BREEDING FOR QUALITY IN SOME VEGETABLES

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MEDEDELING 191 APRIL 1963

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Estratto da « *Atti dell'VIII Convegno Annuale della Società Italiana di Genetica Agraria* », Bergamo 26-28 Ottobre 1961 in « *Genetica Agraria* » - Vol. XVI - Fasc. 1-2 - 1962

PAVIA - TIPOGRAFIA VISCONTEA - 1962

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Introduction

When planning a plant breeding project, two important things must be considered. In the first place the characters which must be improved and in the second place the breeding technique that is most promising for the actual project.

In considering the characters which must be worked upon, the usefulness of studying their genetics is generally accepted. But if a character is complex, it should first be analysed in a physiological way in order to find the really controlling factors. As many characters of horticultural plants are of a complex nature, we have not been satisfied by adapting the outfit of our institute to genetical and cytological work only, but have also adapted it to the physiological and chemical analysis of plant performance. To that purpose, a phytotron and a chemical laboratory are incorporated.

This outfit is a great help in finding the basis for the improvement of quality in vegetables and other plants. Not all quality problems are of a physiological nature, of course. In fact, what counts as quality in the trade may be anything. It may be a traditional size, shape or colour of the fresh or processed produce. It may be a certain resistance against deteriorating conditions or organisms. Or it may be in the field of anatomy, flavour, or chemical composition.

In what is following I have chosen some examples from our current research work. Nothing of what I shall discuss has been completed. It will be a kind of progress report on projects which are going on. Some projects are still in a phase of purely empirical investigations, some are far enough developed to show some of the causal relations within the plant and in the interaction of plant and growth conditions.

Lettuce quality when grown in the winter season

Lettuce is grown in the Netherlands all the year round; during the summer outdoors, during the winter in glasshouses or frames. Until about 1950 May King was the only variety grown to some extent under glass. But, during the dark months of autumn and winter, its quality is not fully developed; its head remains loose, it does not sufficiently fill up, under those conditions its quality is not good enough.

A first principal change occurred with the appearance of the varieties Proeftuins Blackpool, Regina and Interrex, all of which had their origins in chance findings of off-types. These varieties give a better head when grown under glass during autumn or winter. From this empirical fact we may conclude that they are evidently better adapted to the growth conditions prevailing in that period.

A second change was more intentionally brought about by intercrossing these new early varieties and some others, and testing the resulting progenies under the conditions of the practical cultures. Our Institute did the breeding and selecting work (Mr. J. A. HUYSKES and Mr. C. M. RODENBURG). The Experiment Station for Glasshouse Crops at Naaldwijk provided the glasshouses and the right cultural conditions (Mr W. VAN SOEST, director, Mr. K. OLIEMAN, foreman, and Mr. W. P. VAN WINDEN, assistant). From this co-operation resulted a series of F_5's which, in proportion to Proeftuins Blackpool, Regina, and Interrex, gave an increase in the individual head weight of 10-50%.

The method used to reach this result was completely empirical. It gives the impression to be a case of transgression, but causal relations have thusfar not been analysed.

A larger fibreless top in asparagus

In asparagus the fibre content of the harvested spear is an important factor of quality. With the exception of its top a spear is normally more or less fibrous. Consequently, if a whole spear is taken for canning, the fibres must be removed by hand before processing. This has its difficulties like irregular availability of labour etc. To avoid these, canners in the U.S.A. are inclined to harvest the fibreless tops only. To this end they use the method of field snapping. This means that a spear is gripped at the tip and bent over. It snaps off at the point where, looking downwards, the fibre begins to be tough.

As a harvesting method this method is restricted to so-called green asparagus, which grows above the soil surface. But as a method of selecting an asparagus variety for a longer fibreless top it can be used for white asparagus as well. White asparagus is, of course, grown under a cover of earth, but for the purpose of selection it may also be grown green for one or more years.

This prompted Mr. J. A. HUYSKES of our Institute to start an investigation of the possibility of breeding an asparagus variety with a longer fibreless top. First of all, in an initial experiment the validity of the American method for application to Dutch asparagus was proved. Then the relation between the length of the fibreless top and the length of the whole spear above the soil surface was determined. In co-operation with the statistical department of our Institute (Mr. J. H. A. FERGUSON) regression lines were calculated for two fields (in 1957 and 1958). In the field of 1958 the fibreless tops appeared to be relatively larger than in the field of 1957. This is attributed to the fact that in the 1958-field the plants stood about 15 cm. deeper in the soil than in the 1957-field, so that of the 1958 plants a greater part of the fibrous part was hidden in the soil. So when selecting for a long fibreless top, attention must be given to the planting depth. In addition to this there are indications that the growth rate of the plants, as controlled by the growth conditions (e.g. temperature), may be another factor which must be taken into account.

In order to increase the capacity of the selection method Mr. HUYSKES has devised an apparatus consisting of a board, prepared in such a way that it enables a quick reading of the proportional length of the fibreless top of a growing spear. See Fig. 1.

He found a great variability in the proportional length of the fibreless top. At a total spear length of 20 cm. it varied from 5 to 18 cm.

For further breeding purposes plants with a proportional fibreless top of > 13/20 were chosen. About 1% of the checked plants satisfied this arbitrary selection standard. The progenies of these plants are growing now, and waiting for further selection when they will be big enough.

This method is still essentially empirical. But in this case, the testing method is not necessarily incorporated in the usual cultural method.

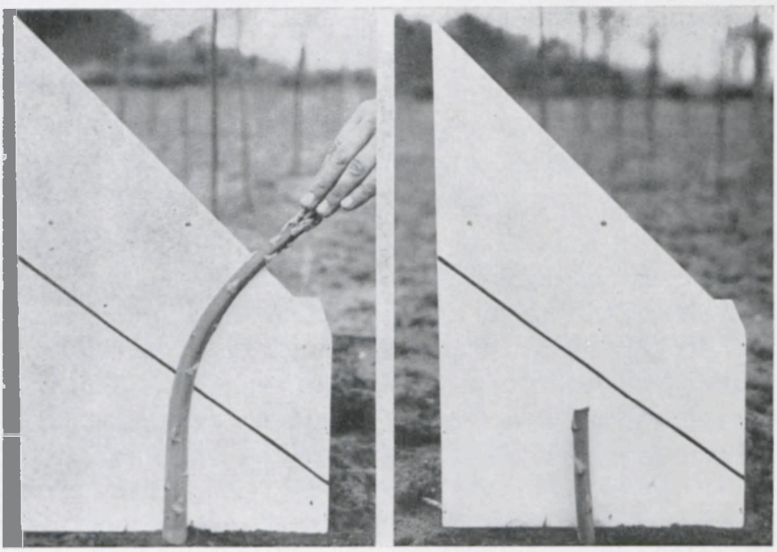

Fig. 1
Board enabling a quick reading of the proportional length of the fibreless top of a growing spear.

However, we think that it will be useful to go deeper into it, and that e.g. an investigation into the anatomical possibilities of asparagus may prove necessary. For if the fibre content of the plants is reduced very much, it may be that they will become too weak. In that case the finding of plants with a different system for mechanical strength might be promising.

Quality of peas as influenced by ripening diversity on a plant

For peas it is well known that an individual seed has an optimal phase of organoleptic quality. When too young the seed is watery and lacks flavour. When too old, the seed of a round seeded variety becomes mealy and that of a wrinkled seeded variety too hard skinned.

As the optimal organoleptic phase correlates with a certain degree of solidity of the seed, this phase can be determined with the aid of a tenderometer.

The difficulty for a canner is that on the same plant the peas do not all ripen at the same time. This makes it impossible to harvest all the peas of a plant in the optimal phase of quality. As this reduces the average quality of the peas harvested at a certain moment, pea breeders try to breed varieties that develop all their seeds in as short a period as possible. This has prompted Mr. E. KOOISTRA of our Institute to investigate the relation between the morphological composition of a pea plant and the possibilities of reduction of the ripening diversity on the plant.

An important view point is that the seeds of one pod ripen about simultaneously. Therefore Mr. KOOISTRA thinks it useful to breed varieties with many seeds in a pod. In the available varieties the number of seeds per pod varies from 5 to 10 or 12. The variety Elberta of Nunhem has about 10 seeds per pod. Among the Serpette types are also varieties with 10 or even more seeds per pod. So these varieties can be used as breeding parents for raising the number of seeds per pod.

Further, most varieties develop about four levels of two pods each per plant. The lowest level ripens first, then the second from below, then the third and then the fourth. The pods of one level ripen about simultaneously. So it seems attractive to reduce the number of levels and to increase the number of pods per level. Some American varieties like RN 31 and Multifreezer have 3 pods per level, but the third pod is somewhat behind in ripening and its seed setting is not satisfactory.

Therefore Mr. KOOISTRA tries to select plants with 3 pods per level which ripen simultaneously and with a good seed setting, also under unfavourable conditions. It seems possible that Brotherton has meanwhile realised this object in his new variety G 17 Canner Multipod.

Another line of investigation is the crossing of ordinary varieties with fasciata types to see if it is possible to get two flower stalks each with two flowers at the same knot. This would then give 4 pods per level.

A similar result might be possible in plants that make more branches directly at the base of the plant. A plant consisting of 3 branches with two levels of two pods would make 12 pods, ripening in two flushes. However, a plant consisting of one stem would have to develop 6 levels of 2 pods each to give the same number of pods. But in this case the pods would ripen in six flushes.

Yet another line of investigation is the shortening of the internodes. There may be a possibility that the difference of development of two levels would be smaller if they were nearer each other because of shorter internodes.

In this case the approach of the problem is directly based on the causal relations between the morphological characters of pea plants and the difference in ripening period of their seeds.

Bitterfree and seedless cucumbers

Some years ago the quality of the long green cucumber that used to be grown in frames became problematic when the frames were largely replaced by glasshouses. The same cucumber type that was very satisfactory when grown in frames showed a tendency to bitterness when grown in glass-houses.

This problem has relatively quickly been solved by breeding work, in two phases.

Among the European cucumbers some are found which have a bitter principle throughout the plant except in their fruits. Reusraths Bitterfreie in Germany is an example of this type, Rijk Zwaan's Vetobit and Nobit in Holland are other examples, and Ohlsens Enke in Denmark and Sweden has material of this type which gives a third example.

In the breeding procedures this type of absence of bitterness is very difficult, because:

1. If bitterness is genetically present, it does not always show. Therefore, all the fruits of a plant must be tasted, and then one is still not quite sure.
2. As selection is only possible on fully grown plants and each fully grown plant requires much glasshouse room, which is expensive, one can usually only select a small number of plants.

It is, therefore, not surprizing that the varieties of this type thusfar selected, do not yet satisfy most cucumber growers.

Now it is a happy circumstance that this character of bitterfree fruits is genetically dominant. This makes it possible to produce hybrids of a variety with bitterfree fruits crossed with a variety with bitter fruits. The fruits of these hybrids are then practically non-bitter, and by choosing a good partner the general horticultural characters may be improved.

However, Mr. ANDEWEG of our Institute found a way to improve the cucumber more fundamentally. He knew that Rehm & Wessels (1957) in some other cucurbitaceae (C. maxima, C. mixta, C. pepo, C. melo, Luffa cylindrica) had found individual plants which completely lacked the bitter substance. They did not find such plants in cucumber. But ANDEWEG tested about 15000 plants raised from seeds imported from many parts of the world. And in those 15000 plants he detected one that was completely bitterfree. This plant was increased by selfing and crossed and back crossed to popular Dutch varieties. This type implies the total absence of the bitter principle in all parts of the plant. ANDEWEG found that this type of non-bitterness depends on one recessive gene.

Testing for non-bitterness of this type is possible in two ways:

a) By tasting small pieces of the cotyledons;
b) By a physicochemical method, developed by Mr. J. W. DE BRUYN, phytochemist of our Institute.

In this latter case part of a cotyledon is also sufficient for making the test. The bitter principle of cucumber is cucurbitacin-C (C32 H50 08). If it is extracted with chloroform and a drop of the extract is put on filter paper moistened with a saturated solution of SbC_l 3 in chloroform, it will give fluorescence under an U.V. lamp. Absence of fluorescence indicates absence of cucurbitacin-C.

The great advantage of having discovered this type of nonbitterness and the physicochemical test is that great numbers of seedlings can be tested when they are quite young and do not yet occupy any considerable room. In this way sufficiently great numbers of bitterfree plants can be produced so that successive selection for different disease resistances can be executed, still leaving a sufficiently great number of plants for selection for productivity and other characters.

A more or less extended seed setting in cucumber for consumption is considered as another bad quality.

To make seed setting impossible ANDEWEG is developing purely female bitterfree plants, in this way combining two requirements of quality in the same material.

From Prof. PETERSON of the Michigan State University he received initial material, which is purely female. Prof. PETERSON also found a method to produce male flowers on genetically female plants, by spraying them periodically with gibberellin A 3 in a concentration of 1500 p.p.m.

The genetic background of the purely female plants is not yet quite clear. But when crossed to Dutch hermaphroditic varieties the F2 gives about one purely female plant in 16. Of the other 15 plants some have more female than male flowers and some show the reverse picture.

Shape and colour of carrots

In the quality of carrots shape and colour of the roots are important factors. After we had experienced that these characters may show much fluctuation even under growth conditions that superficially did not make the impression of great variation, we decided to investigate the controlling factors in this fluctuation. Mr. J. W. DE BRUYN, phytochemist of our Institute, took the responsibility for the chemical analyses and I myself for the physiological investigations.

The colour in our orange carrot varieties is caused by carotenoids. We mostly determined its content as mg/10g dry matter.

It was known that the carotene content generally increases with an increase in size of the roots up to a certain level, beyond which the root may still grow larger without the carotene content increasing to any significant extent. The level of the maximum may vary in different years. Therefore the maximum cannot be used as a representative value. But during the period before the maximum has been reached, there is a proportion between the total carotenoid content and the average root weight as expressed in grammes of dry weight. Therefore the total carotenoid content in proportion to the average dry root weight (before the maximum was reached) is taken as a typical value. This proportional value was always determined in a series of successive harvests, so that it could be graphically expressed as a curve. These curves could be determined under different growth conditions.

From these experiments the conclusion could be drawn, that both the shape and the carotenoid content of the root are an expression of the phase of ripening of the root. All the growth conditions that influence the shape and the colour of the root do so through their influence on the ripening equilibrium.

The ripening equilibrium is the result of two activities in a root:

primary vegetative growth ⇄ *root ripening (root thickening and colouring)*

Both activities may go on simultaneously, but, if the equilibrium is shifted more to the left, the primary vegetative growth may predominate over the ripening, with the result that the root will grow pointed and bleak. The proportional carotene content will then be low.

In the reverse case, if the equilibrium will lie more to the right, ripening may predominate over the primary vegetative growth, with the consequence, that the root will thicken, become rounded at the tip and well-coloured, but it will remain smaller.

The ripening equilibrium is controlled mainly by the temperature and the planting distances, and to a smaller degree also by the water content and the oxygen content of the soil.

A practical conclusion of these experiments for breeding purposes is the following. If I want to breed a well-coloured and well-shaped carrot variety, I must take into consideration the temperature level at which they must grow and ripen. If I want a big carrot that has to be grown on a rather cold peat soil, I shall have to breed a carrot that can ripen at a rather low temperature. If I want a small carrot that has to be grown during warm weather in the summer, I should not use for that purpose a carrot that has been selected for growth and ripening during cold early spring weather, but one that has been selected at a high temperature level.

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Summary

1. In many plant breeding projects a functional analysis of the characters that must be improved should precede a genetical analysis. It may be necessary to start this functional analysis in a purely empirical way. However, in order to find the really controlling factors inside and outside the plant, a follow-up of morphological,

chemical, or physiological investigations may be equally unavoidable. This certainly applies to many cases in which one tries to improve the quality of a plant.

2. Some current projects of the author's associates and of himself are discussed.

3. In two projects the improvement is approached in a purely empirical way. It concerns breeding for lettuce varieties with a better heading capacity during the winter season in glasshouses, and devising a method to select asparagus for a longer fibreless top.

4. In a pea-project breeding for more uniformity of quality at one harvesting time is based on a study of the morphological structure of pea plants.

5. Testing a great number of young seedling plants, and developing a physicochemical test for cucurbitacin-C, provided a rational basis for the breeding of bitterfree cucumber varieties.

6. The results of a series of physiological investigations analysing the factors controlling the ripening equilibrium in carrot roots, indicated how to breed for shape and colour for different growth conditions.

Sommario

1. In molti piani di miglioramento di piante una analisi funzionale dei caratteri che devono essere migliorati, dovrebbe precedere l'analisi genetica.
   Può essere necessario cominciare questa analisi funzionale in un modo del tutto empirico. Ma, per trovare i fattori veramente determinanti e nella pianta e fuori di essa, una indagine morfologica, chimica o fisiologica sarebbe ugualmente inevitabile. Questa considerazione s'applica in molti casi nei quali si tenta di migliorare la qualità della pianta.

2. Vengono discussi alcuni piani, attualmente in corso, dell'autore e dei suoi collaboratori.

3. In due piani il miglioramento è indirizzato in un modo del tutto empirico: miglioramento delle varietà di lattuga con una migliore capacità ad accestire durante l'inverno in serre e l'elaborazione di un metodo di selezione dell'asparago con una cima più lunga e senza fibre.

4. In un piano per il pisello, il miglioramento, nel senso di una maggiore uniformità della qualità per ciascun tempo di raccolta, è fondato sullo studio della struttura morfologica delle piante dei piselli.

5. Il saggio di una grande quantità di piante giovani, cresciute da seme e l'uso di un saggio fisio-chimico per la cucurbitacina C, ha fornito una base razionale per la selezione di varietà di cetriolo non amare.

6. *I risultati di una serie di indagini fisiologiche,* — analizzando i fattori determinanti l'equilibrio di maturazione in radici di carota — indicano come si può migliorare colore e forma in diverse condizioni di sviluppo.

PRIJS F 0,50