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VARIATION IN SOME AGRONOMICALLY IMPORTANT CHARACTERS IN A GERMPLASM COLLECTION OF BEET (*BETA VULGARIS* L.)

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SUMMARY

A geographically representative selection of germplasm of *Beta vulgaris,* section *Beta* has been assessed for characteristics important in sugarbeet breeding, including downy mildew resistance, resistance to aphid colonisation and infection by the beet virus yellow complex. The occurrence of maintainer lines for cytoplasmic male-steriles was also investigated. Desirable qualities were found in some accessions, including nothern European wild *vulgaris* ssp. *maritima* and some old multigerm cultivars of fodder beets.

INTRODUCTION

The section *Beta* of the genus *Beta* is well known to sugar beet breeders because of the attention directed to the close relatives of cultivated beet, especially *B. vulgaris* ssp. *maritima,* in searches for disease resistance and other desirable characters. A small number of accessions represented by both wild and cultivated forms within the beet germplasm collection held at the University of Birmingham (comprising over 900 accessions) has been assessed for a number of agronomically important characters including resistance to downy mildew, aphid colonisation and beet yellows virus. The occurrence of 0-type sterility maintainer genes (OWEN, 1945) was also investigated, A summary of all the accessions studied and referred to in the various sections is presented in Table 1.

Downy mildew resistance. Downy mildew of sugar beet is caused by *Peronospora farinosa* (FR.) f. sp. *betae* (BYFORD, 1967). The use of genetic resistance to this disease appears to be a practical method of reducing crop losses through infection. Sugar beet varieties currently recommended for commercial use have good levels of resistance, but new source of resistance might enhance this resistance as well as provide insurance for the future. Downy mildew resistance was assessed in 60 of the Birmingham accessions, representing a range of taxa.

Resistance and aphid (Myzus persicae) colonisation and beet yellows virus. An assessment was made of the resistance of 32 accessions of *B. vulgaris* when exposed to colonisation by *Myzus persicae* (SULZ). Previous studies of resistance in sugar beet (LOWE & RUSSELL, 1969) have used the terms 'resistance to settling', 'resistance to multiplication' and 'tolerance'. The first term concerns the behaviour of the aphid immediately after first contact with the plant. 'Resistance to multiplication' may be the result of continued non-preference or to antibiosis disturbing the physiology of the aphid or to a combination of both, but the relative importance of these mechanisms has not been assessed.

LOWE & RUSSELL (1969) reported that resistance to aphids was inherited in the material they examined. Their experiments indicated that the inheritance of the different types of aphid resistance was complex, suggesting a character under polygenic control.

There are two different viruses which can cause 'virus yellows'; beet yellows virus (BYV) and beet mild yellowing virus (BMYV). They are unrelated but have an additive effect in depressing the yield of plants containing both (HEATHCOTE, 1978). Both are transmitted by aphids.

Table 1. Description of accessions of *Beta vulgaris* used including summary of evaluation results.

Accession	Sub-species	Original source and description	Breeding potential			
			mildew	aphid	BYV	O-type
144	*adanensis*	Turkey-wild				+
148	*adanensis*	Turkey-wild	+			
43	*cicla*	cv. Swiss Chard	+			+
159	*cicla*	Turkey-landrace	+			+
62	*maritima*	Hungary – wild				+
94	*maritima*	U.K. – wild			+	
99	*maritima*	U.K. – wild	+	+	+	+
235	*maritima*	Turkey – wild				+
347	*maritima*	France – wild		+		
380	*maritima*	U.K. – wild			+	
140	*vulgaris*	Turkey-landrace				+
143	*vulgaris*	Turkey-landrace				+
161	*vulgaris*	Turkey-landrace				+
176	*vulgaris*	Turkey-landrace				+
193	*vulgaris*	Turkey-landrace		+		
239	*vulgaris*	Portugal-cv. fodder	+			
241	*vulgaris*	Portugal-cv. fodder	+			
264	*vulgaris*	France-cv. table	+			
270	*vulgaris*	U.S.S.R.-cv.	+		+	
277	*vulgaris*	U.S.S.R.-cv.	+			
289	*vulgaris*	Greece-landrace	+			
291	*vulgaris*	Greece-landrace	+			
320	*vulgaris*	Greece-wild	+			
325	*vulgaris*	Greece-wild	+			
378	*vulgaris*	U.K.-cv. Vytomo	(control)			
387	*vulgaris*	U.K.-PBI breedling line	(control)			

O-type or sterility-maintainer genes. The inheritance of cytoplasmic male sterility in sugar beets was first described by OWEN (1942). He suggested that this kind of male sterility is controlled by a cytoplasmic factor and at least two or possibly more Mendelian factors. All plants with the male-sterilizing cytoplasm and recessive maintainer genes (rf) are male sterile. Either the normal cytoplasm or the dominant maintainer (restorer) genes lead to male fertility. A plant with normal cytoplasm and the recessive maintainer genes can be used as the pollinator to establish and to maintain a male-sterile line and is known as an O-type plant.

A survey of the Birmingham accessions was carried out in order to identify genotypes containing the recessive (rf) maintainer genes for assessment and possible use within a sugar beet breeding programme.

METHODS

Downy mildew resistance. The seedlings were screened in two separate tests in a glasshouse heated to give 10 hours (0800 to 1800 h) at c. 18 °C and 14 hours at c. 15 °C. A high humidity (c. 95–98%) was maintained by use of automatic mist propagators. Daylight was supplemented with (0400 to 0800 h) light from fluorescent neon tubes placed above the seedlings. The design of the screening procedure followed that described by BROWN (1977).

All seeds were washed in a waterbath at 25 °C for two hours to remove germination inhibitors. The seeds were then surface sterilized using a 5% sodium hypochlorite solution for two minutes, thoroughly rinsed and allowed to dry overnight at room temperature before sowing. Rows of seeds were sown in a sterile soil-based compost in plastic seed trays. After emergence each plot was thinned at random to approximately 14 seedlings per row. Each test thus contained 14 seedlings and was replicated four times in randomised blocks. The seedlings were sprayed twice at the cotyledon stage with inoculum at c. 0.1 lm ^{2} to ensure infection. The inoculum was prepared as for the drop inoculum technique (RUSSELL, 1969) but diluted one thousand-fold prior to spraying. Between seven and ten days after the appearance of disease symptoms, all seedlings were scored for disease incidence on a scale of 0 to 5 in which 0 represented absence of symptoms and 5 the death of the seedling. Accessions 378 (Vytomo) and 387 (PBI breeding line) were included as susceptible controls and formed the basis for further comparisons. The populations studied are listed in Table 2 and described in Table 1.

Aphid colonisation and beet yellows virus. A stock of *M. persicae* which had originally been collected from a field population, was supplied by the Plant Breeding Institute, Cambridge. The aphids were reared on Chinese cabbage, *Brassica perkinensis* RUPR., and subsequently transferred to the experimental material.

The test plants of all accessions were grown individually in 11 cm pots with 20 replicates per accession. Replicates were arranged in randomised blocks taking account of different growth rates of individual accessions and of the size of the glasshouse compartments used.

Samples of apterous adult *M. persicae* were stored individually from the cultures and confined in gelatine capsules in groups of five for up to four hours before being

Table 2. Mean scores for downy mildew infection.

Test 1:	Accession No.	Mean score	Test 2:	Accession No.	Mean score
	43	1·5		193	1·2
	99	1·4		241	1·1
	148	1·9		264	0·9
	159	1·8		277	1·9
	239	0·9		291	1·2
	270	1·2		320	1·3
	289	1·7		325	1·9
Control	378	2·9	Control	378	3·1
Control	387	3·4	Control	387	3·4
	Overall mean	= 2·6		Overall mean	= 2·4
	S.E.	= ±0·2		S.E.	= ±0·3
	L.S.D. (5%)	= 0·5		L.S.D. (5%)	= 0·7

placed on the plants at the two to four leaf stage. This handling and starvation does not affect the aphid's response to beet varieties (LOWE, 1974) and no mortality occurred in the capsules.

The numbers of *M. persicae* on individual plants were recorded after a period of five days, allowing an estimated of resistance to settling and aphid multiplication. The scoring system used to describe the aphid infestation of individual plants is given in Table 3.

A plot containing a number of the same accessions grown outside was found to have been colonised by aphids and showed beet virus yellows symptoms towards the end of the growing season. This plot was scored on a 0 to 5 scale; 0 indicating freedom from disease symptoms and a 5 score representing severe virus yellow infection. Accessions included in the field trial are listed in Table 4 with further details in Table 1.

O-type genes. In order to recognise O-type lines, crosses were made between a male sterile line and single plants selected from accessions. Assessment was then made of the progeny to see if male sterility was maintained. Such crosses were made in isolation using polypropylene paper bags in a glasshouse.

The populations included in the study are given in Table 5 and further details given in Table 1. It was possible to include only three plants (genotypes) per accession in

Table 3. Scoring system for aphid infestation.

0	0– 6
1	7– 15
2	16– 25
3	26– 40
4	41– 55
5	56– 75
6	76–100
7	101–140
8	141–190
9	over 190

Table 4. Levels of virus yellows infection under field conditions.

Accession No.	Number of plants scored	Mean score	S.E. (±)
94	20	0·6	0·1
99	15	1·5	0·1
270	15	2·0	0·3
380	18	1·4	0·2
378 (control)	20	2·6	0·2

Scored 1 to 5; 1 = resistant, 5 = fully susceptible.

the crossing programme. Seed was removed from the male-sterile plants when ripe and planted in the autumn to allow vernalisation during the winter period and flowering the following year. Seeds were sown in 8 metre rows with approximately 5 grams of seed to each row giving between 50 and 60 plants per row. Two such plots were sown to allow replication. During flowering the progeny were assessed using the scale given in Table 5.

The two plots were both examined so that in the majority of accessions approximately 100 to 120 plants were assessed and given overall male sterility scores. Occasionally poor germination or poor survival over winter resulted in reduced numbers.

RESULTS

Downy mildew resistance. Results were computed separately for the two tests as mean disease scores of 56 seedlings. The accessions demonstrated a wide range of variation for reaction to downy mildew (mean scores between 0.9 and 3.4). Those with apparent resistance are shown in Table 2.

Aphid colonisation and beet yellows virus. Analysis of the mean scores for aphid infestation for the 32 different accessions indicated that considerable variation exists within the material studied. High levels of resistance were found within accession nos. 99 and 347 in particular, which were of *B. vulgaris* ssp. *maritima*. Both of these showed a mean score of 0.9 which is comparable with a resistant control (PBI breeding line) which scored 1.0. All other accessions were found to be considerably less resistant than this control.

The assessment in the field for symptoms of beet yellows virus also indicated considerable variation in terms of reaction. Four accessions were found to be comparatively free of symptoms, compared with Vytomo, a resistant control (Table 4).

O-type genes. In the majority of the accessions studied, there was production of pollen on the test plants to varying degrees, with scores of 7 to 9. The plants of these accessions therefore carried some male fertility restoring factor.

Other accessions were of particular interest as they indicated the presence of maintainer genes. The results are presented in Table 5.

Table 5. Accessions of *B. vulgaris* expressing the maintainer character.

Accession No.	Subspecies	'Maintainer' score[1]
144	*adanensis*	2
159	*cicla*	2
43	*cicla*	3
62	*maritima*	3
99	*maritima*	2
235	*maritima*	4
140	*vulgaris*	2
143	*vulgaris*	3
161	*vulgaris*	1
176	*vulgaris*	2

[1] Scale used in scoring degree of male sterility as follows: 1 White anther; 3 Yellow-brown anther, no pollen; 5 Traces of pollen; 7 Some pollen cleary visible; 9 Copious pollen. Scores of 1 to 3 indicate that the parents are potentially O-type.

DISCUSSION

The studies presented here examine a number of accessions within the Section *Beta* from a wide geographic distribution (Table 1). The characters resistance to downy mildew, aphid colonisation and virus yellows, and male-sterility are all important in sugar beet breeding.

Resistance to downy mildew was found in all members of the Section and throughout its distribution. Similar results for resistance to aphids reflected the wide range of variation that exists.

The potential value of natural populations of *B. vulgaris* to plant breeders is demonstrated as well as that of landraces and old cultivars. The obstacles to using natural populations as sources of disease resistance and other desirable characters, as opposed to commercial breeding lines, are the wild characters which accompany the transfer of the desired characteristics. Extensive backcrossing is often required to eliminate such undesirable qualities and may make the transfer of any polygenic character difficult or incomplete. MARGARA & TOUVIN (1955) obtained hybrids of sugar beet with *B. vulgaris* ssp. *maritima* that demonstrated relative tolerance to virus yellows, but found that repeated backcrossing failed to remove such undesirable characters as low sucrose percentage or the forked-root tendency. However, the use of wild forms within the Section *Beta* may be preferable to that of species from other sections of the genus, such as *B. patellaris* currently being used for nematode resistance (SPECKMANN & DE BOCK, 1982).

The occurrence of O-type plants was observed in a number of accessions (see Table 5). The role these play in conjunction with cytoplasmic male-sterility within natural populations is not clear, though the system may well help to prevent excessive inbreeding in annual types of *B. vulgaris*. In terms of utilisation, few of the O-type plants were of sufficiently high standard agronomically to merit further investigation with the exception of four which may be of further use.

These studies have emphasised possibilities of using members of the Section *Beta* as sources for desirable characteristics to incorporate into commercial breeding programmes and to widen the genetic base of the crop.

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