costs. Firstly, chemical weed control, principally as a pre-planting treatment, has been introduced. However, there are only a few chemicals registered for this use, and they have their limitations. Ideally, a cultivar resistant to the highly effective and widely used triazines would be desirable. The production of such a cultivar is now possible since Souza - Machado at Guelph has been able to incorporate resistance found in some cruciferous weed species into rutabagas (1981). In this transfer, resistance was only obtained when the weed species was used as the maternal parent. An alternative approach - the screening of existing cultivars - has been taken by Johnston at Aberystwyth who showed that Vosega was the most resistant to desmetryne.

The second advance has been in the development of precision seeding. This gives the grower the opportunity to maximize his yield of desired size roots through optimum plant spacing. With precision seeding, the need for rapid seedling development is increased. Denton (1976) showed that a significant genotype-temperature interaction occurred when he grew several cultivars at different temperatures. The development of cultivars able to germinate and develop at low soil temperatures would be a profitable field of co-operation between the physiologist and breeder.

Losses due to seed borne diseases, or to disease and pest attacks of young seedlings, must also be controlled. Traditionally, the use of chemicals has been used for such control and little has been done in the way of incorporating such resistances into new cultivars. Breeding for resistance to rhizoctonia, a fungus which not only causes seedling loss but continues to attack the developing crop, and results in roots unsuitable for storage, appears to be a worthy objective. In England, Fletcher (1979) showed that at harvest the roots of Victory were more severely infected than were those of Acme or Peerless.

Similarly, phoma can result in the infection of seedlings, growing plants and eventually can be an important agent for root decay. Cruickshank and Smith working in New Zealand through the 50's and 60's showed differences in susceptibility of cultivars to this organism. Based on their findings that Parkside had considerable resistance, a breeding program to incorporate this resistance along with that to clubroot has led to the introduction of the cultivar TINA this year (Butel, personal communication).

I have discussed these two fungal diseases as examples of diseases which can develop during the life of the plant causing losses from seedling stage through to storage. Two bacterial diseases usually associated with storage losses are of major importance - Xanthomonas, the cause of black rot; and Erwinia, the cause of bacterial soft rot. Infection may take place earlier (indeed Xanthomonas is known to be seed borne). Bain, in the 1950's, showed differences between cabbage cultivars in Xanthomonas susceptibility, and also between various introductions of other brassica species. We have

attempted to use his seed inoculation technique to determine if differences exist between rutabaga cultivars, but so far have been unsuccessful in establishing infection. Resistance to Erwinia soft rots has been found by the Japanese and resulted in the development of the cultivar Nemuro. Our own investigations have confirmed the good keeping quality of this cultivar as well as that of Sator Otofte, and Pandur (Proudfoot, 1980).

Fortune, bred at St. John's from a cross of York and Wilhelmsburger, has shown good resistance to a complex of fungal and bacterial pathogens. We have found that with our normal growing, harvesting, handling, and storage techniques we can readily select for long storage (November to May) without artificial inoculation of organisms. Selection for freedom from growth cracking also provides a useful contribution in reducing storage losses.

Leaf diseases are less of a problem than root diseases. We have obtained differential cultivar reaction to downy mildew with Fortune appearing resistant. The Canadian cultivar Chignecto showed a high level of resistance to powdery mildew in Britain, as has Ruta Otofte. Brain and Whittington (1980), in a diallel experiment with 5 cultivars, demonstrated that resistance is initially recessive, but later in plant development was partially dominant. Chemical controls for both diseases have been successfully used.

I have left a discussion of clubroot to the end of this section of the paper - not because it is unimportant, but because I feel that it has probably been exhaustively discussed already in the Eucarpia ICWG Conference.

Recognizing that it is of major importance, and that successful chemical control measures have yet to be developed - certainly for use under our conditions - breeding for resistance continues to be the major objective of our program. The excellent review by Crute, Gray, Crisp and Buczacki (1980) covers this topic extremely well and there are just a few points in connection with breeding for resistance that I would emphasize. Firstly, we need information on how long a cultivar with race specific resistance will remain resistant. Secondly, does generalized non-specific field resistance (or tolerance) occur in B. napus or in its progenitors oleracea and campestris?

In addition, we need to stop deluding ourselves by thinking that races usually occur singly, e.g. Ayers (1972) and Linnasalmi and Weisaeth (1978) both found mixtures of races in the one field. The need for establishing a cut-off point in population studies supports such findings, though lack of purity of host plants also leads to confusion in interpreting results.

In connection with the transfer of one or more genes for clubroot resistance from B. campestris cultivars or the E.C.D. set, we should not forget that we are also transferring genes for other characteristics, which may or may not be desirable. My experience with Ayers' hybrids, in which the resistance of Gelria to races 1 and 4 was transferred into the York x Wilhelmsburger cross, shows that susceptibility to leaf eating caterpillars, to root maggot injury as well as poorer storage ability and self-incompatibility, were also present in the hybrid derivatives. In our storage evaluation trials last year, the New Zealand cultivar Kiri of similar origin to Ayers' material displayed poor storage ability.

Clubroot may be regarded by some as the most serious problem for rutabaga production, but it has a strong competitor in root maggots (cabbage and turnip root fly larvae) - pests which have engaged the attention of the entomologist for even longer than the 100 years during which plant pathologists have been studying clubroot.

Our industry in North America, and I suspect yours in Europe and elsewhere, depends heavily on the use of chemicals to reduce larval populations to a level where damage is minimal. I have mentioned the susceptibility of some B. campestris genotypes to injury, but differences between cultivars of B. napus have been reported, e.g. by Swailes (1959) who found that Wilhelmsburger was the most resistant cultivar tested. This year we are examining a number of cultivars and breeding lines with the hope of isolating resistant roots which could be used in a breeding program. The resistance of insects to chemicals appears inevitable and breeding resistant cultivars less susceptible to injury is an acceptable way of reducing our total dependence on chemicals.

Other insect problems tend to pale into insignificance compared to the root maggot problem. Control of aphids for reducing both virus infection and direct yield losses has been obtained in New Zealand by developing resistant cultivars. Development of virus resistant lines has been undertaken at the N.V.R.S. and in Quebec where Doucet was able to select out of the old American variety Macomber plants resistant to T.M.V.

There are few references to other insect problems in rutabagas but our experience confirms that in general leaf damage from caterpillars is much less than in B. campestris. Svads (1980) has recently shown that leaves of Wilhelmsburger were much less susceptible to injury by larvae of the cabbage white butterfly than were those of other cultivars where Sator Otofte was the most susceptible.

I want to spend a few minutes discussing quality of roots and to point out that it should be possible to develop cultivars with consumer appeal and of a higher nutritional value than presently occurs in existing cultivars. Dry matter contents can be increased - we know that variation within napus exists, e.g. N.I.A.B. Leaflet No. 6 (1979) shows Sator Otofte with 10.4% DM and Doon Major with only 8.0%. The vitamin C contents of roots of different cultivars are known to be variable and our studies have shown Wilhelmsburger to have 73 mg/100 g as compared to York with 41 mg/100 g total ascorbate (Proudfoot and Haard, unpublished). Two lines from a cross of cultivars York and Wilhelmsburger had 44 and 56 mg/100 g, respectively. It is of interest that Wilhelmsburger has been recommended in the UK for processing as it discolors much less after peeling than other cultivars (Round and Davies, 1976). Lack of boron results in the characteristic water core or brown heart and differences in cultivars have been reported (Hansen, 1948). The acceptability of cultivars as measured by a taste panel resulted in selection of the cultivar Altasweet which only differed from other cultivars in having a higher soluble solids content (Cumming and Chipman, 1977).

Concern has been expressed at the presence of certain glucosinolate compounds in rutabagas. Mullin (1980) showed that the cultivar York was extremely high in goitrin, and this finding has recently been confirmed by Jurges & Robbelen who suggest that a seed selection technique for low glucosinolate content is feasible. Our survey of a number of rutabaga and turnip cultivars showed that extreme variability existed for several nitrile and isothiocyanate derivatives. Techniques similar to those used in the breeding of double zero rapeseed cultivars await to be developed for use by vegetable breeders.

Normally, individual roots of rutabagas are fully self-fertile but it is suspected that some between plant pollination occurs during seed multiplication. Traditionally, breeding has consisted of intercrossing selected parent plants and after several generations of selfing the resulting progeny are assessed for yield. Disease testing, and selection for shape, etc., is usually carried out during early generations. Pedigree or mass methods of breeding have been used.

Performance of inbred lines selected from individual cultivars has been investigated by workers at the SPBS. Following on from this approach, hybrid vigor has been demonstrated in intercrosses of selfed lines of diverse origin. Commercial development of hybrid vigor is still awaited, though a suggested scheme utilizing self-incompatibility was proposed by Gowers in 1974. However, the introduction of self-incompatibility, along with clubroot resistance, from B. campestris offers a considerable range of S alleles which could make this method more attractive. The use of cytoplasmic male sterility in brassica species has been studied by Bannerot, and other workers, particularly those in Japan (Shiga, 1980), but again this method has as yet not been widely used in production of commercial cultivars.

The biennial nature of B. napus has hampered the speed at which cultivar development can be undertaken. The use of controlled temperature conditions to induce flowering has been investigated by Gowers and others at S.P.B.S. (1979). Unfortunately, if selection for desirable root shape is to be undertaken at an early stage in the breeding program, such methods appear to have limited application.

More recently the use of haploids, or production of homozygous diploids (doubled haploids), derived from anther cultures have been suggested as rapid means for producing new cultivars. The work of Keller, Sacristan, Ingram and others in developing cell culture techniques suitable for large scale production of plants, along with the use of mutational agents suggests that it may well be possible to produce plants that are resistant to disease, or to herbicides or with specific nutrient requirements.

Certainly, the future looks bright for improving this crop - at least we can be sure that there are no shortage of problems which may be amenable to solution through plant breeding!

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BIOSYSTEMATIC STUDIES IN THE BRASSICA OLERACEA GROUP

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Ancient literature reveals that the domestication process of B. oleracea s. lat. started very early (for references see Toxopeus 1974). Theophrastos (370 - 285 B.C.) makes clear that several different edible coles were cultivated in Greece. At that time not only primitive forms with a much-branched habit, similar to the wild species of Greece, but also more domesticated forms resembling stem kales and types with curly leaves were already in cultivation. In some regions at least domestication probably started with the collection of seeds or cuttings of wild species growing close to human settlement, and which were sown or planted in cultivated ground. The leaves were probably used both for human consumption and for feeding domestic animals. In some cases very primitive cultivars and to a limited extent also wild species are still in cultivation, for example in some of the Aegean Islands very primitive kales, much resembling wild B. cretica, are grown. In Yugoslavia primitive forms, more resembling wild progenitors than modern cultivars, have been observed (Gustafsson 1979). Thus even in ancient times more or less wild and cultivated forms of varied origin were brought together, which at least to some extent resulted in hybridization and introgression followed by natural and human selection. Some of the present cultivars are probably products of allogenous transformation (Mayr 1963) leading to reticulate evolution, while others have evolved more directly from a particular progenitor. However, information on the origin of the different cultivars is restricted and to some extent also contradictory.

To increase our knowledge of the B. oleracea group a biosystematic investigation was started in 1974 under the direction of Professor S. Snogerup (Institute of Systematic Botany, University of Lund, Sweden). The main aim of the research programme, which includes taxonomy, morphological variation and crossing experiments, is to elucidate the biological and phytogeographical differentiation between wild species and their relationship to cultivated forms.

The wild species

The B. oleracea complex is a polymorphic aggregate of species with the chromosome number 2n=18. All the species are perennial and inhabit maritime cliffs

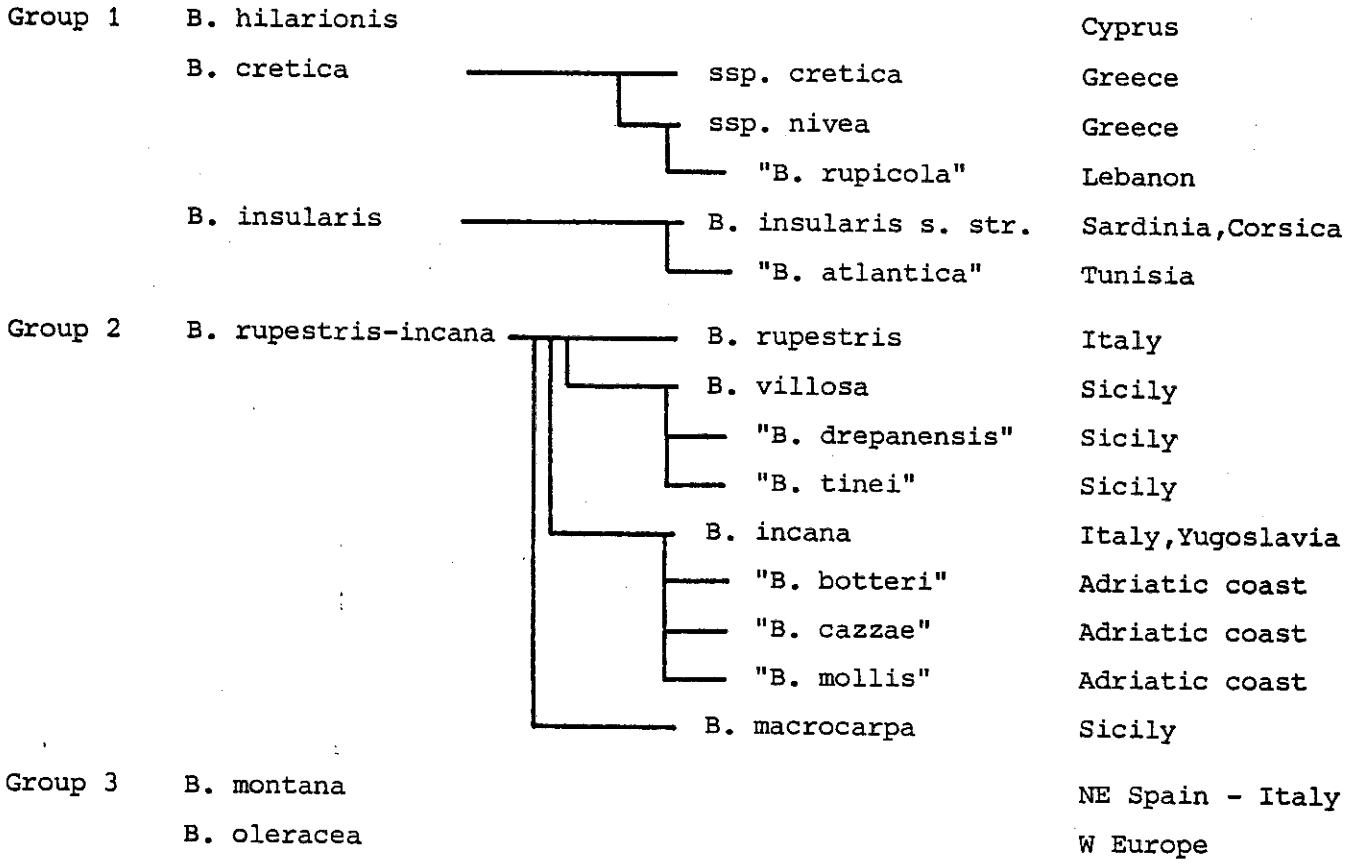

Table 1. Supposed phylogenetic relationship between the wild taxa of the Brassica oleracea group (2n=18) and their distribution.

or rocky islets. The delimitation of the group varies considerably from one author to another (for references see Snogerup 1980) and the various taxa have mostly been included in B. oleracea s. str. However, biosystematic studies show that the complex is composed of quite distinct species or species groups which are distributed regionally. The phylogenetic relationship is still somewhat uncertain, but the current view is presented in Table 1. The species of the first group (B. hilarionis Holmb., B. cretica Lam., B. insularis Moris.) are characterized by a woody much-branched habit and glabrous, fleshy and stiff leaves. The taxonomically difficult B. rupestris - incana group is characterized by the tendency to form a tall main stem with an apical inflorescence before further branching occurs. The leaves are large, petiolate and have a weak structure. Hairs are present on the seedlings, but adult plants of most taxa are rather hairy too. B. montana Pourr. is a shrubby perennial, with lobed green leaves which are glabrous or sometimes slightly hairy. It is a taxon of doubtful origin and affinity. B. oleracea L. differs from other species in the special greyish-blue surface of the leaves. The whole plant is quite glabrous. The taxa are presented in greater detail in Gustafsson (1979) and Snogerup (1980).

Differentiation pattern

The speciation of the complex can be characterized as allopatric and the re-

latively wide morphological variation is the result of a combination of local and regional differentiation. In most regions of the total area of distribution the species consist of spatially isolated populations which are small in both numbers and area. Isolation and local adaptation has often given rise to morphologically distinct populations which form a regional taxon together with morphologically similar adjacent populations. However, on Sicily, where several taxa of the rupestris - incana group occur more or less sympatrically, the differentiation pattern can be influenced by hybridization and introgression. The reproductive isolation is generally weak and transitional form-series between B. villosa Biv. and B. rupestris Rafin. have been observed.

Crossing experiments

Crossing experiments have been performed on a large scale in order to investigate differences in crossing ability and to derive information on the prospects of gene transfer from one species or cultivar to another. About 700 crosses have been made, both representing intraspecific and interspecific combinations.

Crosses are readily performed between all species and the germination of hybrid seeds is high. In F_1 the vegetative and generative development is usually normal. Most hybrids have the chromosome number 2n=18, only single cases of deviating numbers occur (2n=17, 27, 36). Information on meiosis is limited (see Gustafsson et al. 1976), but available data indicate that meiotic disturbances can often be traced back to secondary pairing or to its consequences. The breeding barriers between populations and taxa are probably caused chiefly by genic or microstructural differences rather than by major chromosomal differences. Only in some cases of much reduced fertility in hybrids do translocations seem to be involved.

Fertility in intraspecific crosses: Male fertility (% morphologically good pollen) is generally high (>90%), but highly reduced fertility (c. 50%) has been observed in crosses between populations of B. cretica ssp. nivea and in crosses between Sicilian and Yugoslavian populations of B. incana.

Fertility in interspecific crosses: The results are summarized in Fig. 1. Some general conclusions can be drawn, although the variation is fairly wide in most combinations. The interfertility in crosses between the Sicilian taxa is high. Crosses between the rupestris - incana group and other species generally have highly reduced fertility, while other crossing combinations show only slightly reduced (70-90%) or high (90-100%) fertility values.

Crosses between wild species and cultivars: The cultivars used have been chosen to represent forms that differs as much as possible. The main amplitude of variation in fertility is summarized in Table 2. Generally speaking crosses between the cultivars and B. oleracea and B. insularis respectively show fairly high fertility values, while most crosses involving B. montana and B. macrocarpa have low fertility values. B. alboglabra deviates from the other cultivars in

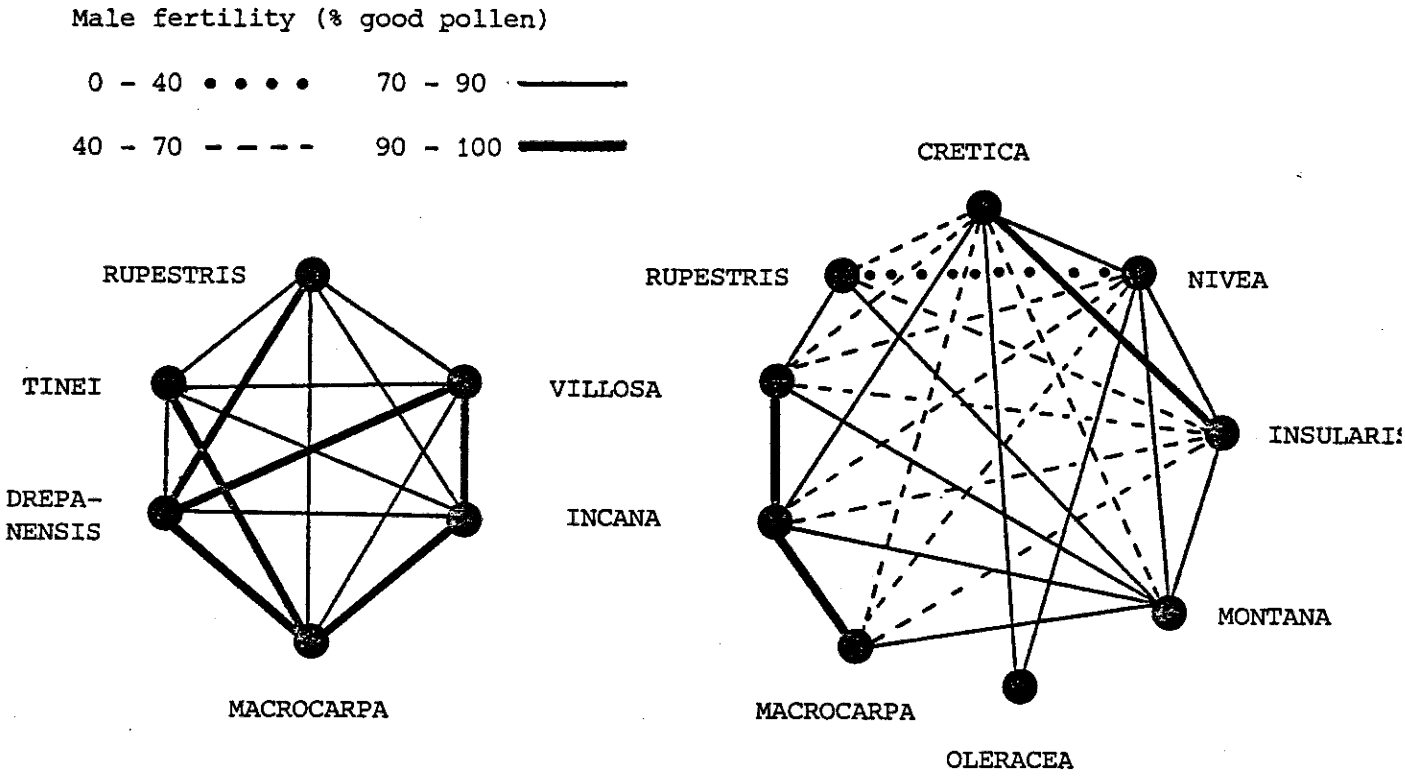

Fig. 1. Crossing polygons indicating mean fertility values (F_1) in crosses between the wild species of the Brassica oleracea group.

Wild species	Cultivar: Broccoli	Cauliflower	Cabbage	Green kale	Kohlrabbi	Marrow stem kale	B. alboglabra
oleracea	90-100	-	90-100	-	-	-	-
insularis	70-90	70-90	90-100	70-90	70-90	90-100	70-90
cretica	70-90	70-90	70-90	70-90	70-90	70-90	40-70
rupestris-incana	70-90	40-70	70-90	70-90	70-90	70-90	40-70
montana	70-90	40-70	40-70	70-90	40-70	-	40-70
macrocarpa	40-70	40-70	40-70	90-100	40-70	40-70	40-70

Table 2. Male fertility values in crosses between wild species and seven cultivars. The figures indicate the variation amplitude observed in F_1.

having low fertility values in most combinations.

In F_2 the majority of the hybrids are vigorous, but show wide variation in fertility. In some F_2 families deceased, and in others restored, fertility have been observed but more data are needed before any certain conclusions can be drawn.

The results of the crossing experiments indicate that (1) breeding barriers resulting in reduced hybrid fertility, exist between some of the wild species but not between others; (2) male fertility and seed setting is variable in both F_1 and F_2, but in most combinations sufficient to allow the production of further hybrid and backcross generations; (3) in most cases genes or gene blocks, which are valuable from an agricultural point of view, can be transferred from wild species to different cultivated forms.

Origin of cultivated forms

Most previous authors believe that the cultivars have a monophyletic origin, viz. from wild western European B. oleracea (for references see Snogerup 1980). It is true that several cultivars show morphological traits which are also found in B. oleracea. But on the other hand, many cultivars show morphological characters which are found in other wild species. The development of a tall main stem, the apical inflorescence and the presence of hairs on the seedlings are typical of the B. rupestris - incana group, but these characters also appear in the stem kales. The shrubby habit, the mode of branching and the fleshy leaves of B. cretica are also found in bush kales. This and other information indicates that the cultivars are probably of polyphyletic origin. But hybridization, introgression and backcrossing, planned or spontaneous, have certainly played an important part in the evolution of the present-day cultivars. However, backcrossing towards B. oleracea or cultivars derived from wild oleracea, which has probably occurred frequently, makes it difficult to discover other points of origin.

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THE UTILITY OF MALE STERILITY IN CAULIFLOWER

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1. Introduction

The title prompts at least two questions:
- will cauliflower hybrids be of much value in practice and (if so),
- is male sterility of much use for the production of hybrid seeds.

The utility of cauliflower hybrids is a moot point. Some specialists are in favour o (at least trying) them, namely:
- Y.Hervé, cauliflower breeder of INRA in Rennes, France (personal communication).
- Mrs. J.Hoser - Krause, research worker in Skierniewice, Poland (J.HOSER-KRAUSE, 1978).
- R.F.Murphy, research worker in Dublin (R.F.MURPHY, 1981).
- M. Nieuwhof, former research worker on cole crops, Wageningen, The Netherlands (M.NIEUWHOF, 1974).

Cauliflower hybrids are available from Takii Seeds, Japan. Dutch Seed Firms also are interested.
Some people do not have definite preference for the breeding of hybrids, namely:
- P.Crisp, research worker in Wellesbourne, U.K. (A.R.GRAY and P.CRISP, 1977).
- Frau Prof. Garte in Rethmar, German Federal Republic (ANONYMUS, 1977).

Obviously the breeding of hybrids is not unanimously seen as the best method for the improvement of the cauliflower crop, but quite a few people prefer to explore this breeding area.
In my opinion hybrid varieties could be outstanding in respect of combining the following most important characters: high field, uniformity and stability.

2. Self-incompatibility or male sterility.

In cauliflower both phenomena occur.
Broadly speaking male sterility deserves preference over self-incompatibility. For cole crops the two systems (if available) are equally useful (Q.P. VAN DER MEER and M. NIEUWHOF, 1968).
In cauliflower self-incompatibility is of limited importance because a high percentage of plants show a high level of self-compatibility. Introduction of genes for strong self-incompatibility will be much more time consuming and costly than the introduction of cytoplasmically determined male sterility (if available).

3. Male sterility.

Initially the availability and utility of male sterility were very limited because only chromosomally determined male sterility (of the vestigial type) was found (J.R.JENSMA, 1957).
Later environment-dependant (temperature, day length) male sterility was found by Engel and by Nieuwhof (P.WILLIAMS, 1974; M. NIEUWHOF, 1968). The use of this type seems unappealing because the realization of constant temperatures and day lengths is very costly.
Also a strong gametocidal effect of gibberellins was found (Q.P. VAN DER MEER and

R. VAN DAM, 1979). However the long flowering period of cauliflower and the adverse effect of gibberellins on seed yield are serious handicaps.
The possibility of large scale vegetative propagation of plants possessing chromosomally determined male sterility and the male sterility obtained as a result of species crosses seem to be the most promising recent developments.
Vegetative propagation of male sterile plants has its limitation because for many experimental hybrids and, for sufficient diversity, many male sterile clones will be needed. Mainly because of higher costs this method will always be inferior to a cytoplasmic male sterility system.
Recently several research workers succeeded in obtaining male sterile material by species crosses. Pearson (Cornell, New York State) crossed B.nigra with B.oleracea. Bannerot (Versailles, France) crossed male sterile Raphanus sativus with B.oleracea and Chiang (St.Jean, Canada) crossed B.napus with B.oleracea. At our request these research workers kindly sent us off-spring seeds of these crosses. We also received male sterile broccoli from Dickson (Geneva, New York State) and male sterile B.napus from Shiga (Yatabe, Japan).
Up to now our experiments have yielded the following results:
In a large collection of autumn cauliflower varieties we found only a very low frequency of maintainer genes in respect of the male sterile material from Pearson and Dickson. A small number of pair crosses did not yield maintainer lines. Further drawbacks were relatively small flowers of the Pearson material and malformated siliques of the Dickson material.
Very probably the chilling phenomenon of the Bannerot material is well known. We tried to find restorers of this phenomenon in (again) a large collection of autumn cauliflower varieties. We could make some progress. Oze White Top gave the best results, however, the second backcross to this variety did not show much progress.
From Shiga we received male sterile material of the swede rape variety Bronowski. Plants of this stock, being not completely male sterile,were pollinated (in the open) with cauliflower. No plants were obtained that could be napus-oleracea hybrids.
In May 1980 we received material from Chiang.
Only the (B, A-1 ms x Snow Crown) material - being B_2 material of the cross B.napus x B.oleracea - reached the flowering stage in 1980 (September). The first flowers of some plants showed some pollen shedding, but later all flowers were completely male sterile. Pollination was realized with the Flora Blanca variety. The offspring - B_3 - started flowering in August 1980. Most plants, flowering in a greenhouse, produced some pollen.
The (B_1 - 20 x A_1 CT) A x A_1 CT - being B_3 material of the cross B.napus x B.oleracea (4 n) - only flowered in March 1980 in a greenhouse and later on in the open. This material was completely male sterile. This material was also pollinated by cauliflower. The offspring will be investigated in 1982.
All the Chiang material was free from chilling.
From this material we hope to derive the male sterile plant type we need for hybrid seed production. For this purpose the following characters are essential:
- Stable, completely cytoplasmically determined and generatively reproducible male sterility showing clear symptoms.
- No chilling or other cytoplasmically determined off-characters.
- Good female fertility.

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COMPARISON OF STIGMA PROTEINS FROM BRASSICA OLERACEA BY ISOELECTRIC FOCUSING WITH REFERENCE TO S-ALLELE SPECIFICITY

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Introduction:

Self-incompatibility is a useful tool in F_1-hybrid breeding in Brassica oleracea. Identification of S-alleles of parental lines however by seed set or pollen tube observation after test pollinations means a laborous procedure. Therefore breeders are interested in simple methods for S-genotype determination. In recent years several attempts were made to obtain informations on the molecular level of self-incompatibility reactions between pollen and stigma. Studies of stigmatic homogenates have revealed that S-specific proteins exist in Brassica which are detectable by immunochemical methods (NASRALLAH, 1979). Many S-genotypes produce differential glycoproteins that can be separated by polyacrylamide IEF[1] (NISHIO + HINATA, 1977a, 1977b, 1978, 1980; HINATA + NISHIO, 1978). S-specific electrophoretic patterns are proposed to be useful for identification of multiple alleles at the S-locus (NISHIO + HINATA, 1980).

Some S-genotypes, however, failed to show specific S-correlated bands after electrophoretic separation (NISHIO + HINATA, 1971a, 1980).

For this reason own experiments were carried out to perform IEF analyses of stigma extracts of Brassica oleracea, adapting a sensitive staining procedure for visualisation of proteinacious molecules (ALLEN, 1980). Attempts have been made to compare genotypes of botanical varieties of Brassica oleracea with known and unknown S-genetic background. Additionally, the patterns of S-allele markers in stigmas were studied during floral development in order to check S-specificity of distinct bands.

Material and methods:

Stigmas were collected from several genotypes of Brassica oleracea of various botanical varieties homozygous for the following S-alleles:
S2, S5, S6, S7, S12, S13, S14, S15, S16, S22, S23, S24, S25, S28, S29, S32, S36, S45, S50. S-allele numbers are those of K.F. THOMPSON, Plant Breeding Institute, Cambridge, England. Clones (kindly supplied by Gemüsezuchtgenossenschaft Marne, FRG) were used which partially derived from international test material, mainly representing kale types (B. oleracea var. acephala). Other material consisted of inbred progenies obtained from commercial varieties of the cabbage type (B.oleracea var. capitata). Finally,selfed progenies segregating for S-alleles and individuals of open pollinated varieties were studied.

Usually stigmas were prepared from opened flowers without anther dehiscence. In some cases they were collected during floral development, that means from fully closed buds, "yellow" buds, flower at anthesis and flowers after anther dehiscence.

Stigmatic extracts were subjected to isoelectric focusing on polyacrylamide slabs in a pH range from 3.5 to 9.5. Analytical details are given in the tables 1 and 2.

1) Abbrevations: IEF, isoelectric focusing; PAS, periodic acid-Schiff reagent; FITC-Con A, Concanavalin A-fluorescein isothiocyanate

After focusing proteins generally were stained by a silver-diamine method. The results were compared with Coomassie, PAS or FITC-Con A procedures for protein or glycoprotein staining, respectively (Table 2).

Table 1: Isoelectric focusing of stigma extracts from Brassica oleracea

Gel compostition:	Polyacrylamide, T = 5 %, C = 3 %
pH-range:	3.5 - 9.5; 3.5 - 10 (LKB-Ampholine, Sweden)
Slab:	0.3 x 115 x 200 mm
Sample:	10 - 20 µl
Staining procedures:	Proteins: Silver-diamine (ALLEN, 1980); Coomassie R-250. Glycoproteins: PAS; FITC-Con A (NISHIO + HINATA, 1980).

Table 2: Preparation of stigma extracts from Brassica oleracea for isoelectric focusing

25 (50) stigmas (freshly prepared or frozen),

↓ add 70 µl 5 mM potassium phosphate buffer pH 6.0 (containing 2.5 % sucrose and 0,1 % ß-mercaptoethanol) (PIETSCH, 1980)

homogenize in an "Eppendorf"-micro tube,

↓ add 70 µl 1.2-dichloroethane, mix,

centrifuge (3000 x g, 15 min, 4° C),

↓

use supernatant for IEF.

Results and discussion:

Isoelectric focusing of stigmatic extracts followed by sensitive silver-diamine staining of proteins revealed distinct banding patterns for different S-genotypes. Visualisation of proteins with Coomassie and also staining glycoproteins by PAS and FITC-Con A reactions, however, decreased number of bands leading to insufficient characterization of some S-homozygotes (Fig. 1 and Fig. 2). The technique applied was suitable to detect differences between plant families raised from selfed species segregating in S-alleles. The procedure was applicated, too, to describe breeding stocks by means of their differential stigmatic proteins. The individuals of vegetatively propagated genotyps showed identical results after focusing. In some cases, however, different patterns were obtained from genotypes of various sources which were assigned to have identical S-allele constitution, but belonged to distinct varietal types. Further studies including re-estimation of S-genotypes of research material by test pollination are required to establish whether S-proteines may be modified by a varying genetic background.

Patterns of stigmas analyzed due to floral development showed a gradual increase in protein concentration when samples, prepared of youngest buds were compared to those of flowers after anther dehiscence. The physiological shift from self-compatibility of immature stigmas to incompatibility exhibited by fully developed flowers was not reflected by an abrupt appearance of single S-specific bands after IEF, as has been reported for some Brassica genotypes (NISHIO + HINATA, 1977).

So the question remains still open wether the proteins species which can be extracted from stigmatic homogenates generally represent S-specific (i. e. S-functional) molecules directly involved in incompatibility reactions between stigma and pollen. On the other hand IEF analysis of stigma components gives valuable information to the breeders when the banding pattern is used as a characteristic S-marker for the specific breeding line.

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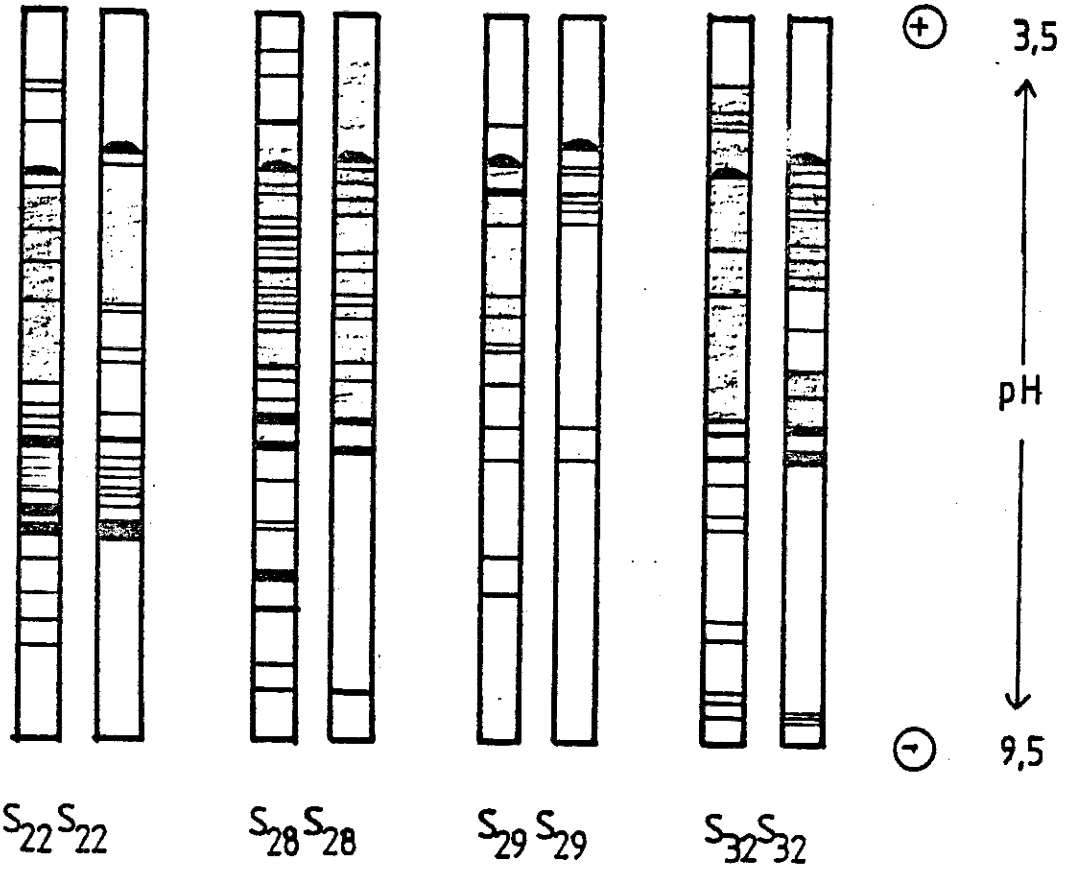

Fig. 1: Isoelectric focusing of stigma extracts from Brassica oleracea S-homozygotes. Comparison of protein staining procedures: silver-diamine (left), Coomassie R-250 (right)

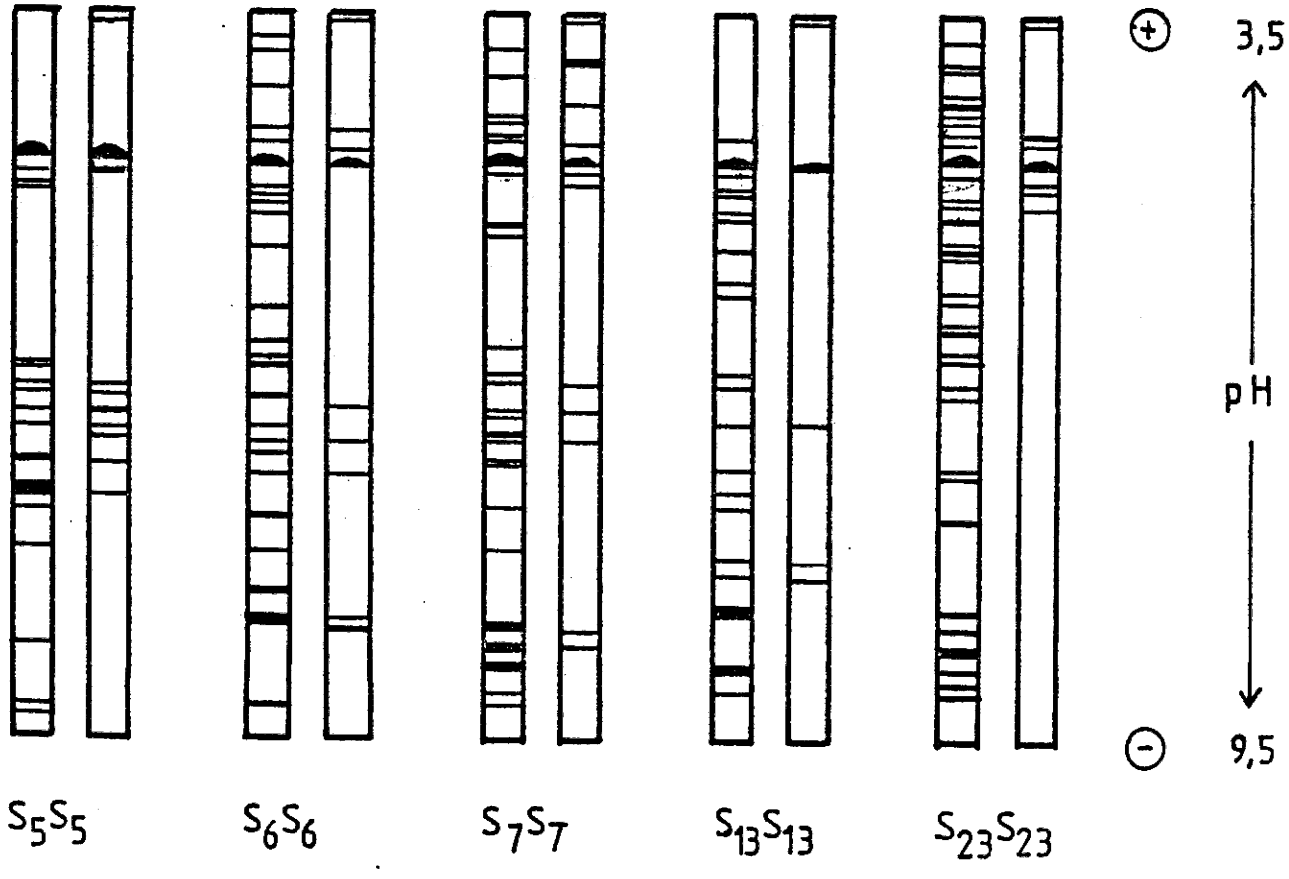

Fig. 2: Protein (left) and glycoprotein (right) banding patterns after isoelectric focusing of stigma homogenates of Brassica oleracea homozygotes detected by silver-diamine staining (left) and PAS reaction (right)

ALLOZYME FREQUENCIES AND THE ASSESSMENT OF GENETIC DIVERSITY IN BRASSICA CAMPESTRIS

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Introduction

Biochemical markers that can be analysed rapidly and are readily identifiable are an attractive tool for breeding and research. For example, in B. oleracea, certain acid phosphatase allozymes present either in seed or leaf extracts, are used routinely for determining sib frequencies in many F_1 hybrid cultivars. The identification and genetic control of acid phosphatase allozymes in seeds was described by te Nijenhuis (1971) and Wills, Fyfe and Wiseman (1979) and in cotyledons by Wills and Wiseman (1980).

The occurrence of apparently homoeologous loci in B. campestris and their expression in the amphidiploid B. napus was discussed by Wills (1979). This paper presents more detailed information on the frequencies and distributions of acid phosphatase allozymes within B. campestris cultivars and discusses the application of isoenzyme studies to the genetic structure and history of the species with special regard to the assessment of genetic diversity in conserved population samples.

Materials and Methods

Seeds were obtained from a number of commercial and other sources. Cultivar names used are those given by the supplier. Most samples were grown only for about four weeks before being discarded and so cultivar identity and chromosome numbers have not been confirmed.

Extracts of individual seeds or seedlings were separated by electrophoresis and stained for acid phosphatase as described by Wills, Fyfe and Wiseman (1979) and Wills and Wiseman (1980). Allozyme bands were characterised by their mobilities relative to brilliant yellow. Various sample sizes were used, ranging from 20 to 223.

Results

Seed extracts of 28 cultivars gave a total of 7 bands with mobilities of from 0.36 (band a) to 0.28 (band g). Individual seeds yielded either one or two bands. This pattern of band occurrence in cultivars, taken with analyses of segregating self and cross families indicate that each band is under the control of an allele at a single locus. The gene is denoted acp-1. A weaker staining zone with greater mobility and also an intensely staining zone near the sample origin were not considered to be associated with this locus.

Cotyledon extracts of 37 cultivars gave either a single band or an equispaced triplet. As in B. oleracea, the two distal bands of a triplet corresponded to parental bands while the intermediate one results from the dimeric structure of the enzyme. Altogether 10 bands were found with mobilities of from 0.78 (band a) to 0.58 (band j) - a much greater range of mobilities than that in B. oleracea. Many selfs and crosses have been made to test whether these bands are all allozymic. The tests are not yet completed but the available results suggest the occurrence of two possible complications. Firstly that a null allele might exist, leading to misclassification of heterozygotes as homozygotes and secondly, that band h may have a slightly different mobility in some heterozygous combinations than in others. For the purpose of this paper the silent allele and the possible band shift have been ignored and it is assumed that there are 10 active alleles. The gene is denoted acp-3 by analogy with the homoeologous acp-3 of B. oleracea.

To test for possible linkage between the two loci, seeds of a self and a cross family from parent plants of known genotype were split in half. One half of each was analysed for acp-1 and the other half, containing the embryo, was germinated and seedlings analysed for acp-3. Results (table 1) for the self family show that each gene gave the expected 1:2:1 ratio and that they were independently inherited.

Table 1. Joint segregation of acp-1 and acp-3 allozymes in a self-family

		acp-1			
		cc	cf	ff	
acp-3	aa	3	22	8	33
	ah	20	38	11	69
	hh	13	14	7	34
		36	74	26	136

acp-1 chi-squared (2 d.f.) 2.53 P>0.20
acp-3 " " (2 d.f.) 0.04 P 0.98
linkage chi-squared (4 d.f.) 1.50 P>0.80

These results are similar to those obtained for B. oleracea, where it was also possible to show that the incompatibility locus was not linked to either gene (Wills and Wiseman, unpublished).

Table 2. Proportions of cultivars in which individual bands occurred

band acp-1 (seed)	a	b	c	d	e	f	g
28 cvs	0.11	0.25	0.64	0.64	0.75	0.46	0.29

band acp-3 (cotyledon)	a	b	c	d	e	f	g	h	i	j
37 cvs	0.27	0.08	0.38	0.08	0.95	0.03	0.03	0.59	0.27	0.03

Table 2 gives the relative frequency in a range of cultivars of allozymes of both genes. Some such as acp-1^c, 1^d, 1^e and acp-3^e and 3^h are frequent, being found in most cultivars, while others like 1^a and 3^f, 3^g and 3^j are rare. The actual number of bands found in each of a number of cultivars is given in table 3. The cultivars were chosen to illustrate the extremes of variability in turnips differing in flesh colour and use, in oil-seed forms and in Chinese cabbage.

Table 3. Numbers of acp-1 (seed) and acp-3 (cotyledon) allozymes in a range of cultivars

	acp-1	acp-3
The Bruce	6	7
Snowball	6	5
Debra	4	5
Golden Ball	3	2
Tokyo Cross	2	2
Civasto	4	3
Appin	2	2
Solo	5	2
Rapido	4	2
Dark Fan Leaf	3	3
Granaat	2	2
Nagaoko King F_1	1	1

Older turnip types such as Snowball and The Bruce have the most variation and this does not appear related to flesh colour. Loss of variability is

obviously related to breeding activity, the least variable being F_1 hybrids and cultivars obtained by crosses between two individual plants. The process of erosion can be further illustrated by comparisons of the genotypes of certain cultivars with those from which they were bred. Thus in breeding Brimmond from The Bruce the number of seed allozymes was reduced from 6 to 3, and in breeding Findlay from The Wallace it was reduced from 4 to 2.

Similar erosion also occurs when a cultivar is multiplied from small numbers of selected plants. Reduction is, of course, intentional in respect of variation which is regarded as undesirable for crop uniformity. In five different samples of The Wallace the frequency of band 1^a had the greatest value of 0.088 in one sample and was 0.0 in two others. Sample sizes were small, varying from 36 to 60, but it was also possible to show that the samples differed significantly in both allele, and band frequency (chi-squared for 16 d.f., 33.24, $P<0.01$; and 54.72, $P<0.001$ respectively).

Larger samples of Snowball and Debra were analysed for acp-1 and acp-3 and the hypothesis that alleles were in Hardy-Weinberg equilibrium was tested by chi-squared. A correlated value of chi-squared was obtained by pooling all classes with an expectation of less than 5. For Debra acp-1 chi-squared was 58.61 (3 d.f.) and probability <0.01, while acp-3 gave a chi-squared of 7.07 (3 d.f.) and probability >0.020. Probabilities were non-significant for both loci in Snowball. The poor fit for Debra seed allozymes may have been due to misclassification of 1^{cd} heterozygotes. Recalculating chi-squared on this assumption gave a value of 1.57 (2 d.f.) with probability >0.30.

When selfing and random outcrossing both occur in a population the proportion of homozygotes is expected to be greater than when there is only outcrossing. The model for equilibrium proportions given by Marshall and Weir (1979) was fitted for allele frequencies in the Debra and Snowball samples. It was found that the proportion of selfing that minimised the chi-square test for goodness of fit was 20% for each locus in Snowball and 10% for acp-3 only in Debra.

Discussion

The need for genetic conservation of the brassica crop species was clearly recognised in discussions (unpublished) at the Eucarpia 'Cruciferae 1979' Conference. Genetic conservation has been defined as "the collection and systematic preservation in gene resource centres of as wide a representation as practicable of the genetic variation within those plant species upon which man depends, including samples of their endangered wild progenitors and relatives" (Brown, 1978).

The important brassica materials to be conserved include land races and old cultivars, and populations of wild relatives. Collection and conservation do not present major difficulties, provided that the necessary facilities are made available and that the desirable materials still exist; but the assessment of the level of genetic variation within a sample is more difficult. Some targets with immediate relevance to breeding problems can easily be specified, for example screening for incompatibility alleles or disease resistance, but these measure only a small part of the total genetic variation and require considerable resource inputs. A number of mendelian genes are known in B. oleracea (Wills, 1977), although they are rare, and few have been described for B. campestris. Although there is marked morphological variation in the latter species it is probable that many genes are involved and their interactions are not fully understood. For these reasons a useful measure of the genetic variation within a sample cannot be obtained from the assessment of morphological markers.

By contrast, an analysis by electrophoresis of protein variants can be used to obtain estimates of genetic variation from many samples at low cost compared to field plot assessments. Thus, although the data presented for acid phosphatase allozymes relate only to two loci, the results indicate that allelic ranges and frequencies can be used to characteristic cultivars and to reveal

something of their breeding structure. For example, The Bruce and Snowball showed the greatest number of alleles at both loci and there were progressive reductions down to two or even one allele at each locus in hybrid cultivars. Also, The Bruce and The Wallace were the only cultivars in which the rare allele acp-1^a was found and Appin the only one to have 1^g. Similarly acp-3^f was recovered only from The Bruce and 3^j only from Tokyo Cross. Alleles at these loci can be regarded as genetic markers of chromosome segments, and alleles that are rare in the species as a whole but relatively frequent in certain cultivars or populations are therefore of particular interest.

Further treatment of the detailed results of allozyme analysis would permit the construction of appropriate statistics, for example an index of genetic distance or genetic diversity, as further aids in describing the genetic structure of the species. In addition investigations of other enzymes, such as esterase, and other procedures, such as isoelectric focussing, have shown that data could be assembled for additional polymorphic enzyme loci that would considerably increase the measured range of variation and thus the proportion of marked chromosome segments within the genome.

Acknowledgements

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BREEDING OF EARLY CABBAGE ADJUSTED FOR CULTURE UNDER PLASTIC TUNNELS

By

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In recent years early production of cabbage grown under plastic tunnels has received considerable attention in Norway, especially in the southernmost parts of the country. By this method of cultivation the seeds are usually sown about the 10th of February in small pots. The seedlings are kept in glasshouse for about 6 weeks. They are then transplanted to the field and covered with plastic tunnels for about one month. In order to be able to market the yield as early as possible, early and uniform varieties with as high yielding capacity as possible are highly required.

Among the varieties available in the 1960-ies and '70-ies various selections of Golden Acre were of greatest interest.

In the late 1960-ies Mr. Vik was wondering if it was possible to improve Golden Acre further in respect of earliness, yielding capacity and uniformity. We discussed this problem together for a while, and came to the conclusion that we should carry out a simple selection experiment. In 1969 two farmers (Odd Vigenes and Ole Holthe) had two fields fairly close to the Exp. Station Landvik planted with the variety Golden Acre (0212 L. Dahnfeldt). Among about 10 000 plants inspected by eye 200 were selected before cutting in early June and brought to the Exp. Station. In the spring of 1970 only 11 plants had survived. These plants were allowed to open pollination in an isolated plastic house and seed harvested individually (fig. 1).

In 1971 the 11 half sib families were grown side by side under plastic tunnels without replications. Based on visual evaluation only two families were chosen for further breeding. Within these two families 51 and 35 plants respectively were selected by eye. In the early spring of the next year (1972) only 17 plants were left.

These plants were placed in an isolated plastic house, allowed to open pollination and seed harvested individually.

FIG. 1. BREEDING OF THE VARIETY LADI

1969	MASS SELECTION OF 200 AMONG 10 000 PLANTS OF THE VARIETY GOLDEN ACRE (0212 L. DAHNFELDT)
	↓
1970	SEED PRODUCTION OF 11 SURVIVING PLANTS IN AN ISOLATED PLASTIC HOUSE
	↓
1971	PROGENY TESTING AND SELECTION OF 86 PLANTS WITHIN TWO FAMILIES
	↓
1972	SEED PRODUCTION OF 17 SURVIVING PLANTS IN AN ISOLATED PLASTIC HOUSE
	↓
1973	PROGENY TESTING AND SELECTION OF 125 INDIVIDUAL PLANTS WITHIN 4 FAMILIES
	↓
1974	SEED PRODUCTION OF BULKED POPULATION
	↓
1975-'80	TESTING OF THE BULK POPULATION IN COMPARATIVE LOCAL VARIETY TRIALS. SEED MULTIPLICATION
	↓
1979	RELEASE OF THE VARIETY LADI

In 1973 the 17 individual mother plant progenies were laid out in a randomised block experiment with three replications and covered with plastic tunnels. Fig. 2 shows total and standard yield of the 17 families.

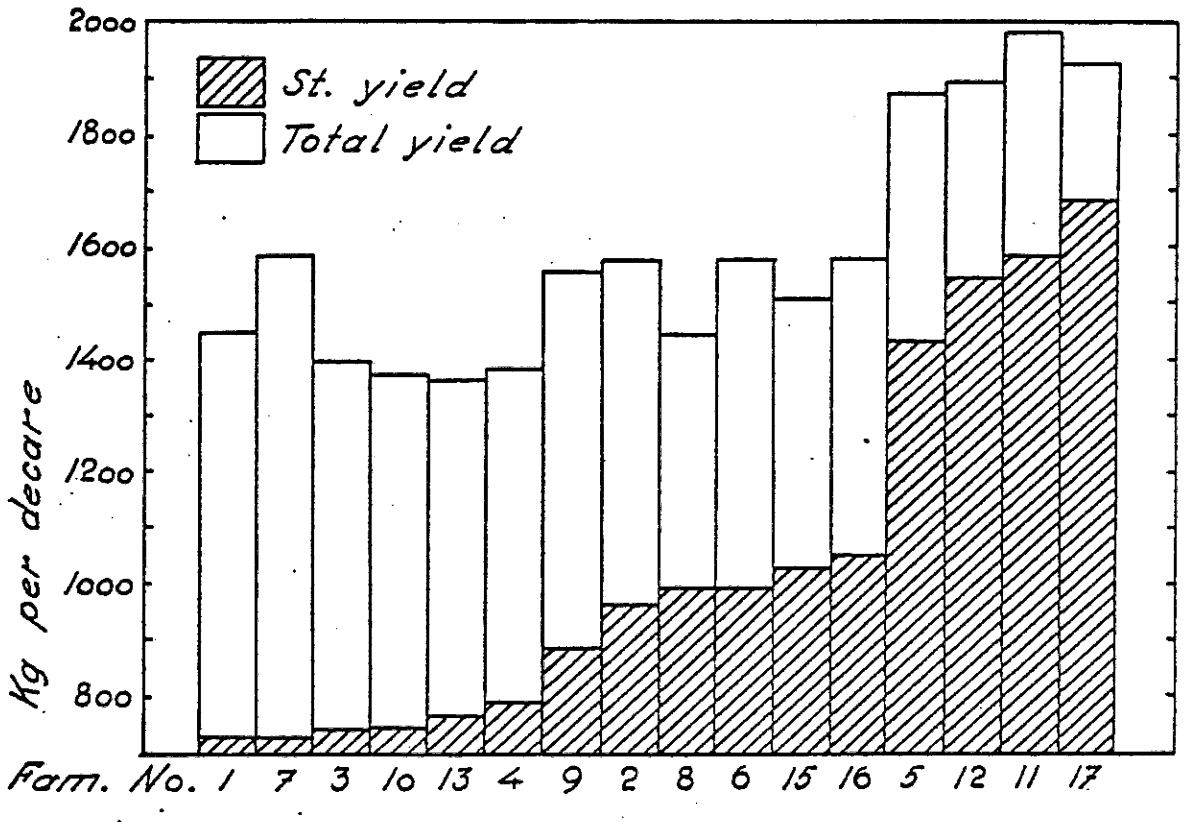

FIG. 2. YIELD OF 17 PROGENY FAMILIES HARVESTED 1973

Based on these data the families 5, 11, 12 and 17 were selected. Mass selection was applied within each family by picking out from 22 to 43 of the best looking plants by eye (in total 125 plants). The surviving plants in the spring of 1974 were grown and seed harvested as a bulked population. During the years 1975, '76 and '77 this population was seed propagated and compared with Golden Acre and other actual varieties in ordinary field trials. This first series of trials was directed by one of the breeders (VIK). From 1977 to 1980 the selected population was also included in official trials, the results of which have been published by GUTTORMSEN (1980). As a result of the comparative trials our selected population in Golden Acre was released as a new variety in 1979 under the name of Ladi (fig. 1). The results of the first series of trials are shown in table 1.

TABLE 1. AVERAGED MEANS OF 9 YIELD TRIALS IN SOUTHERN DISTRICTS OF NORWAY DURING THE PERIOD 1975, '76 AND '77

VARIETY OR POP.	LEAF COVER (1-10)	DAYS TO 50 % READY FOR HARVEST	DEVIATING PLANTS (%)	WEIGHT PER HEAD (G)	STANDARD YIELD (KG/DECARE)	REL.	DISCARDED YIELD (%)
LADI	8.5	60	7.7	709	2 608	119	6.9
GOLDEN ACRE SPECIAL	8.1	61	9.3	639	2 189	100	10.1
TOFTØGARD	7.3	61	10.0	659	2 329	106	8.0
MARNER ALL FRÜH	8.3	60	12.7	694	2 408	110	8.9
HISPI, F_1 HYBR.	8.8	58	2.0	414	1 530	70	20.8
DITMARSKER TREIB	9.0	61	20.0	684	1 998	91	16.2
VELA, F_1 HYBR.	9.3	-	13.9	575	1 685	77	20.1

The table shows that Ladi was earlier than Golden Acre, gave 19 % higher standard yield and had about 11 % higher head weight.

The data from the official trials presented by GUTTORMSEN (1980) seem to be most complete for the years 1979 and 1980. In his tables 3 and 4 he has presented averages for 7 trials in the first and 9 trials in the second of these years respectively. In table 2 is presented the overall means of all 16 trials conducted in 1979 and 1980.

TABLE 2. RESULTS OF 16 LOCAL TRIALS CONDUCTED IN 1979 AND 1980. AVERAGES OVER TRIALS

VARIETY	SEED SOURCE	1ST. HARVEST				2ND. HARVEST			
		YIELD		G/HEAD	UNI-FORMITY (1-9)	YIELD		G/HEAD	UNI-FORMITY (1-9)
		KG/DAA	REL.			KG/DAA	REL.		
GOLDEN ACRE	LD	872	100	283	5.6	2 574	100	686	6.0
LADI	LV	1 070	123	331	5.9	2 638	102	705	6.1
GOLDEN ACRE	RS	875	100	294	5.3	2 473	96	657	4.7
EGA	OEK	824	94	280	5.2	2 370	92	666	5.1
MARNER ALL FRÜH	SPER	888	102	301	5.7	2 730	106	715	5.7
GOLDEN CROSS	TAK	1 125	129	344	7.0	2 520	98	662	7.8
GOLDEN ACRE	BEJO	931	107	286	4.9	2 442	95	661	5.8

The table shows that the data are in quite good agreement with data presented from our own trials in table 1. The few official data from Northern Norway presented by GUTTORMSEN (l.c.) in his table 5, indicate that Ladi does not show the same superiority there as it does in Southern Norway.

Uniformity is always important in cabbage breeding, and still more so in breeding for such an expensive method of cultivation as growing under plastic tunnels. A special experiment was therefore set up in 1981 (2/81) to compare the uniformity of Ladi with the variety from which it has been derived. The experiment had 9 randomised blocks, and the four characters listed in table 3 were measured on 10 heads on each plot.

TABLE 3. UNIFORMITY OF LADI AND GOLDEN ACRE SPECIAL MEASURED BY THE COEFFICIENT OF VARIATION (C.V.) IN A TRIAL DESIGNED FOR THIS PURPOSE (2/81). THE TRIAL HAD 9 RANDOMISED BLOCKS AND THE OBSERVATIONS WERE TAKEN ON ALL HEADS (10) IN EACH BLOCK

VARIETY	WEIGHT OF HEADS		DIAMETER OF HEADS		HEIGHT OF HEADS		LENGTH OF INNER STALK	
	$\bar{X}$	C.V.	$\bar{X}$	C.V.	$\bar{X}$	C.V.	$\bar{X}$	C.V.
LADI (1)	631	23.8	12.4	1.31	12.9	1.18	5.94	15.5
GOLDEN ACRE SPECIAL (2)	509	26.6	12.0	1.52	12.5	1.23	5.36	14.4
DIFF. (1-2)	122	-2.6	0.4	-0.21	0.4	-0.05	0.58	1.1
SIGNIFICANCE LEVEL OF DIFF.	*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

The table shows that head weight of Ladi was significantly increased as compared to Golden Acre Special. Uniformity of the four characters measured by the coefficient of variation (C.V.) was, however, not significantly changed. In the same experiment the number of heads ready for harvest was counted at three different dates. Fig. 3 shows clearly that Ladi is earlier than Golden Acre Special.

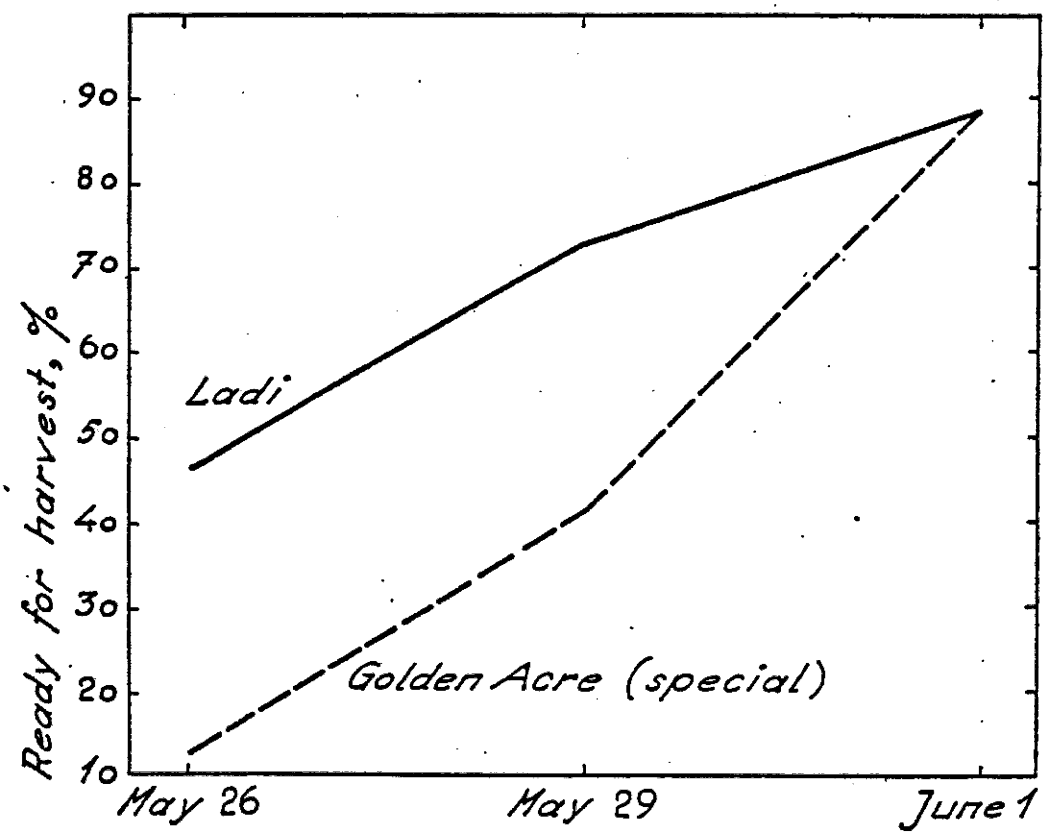

FIG. 3. PERCENTAGE OF HEADS READY FOR HARVEST AT THREE DIFFERENT DATES. TRIAL 2/81

In 1979 a new cycle of selection within the variety Ladi was started. In a field belonging to Odd Vigenes, about one hectare in size, 100 plants were selected by eye. In the spring of 1980 79 plants had survived. These were placed in an isolated plastic house, seed harvested individually, and the progeny families laid out in a randomised block experiment with two replications in 1981. The varieties Ladi and Golden Acre Special were included for comparison. Table 4 presents the main results from the analysis of variance of this experiment. The table shows that significant genetic variability is still left within the variety Ladi, especially for earliness. Based on the results from this variability experiment, we have selected 14 families for earliness, uniformity and scores for total value. The next year these families will be subjected to seed multiplication as a bulked population and later on tested in local variety trials.

TABLE 4. RESULTS FROM THE ANALYSIS OF VARIANCE OF PROGENY TRIAL 1/81. 79 PROGENY FAMILIES

CHARACTER	F-VALUE	SIGNIFICANCE LEVEL	HERITABILITY (h^2)
SCORE FOR UNIFORMITY (MAY 11)	1.47	•	0.32
SCORE FOR PLANT SIZE (MAY 11)	1.45	•	0.31
EARLINESS (MAY 29)	1.97	***	0.49
SCORE FOR TOTAL VALUE BEFORE HARVEST	1.48	•	0.32
STANDARD YIELD	1.04	N.S.	-
LENGTH OF INNER STALK	1.27	N.S.	-
HEIGHT OF HEADS	1.07	N.S.	-
HEAD DIAMETER	1.37	N.S.	-
SCORE FOR FROST DAMAGE (MAY 27)	1.38	N.S.	-

Conclusion

The variety Ladi is based on very few plants selected from the variety Golden Acre. With such a narrow genetic base inbreeding is to be expected. So far unfavourable inbreeding effects have not occurred. Ladi is a good seed producer and perform well in vegetative characters, as the data presented here show.

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GENETIC VARIATION AND INHERITANCE OF TOLERANCE TO CLUBROOT (PLASMODIOPHORA BRASSICAE WOR.) IN CABBAGE

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Report nr. 102

For the last 25 years Dr. Gunnar Weisæth has been working on the resistance of cabbage to clubroot. My investigations are a direct continuation of his work.

In my experiments I have chosen ten cabbage genotypes and crossed them diallelic (table 1). Genotypes 0-7 are genotypes selected by Weisæth for their resistance over a long period of time. Genotype 8 is from the American variety 'Badger Shipper'. The last variety is a genotype from the Norwegian variety 'Aglo'. This genotype has not been selected for resistance to clubroot.

Before starting on the diallel crossings, all the genotypes were cloned from leaf shoots. None of the parental clones were inbred before they were included in the present experiment. The diallel cross was complete, that means that all the individual combinations were fertile.

In 1980, 120 plants of each crossing was produced. They were planted out in the field in ten randomised blocks. In addition to the 100 family crosses, the 10 parents were vegetatively propagated and included in the block experiment. Five other varieties were also included later on.

The first five blocks of the experiment was planted out in a field that was heavily infected with clubroot, while the residual five blocks were planted out on uninfected soil. Each plot had two rows of 6 plants spaced with 50 cm between plants and the rows were set 60 cm apart.

A number of observations were made on several different characters. In the following, we shall be concentrating especially on the character tolerance to clubroot.

Among the blocks on infected soil, the fifth was not taken into consideration because of uneven infection on that part of the field.

As an indication for tolerance, I have compared the yields from 4 replications on infected soil and the yields from 4 coresponding replications on uninfected soil. The following formula was used to express tolerance (table 2). The formula expresses the percentage of yield achieved on infected soil as compared to yield on uninfected soil.

Hayman's analysis of variance

A Hayman analysis of variance (HAYMAN 1954) was carried out on the data from the experiment (table 3).

Table 1. Parental clones in the diallel cross.

Genotype	Origin	References
0	'Resista' ('Jåtunsalgets v.k.' x 'Bømerwald')	Weisæth 1968
1	"	"
2	"	"
3	"	"
4	"	"
5	TK 704 ('Rossebø' x 'Bømerwald') x 'Bindsachsen'	"
6	"	"
7	K 707 ('Rossebø' x 'Bømerwald')	"
8	'Badger Shipper' (Brassica oleracea capitata x B.o. acephala)	Chiang & Grant 1975
9	'Aglo' (Selected in 'Toten amager')	

Table 2. Definition of tolerance.

$$\text{Tolerance} = \frac{Y_{ij} \cdot 100}{Y_{uj}}$$

Y_{ij} = yield observed on infected soil of clone or family i in block j.

Y_{uj} = yield observed on uninfected soil of clone or family u in block j.

Table 3. HAYMAN's (1954) analysis of variance of the diallel table

Source of variation	D.F.	M.S. Tolerance to clubroot
(a) Effect of parents	9	6674.33 ***
(b) Reciprocal sums after parents	45	748.98 ***
b_1 mean dominance deviation	1	0.00
b_2 further dominance deviation	9	600.96 *
b_3 remaining discrepance in reciprocal sum	35	808.44 ***
(c) Average maternal effects	9	156.15
(d) Additional reciprocal differences	36	170.05

* Significant at 0.05 level

** Significant at 0.01 level

*** Significant at 0.001 level

The significance of the item (a) in this analysis shows additive genetical variation among the parents, while the significance of (b) indicate that there is also non-additive variation in the material present.

Item (b) is subdivied into three components. No significans of (b_1) shows that there is no evidence to show any difference between the overall means of parental clones and the F_1 progeny families.

Slight significance of (b_2) indicate that there is assymetry in the gene distribution. Dominance is indicated by significance of the items (b_2) and (b_3).

No significance of (c) and (d) show that there was no maternal effects in the material.

In figure 1, the distribution of family means for tolerance to clubroot (four blocks) are presented in a grafic form. The diagram shows a good approch to a normal continuous distribution.

The continuous distribution shows that tolerance to clubroot should be considered as a quantitative character. In other words there must be a number of genes present which control tolerance.

Heritability in the broad sense

In Hayman's analysis of variance I found a heritability in the broad sense of 0.86 (table 4). I therefore conclude that 85 percent of the variation was a result of genetic variation.

Heritability in the narrow sense

To estimate heritability in a narrow sense, I have used the "mean covariance of arrays" and "the variance of the parental clones". This gives an estimate for heritabilityi in a narrow sense of 0.70 (table 5).

From this we can conclude that 70 percent of the variation is caused by additive genetic effects, while 15 percent of the variation is caused by non-additive effects, mainly dominance. The residual 15 percent is caused by environmental factors.

The W_r/V_r - graph

The W_r/V_r -graph shows (fig. 2) the regression of "the covariance of arrays on array variances".

The slope of the regression line (b>0) indicates that dominance is present, although incomplete. The graph also indicate that parents 9 and 4 exhibits the greatest dominance effects while parent 8 (from 'Badger Shipper' possesses most recessive genes. It is perfectly clear that there is no over dominance present.

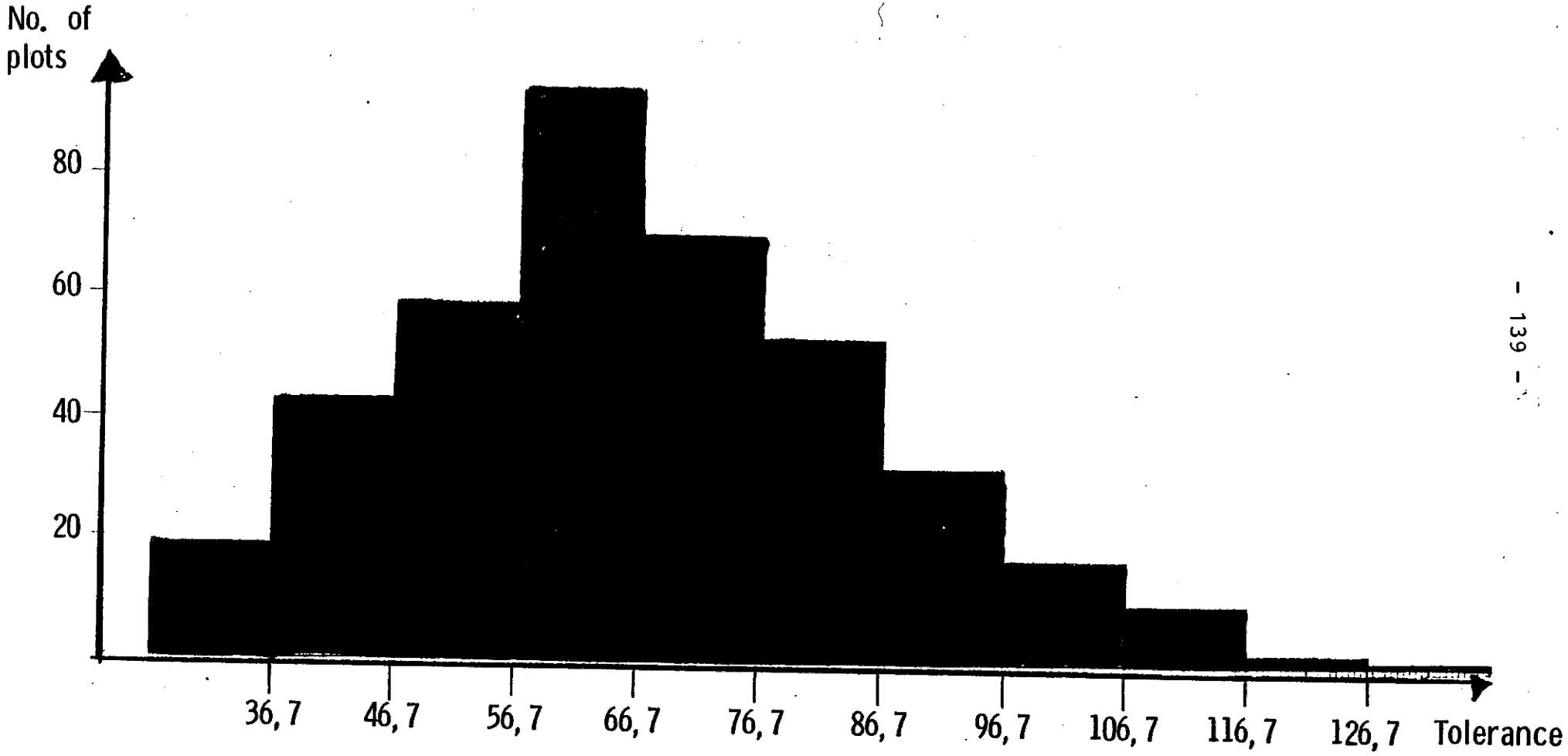

Fig. 1. Distribution of tolerance to clubroot.

Table 4. Estimation of broad sense heritability from the Hayman's analysis of variance. ($h^2_{b.s.}$)

	D.F.	V	M.S.
Block	r - 1 = 3	$\sigma^2_e + f\sigma^2_r$	332.67
Families	f - 1 = 99	$\sigma^2_e + r\sigma^2_f$	1023.23
Error	(r - 1)(f - 1) = 297	σ^2_e	148.79

r = number of blocks

f = number of families

$$\sigma^2_f = \frac{\text{Variance of families - error variance}}{r} = \frac{1023.23 - 148.79}{4}$$

$$\text{Hereditability } (h^2_{b.s.}) \text{ in the broad sense} = \frac{\sigma^2_f}{\sigma^2_f + \frac{\sigma^2_e}{r}} = 0.856$$

Table 5. Estimation of narrow sense heritability ($h^2_{n.s.}$) from genetic and environmental components in the diallel experiment (Aastveit 1966).

Statistic	Description	Genetic composition	
$\bar{V}_p$	The varianse of the parental clones	1/2 D + 1/4 H + E	332.45
$\bar{W}_r$	The mean covariance of arrays	1/4 D	116.46

$D = (4uv(d + d(q - p))^2)$

$H = (16u^2v^2h^2)$

$$\text{Heritability in the narrow sense} = \frac{1/2\ D}{1/2\ D + 1/4\ H + E} = 0.70$$

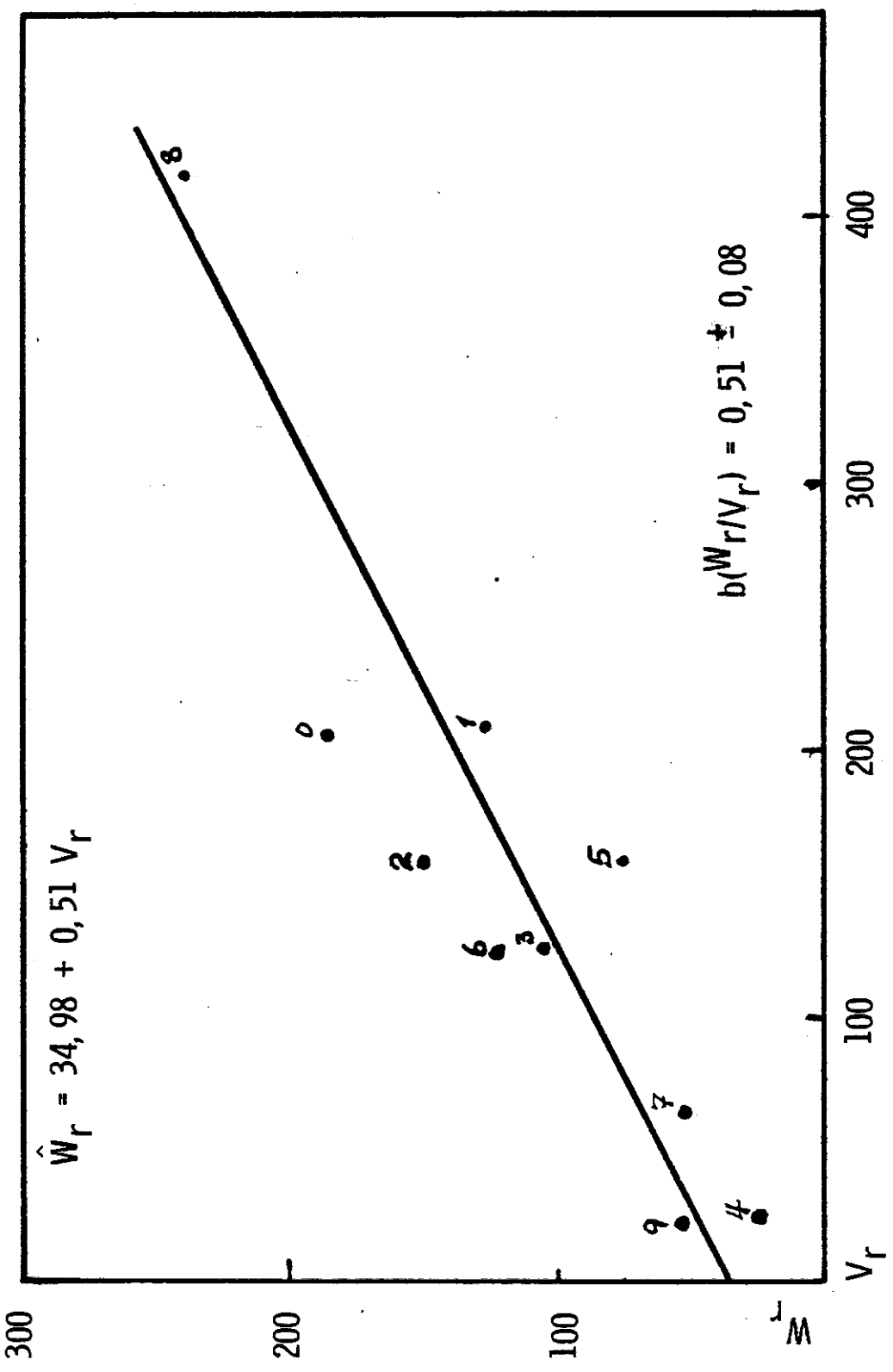

Fig. 2. (W_r/V_r)-graph for tolerance to clubroot

The correlation between the growt period and attack of clubroot

There was a significant relationship between the length of the growt period and attack of clubroot. Genotypes with a longer growt period are more strongly attacked by clubroot.

Whith the regression (r) between attack and growth period one gets a negative correlation.

R^2 (the squared factor) is 0.37, which means that 37 percent of the variation in tolerance to clubroot was due to the length of the growth period.

Conclusions

1. Tolerance to clubroot is inherited as a quantitative character.
2. Tolerance to clubroot is inherited recessively.
3. Heritability in the narrow sense is high, - great response to selection is therefore to be expected.
4. There is no over dominance and we cannot expect heterosis effects.
5. Genotype 8 (from 'Bagder Shipper') is the most tolerant and most recessive.
6. Tolerance to clubroot shows incomplete dominance.

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NEW BRASSICA OIL AND FODDER HYBRIDS OBTAINED BY INTERSPECIFIC CROSSING

by

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Trials aimed at obtaining new seed and leafy genotypes within Brassica genus by hybridization between B. oleracea, B. campestris and B. napus were started in 1976. This paper presents some features of the hybrids obtained.

Material and methods

Parental forms for crossings were selected from our own winter and summer forms Brassica genus collection, considering such agricultural features as intensity and vigour of vegetative growth in autumn, winterhardiness, intensity and vigour of spring vegetative growth, earliness of generative development, seed production, quality features such as fatty acids composition in seeds, glucosinolates, protein and fibre content in seeds and green matter.

Crosses were conducted by conventional methods (Andersson & Olsson 1961). In the last year (1980) in vitro excised ovaries and embryo culture techniques were also applied (Inomata 1978). F_1 plants gained on crossings were observed in controlled conditions; further generations also in the field. Hybrid identifications were started already in the F_1, by cytological analyses. In cases of genomic similarity (equal number of chromosomes of parental forms) immunological analyses were also applied. As one of the criterion of hybridity differences in the seed coat relief may be used too (Mlyniec, Barcikowska, Balicka, Chwalek, Wiatroszak 1979, Röhm-Rodowald in preparation). Quality analyses of seeds and green matter of hybrids were started partly in the F_3 generation.

Results and discussion

About 4000 cross pollinations were carried out in 38 combinations. Results of crossings conducted by conventional methods are presented below:

Crossability of B. oleracea, B. campestris and B. napus

Crosses	No. of pollinated flowers	Pods No.	Seeds No.	Hybrid No.	Plants %(X)
B.o. x B.c.	107	3	3	00	0
B.c. x B.o.	1296	92	461	1	0.061
B.c. x B.n.	467	178	576	8	1.7
B.n. x B.c.	992	454	3335	26	2.5
B.o. x B.n.	240	0	0	0	0
B.n. x B.o.	260	38	203	0	0
B.c. x B.c.(xx)	641	301	2395	30	4.6

(x) - in relation to the No. of pollinated flowers
(xx) - different subspecies acc. to Olsson's classification (1954).

Results given above should be completed by the information that owing to the in vitro technique, from 1350 crosses between B. campestris ssp. oleifera (cvs. Candle and Torpe) and B. oleracea (convar. capitata and acephala) - 13 hybrid plants (1% of the crossings) were obtained. Numbers given above are in agreement with the crossability of Brassica species presented in the literature (Sinskaja after Davey 1959, Inomata 1978).

Following hybrids of F_3 and F_4 generations of different, more or less phenotypically stabilized lines (numbers given in brackets) have until now been derived:

1. B.c. ssp. pekinensis x B.c. ssp. trilocularis Yellow Sarson (21)
2. B.c. ssp. pekinensis x B.n. ssp. oleifera cv. Bronowski (8)
3. B.n. ssp. oleifera cv. Bronowski x B.c. ssp. pekinensis (45)
4. B.c. ssp. pekinensis x B.n. ssp. oleifera cv. Pluto (4)
5. B.c. ssp. pekinensis x B.n. cv. Asparagus Kale (2)
6. B.c. ssp. oleifera cv. Pluto x B.c. pekinensis (4x) (4)
7. B.n. cv. Akela x B.c. ssp. pekinensis (10)
8. B.n. cv. Siberian x B.c. ssp. oleifera cv. Arctus (2)
9. B.n. cv. Siberian x B.n. cv. Asparagus Kale (intraspecific) (12)

In 1980; as the result of crossing between B. campestris ssp. pekinensis cv. Granaat and B. oleracea var. acephala cv. Normal one haploid plant (2n = 19) of great vitality was identified (Balicka, Barcikowska, Mlyniec, Zwierzykowska 1980).

Hybrids nos. 2, 3, 5, 7 and 8 cytologically represented sesquidiploids of 2n = 29 chromosomes. They are being multiplied and selected to stabilize the chromosome number and genomic constitution at that of B. napus (MacNaughton, Ross 1977-78). Hybrids Nos. 1, 4, and 6 were of 2n = 20 and intraspecific hybrid No. 9 of 2n = 38 chromosomes.

Hybrids Nos. 1, 4 and 6 derived from crosses between different subspecies of B. campestris (Olsson 1954) regarded by certain taxonomists as distinct species (among others: Helm 1963) do not represent fertility disturbances but great phenotypical variability, even within lines. This is observed in a very high degree in the progeny of hybrids Nos. 2 and 3. Variation ranges from the typical seed forms of a distinguished main stem and high seed yield to the abundant leafy forms. Variation concerns also earliness of flowering, length of the vegetation period and such markers as antocyanin colouration and presence of wax on the stem and leaves. The latter, against Heyn (1977) seems to be dominant to glossy.

Ssp. pekinensis introduced (as expected) into hybrids intensity and vigour of vegetable growth and earliness of generative development. But particularly in the case when they were the maternal partner of crossing (hybrids Nos. 4 and 5) winterhardiness was low (12-35%). Winterhardiness of reciprocal hybrids (Nos. 6 and 7) varied highly (60-100%). The most winterhardy lines are promising as a potential substitude for Perko which as a winter aftercrops was not in every year reliable in Poland (COBURU 1978).

Hybrids without contribution of ssp. pekinensis derived from crosses with B. napus cv. Siberian (Nos. 8 and 9) represented about 100% winterhardiness and very high green mass production

in spring time, but were in general slower in vegetative growth (both in autumn and in the spring) and in generative development.

According to winterhardiness as well as intensity and vigour of vegetative growth hybrid lines and even forms within lines were evaluated as initial material for late summer, late autumn and winter aftercrops.

Within variability observed in hybrid progenies there also occur forms which can be considered as seed oleiferous types. Of special interest are those obtained in partnership of yellow seed coat colour B.c. ssp. trilocularis Yellow Sarson. Lines of lighther than average and yellow seed coat colour represents larger than parental forms variation range in oil, protein and fibre content in seeds.

By Paper Test Method there were found in F_3 of hybrid No. 2 five plants of 0-glucosinates content. Lower than average glucosinates content was also found in F_3 progeny of hybrids No. 1. Forms of zero and lower glucosinolate content provide comparatively high seed production and these from hybrid No. 1 were of yellow coloured seed coat.

The quality features (particularly low erucic acid, glucosinolates and fibre content in seeds) represented by parental forms selected for crossings: B.c. ssp. pekinensis and trilocularis as well as B.n. Bronowski, may be afforded even if it to some extent a response to the quality demand formulated first by Röbbelen (1975 and 1976) and completed later by Downey (1979) for hypothetical rape of the future.

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"Pair-cross" hybrids - a possible method for variety production.

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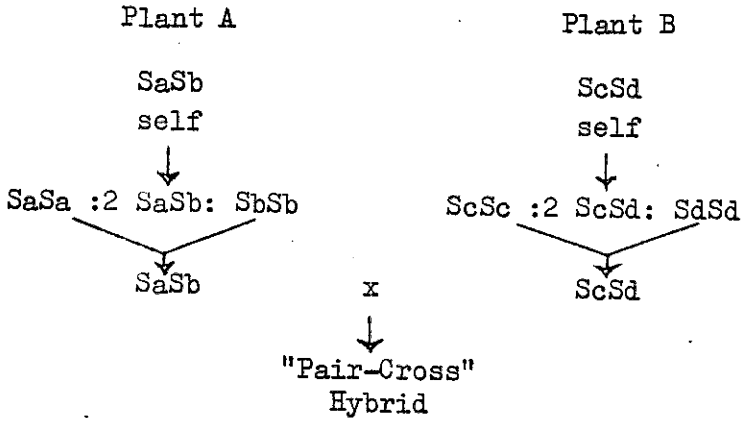
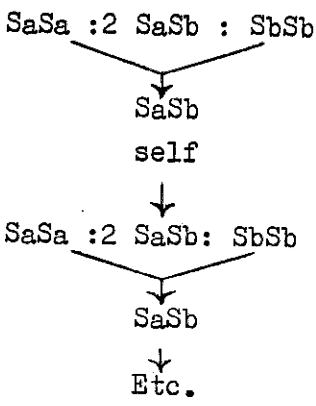
Any individual in an outbreeding population can be considered to be an F_1 hybrid between two hypothetical inbred lines. A pair-cross between two individuals is, therefore, equivalent to a double-cross hybrid from four hypothetical lines. If the parent plants of a pair-cross could be multiplied up to a field scale in such a way as to maintain their genetic constitution, they could be intercrossed to produce the equivalent of a double-cross variety.

Vegetative propagation or culture could be used to multiply such lines, but this would be labour intensive and expensive. In some Brassicas crops the self-incompatibility system could enable a multiplication to be made from bud-pollinated progenies. Selfing an individual plant would produce a family with SaSa : 2 SaSb : SbSb, which would be self-incompatible but (with co-dominance) would have half of the offspring cross-compatible.

In the absence of selection or drift, mass-multiplication of a selfed progeny would give a self- and cross-incompatible population with the same gene frequencies as the original plant. Two such families could, therefore, be cross-pollinated to give the equivalent of a double-cross hybrid.



Theoretically, it should be possible to maintain the single-plant progenies by alternate selfing and inter-crossing:-



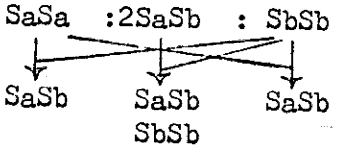
However, unless a large number of plants were bud-pollinated at the selfing stage, this scheme could rapidly lead to inbreeding depression. The associated low seed yield would not only be manifest in the maintenance of the lines, but also in the final cross. With a normal double-cross the major advantage of the method is the high seed yields produced by crossing two F_1 hybrids. To make use of the pair-cross scheme, it would appear necessary that the parent plants should be maintained by vegetative propagation or culture.

The number of pair-crosses made for evaluation and testing would, therefore, be largely dependent on the number of plants which could be maintained for a two year period, during which the pair-crosses would be produced and evaluated in trials. If the scheme were to be run on an annual cycle, this would mean the maintenance of 100 lines if only 25 pair-crosses were made each year.

The other main factors which would influence the number of pair crosses made would be the number of lines which could be handled in trials and how many pair-crosses could actually be produced. In turnips, for instance, up to 100 lines could be sown in a trial with three or four replicates if using single drills of 10m. In kale, however, only 40 lines could be handled for the same trial area using five drill by 5m plots. The number of lines evaluated depends, therefore, on the crop involved and the facilities and labour available. If a large number of pair-crosses could be produced, they could initially be sown in small plots for observation, with a fully replicated trial of a small number of selections being carried out the following year using residual seed. With brassicas, if large plants were used for the crosses, sufficient seed could be obtained for multi-site trials of the best selections. This would mean, however, that the selected lines would have to be maintained for a further year by propagation or culture.

It is assumed that the pair-crosses would be made by isolating the pairs of plants in large bags and using blow-flies to effect cross-pollination. If there was a discrepancy between blow-fly pollination and natural pollination in the field (Faulkner, 1971) there could be a problem in predicting the results of the final multiplication from the seed produced by blow-fly pollination. In swedes, however, observations of worker-bees has not produced any evidence of discrimination, even when different flower colour has been involved. It would appear, therefore, that the prediction of results would have to be determined independently for any particular crop.

During the course of seed production and trialing, any problems associated with a specific pair-cross should become obvious. The major problems which could be encountered are cross-incompatibility, partial self-compatibility, mutual weakening and dominance. With cross-incompatibility, low seed set from the pair-cross would eliminate any such combination immediately. Excessive variability in trial would enable cases of self-compatibility or mutual weakening to be eliminated. Dominance would, therefore, appear to be the most serious problem, as this would not be detected until the selfed progenies were mass-multiplied. Instead of half the population being self- and cross-incompatible, all the plants would set seed because the heterozygotes would be cross-compatible with the recessive plants.



If such a family was used to produce a "pair-cross" hybrid, approximately 25 per cent of the progeny would be cousins or sibs. Although these would be more nearly equivalent to F_2s as opposed to sibs from inbred lines, they would probably be unacceptable even for an agricultural crop.

It would be advantageous if the plants used for the pair-crosses could be selected for important agronomic characters, especially if the inheritance of the characters was known and could be predicted in the final cross. However, in the important cases with agricultural brassicas, such as SMCO in kale or even clubroot resistance in turnips, the outcome appears largely unpredictable. The "pair-cross" method would, however, enable the results of the crosses to be observed almost immediately from tests and trials carried out in the year following the production of the initial crosses.

The problems involved in the "pair-cross" method must, of course, be considered in comparison with the standard procedures for an outbreeder. With F_1s or more complex hybrids, inbred lines have first to be produced and then intercrossed to find suitable high-yielding combinations. Also the inbred lines are difficult to maintain and multiply, with the result that hybrids take many years to produce and are very expensive. With mass-selection, or similar methods, it usually requires several generations for selection to be effective which, in the case of biennials, means ten to fifteen years to produce a cultivar.

In comparison to the problems which may be encountered, the speed with which a "pair-cross" hybrid could be produced could make the method an attractive economic proposition.

Year 1:	Pair-crosses produced.	Single plants propagated.
Year 2:	Single-site trials.	Selfed seed produced.
Year 3:	Multi-site trials of selections.	Multiply seed of best lines.
Year 4:		Pair-crosses produced.
Year 5:	Submission to Official Trials.	

If the selfed seed could be produced simultaneously from the plants of the initial pair-crosses, submission to official trials may even be possible in the fourth year. Although this may be optimistic, in comparison to normal breeding methods, the "pair-cross" hybrid appears to be an extremely interesting proposition.

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RESISTANCE BREEDING IN OIL RAPE

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The acreage of oil rape in Sweden is 150 - 170.000 hectares or 5 - 6 % of the arable land. However, in some areas oil rape is very intensively grown and crop rotations with oil rape every third or every fourth year are quite normal for instance in southern Sweden. Because of this intensive oil rape growing the attacks by fungi are increasing. In most countries only one or two cruciferous species are grown as oil crops. In Sweden five cruciferous species are grown: winter rape, winter turnip rape, summer rape, summer turnip rape and white mustard. Cultivation of many cruciferous species, often in the same area, favous the parasites because host plants in susceptible stages are available during long periods. The annual losses in yield in oil rape in Sweden caused by fungi are estimated to about 30 millions Swedish crowns. The most important fungi and diseases are:

Verticillium dahliae	Leaf mottle
Phoma lingam (Leptosphaeria maculans)	Canker
Sclerotinia sclerotiorum	Stalk rot
Plasmodiophora brassicae	Clubroot
Alternaria sp.	Black spot
Peronospora brassicae	Downey mildew

Verticillium, Phoma and Sclerotinia all cause premature ripening in oil rape. Under Swedish conditions the symtoms are usually visible only about a week before the stage of yellow ripening. The symtoms sometimes are mistaken for insect damages. Premature ripening results in poor seed quality, decreased oil content, decreased seed yield and increased disposition to shattering. Verticillium causes very big losses in yield in winter rape in the southwestern corner of Sweden. This fungus is relatively unknown in other European countries. Concerning Phoma and Sclerotinia the attacks are not as severe in Sweden as in France, Germany, Holland and United Kingdom.

Selection for improved resistance to Verticillium has been carried out in winter rape in heavily infested fields since 1970. Clear differences in resistance have been found among varieties and breeding lines (Jönsson, 1978). Among varieties with good resistance to Verticillium may be mentioned Norde, Rapora and Herkules. Improved screening methods for resistance to Verticillium in greenhouse are under development.

Swedish materials of winter rape are tested for resistance to Phoma and Sclerotinia in France, Germany and Holland. Clear differences in resistance to Phoma have been found and the most resistant lines have been used as parents in the breeding work. The French winter rape variety Jet Neuf owns a good resistance to Phoma. Unfortunately this variety is more susceptible to Sclerotinia than Swedish winter rape varieties.

Information about the breeding work for improved clubroot resistance has been given in another paper this week.

The fungus Alternaria causes bad seed quality, low oil content, low seed yield and increased disposition to shattering. Both winter and summer forms of oil rape and oil turnip rape are susceptible. The fungus is favoured by high humidity and therefore the most severe damages occur in the late ripening summer rape. Search for gene sources for resistance to Alternaria is going on at Svalöf but so far only very small differences in resistance between lines have been found within brassicas.

Winter rape varieties suitable for cultivation under Swedish conditions must be very winterhardy. This property is very composed. Winterhardy varieties must have a good cold resistance, a low growing point and a suitable dormancy period but also a rapid development in autumn to reach the proper stage for overwintering. A prerequisite for a rapid development is a good resistance to Peronospora. In nonresistant varieties the cotyledones some years can be almost totally destroyed by the fungus. The plants survive, because the first real leaves are resistant but the plant development is considerably delayed. Therefore attacked plants will not reach the optimal stage of development before winter comes. Tests for Peronospora-resistance can easily be carried out at the seedling stage in greenhouse. Very big differences in resistance have been found among varieties and breeding lines.

Gene sources for resistance to most of the fungi attacking oil rape are available and as resistance breeders we are optimistic about the possibilities to produce materials with improved resistance to one or more of these fungi. However, from the oil plant breeders' point of view the situation is different. Many other important breeding goals must be taken into consideration.

Important breeding goals in oil rape

- High seed yield
- High oil yield
- Good winter hardiness
- Rapid growth in autumn
- Good stalk stiffness
- Shattering resistance
- Early ripening
- Resistance to fungi
- (Resistance to insects)
- Improved oil quality:
  - Erucic acid, <1 %
  - Linoleic acid, >40 %
  - Linolenic acid, <5 %
  - Palmitic acid, >10 %
- Improved meal quality:
  - Low glucosinolate content, <30 µmol
  - High protein content, 45-50 %
  - High energy content
    - Yellow seed coat
    - Low fibre content
    - Bigger seed size

The breeding for improved oil and meal quality has so far been very successful. Further progresses can be obtained and the quality properties will be given high priority in the plant breeding work also in the future. Like in most other crops high yield, winter hardiness, good stalk stiffness and earliness are very important breeding goals which can't be neglected. Resistance to fungi is very important in oil rape but only in combination with most other desirable properties. Many years of extensive plant breeding work must be carried out before most of these desirable properties are combined in market varieties of both summer and winter forms of oil rape and oil turnip rape. However, the realization of such a big breeding program is an exciting challenge to all oil plant breeders.

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