

# RESISTANCE TO TOP YELLOWS AND FUSARIUM WILT IN PEAS

N. HUBBELING

Institute for Phytopathological Research, Wageningen

Received 27 Febr. 1956

## 1. INTRODUCTION

Top yellows, a virus disease in peas and broad beans, had been known in Western Europe for at least thirty years as "*Fusarium solani* foot disease", but as a result of visiting L. QUANTZ at Braunschweig (Western Germany) in the summer of 1954, the present writer learned the real cause of the disease. In spite of this discovery the Plant Breeding Station of the "Centraal Bureau" at Hoofddorp introduced the resistant pea varieties Rondo and Stijfstro (= *Erecta*) as long ago as 1943 and 1944 respectively.

*Fusarium* wilt of peas has been known in the Netherlands for only about ten years, and the first wilt-resistant Dutch pea variety, Vares, bred by the station mentioned above, was introduced in 1953.

Nowadays resistance to top yellows and wilt are the principal breeding objectives of most pea breeders in the Netherlands. In this article the writer describes the diseases concerned, and discusses methods for testing for resistance. In addition many commercial varieties are listed in order to give information on their resistance or susceptibility in so far as these properties are known.

## 2. TOP YELLOWS

### *Cause*

As long ago as 1948 the writer suspected that the disease was caused by a virus, but he did not succeed in confirming that it could be transmitted via the juice from diseased plants; moreover, preliminary experiments with pea aphids did not support this assumption. It was not until the results of research by QUANTZ and VÖLK (1954) and DE FLUITER and HUBBELING (1955), that it was proved that the virus could not be transmitted mechanically via the juice, and that a long feeding period of the aphids was necessary in order to infect the plants.

Since translocation is impeded it is obvious that affected plants are liable to succumb to secondary parasites in the soil, such as *Fusarium solani* and *Fusarium culmorum*. Using these fungi, isolated from the roots of infected plants, it would seem that infection cannot be accomplished, in Western Europe at least, without weakening or injuring the plants in some way beforehand. Contrary to European experience, however, is the occurrence of the parasitic *Fusarium solani* f. *pisi* (JONES) SNYDER and HANSEN in the southern states of North America.

In Germany the disease is called "Blattroll" and, in agreement with the Dutch name, it has been called "Jaunisse du pois" in Belgium (ROLAND, 1955). ROLAND proposes to refer to the virus as *Pisum virus* 8. Contrary to our experience, however, he has described a yellowing of the leaf edges half-way up infected plants of the variety Kelvedon Wonder; in our field trials this variety has proved to be resistant to top



FIG. 1. SYMPTOMS OF TOP YELLOWS IN A PEA PLANT. NARROWING, CURLING AND CHLOROSIS OF LEAVES IN APICAL PARTS AND LATERAL SHOOTS IS CHARACTERISTIC. IN ADDITION, TOP LEAVES ARE SOMEWHAT POINTING UPWARDS

yellows. At Gembloux (Belgium) the writer observed very heavy damage due to top yellows in many susceptible pea varieties. Varieties known as resistant in the Netherlands remained healthy there, confirming that the symptoms must certainly have been due to top yellows.

### *Symptoms*

Characteristic symptoms of the disease in peas are that growth is inhibited and the stems and leaves turn pale beginning generally in the apical parts where the leaflets often remain narrow and pointed, folded together or heavily curled and pointing upwards. Older leaves assume a twisted and yellowed appearance. All aerial parts of affected plants become rigid and brittle; later the bases of the stems and the roots show a red internal discoloration and ultimately the plants collapse completely. Plants may have become infected long before the discoloration shows. As with sugar beet yellows and potato leafroll, the virus induces phloem necrosis, which obstructs translocation from the leaves to the stems and roots. QUANTZ made this necrosis clearly visible in microscopical preparations by staining with fuchsine.



FIG. 2. SOME PLANTS WITH TOP YELLOWS IN A PLOT OF DWARF PEAS OF THE VARIETY SERVO. HEAVY STUNTING OF PLANTS INDICATED BY ARROWS; CHLOROSIS IN APICAL PARTS OF MOST OTHER PLANTS IS CLEARLY VISIBLE

### *Damage*

The damage caused by top yellows is not confined to a stunting of growth accompanied by yellowing and withering of the affected plants. It results in reduced yield, often associated with a high proportion of small, undeveloped seeds.

If symptoms occur early in the season, the yield reduction is more serious; this is connected with the contamination of an ever-increasing number of scattered plants in the course of the summer. Only in exceptional cases are all plants attacked. Plants that were first infected can generally be discovered later in a stunted, yellow, semi-withered condition – without any pods – amidst the surrounding crop. The later the infection takes place, the longer the plants can grow and produce pods and a spreading infection affecting an ever-increasing number of plants therefore results in the plants having very irregular height and uneven development i.e. a very irregular stand.

### *Occurrence*

This virus disease has little significance in the northern provinces of the Netherlands, because winged aphids do not occur there until late in the season. Very susceptible pea varieties, such as Servo, Unica and Mansholt's Pluk are still successfully grown in these northern districts but in the central and southern districts of the country, however, where the disease can spread over wide areas, the situation is quite different.

Here the cultivation of susceptible varieties involves great risk, though some susceptible but very early ripening varieties, such as Alaska and Venlose Lage (de Grace) are still grown on a comparatively small scale. When these varieties have been sown early, they have usually produced a sufficient number of pods before any heavy infection occurs. By contrast, in northern and southern France such varieties become infected so early and so heavily that often all plants become severely damaged. This is not only the result of very early development of winged aphids, but also of the extensive cultivation of lucerne.

*Hosts*

Lucerne is an important winter host of the pea aphid and the virus. Experience has shown over a long period that a heavy attack of peas often takes place in the vicinity of lucerne fields. QUANTZ also mentions broad beans and field beans (*Vicia faba*), *Vicia sativa*, *Vicia narbonensis* and *Pisum melanocarpum* as being host plants of the top yellows virus. DE FLUITER and HUBBELING (1955) found that white clover can

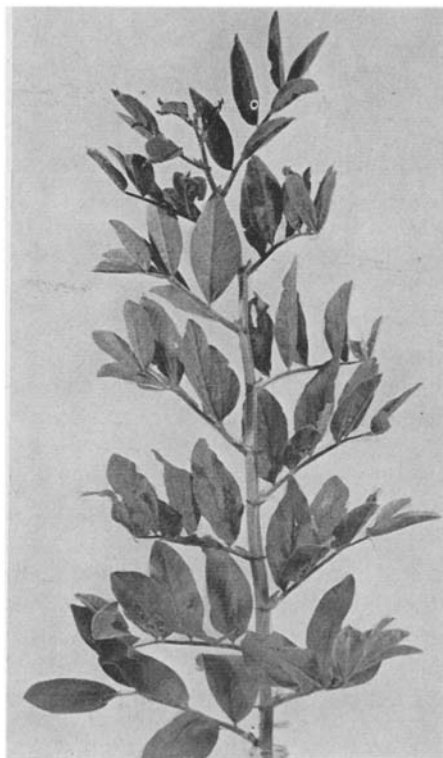


Fig. 3



Fig. 4

FIG. 3. FIRST SYMPTOMS OF TOP YELLOWS IN BROAD BEANS. LEAVES ARE FOLDED LENGTHWISE AND POINTING UPWARDS. THEY ARE LESS GLOSSY AND COLOURED SOMEWHAT BRIGHTER THAN NORMALLY

FIG. 4. SYMPTOMS OF TOP YELLOWS IN OLD PLANT OF BROAD BEAN. LEAVES SHOW INTERVEINAL CHLOROSIS AND DROP PREMATURELY. THEY ARE HEAVILY ATTACKED BY GREY MOULD (*BOTRYTIS FABAE*)

harbour the virus, whilst perhaps occasionally red clover may be attacked. The symptoms in these host plants largely agree with those in peas. Yellowing or rolling of the leaves in the tops of the plants, and retardation of stem growth are always characteristic symptoms. In broad beans a lengthwise curling and vertical erection of the leaves is the first most striking symptom. Later the plants turn yellow, beginning at the apex. The leaves turn greenish-yellow – the veins remaining green for some time – and drop off prematurely. Conspicuous is the rigid and brittle structure of the leaves caused by the accumulation of assimilated material as a result of phloem necrosis. Besides the soil fungi which benefit from this weakening of the plants, *Botrytis fabae* also appears to take advantage of it, in particular when it invades the yellowing leaves, which soon start to drop off. Under these conditions the fungus then causes numerous large, grey patches with concentric rings on the leaves, whereas in healthy plants it usually only produces small brown spots (chocolate spot).

#### *Vectors*

Although the green pea aphid *Acyrtosiphon pisum* HARRIS is undoubtedly the principal vector of the virus, QUANTZ and VÖLK (1954) also obtained some positive results with *Macrosiphum euphorbiae* THOMAS and *Megoura viciae* BUCKT. With the aid of these aphids it proved possible to transfer the virus from peas to broad beans and vice versa. DE FLUITER and HUBBELING (1955) found that the pea aphid and the potato top aphid, taken from diseased lucerne and white clover, after a feeding period of a week, infected peas and broad beans. They also established that pea aphids from a lucerne field without distinct disease symptoms, produced top yellows in peas and broad beans.

#### *Resistance*

Because a considerable portion of the plants in a field escapes infection, selection for resistance in a population derived from a crossing is unreliable. Only by means of line selection can the resistance of selected plants be tested, especially since resistance is presumably due to one or more dominant genes. Certain pea varieties do not remain free from symptoms under all conditions as in the case with tolerant or slightly susceptible varieties that exhibit a weak distortion of the leaves. Such varieties do not suffer from this weak attack, however, and do not turn pale or yellow. The best policy is of course to select varieties which show no symptoms at all.

Because many resistant pea varieties are known – see collection listed in Table 1 – it is usually possible to choose both parents from this collection. The great advantage of this procedure is that it is not necessary to select for resistance, as all the descendants from such crosses already possess this common character. When resistant varieties are crossed with varieties developing weak symptoms it is not impossible that later populations will produce some susceptible plants.

N. HUBBELING

TABLE 1. SURVEY OF PEA VARIETIES, SUSCEPTIBLE OR RESISTANT TO TOP YELLOWS AND FUSARIUM WILT

Varieties ( <i>Rassen</i> )	Top Yellows* ( <i>Top- vergeling</i> )	Fusarium Wilt* ( <i>Amerikaanse vaatziekte</i> )	Varieties ( <i>Rassen</i> )	Top Yellows* ( <i>Top- vergeling</i> )	Fusarium Wilt* ( <i>Amerikaanse vaatziekte</i> )
Abundance (Bliss'-)	r	s	Columba (Breustedt's-)	s	r
Admiral Beatty	r	?	Commando (Delwiche-)	s	r
Alaska dark green	v	r	Concordia	s	rs
Alaska (Express, Haar- steegse)	v	r	Confidence	r	r?
Alaska (Sweet-)	v?	r	Conserva	s	v
Alderman	r	r	Conservenwonder (Mer- veille des Conserves)	s	v
Alderman (Dwarf-)	s	r	Conso	r	v
American Wonder	s	v	Continental	?	r
Annonay (d'-)	s	rs?	Couturier	v	r
Aureool	t	r	Daisy (Dwarf Telephone)	s	v
Aurora	v	r	Début	s	v
Automobile	s	?	Delex (Dippe's-)	r	v
Avanti	v	v	Deli (Dippe's-)	r	?
Balder	rs	r	Délices des Conserves	s	r
Battelse	v	r	Delikatess	r	v
Batt's Wonder	?	v	Delisa (Schreiber's-)	r	v
Beta	r	v	Diamant (Haubner's-)	r	r
Bienvenue	s	?	Director	r	r
Big Ben	r	r	Dolfijn	s	r
Blauwschokker	s	rs	Douce Provence	v	v
Boordevol	s	v	Duplex (Early-)	r	v
Bouquet	v	v	Duplica (Schreiber's-)	t	r
Brilliant (van Waveren's-)	t	r	Early Badger	v	r
Brunsviga (Terra's)	t	v	Early Harvest	s	r
Brunswick Folger	s	r	Early May (Vroege Mei)	v	rs
Burpeeana	r	v	Early Perfection	s	v
Canner King	s?	r	Early Surprise	s	r?
Canner Perfection	?	r	Early Sweet	s	r?
Canner (Small late)	r	r	Eersteling	v	v
Cansweet	s	r	Elberta	s	v
Caractacus	s	r	Elf	r	r
Cavalier	v	r	Emigrant	t	r
Celsior	r	r	Eroïca	s	r
Censeur	r	v	Espoir de Gembloux	s	v
Centurion	r	rs	Everbearing	r	?
Ceres (Breustedt's-)	r	r	Exalda (Terra's-)	r	v
Chancellor (Lord-)	s	r	Excelsior (Nott's-)	rs	rs
Chemin long hâtif	s	s	Express à longue cosse	v	?
Chemin long tardif 4	t	r	Fairbeard's Nonpareil	s	?
Clamart demi main	?	v	Favorite (Woodw-)	r	?
Clamart trois gousses	s	r	Feltham First	v	v
Clause 50	rs?	r	Fill Basket (Plein le pa- nier)	r	?
Clauserva	rs	r			
Climax	r	r			

\* r = resistant (*resistent*); t = tolerant or slightly susceptible (*tolerant of weinig vatbaar*); s = susceptible (*vatbaar*); v = very susceptible (*zeer vatbaar*); rs = segregating (*splitsend*).

RESISTANCE TO TOP YELLOWS AND FUSARIUM WILT IN PEAS

Varieties ( <i>Rassen</i> )	Top Yellows* ( <i>Top- vergelng</i> )	Fusarium Wilt* ( <i>Amerikaanse vaatziekte</i> )	Varieties ( <i>Rassen</i> )	Top Yellows* ( <i>Top- vergelng</i> )	Fusarium Wilt* ( <i>Amerikaanse vaatziekte</i> )
Fin des Gourmets . . . . .	s	r	Kelvedon Standby . . . . .	r	v
Finette . . . . .	s	v	Kelvedon Triumph . . . . .	r	r
Foli (Dippe's-) . . . . .	r	v	Kelvedon Wonder . . . . .	r	v
Fondant sucré . . . . .	r	?	King of the Dwarfs . . . . .	r?	r
Fordhook Wonder . . . . .	?	r	Kloostererwt . . . . .	r?	r
Foremost . . . . .	r	?	Koning d. Middelvroegen	r	r
Forto . . . . .	s	rs	Konservärt . . . . .	r?	v
Furore . . . . .	r	v	Konservenperle . . . . .	s	v
Gems . . . . .	?	v	Konservenstolz . . . . .	r?	v
Giant Laxtonian . . . . .	?	v	Koroza . . . . .	r	r
Giant (Midseason-) . . . . .	?	r	Krombek (Limb. Groene-)	s	v
Glacier . . . . .	s	v	Krombek (Nunhem's-) . . . . .	s	v
Gladiateur . . . . .	r	?	Krombek (Nunhem's		
Gloire de Quimper . . . . .	v	v	Lente-) . . . . .	s	v
Gonthier vert . . . . .	r	?	Kronborg . . . . .	r	v
Grace (de-) . . . . .	v	v	Kronenerbse (Gelbe-) . . . . .	s	r
Green Crop . . . . .	?	v	Laurell . . . . .	r	v
Gradus . . . . .	r	r	Laxall . . . . .	v	rs
Greka . . . . .	v	r	Laxtonian . . . . .	s	?
Gruno (green seeded) . . . . .	s	r	Laxton's Progress . . . . .	r	v
Gruno Rozijn (grey seeded) . . . . .	s	r	Laxton's Superb . . . . .	r	v
Hada (Terra's-) . . . . .	r	rs	Lentedopper (Alaska, late type) . . . . .	v	v
Hamund . . . . .	r	v	Lincoln (Greenfeast, Hustler, Nain Sans		
Helda . . . . .	s	r	Rival, Prodigé) . . . . .	r	rs
Helios . . . . .	?	v	Lincoln (green seeded) . . . . .	r	rs
Heralda (Dippe's-) . . . . .	r	rs	Little Marvel (Petite		
Heraut . . . . .	r	r?	Merveille) . . . . .	s	v
Horat . . . . .	t?	r	Lolo . . . . .	?	r
Horsford Market . . . . .	?	v	Loyalty . . . . .	r	?
Hundredfold . . . . .	r	v	Major . . . . .	r?	r
Hyalite . . . . .	s	r	Mansholt's Pluk . . . . .	v	v
Icer . . . . .	s	rs	Marché de Bern . . . . .	t	r
Ideal . . . . .	s	v	Mardelah . . . . .	s	r
Imperial . . . . .	s	rs?	Markant . . . . .	?	v
Impudance . . . . .	?	rs	Melting Marrow (Impr.-)	?	r
Institut de Gembloux . . . . .	s	r	Merit (Wisconsin-) . . . . .	r	r
Ivora . . . . .	s	r	Meteor (Petit Provençal, Eminent) . . . . .	v	v
Jubilee . . . . .	r	r	Michaux de Hollande . . . . .	s	?
Juvel . . . . .	?	r	Michaux de Paris . . . . .	s	?
Juwel (van Waveren's-) . . . . .	r	r	Mira (Breustedt's-) . . . . .	t	rs
Kelvedon Champion . . . . .	r	v	Miracle . . . . .	t	rs
Kelvedon Hurricane . . . . .	s	r	Monarch Canner . . . . .	?	r
Kelvedon Monarch . . . . .	r	r	Monopol . . . . .	v	v
Kelvedon Perfection . . . . .	r	v	Morse's Progress . . . . .	r	?
Kelvedon Spitfire . . . . .	r	v	Morse's Market . . . . .	r	r
			Multifold . . . . .	r	r

N. HUBBELING

Varieties ( <i>Rassen</i> )	Top Yellows* ( <i>Top- vergelng</i> )	Fusarium Wilt* ( <i>Amerikaanse vaatziekte</i> )	Varieties ( <i>Rassen</i> )	Top Yellows* ( <i>Top- vergelng</i> )	Fusarium Wilt* ( <i>Amerikaanse vaatziekte</i> )
Multipod . . . . .	s	?	Salzmünder Frühe . . . . .	r	r
Mai (Nain de-; Venlose Lage) . . . . .	v	rs	Salzmünder Grüne . . . . .	r	r
Nain extra hâtif à chassis	v	rs	Saxa vert . . . . .	r	v?
New Era . . . . .	?	r	Senator (Sénateur, Nun- hem's Suikerzoete) . . . . .	r	v
Nova (van Waveren's-) . . . . .	r	r	Serpette amélioré (Verbe- terde Witte Krombek)	s	r
Ohle Ohlsen . . . . .	v	v	Serpette cent pour un (Stamkrombek Gele)	s	r
Oliva . . . . .	t	v	Serpette d'Auvergne (Witte Krombek) . . . . .	s	r
Onsa (Terra's-) . . . . .	s	v	Serpette guilloteaux (Edelkrombek) . . . . .	t	r?
Onward . . . . .	r	v	Serpette vert de Paris (Mechelse Krombek).	t	r
Österlen . . . . .	?	r	Servo . . . . .	v	v
Ostgöta . . . . .	?	r	Sharpe's Standard (Le Delicieux) . . . . .	r	?
Ötöfte . . . . .	?	r	Shasta . . . . .	?	r
Peacemaker . . . . .	s	r	Sherwood . . . . .	r	r
Perfectah . . . . .	r	r	S.I.3 . . . . .	r	v
Perfection . . . . .	r	r	Siegerin (Haubner's-) . . . . .	r	v
Perfection dark seeded . . . . .	t	r	Signal . . . . .	?	v
Perle verte . . . . .	s	v	Splendor . . . . .	r	rs
Petit Breton . . . . .	s	r	Springtide . . . . .	?	v
Petit Cevenol . . . . .	s	r	Sprinter (van Waveren's-)	t	v
Phenomenon . . . . .	?	r	Stern (van Waveren's-) . . . . .	r	v
Pilot (Aviateur) . . . . .	s	?	Stijfstro C.B. . . . .	r	v
Pioneer . . . . .	r	v	Stratagem (Impr-) . . . . .	r	r
Pixie . . . . .	r?	r?	Stride (Giant-) . . . . .	r	r
Poulwell Pea . . . . .	?	v	Supergrade . . . . .	r	v
Premium Gem . . . . .	v	rs	Superlaska (Alaska 14) . . . . .	r	v?
President Wilson . . . . .	r	?	Surpass . . . . .	r	v?
Pride (Wisconsin-) . . . . .	r	r	Surprise . . . . .	s	v?
Primavera . . . . .	?	v	Surproduction . . . . .	s	r
Primus . . . . .	r	rs	Téléphone . . . . .	r	v?
Quarante deux de Sar- celles (Meikoningin)	v	v	Téléphone nain (Dwarf Telephone) . . . . .	rs	v
Rapida (Schreiber's-) . . . . .	r	v	Tenex . . . . .	r	v?
Rasper Gele . . . . .	s	r	Thomas Laxton . . . . .	s	v?
Rasper Groene . . . . .	s	r	Titan (van Waveren's-) . . . . .	r	r
Rika . . . . .	r	?	Triomphe de Maninet . . . . .	v	v
Roem van Alkemade . . . . .	v	v	Unica . . . . .	v	v
Roi des Conserves (Con- servenkoningin) . . . . .	r	v	Union Jack . . . . .	s	v
Roi des Serpettes (Vlijmse Krombek) . . . . .	v	r	Urania . . . . .	t	v
Rondo C.B. . . . .	t	v	Vares . . . . .	t	r
Sabre . . . . .	v	?	Velocity . . . . .	?	v
Safir . . . . .	?	v	Victory Freezer . . . . .	?	v
Salzmünder Edelperle . . . . .	r	r	Viktoria (Dippe's Gelbe-)	r	r
			Vinco . . . . .	t	r



## RESISTANCE TO TOP YELLOWS AND FUSARIUM WILT IN PEAS

Varieties ( <i>Rassen</i> )	Top Yellows* ( <i>Top- vergeling</i> )	Fusarium Wilt* ( <i>Amerikaanse vaatziekte</i> )	Varieties ( <i>Rassen</i> )	Top Yellows* ( <i>Top- vergeling</i> )	Fusarium Wilt* ( <i>Amerikaanse vaatziekte</i> )
Virtus . . . . .	t	v	Wunder von Weissenfels		
Volontaire . . . . .	rs	?	(van Waveren's-) . . .	r	v
Vreeza . . . . .	s	rs	Wonder (Witham-) . . .	s	rs
			World's Record . . . . .	s	v
Wando . . . . .	r	v	Wyola . . . . .	r	r
Weibull 1541 (Piccolo) .	r	r	Zeiner's Grüne Bastard		
Willet's Wonder . . . . .	v	v	(Profusion, Vedette)	t	r
Wisconsin Early Sweet .	s	?	Zeiner's Kurz und Gut .	r	r
Wonder (Dordrecht-) . .	t	v	Zelka . . . . .	r	r
Wonder of England (Merveille d'Angleterre)	s	r			

Although there is not yet a simple method of testing for resistance which is in all respects reliable for the practical breeder, a number of indications can be given to render selection for resistance a feasible procedure for practical purposes viz.

1. Sow in the vicinity of well-established lucerne or white clover fields planted several years previously.
2. Transfer aphids from a well-established infested lucerne field to plants which are to be tested.
3. Sow susceptible varieties like Unica between the varieties or lines to be tested.
4. Omit insect control, which might adversely affect the development of aphids, so long as infection has not yet taken place.
5. Do not sow too early. There is more chance of infection by winged aphids when sowing is done in the second part of April or the beginning of May.
6. In districts where aphid attacks occur rarely, e.g. in the northern part of the Netherlands, it is difficult to select for resistance. The best results may be expected in the central and southern part of the country.
7. It is necessary to continue with line selection until no further segregation of susceptible plants occurs.

### 3. FUSARIUM WILT

#### *Cause*

Fusarium wilt is caused by the soil fungus *Fusarium oxysporum* f. *pisi*, race 1 SNYDER and HANSEN (= *Fusarium orthoceras* var. *pisi* LINFORD).

#### *Symptoms*

The commencement of attack is indicated by the stems diverging in all directions, and malformation and discoloration of the leaves occur as well. These become twisted and wilt and turn greyish green after losing their sheen and fresh colour. The distortion and discoloration shows first on the oldest leaves and gradually spreads to the apex, severely restricting plant growth. They wither entirely during warm, sunny weather and



FIG. 5. FUSARIUM WILT IN SUSCEPTIBLE PEAS. THE YOUNG PLANTS FALL APART AND WILT. THE LEAVES TURN DULL GREYISH GREEN AND ROLL

ultimately only thin brown skeletons of immature stems can be found and even these remnants rot away in the end.

#### *Damage*

The total annual damage inflicted by the disease has been estimated at tens of thousands of guilders. Such estimates nearly always relate to fields where the disease has not occurred before. This is because in regions where the soil is known to be infected, resistant varieties are usually grown. If the soil is once infected, susceptible varieties are vulnerable to attack even after a long period e.g. 7 or 8 years. As a rule the whole crop is lost when an attack of wilt occurs. The disease often begins in small localised areas, but they soon enlarge and link up, leading to complete failure of large fields of peas by the end of the same season. If small fields are attacked in an early stage, it is sometimes possible to grow a crop of beans instead.

#### *Occurrence*

The first fields attacked were in the provinces of Brabant (West), South Holland and Groningen. In the course of years more and more fields have become infected, and the disease has spread to other provinces, especially in areas of old heavy clay and reclaimed peat sub-soils. Only the province of Zeeland has remained free from it so far and apparently the disease does not occur, or occurs but rarely, in young calcareous polders.

The disease can be transmitted through the seed, though this may occur only after

repeated pea growing in the same field. After two crops of a susceptible variety the fungus has built up in the soil to such an extent that a failure, originating from a single spot, may be inevitable. Normally, however, at least 8 to 10 years elapse before a susceptible pea variety is grown a second time in the same field; moreover a latent infestation occurs in fields where no peas have been grown within memory. Few differences can be noted in the symptoms shown by markedly different varieties. At best there are a few varieties which remain green a little longer and sometimes succeed in developing some (green) pods with mature seeds before they are destroyed in a heavily infested field. In general the rapidity with which the plants die is closely associated with the degree of infection of the soil. On infested fields resistant plants develop quite normally and generally only differ from crops grown on healthy fields by the presence of some dry leaves at the stem bases. Resistant plants can also succumb to wilt at soil temperatures of over 28 °C. In the Netherlands such temperatures are exceptional at ground level in the field and this aspect is therefore not important. When selection is carried out in a glasshouse or in tropical regions, however, this factor must be taken into account.

To summarize, the degree of attack by fusarium wilt to peas depends on:

1. The degree of infection in the soil.
2. The soil temperature. Disease symptoms occur in seedlings hardly 6 cm high at temperatures of over 20 °C.
3. The habit of susceptible pea varieties to wilt rapidly.

#### *Resistance*

Resistance can be tested in a very simple way, viz. by sowing in uniformly heavily infested soil. For this purpose it is possible to start either with susceptible varieties which may sometimes produce occasional resistant plants, or with populations of susceptible and resistant varieties. The first method of selection can soon lead to positive results because in varieties of self-fertilizing plants such as peas heterogeneous plants rarely occur. On the other hand, in selecting progenies of resistant plants from a population, susceptible plants often occur in the lines. Since resistance is due to one dominant factor it is possible to select lines which are sufficiently and homozygously resistant, provided selection is practised on a fairly large scale.

Selection for resistance to fusarium wilt can also be successfully effected on a smaller scale, viz. by using the method of repeated backcrossing, provided, however, that the recurrent parent possesses good qualities i.e. it should only lack the genes for resistance. Furthermore it is necessary in this method to sow repeatedly on infested soil, as long as backcrossing is continued. In addition another year has to be devoted to line selection in order to choose homozygously-resistant lines. A result of this backcrossing is, therefore, that the new resistant variety is not distinct in appearance from the recurrent parent. This has the advantage that the value of the variety is already known. In this connection it could be argued that only in infected regions would there be a case for growing the new resistant variety, unless the established variety was withdrawn from circulation. However, if a new variety was introduced which, apart from its resistance, was also in other respects distinguishable from the recurrent parent, it would be in demand outside the infected areas as well.



FIG. 6. TESTING OF PEA VARIETIES IN A SOIL INFESTED WITH FUSARIUM WILT. THE SUSCEPTIBLE PLANTS HAD DIED VERY EARLY, SO THAT BLANKS OCCUR IN PLACES WHERE SUSCEPTIBLE VARIETIES HAD BEEN SOWN

A third method of developing a resistant variety is to make a cross between two resistant varieties. Under such circumstances it is essential to choose the parents carefully so as to allow the breeding objective to be attained without having to resort to subsequent selection for resistance. The resistance of the two parents at the outset should of course be beyond any doubt.

#### 4. COMBINED RESISTANCE TO TOP YELLOWS AND FUSARIUM WILT

There is much to be said in favour of breeding varieties resistant to both diseases, but the choice of parents with combined resistance is rather restricted (see Table 1). Although resistance to both diseases can be obtained as a result of a cross between such resistant parents, and without practising selection, it depends on the breeding objective whether there is sufficient opportunity left to select for other characters. If it is not possible to choose parents with both types of resistance, it is easy to find varieties which are resistant to top yellows, as they occur more frequently than wilt-resistant varieties. There are also practical advantages in choosing parents which are both at least resistant to top yellows; in this case it is possible to secure resistance to the two diseases by carrying out line selection for wilt resistance during only one year. The alternative – using wilt-resistant parents – is to obtain pure lines in order to be sure of resistance to top yellows and it is desirable to test for resistance during two consecutive years.

With a view to the choice of parents, as described above, a detailed survey is given of the resistance and susceptibility of many pea varieties to both diseases.<sup>1)</sup> In the case of the varieties described as susceptible, it is not impossible that some resistant plants may result. However, a few thoroughly selected varieties, such as Unica, appear to be completely susceptible to both diseases. Kelvedon Wonder is completely resistant only to fusarium wilt. Susceptible varieties, in which a less strict selection has been practised, can sometimes produce resistant lines, particularly when they have resulted from a cross involving a resistant parent.

## 5. SUMMARY

Top yellows, a virus disease of peas, broad beans and field beans (*Vicia faba*), had been known in the Netherlands as "Fusarium solani foot disease" for more than thirty years. L. QUANTZ (Braunschweig, Germany) who has named it "Blattroll", told the writer in 1954 that the disease is disseminated only by aphids.

On account of an abundant development of winged pea aphids (*Acyrtosiphon pisum* HARRIS) on lucerne in the central and southern districts of the Netherlands, the disease generally spreads early and on a very large scale in those areas, especially because lucerne appears to be a winter host plant for aphids and for the virus. In the northern provinces top yellows as a rule does not occur before the end of the season, because lucerne and aphids are unimportant in that region.

White clover also appears to be a winter host for the virus. QUANTZ and VÖLK further report that *Vicia sativa*, *Vicia narbonensis* and *Pisum melanocarpum* are also host plants. *Macrosiphum euphorbiae* appears to be able to transmit the virus as well. By sowing peas late, and in the vicinity of well-established lucerne or white clover fields it is possible to select successfully for resistance in the central and southern districts of this country. Presumably the resistance has a dominant inheritance.

Wilt disease, caused by the fungus *Fusarium oxysporum* f. *pisi*, race 1 necessitated the growing of resistant varieties in infested districts. A rapid destruction of the plants is encouraged by the presence of uniformly heavily infested soil, high soil temperature, and high sensibility of susceptible pea varieties. The fungus can be transmitted via the seed. Testing for resistance can be carried out by growing on an infested field, resistance being governed by one single dominant gene. In lines derived from resistant plants selected from populations resulting from crosses, susceptible plants may therefore occur from time to time. In contrast resistant plants in commercial varieties which have been grown for many years, generally appear to produce homozygously resistant lines.

Testing for resistance to both diseases can be omitted if crosses are made between resistant varieties. Testing of the populations against one of the diseases becomes

<sup>1)</sup> The listed varieties have been tested on behalf of the Institute for Research on Varieties of Field Crops (IVRO), the Institute of Horticultural Plant Breeding (IVT) and for the Association for the Study of Leguminous Crops (PSC), at Wageningen. In addition the Plant Protection Service (PD) at Wageningen made available the results of their tests of fusarium wilt resistance of a number of pea varieties.

necessary if the parents only possess, in common, resistance to one of the diseases. In that case selection for resistance to fusarium wilt can be carried out more easily, using parents which are both resistant to top yellows. This is more practicable, because this resistance occurs more frequently than resistance to fusarium wilt.

#### ACKNOWLEDGEMENT

The author wishes to express his sincere thanks to Mr. J. D. REYNOLDS, Technical Officer of the Home Grown Threshed Peas Joint Committee, Peterborough, England, for his kind examination of this article.

#### 6. SAMENVATTING

##### *Resistentie tegen topvergeling en Amerikaanse vaatziekte bij erwten*

Ruim dertig jaar lang werd topvergeling, een virusziekte van erwten, tuin- en veldbonen, aangeduid met „voetziekte”. Van L. QUANTZ (Braunschweig), die deze ziekte met „Blattroll” betitelde, werd in 1954 vernomen, dat de verspreiding er van uitsluitend door bladluizen geschiedt.

Tengevolge van topvergeling worden verspreide planten van vatbare erwten- of tuinbonenrassen sterk in groei geremd en lichtgeel van kleur, beginnend in de groeitoppen. De oogst is dan gering en de zaden krijgen vaak niet de normale grootte. De bladeren worden bovendien smal en spichtig en krullen vaak iets op, terwijl ze zich verticaal oprichten. Nooit worden alle planten tegelijkertijd aangetast, terwijl vaak talrijke planten aan de ziekte ontsnappen, hetgeen een zeer ongelijkmatige stand van het gewas tengevolge heeft.

Wegens overvloedige ontwikkeling van gevleugelde erwtenbladluizen (*Acyrtosiphon pisum* HARRIS) op lucerne in het centrum en zuiden van Nederland, wordt de ziekte daar meestal vroeg en massaal verbreid, vooral omdat lucerne een winterwaardplant van bladluis en virus blijkt te zijn. In de noordelijke provincies ziet men topvergeling in de regel pas tegen het einde van het seizoen. Ook witte klaver bleek een winterwaardplant te zijn van het virus. QUANTZ en VÖLK vermelden voorts *Vicia sativa*, *Vicia narbonensis* en *Pisum melanocarpum* als waardplanten. De aardappeltopluis *Macrosiphum euphorbiae* THOMAS blijkt bovendien in staat te zijn het virus te verbreiden. Door middel van late teelt van erwten in de nabijheid van overjarige percelen lucerne of witte klaver is in het centrum en zuiden van Nederland meestal met succes op resistentie te selecteren. Vermoedelijk is de erfactor voor resistentie dominant.

Amerikaanse vaatziekte, veroorzaakt door *Fusarium oxysporum*, *pisi*, ras 1, maakt de teelt van resistente rassen op besmette terreinen noodzakelijk. De stengels van de zieke planten wijken uiteen, de bladeren worden grijsgroen, verwelken en verdorren. De planten sterven meestal, voordat ze tot vruchtzetting zijn gekomen. Een snelle afsterving wordt bevorderd door:

1. zwaar besmette grond,
2. hoge bodemtemperatuur,
3. grote gevoeligheid van vatbare erwtenrassen.

De schimmel kan met het zaaizaad overgaan.

De toetsing op resistentie kan eenvoudig geschieden door uitzaai op besmette terreinen. De resistentie berust op 1 dominante erfactor.

In lijnen afkomstig van resistente planten uit kruisingspopulaties kunnen derhalve nog vatbare planten uitsplitsen. Resistente planten in jarenlang voortgeteelde rassen blijken daarentegen meestal homozygoot te zijn.

Men kan zich de toetsing op resistentie tegen beide ziekten besparen, indien men kruisingen maakt van rassen, die hiertegen al resistent zijn. Toetsing van de kruisingspopulaties tegen één van beide ziekten wordt noodzakelijk als men zijn geniteurs zodanig kiest, dat ze steeds beiden resistentie tegen één ziekte gemeenschappelijk hebben. In dat geval kan het gemakkelijkst op resistentie tegen amerikaanse vaatziekte worden geselecteerd, waartoe dus resistentie tegen topvergeling in beide ouders voorondersteld wordt.

De toetsing op resistentie tegen amerikaanse vaatziekte werd verricht op percelen zware kleigrond, die in voorafgaande jaren besmet bleken te zijn geworden. In de regel waren dergelijke terreinen niet anders dan tegen hoge prijzen van landbouwers te pachten.

Aanvankelijk werd getoetst door de Plantenziektenkundige Dienst te Zegswaard en Hoeven, waarvan de resultaten welwillend ter beschikking werden gesteld door Dr. J. A. A. M. H. GOOSSENS. In 1952 werd door Dr. J. C. 's JACOB een terrein te Nieuw Beerta gebruikt. In de jaren 1953 tot en met 1955 werd de toetsing verricht op besmette velden van het I.P.O. te Wageningen.

De toetsing op resistentie tegen topvergeling werd in 1952, 1953 en 1954 uitgevoerd op het landbouwproefbedrijf "Zeeland" te Wilhelminadorp, en in 1955 op het bedrijf van de Heer M. MURRE te Rilland Bath. Daarbij werd respectievelijk veel medewerking ondervonden van de Heer J. WISKERKE, chef van het proefbedrijf "Zeeland" en van het Rijkslandbouwconsulentschap te Goes.

Bijna tweederde deel van de rassen werd getoetst op verzoek van het Instituut voor Veredeling van Tuinbouwgewassen te Wageningen. De overige rassen werden getoetst voor de Peulvruchten Studie Combinatie, voor het Instituut voor Rassenonderzoek van Landbouwgewassen en voor particuliere kwekers. Schrijver is deze instellingen en personen zeer erkentelijk dat zij ermee accoord gingen, de verkregen resultaten uitvoerig in dit samenvattend artikel te publiceren.

## 7. REFERENCES

- FLUITER, H. J. DE en HUBBELING, N., Waarnemingen over topvergeling bij erwten. (Observations on top yellows of peas). *T. Pl. ziekten* **61** (1955): 165-175.
- GOOSSENS, J., Een voor ons land nieuwe vaatziekte der erwten. ("The American Wilt" of peas, a new disease for the Netherlands). *T. Pl. ziekten* **54** (1948): 75-80.
- HUBBELING, N., Een virus als oorzaak van de zogenaamde "voetziekte" bij erwten. *Zaadbelangen* **8** (1954): 181-183.
- HUBBELING, N., Amerikaanse vaatziekte bij erwten en het kweken van resistente rassen. *Zaadbelangen* **8** (1954): 258-259.
- KERLING, L. C. P., Het overgaan met zaad van de Amerikaanse vaatziekte van erwten. (Seed transmission of Fusarium wilt of peas). *T. Pl. ziekten* **58** (1952): 236-239.

N. HUBBELING

- QUANTZ, L., Untersuchungen über die Viruskrankheiten der Ackerbohne. Mitt. Biol. Bundesanst. Land-u. Forstwirtsch. **80** (1954):171-175.
- QUANTZ, L. und VÖLK, J., Die Blattrollkrankheit der Ackerbohne und Erbse, eine neue Viruskrankheit bei Leguminosen. Nachr. bl. deutschen Pflanzenschutzdienstes **6** (1954):177-182.
- ROLAND, G., Note sur un virus attaquant les légumineuses. Parasitica **11** (1955):66-68.