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Seria ANIMALIA NOCENTIA N. 20 — Satja TUHOELÄIMET n:o 20

THE EFFECT OF STUBBLE HEIGHT OF SPRING CEREALS ON CERTAIN PESTS

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In Finland there are a total of 108 known pest species causing damage to cereals (VAPPULA 1965). A small proportion of these occur in the stem of the cereal at the time of harvesting and consequently remain in the straw or stubble. This category includes, for example, the eggs of the leafhoppers *Javesella pellucida* (F.), *Megadelphax sordidulus* (Stål) and *Dicranotropis hamata* (Boh.) *(Hom., Delphacidae)*, the eggs of *Leptoterna dolabrata* (L.) *(Het., Miridae)* as well as the larvae of *Eurytoma suecica* v. Rosen *(Hym., Eurytomidae)*. The aim of the present investigation was to establish the height in the straw occupied by the above-mentioned eggs and larvae as well as the effect of different harvesting methods on the populations of these species. This work is related to a larger project on the population dynamics of delphacid leafhoppers although it is mainly quite an independent study.

This research has been financed in part by a grant made by the U.S. Department of Agriculture, Agricultural Research Service.

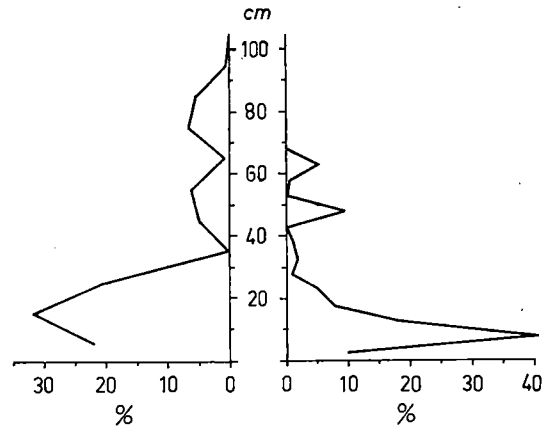

Fig. 1. Height in oat straw occupied by eggs of delphacid leafhoppers (left) and overwintering eggs of plant bugs (right) at the time of harvesting by binder. The material studied comprised 713 eggs of delphacids and 211 of plant bugs.

Kuva 1. Delphacidi-kaskaiden (vas.) ja sängessä talvehtivien luteen munien (oik.) sijaintikorkeus kaurassa itsesitojalla leikkaamisen aikana. Delphacidimunia on aineistossa 713 ja luteen munia 211.

Methods and results

The straw height occupied by delphacid leafhopper eggs was studied in 1958 and 1959 at Laihia and Ylistaro (about 63°N and 22°E) in four oat fields about one week before harvesting by binder (Fig. 1). According to samples collected with netting apparatuses at the beginning of the oviposition period of *J. pellucida*, over 95 % of the delphacid leafhoppers in each of the fields were of this species. Some of the eggs in the straw were probably *M. sordidulus* and *D. hamata*, and they were situated at approximately the same height as those of *J. pellucida*.

The straw height occupied by overwintering eggs of plant bugs was studied in the region

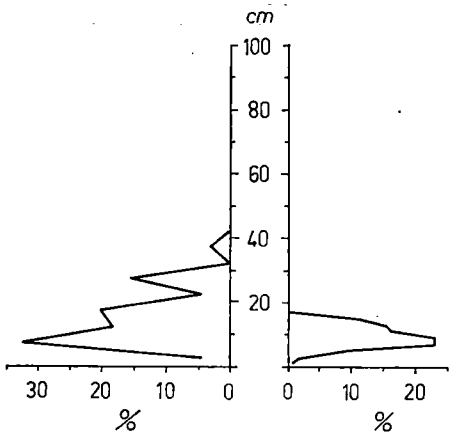

Fig. 2. Height in spring wheat straw occupied by overwintering eggs of plant bugs (left) and larvae of *Eurytoma suecica* (right) at harvest time. The number of plant bug eggs studied was 65, while the data on *E. suecica* have been taken from NILSSON (1960).

Kuva 2. Sängessä talvehtivien luteen munien (vas.) ja Eurytoma suecica-toukkien (oik.) sijaintikorkeus kevätvehnässä. Luteen munia on aineistossa 65 ja E. suecican sijaintikorkeus on esitetty NILSSONin *(1960) mukaan.*

to the east of Vaasa in South Ostrobothnia. In the years 1958—1964 crop samples (à 100 plants) were taken from 120 oat fields and 112 spring wheat fields during the period August 2—September 18. These samples contained only small numbers of overwintering eggs (Figs. 1 and 2). Some of these were taken for rearing, but evidently the bulk of them were of the species *Leptoterna dolabrata.*

The straw height occupied by the larvae of *Eurytoma suecica* depicted in Fig. 2 are from the data of NILSSON (1960) in Sweden. In Finland the larvae appear to be situated at about the same height.

The stubble height of oats and spring wheat was determined in South Ostrobothnia as well as in some other places in western Finland. Sampling was generally done by an observer walking diagonally across the field and taking the first subsample, consisting of about 5 plants with their roots, some 10 metres from the edge of the field. The observer then proceeded a definite number of steps, usually 10, and took another similar subsample. The total field sample comprised about 15—25 subsamples, and 50 individual plants were used for determining the stubble height of the field. The means and standard deviations were not calculated from the average stubble heights of different fields but from the heights of all the plants. The results (Tables 1 and 2) show that the stubble height varied considerably between the different harvest methods. The deviations, however, were quite large. No statistically significant differences in stubble height were found between fields undersown with grass and those without grass.

The numbers of pests remaining in the stubble were calculated from the measurements of stubble height of fields undersown with grass and from the data shown in Figs. 1 and 2. These results are given in Table 3.

The studies were made towards the end of the oviposition period of *J. pellucida*, when some of the eggs had already hatched or been destroyed. In 1957—1960 the proportion of unhatched, healthy delphacid eggs relative to the total number of eggs was determined annually in two

Table 1. Stubble height (cm) of oats after different harvesting methods
Taulukko 1. Kauran sängen pituuden riippuvuus eri leikkuutavoista

	No grass *Ei nurmea*		Undersown with grass *Nurmi*	
	No. of fields *Tutkittuja peltoja*	Mean ± s.d. *Pituus (cm) ja standardipoikkeama*	No. of fields *Tutkittuja peltoja*	Mean ± s.d. *Pituus (cm) ja standardipoikkeama*
Scythe — *Viikate*	4	13.1 ± 4.4	6	14.6 ± 4.6
Mower — *Niittokone*	19	13.5 ± 5.1	10	13.8 ± 4.3
Binder — *Itsesitoja*	14	18.1 ± 6.3	13	18.3 ± 6.0
Sickle — *Sirppi*	2	23.4 ± 6.0	—	—
Combine — *Leikkuupuimuri*	19	24.6 ± 8.1	15	24.3 ± 7.0

Table 2. Stubble height (cm) of spring wheat after different harvesting methods
Taulukko 2. Kevätvehnän sängen pituuden riippuvuus eri leikkuutavoista

	No grass *Ei nurmea*		Undersown with grass *Nurmi*	
	No. of fields *Tutkittuja peltoja*	Mean ± s.d. *Pituus (cm) ja standardipoikkeama*	No. of fields *Tutkittuja peltoja*	Mean ± s.d. *Pituus (cm) ja standardipoikkeama*
Mower — *Niittokone*	2	13.1 ± 5.2	2	14.9 ± 3.6
Binder — *Itsesitoja*	10	20.5 ± 7.5	12	22.6 ± 6.6
Combine — *Leikkuupuimuri*	33	21.8 ± 5.6	9	27.0 ± 6.9

Table 3. Calculated numbers of pests remaining in stubble after different harvesting methods. The figures are percentages of the total numbers of pests occurring in the cereal
Taulukko 3. Eri korjuutapojen jälkeen sänkeen jääneiden munien ja toukkien määrät prosentteina

	Oats *Kaura*		Spring wheat *Kevätvehnä*	
	Delphacid eggs *Delphacidimunia*	Plant bugs eggs *Luteen munia*	Plant bugs eggs *Luteen munia*	*E. suecica* larvae *E. suecican toukkia*
Mower — *Niittokone*	25	48	43	71
Scythe — *Viikate*	29	52	—	—
Binder — *Itsesitoja*	41	63	68	94
Combine — *Leikkuupuimuri*	58	73	79	99

oat fields by taking samples (à 100 plants) at one-week intervals. The numbers of eggs in the samples ranged from 93 to 4 926. The results (Fig. 3) showed that at the time of harvesting by binder, an average of only 5 % (0—17 %) of the total delphacid leafhopper eggs — almost exclusively *J. pellucida* — still remained in the oat plants.

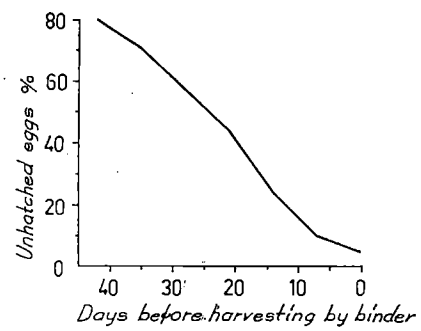

Fig. 3. The percentages of unhatched healthy eggs out of the total number of delphacid eggs in oats. The curve is an average drawn from samples taken from 8 fields.

Kuva 3. Kuoriutumattomien terveiden munien osuus koko delphacidi-munamäärästä kaurassa. Kuvaaja on keskiarvo kahdeksasta pellosta saaduista tuloksista.

At harvest time the oviposition of *L. dolabrata* and *E. suecica* had terminated and since the adults were not due to appear until the following year, only the immature stages were present in the cereal at harvest time.

Discussion

The stubble height of cereals affects the numbers of insect pests in the fields to some extent. Its immediate effect on the abundance of *J. pellucida*, however, is very slight, since at the time of harvesting with scythe, mower or binder only about 5 % of the eggs remain in the oat straw, and since the cereal is subsequently dried outdoors, most of these remaining eggs hatch and the nymphs are left in the field. At the time of harvesting by combine, almost all the eggs have hatched, with the consequence that these methods all lead to practically the same end-result. Even if harvesting were to be carried out earlier, it would have no appreciable effect in controlling *J. pellucida*. The eggs of *M. sordidulus* and *D. hamata* are laid at about the same time as those of *J. pellucida* (cf. RAATIKAINEN 1960, RAATIKAINEN and VASARAINEN 1964), and hence

the harvesting methods affect them in much the same way as *J. pellucida*.

On the other hand, the most important egg predator of *J. pellucida*, *Panstenon oxylus* (Walk.) *(Hym., Pteromalidae)*, occurs at harvest time as a larva in the cereal stems. After harvesting by mower, about 27 % of the population of this species remains in the stubble, while after combine harvesting about 60 % is left in the stubble. Accordingly, the cutting height has an indirect effect on the abundance of *J. pellucida*, since the longer the stubble, the greater the numbers of *P. oxylus* that survive in it, and the following year they can destroy delphacid eggs.

The method of harvesting evidently has a greater effect on the abundance of *L. dolabrata* and *E. suecica* than on the leafhoppers. During threshing, some of the immature stages of these insects are killed, and those remaining in the straw after threshing are usually destroyed, since the straw is often burnt or ploughed into the soil. The greatest chance for survival is in the stubble of cereals undersown with grass. If such fields are harvested by binder or combine, the stubble is generally tall and most of the immature stages will overwinter.

In recent decades the method of cereal harvesting in Finland has undergone changes, first to the use of binders and later to combines, with the result that the stubble remaining in the field is higher than formerly. The main reproductive sites of *E. suecica* are wheat fields (v. ROSEN 1956, NILSSON 1960), so that this species is likely to have increased in recent years. *L. dolabrata* occurs in many other habitats besides cereal fields (e.g. JÜRISOO 1964, p. 109) and thus its numbers have probably not risen as much as those of *E. suecica*. On the other hand, these new harvesting methods may have caused a slight decline in the population of delphacid leafhoppers.

The economic losses produced by *L. dolabrata* and *E. suecica* in Finland are negligible, while those caused by the oat sterile dwarf and European wheat striate mosaic viruses transmitted by delphacid leafhoppers — especially *J. pellucida* — are quite substantial (KANERVO *et. al.* 1957, HEIKINHEIMO 1959, RAATIKAINEN and TINNILÄ 1959, IKÄHEIMO and RAATIKAINEN 1961, 1963, HEIKINHEIMO and IKÄHEIMO 1962, RAATIKAINEN 1962, VAPPULA 1965). The effect of different cutting heights of cereals may modify the extent of damage caused by certain pest species, but since a decline in one species is usually accompanied by an increase in another, the total change seems to be quite small.

Summary

The stubble length of oats and spring wheat was determined after different harvesting methods. Among the pests of cereals, the immature stages of *Javesella pellucida* (F.), *Leptoterna dolabrata* (L.) and *Eurytoma suecica* v. Rosen are situated in the lower part of the straw. The stubble height has only a minor direct effect on the abundance of *J. pellucida*. On the other hand, as a result of the increased cutting height with modern harvesting methods, a greater proportion of the immature stages of *L. dolabrata*, *E. suecica* and *Panstenon oxylus* (Walk.) — of which the latter is the most important egg predator of *J. pellucida* — is able to survive the winter in the stubble.

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SELOSTUS

Kevätviljojen sängen pituuden vaikutus eräisiin tuholaisiin

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Tässä tutkimuksessa pyrittiin selvittämään, millä tavoin viljan leikkuukorkeus vaikutti kevätviljan korsissa leikkuuaikana olleiden tuhohyönteisten määriin. Selvitys keskitettiin kauraan ja kevätvehnään. Kenttätyöt tehtiin suurimmaksi osaksi Etelä-Pohjanmaalla vuosina 1958—1964. — Tutkimus liittyy viljakaskaiden runsaudenvaihtelun selvityksiin, joihin on saatu apuraha U.S.A:sta.

Leikkuuaikana kasvien sisässä on monia tuhoeläimiä, jotka jäävät tavallisesti sekä leikattuun viljaan että sänkeen. Muun muassa viljakaskaan *(Javesella pellucida = Calligypona p.)*, kyyttökaskaan *(Megadelphax sordidulus)*, elokaskaan *(Dicranotropis hamata)* ja korsissa talvehtivien luteiden, etenkin tähkäluteen *(Leptoterna dolabrata)* munat sekä *Eurytoma suecica*-pistiäisen toukat ovat itsesitojalla leikattaessa viljojen alaosissa (kuvat 1 ja 2). Kun eräillä tutkimusalueen tiloilla vilja oli korjattu sirpillä, viikatteella, niittokoneella, itsesitojalla tai leikkuupuimurilla, mitattiin sänkien pituudet (taul. 1 ja 2). Tällä tavoin saaduista aineistoista laskettiin eri leikkuutapojen jälkeen sänkeen jääneiden tuhoeläinten munien ja toukkien määrät (taul. 3).

Kun meillä on siirrytty viimeksi kuluneina vuosikymmeninä yhä yleisemmin aluksi itsesitojan ja myöhemmin leikkuupuimurin käyttöön, ovat kevätviljojen sanget samalla jääneet pitemmiksi kuin aikaisemmin. Tästä on saattanut seurata tähkäluteen ja vehnää vioittavan *Eurytoma suecica*n runsastuminen. Viljakaskaan, kyyttökaskaan ja elokaskaan munista on itsesitojalla leikkuun aikana suurin osa kuoriutunut (kuva 3), ja leikkuun jälkeen niitä kuoriutuu vielä olkiin jääneistä munista. Sängen korkeus ei vaikuta näiden kaskaiden runsauteen välittömästi, mutta niiden *Panstenon oxylus* -nimistä vihollista on pellossa sitä enemmän, mitä pitemmäksi sänki jää. Vihollinen alentaa seuraavana kesänä kaskaiden määrää.

Sängen pituuden muutos aiheuttanee eräiden tuhoeläinten runsastumista ja toisten niukkenemista. Edellä mainitut runsastuneet lajit ovat nykyisin taloudellisesti vähämerkityksisiä ja niukentuneet merkityksellisiä.

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Seria AGROGEOLOGIA, -CHIMICA ET PHYSICA N. 22
Sarja MAAPERÄ, LANNOITUS JA MUOKKAUS n:o 22

THE SOLUBILITY OF SOME IRON AND ALUMINIUM PHOSPHATES IN THE ACETIC ACID-AMMONIUM ACETATE BUFFER SYSTEM

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In soil testing analyses in Finland the amount of readily soluble phosphorus, representing the level of available phosphorus in the soil, is estimated by extraction with 0.5 *M* acetic acid—0.5 *M* ammonium acetate buffer solution at pH 4.65 (VUORINEN and MÄKITIE 1955). It is known that only minute amounts of soil phosphorus bound by iron and aluminium can be extracted in this way but, no particulars of the actual solubility of iron and aluminium phosphates of acid soils in this extractant are known. Some earlier experiments have indicated that the extractability of sparingly soluble soil phosphorus is determined by the actual solubility character or solubility product of these compounds, and not merely by the amount of these difficultly extractable phosphates present in a soil. Successive extraction treatments have also given an indication that this is the case (MÄKITIE 1956, 1960).

Applied phosphates are known to be bound and precipitated mainly by iron and aluminium in our acid soils (e.g. KAILA 1963).

The purpose of the present study was to find out to what extent some phosphate preparations of iron and aluminium are soluble in acetic acid—ammonium acetate buffer solutions containing various ratios of these two components in the same concentration as the soil testing extractant. A series of phosphates similar to naturally occuring minerals were therefore prepared and the solubility determinations carried out by the dissolution method.

The common orthophosphates of trivalent iron and aluminium, prepared in connection with the present study, represent the composition of the isomorphous phosphate minerals; strengite $FePO_4.2H_2O$ and variscite, $AlPO_4.2H_2O$. The acid phosphates; calcium ferric phosphate, $H_4CaFe_2(PO_4)_4.5H_2O$ and potassium taranakite, $H_6K_3Al_5(PO_4)_8.12H_2O$, which are shown to exist in acid soils to which fertilizers have been applied, were also prepared. Further, some colloidal ferric and aluminium phosphate preparations in amorphous form and of uncertain composition were synthesized. The commercial preparation of ferrous orthophosphate (the mineral vivianite, $Fe_3(PO_4)_2.8H_2O$), which is formed in reduced soil conditions, and aluminium phosphate monohydrate were also included in the solubility experiments.

Experimental

1. Iron phosphate preparations

Ferric orthophosphate was prepared according to the method of JACKSON (1958). 30 ml of a 1 *M* aqueous solution of sodium dihydrogen orthophosphate, $NaH_2PO_4 \cdot H_2O$ was added with stirring to 550 ml of 0.018 *M* ferric chloride solution in an one litre beaker. The precipitate was crystallized by digestion on a hot plate during two days. The filtered precipitate was then washed twice with 0.1 *M* sodium chloride solution, then with water and finally with acetone. The composition of the phosphate corresponds to that of the mineral strengite.

Colloidal ferric phosphate was prepared in the absence of extraneous ions by modifying the method originally described by CARTER and HARTSHORNE (1923) and later by CATE *et al.* (1959), as well as by TAYLOR *et al.* (1960). 6.6 g of pure powdered iron was dissolved in 270 ml of 50 % orthophosphoric acid solution diluted to 600 ml with water and oxidized with a small amount of hydrogen peroxide. The amorphous phosphate was precipitated by dilution to 25 litres and washed several times with water.

Calcium ferric phosphate was crystallized according to CATE *et al.* (1959) from a solution containing 26.7 g of dried amorphous ferric phosphate in 200 ml of solution corresponding to the invariant point of the system $CaO - P_2O_5 - H_2O$. The latter solution was prepared by saturation of an 18.5 % orthophosphoric acid solution with calcium dihydrogen orthophosphate monohydrate at 25°C and of pH 1.0 (LINDSAY *et al.* 1959 a). Calcium ferric phosphate crystals were formed during a period of two days at 35°C and these were filtered and washed twice with phosphoric acid solution at pH 1.3 and finally with water.

A commercial preparation (reag. B.D.H., Ltd.) of composition $Fe_3(PO_4)_2 \cdot 8H_2O$ was used as ferrous orthophosphate, vivianite.

2. Aluminium phosphate preparations

Variscite was prepared according to JACKSON (1958). 90 ml of molar sodium dihydrogen orthophosphate solution was added to 530 ml of 0.943 molar aluminium trichloride solution in water with stirring. The solution was digested on the steam bath for 40 hours and the precipitate formed was washed twice with 0.1 *M* sodium chloride solution, then several times with water and finally with acetone (DEMING and CATE 1963).

Colloidal aluminium phosphate was prepared according to the method of TAYLOR *et al.* (1960). 27 g of pure metallic Al was dissolved in 410 ml of 45 % phosphoric acid, filtered and diluted to eight litres at 60°C. Four liters of acetone was added with vigorous stirring, and the precipitate was filtered and washed several times with warm water to pH 3.0. The phosphate was finally filtered and dried at room temperature.

Potassium taranakite was prepared according to the methods of SMITH and BROWN (1959) and TAYLOR *et al.* (1960, 1961). 16.2 g pure metallic Al was dissolved in 657 ml of 53 % phosphoric acid. The solution was filtered and diluted to three liters. The pH was adjusted to pH 3.0 with 10 % potassium hydroxide solution with vigorous stirring. After a digestion period of 24 hours at 50°C the precipitate was filtered, washed and vacuum-dried.

$AlPO_4 \cdot H_2O$ (reag. B.D.H., Ltd.) was used when washed with hot water and dried at 110°C.

3. Dissolution experiments

were carried out by weighing 200 mg of phosphate into 250 ml of solvent. Dissolving was speeded up by regular daily shaking of the closed bottles. The solution was allowed to equilibrate during a period of 28 days at a temperature of 25 ± 1°C. The solutions were separated from insoluble phosphate by filtering.

4. Analytical determinations

Phosphoric acid was determined colorimetrically as the reduced molybdophosphoric blue complex (VUORINEN and MÄKITIE 1955).

Aluminium was determined colorimetrically by means of aluminon (aurintricarboxylic acid) according to the usual procedure (JACKSON 1958).

Iron was determined as the o-phenanthroline ferrous complex (JACKSON 1958).

The availability of iron and aluminium phosphates in soils

Strengite, $FePO_4.2H_2O$, is the main crystallizable product in the course of precipitation of iron phosphates in acid soils. It is very difficultly soluble. Strengite is only a poor source of phosphorus for plants, like other sparingly soluble phosphates (LINDSAY and TAYLOR 1960).

Calcium ferric phosphate, $H_4CaFe_2(PO_4)_4 \cdot 5H_2O$, has been described by CATE *et al.* (1959). In soils it is apparently hydrolysed to strengite

or to strengite-like material (TAYLOR *et. al.* 1963 a). Calcium ferric phosphate is more soluble in water than strengite and colloidal ferric phosphates (HUFFMAN *et al.* 1960). Calcium ferric phosphate and colloidal forms of ferric phosphates have been found to be relatively good sources of phosphorus for plants. It has been observed, on the other hand, that roughly twice as much calcium ferric phosphate as colloidal phosphates are removed by the crop (TAYLOR *et al.* 1960, 1964).

The fixation of phosphorus by aluminium in acid soil is assumed to occur by formation of variscite, $AlPO_4 \cdot 2H_2O$, or different forms of variscite-like phosphates. In crystalline form variscite is shown to be an extremely poor source for plants, but aluminium phosphate in amorphous form is more readily available (TAYLOR *et al.* 1962, 1963 b). With colloidal preparations the solubility of phosphorus is consistently higher at low pH values. Acid potassium aluminium phosphate or potassium taranakite, $H_6K_3Al_5(PO_4)_8 \cdot 18H_2O$, was identified and shown to be formed in soils from monocalcium phosphate by LINDSAY *et al.* (1959 b). It is a relatively stable form of acid phosphate.

In general taranakites, like colloidal aluminium phosphate, are among the more soluble forms of aluminium phosphate in acid soils and they have been observed to be good sources of phosphorus for plants as well (TAYLOR *et al.* 1960). Among them, however, ammonium taranakite is apparently less suitable for phosphorus removal (TAYLOR *et. al.* 1963 b).

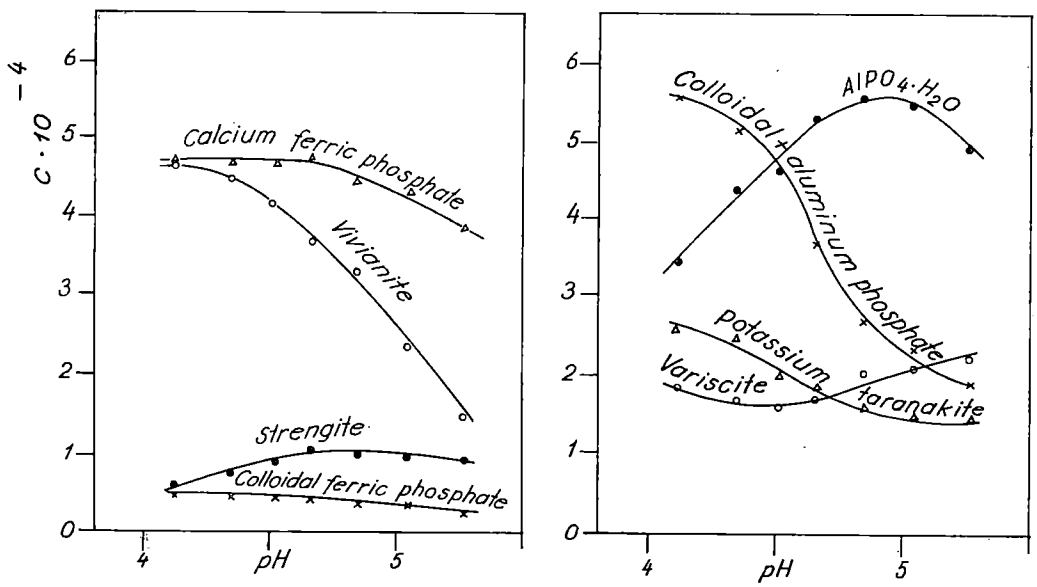
Results and discussion

The solubility curves are shown in Figs. 1—2, where molar concentration of phosphorus as a function of pH are given in the buffer range of acetic acid ammonium acetate solutions. Similar observations have earlier been reported for the solubility of strengite in some acetate buffer solutions (SCHEFFER *et al.* 1955, 1956).

In the case of strengite and variscite, which are phosphates of known simple composition, the solubility products of the phosphates were here determined.

The dissociation equilibrium of strengite,

(1) $FePO_4 \cdot 2H_2O \rightleftarrows Fe^{3+} + H_2PO_4^- + 2OH^-$



Figs. 1—2. Solubility of phosphorus as a function of pH in acetic acid-ammonium acetate buffer solutions. c = molar concentration of P.

Kuvat 1—2. Fosforin liukeneminen (c) pH:n funktiona etikkahappo-ammoniumasetaatti puskuriliuoksissa.

Table 1. Determination of the solubility product (K_S) of strengite and variscite preparations at 25°C; $pK_S = pMe + pH_2PO_4^- + 2pOH^-$

Taulukko 1. Strengiitin ja variskiitin liukoisuustulon määritys (25°C)

Aqueous solvent — *Uuttoliuos*			Strengite $FePO_4 \cdot 2H_2O$			Variscite $AlPO_4 \cdot 2H_2O$		
$^cCH_3COOH$	$^cCH_3COONH_4$	pH	pFe	pH_2PO_4	pKs	pAl	pH_2PO_4	pKs
0.2	0.8	5.27	7.40	4.05	28.91	5.89	3.65	27.00
0.3	0.7	5.05	7.01	4.01	28.92	5.68	3.70	27.28
0.4	0.6	4.85	6.88	3.99	29.17	5.56	3.69	27.55
0.5	0.5	4.66	6.63	3.97	29.28	5.33	3.77	27.78
0.6	0.4	4.52	6.52	4.03	29.51	5.20	3.79	27.95
0.7	0.3	4.35	6.37	4.11	29.78	5.09	3.77	28.16
0.8	0.2	4.12	6.22	4.20	30.18	5.07	3.73	28.56
1.0	0	2.41	5.55	4.38	33.11	3.75	3.69	30.60

gives the equation for the solubility product K_s,

(2) $K_s = [Fe^{3+}] [H_2PO_4^-] [OH^-]^2$

The values, $pK_s = 29.3$ in 0.5 *M* acetic acid — 0.5 *M* ammonium acetate mixture at pH 4.66 and $pK_s = 33.1$ in 1.0 *M* acetic were found at 25°C (Table 1). The latter value is comparable with earlier reported values 33.0—33.2 at the isoelectric point of dissociation at pH 2.75 (CHANG and JACKSON 1957) and the value 33.5 at pH 2.2 (BACHE 1963).

The corresponding values for variscite, $pK_s =$ 27.8 at the equimolar point of the acetate buffer range at pH 4.66 and 30.6 in molar acetic acid solution (pH 2.41) were obtained here according to the solubility product equation,

(3) $K_s = [Al^{3+}] [H_2PO_4^-] [OH^-]^2$

COLE and JACKSON (1951) have reported the value 28.6 for variscite. LINDSAY *et val.* (1959 c) have found the value 30.5 and BACHE (1963) reported the value 27.2 at pH 5.0 and 30.5 at pH 2.1 as pK_s values for variscite.

The solubility product for strengite and variscite as functions of the hydrogen ion concentration in the range of the buffer system studied is shown in Fig. 3. It has to be mentioned that there is also an almost linear relationship between the values obtained in the lower pH range of the buffer system, although these points are not plotted in Fig. 3.

The practical conclusions on the characteristics of iron and aluminium phosphates are that strengite and variscite are sparingly soluble in ammonium acetate solutions (Table 2). The colloidal forms show some deviating behaviour as regards solubility, which is obviously caused by the quality of the preparations, and the age and stage of these amorphous forms. Calcium

Table 2. Dissolution of phosphorus of the preparations by 0.5 M HAc— 0.5 M NH_4Ac buffer solution at pH 4.66 (25°C)

Taulukko 2. Fosforin liukeneminen fosfaateista 0.5 M etikkahappo — 0.5 M ammoniumasetaatti puskuriliuokseen (pH 4.66, 25°C)

% P in the solid phosphate *(% P fosfaatissa)*		Phosphates — *(fosfaatit)*	P-dissolved *(P-liuennut)*
theor.	found		mg/l
		Iron phosphates: — *Rautafosfaatit:*	
18.46	18.3	Strengite, $FePO_4 \cdot 2H_2O$	3.2
		Colloidal ferric phosphate, $FePO_4 \cdot nH_2O$	1.3
19.83	19.6	Calcium ferric phosphate, $H_4CaFe_2(PO_4)_4 \cdot 5H_2O$	14.6
12.35	12.1	Vivianite, $Fe_3(PO_4)_2 \cdot 8H_2O$	11.6
		Aluminium phosphates: — *Alumiinifosfaatit:*	
19.61	19.8	Variscite, $AlPO_4 \cdot 2H_2O$	5.3
(22.13)	21.7	$AlPO_4 \cdot H_2O$	16.4
		Colloidal aluminum phosphate, $AlPO_4 \cdot nH_2O$	11.8
18.46	18.5	Potassium taranakite, $H_6K_3Al_5(PO_4)_8 \cdot 18H_2O$	5.7

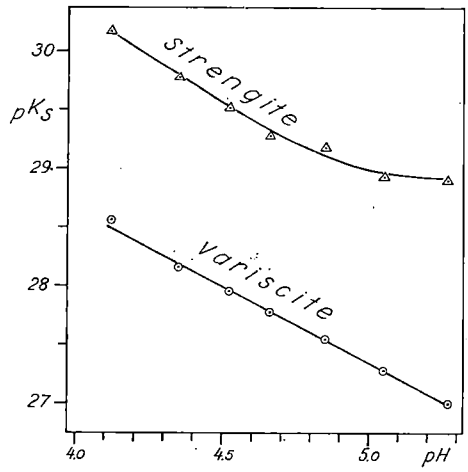


Fig. 3. Effect of pH on the solubility product of strengite and variscite.

Kuva 3. pH:n vaikutus strengiitin ja variskiitin liukoisuustuloon.

ferric phosphate dissolves relatively better in acetic acid—ammonium acetate solutions and the same character appears in the case of vivianite. The solubility of potassium taranakite is of more or less the same order as the solubility of variscite. These experiments are generally in accordance with earlier observations found elsewhere.

The solubility of iron and aluminium phosphates in the 0.5 *M* acetic acid—0.5 *M* ammonium acetate extractant show that in soil testing analysis there must be a strict limit to the amount of phosphorus extractable from acid soils where iron and aluminium phosphates predominate. In natural conditions or in soils where fertilizer phosphates have not been applied for a long time the limit of the maximum amount of extractable soil phosphorus $\sim$ 140 kg P_2O_5, the value corresponding to $\sim$ 900 kg Psf (20 %) per ha or $\sim$ 40 mg P in one litre of soil, as indices used in soil testing analysis. Taking into account the fact that the extraction procedure used in soil testing analysis does not completely dissolve and, in addition, that the so-called common ion effect of iron or aluminium ions in the extract diminishes the amount of phosphorus extractable, the practical values for available phosphorus must be considerably lower. The data of soil testing analysis show, indeed, that the phosphorus values for acid soils (pH < 6) remain low in spite of efforts to increase the readily soluble phosphorus status by generous application of fertilizers.

Summary

Dissolution experiments on some iron and aluminium phosphate preparations have been carried out in order to study the solubility of these phosphates in acetic acid—ammonium acetate solutions, including the 0.5 equimolar buffer solution used as extractant in soil testing analysis.

The solubility of iron and aluminium phosphates in acetic acid ammonium acetate solutions is low. The observed values of the solubility product, $K_s = [Me^{3+}]\,[H_2PO_4^-]\,[OH^-]^2$ in 0.5 *M* acetic acid—0.5 *M* ammonium acetate are $pK_s = 29.3$ for strengite and 27.8 for variscite (25°C). The values indicate that the upper theoretical limit of extractable phosphorus in our acid soils, where all phosphorus is bound by iron or aluminium, is about 140 kg P_2O_5 per hectare (one hectare is equivalent to 2 million litres of soil). The limit may in practice be much lower, in cases where the common ion effect of soluble iron and aluminium ions determines the solubility equilibrium in the extract.

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SELOSTUS

Rauta- ja alumiinifosfaattien liukoisuudesta etikkahappo-ammoniumasetaattiliuoksiin

OSMO MÄKITIE

Maatalouden tutkimuskeskus, Maantutkimuslaitos, Tikkurila

Tutkimuksessa on vertailtu erilaisten synteettisten rauta- ja alumiinifosfaattien liukoisuutta viljavuusanalyysissa käytössä olevaan happamaan ammoniumasetaattiliuokseen sekä vastaaviin eri pH:ta edustaviin asetaattiliuoksiin.

Rauta- ja alumiinifosfaatit liukenevat tunnetusti hyvin heikosti sekä veteen että heikosti happamiin uuttoliuoksiin. Viljavuusanalyysin fosforiluku ilmaisee siten vain suhteellisen pienen määrän vaikealiukoisista rauta- ja alumiinifosfaateista. Fosforiluku on lisäksi riippuvainen rauta- ja alumiini-ionien konsentraatiosta liukoisuustulon edellyttämässä suhteessa.

Eri fosfaattien liukoisuuskäyrät on esitetty kuvissa 1—3, ja fosforin liukoisuus happamaan ammoniumasetaattiliuokseen näistä fosfaateista on esitetty taulukossa 2.

Rauta (III) -ortofosfaatin (strengiitti) ja alumiiniortofosfaatin (variskiitti) liukoisuustulon määritys on esitetty taulukossa 1 ja liukoisuustulon riippuvuus asetaattiliuoksen happamuudesta kuvassa 3.

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KALSIUMKARBONAATTIPITOISESTA APATIITISTA VALMISTETTUJEN EMÄKSISTEN FOSFORILANNOITTEIDEN KÄYTTÖARVOA KOSKEVIA TUTKIMUKSIA

Summary: **Studies on the value of alkaline phosphate fertilizers prepared from calcite-containing apatite**

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Saapunut 1. 12. 1965

Kun Lohjan Kalkkitehdas Oy:n toimesta ryhdyttiin tutkimaan Siilinjärven Kuuslahdesta 1957 löydetyn apatiittiesiintymän käyttömahdollisuuksia, ilmeni pian, ettei seassa olevaa kalsiittia (kalsiumkarbonaattia) ole nykyisin tunnetuin menetelmin mahdollista poistaa riittävän pienin kustannuksin ja niin tarkoin, että tavara soveltuisi superfosfaatin raaka-aineeksi. Siten oli tarpeen tutkia muita mahdollisuuksia valmistaa siitä fosforilannoitteita, joissa raaka-aineen kalsiittipitoisuus ei olisi haittana. Tunnetuimpia sellaisia fosforilannoitelajeja on Saksassa jo kauan valmistettu ja verraten paljon käytetty -ns. renaniafosfaatti (HONCAMP 1931, s. 345—349; COOKE 1956, s. 35—37). Kiintoisalta tuntuisi tuote, josta on käytetty mm. nimitystä hehkutettu trikalsiumfosfaatti (WAGGAMAN 1953, s. 394) tai sulatefosfaatti (COOKE 1956, s. 42—43; FRANCK 1957). Tällaisia lannoitteita valmistettiin pieniä eriä kokeeksi ja maanviljelyskemian ja -fysiikan laitos pani käyntiin niiden vaikutusta koskevia kokeita.

Taulukko 1. Analyysitietoja kokeissa käytetyistä fosforilannoitteista, %
Table 1. Analysis results of the phosphate fertilizers tested, figures are percentages

	Renaniafosfaatti	Kalkkifosfaatti	
		erä I (1960)	erä II (1961)
P_2O_5 totaali — *total*	21.20	21.40	18.20
sitr.happoon liuk. — *sol. in citric acid*	19.14	15.70	15.93 [1]
amm.sitr. liuk. — *sol. in amm. citrate*	19.40	15.55 [1]	13.70
K_2O totali — *total*	3.20	jälkiä [2]	
CaO 1 n kuumaan HCl liuk. — *sol. in hot HCl*	27.9	50.0	44.7
MgO » »	7.1	3.3	3.3
Na_2O » »	6.2	0.5	0.6
S » »	0.1	jälkiä	jälkiä

[1]) Määrät kokeissa tämän mukaan. — *Rates used according to these percentages.*
[2]) *Traces*

Taulukko 2. Maa-analyysien tuloksia astiakokeissa käytetyistä maaeristä
Table 2. Analyses of soils used in the pot trials

	Liejusavi *Gyttja clay* AM 313 Tikkurila	Hiesuinen hietasavi *Clay loam* AM 314 Tikkurila	Urpasavi *Gyttja clay* AM 370 Ylistaro
Humusta % — *Humus %*	4.03	7.89	12.67
pH mitattu vedessä — *pH in water*	5.30	5.75	4.68
pH mitattu 1 n kaliumklor. — *pH in 1 N KCl*	3.90	4.46	3.97
Ammoniumasetaattimenetelmän mukaan mg/l maata [1]) — *By ammonium acetate method mg/l soil* [1])			
vaihtuvaa kalkkia, Ca — *exch. Ca*	1 900	2 240	260
vaihtuvaa kalia, K — *exch. K*	382	299	158
helposti liukenevaa fosforia, P — *readily soluble P*	7.4	5.0	9.6
0.1 n suolahappoon liuk. Mg — *Mg sol. in 0.1 N HCl*	608	486	122

[1]) Uuden ilmaisutavan mukaan (KURKI ym. 1965). — *According to* KURKI *et al. 1965.*

Koelannoitteet

Kokeissa käytetyn renaniafosfaatin valmisti Lohjan Kalkkitehdas Oy:n laboratorio Siilinjärveltä saadusta apatiittirikasteesta. Tavaran, josta tässä käytetään nimitystä kalkkifosfaatti (apatiittirikastetta ja kvartsia sintrattu 1 050° C:ssa), erät I ja II valmisti Lohjan Kalkkitehdas Oy:n tilauksesta toiminimi F. L. Smidt A/S Kööpenhaminassa niin ikään Siilinjärven apatiittirikasteesta. Taulukossa 1 esitetään koelannoitteiden ravinnepitoisuuksia ilmaisevia analyysitietoja. Vertailuperustana oli kaikissa kokeissa tavallinen superfosfaatti (19 % veteen liukenevaa P_2O_5) ja astiakokeissa sen lisäksi vielä tomasfosfaatti (16 % sitruunahappoon liukenevaa P_2O_5).

Taulukko 3. Astiakoe 1. Hiesuisella hietasavella AM 314 saadut tulokset
Table 3. Pot trial 1. Results with clay loam AM 314

	Ilman fosforilannoitusta *Without phos. fert.*	Fosforilannoituksen aiheuttamat erotukset *Differences caused by phosphate fertilizers*							
		superfosf.		renaniaf.		kalkkif.		tomasfosf.	
		2	4	2	4	2	4	2	4
Sato kuiva-ainetta — *Dry matter yield* yht. 4 v:n aikana g/ast. — *total in 4 years g/pot*	140.5	149.6	224.8	47.3	105.0	56.6	92.6	58.4	109.2
Sadoissa kasvinravinteita mg/ast. — *Plant nutrients in harvest, mg/pot:*									
Fosforia, P_2O_5 — *Phosphorus* 1960	71	296	315	157	211	128	232	193	347
—61	337	78	168	78	149	40	191	80	156
—62	155	74	128	78	102	104	92	—42	88
—63	133	87	160	68	64	84	127	121	133
yhteensä 4 v:na — *total in 4 years*	696	353	771	381	526	356	642	352	724
Lann. annetusta fosf. sadoissa % % *of applied phos. recovered in harvest*		35	39	38	26	36	32	35	36
1. v:n osuus koko kasvien käyttämästä lannoitefosforista % — *1st year % of total fertilizer phosphorus utilised by plants*		55	41	41	40	36	36	55	48
Rikkiä, S, yht. 1961—63 — *Sulphur*	89	110	333	41	54	53	75	46	62
Kalia, K_2O, yht. 4 v:na — *Potassium*	3 530	2 886	3 387	789	1 879	1 258	1 325	1 324	1 968
Kalkkia, CaO, yht. 4 v:na — *Calcium*	990	1 092	1 392	182	640	375	790	585	1 126
Magnesiaa, MgO, yht. 4 v:na — *Magnesium*	453	336	590	50	250	98	161	75	266

Taulukko 4. Astiakoe 1. Urpasavella AM 370 saadut tulokset
Table 4. Pot trial 1. Results with gyttja clay AM 370

	Ilman fosforilannoitusta *Without phos. fert.*	Fosforilannoituksen aiheuttamat erotukset *Differences caused by phosphate fertilizers*							
		superfosf.		renaniaf.		kalkkif.		tomasfosf.	
		2	4	2	4	2	4	2	4
Sato kuiva-ainetta — *Dry matter yield* yht. 4 v:n aikana g/ast. — *total in 4 years g/pot*	175.1	45.5	70.5	83.3	129.8	89.0	152.1	68.5	134.0
Sadoissa kasvinravinteita mg/ast. — *Plant nutrients in harvest, mg/pot:*									
Fosforia, P_2O_5 — *Phosphorus* 1960	4	115	238	278	227	269	454	213	209
—61	9	53	121	6	198	21	287	9	318
(kalkitus) — *(liming)* —62	276	—20	110	24	55	23	53	—30	69
—63	231	48	27	29	46	10	—32	16	30
yht. 4 v:na — *total in 4 years*	520	196	496	337	526	323	762	208	626
Lann. annetusta fosforista sadoissa % — % *of applied phosphorus recovered in harvest*		20	25	34	26	32	32	21	31
1. v:n osuus koko käytetystä lannoitefosforista % — *1st year % of total fertilizer phosphorus utilised by plants*		59	48	82	43	83	60	(102)	33
Rikkiä, S, yht. 1961—63 — *Sulphur*	345	43	58	83	81	89	28	98	70
Kalia, K_2O, yht. 4 v:na — *Potassium*	3 771	165	678	821	1 063	577	816	1 131	764
Kalkkia, CaO, yht. 4 v:na — *Calcium*	908	913	1 180	1 548	1 931	2 043	2 512	1 870	1 597
Magnesiaa, MgO, yht. 4 v:na — *Magnesium*	204	112	175	318	534	271	463	114	145

Astiakokeet

Menettelytapa Mitscherlich-astioissa suoritetuissa monivuotisissa astiakokeissa oli sellainen, että fosforilannoitukset annettiin vain ensimmäisenä vuotena ja myöhempinä vuosina seurattiin jälkivaikutusta. Muut lannoitukset annettiin joka vuosi, jottei niiden niukkuus olisi esteenä kasvien kasvulle.

A s t i a k o e 1 vuosina 1960—63 oli luonteeltaan valmisteleva, esim. käytettävissä olevien astioiden vähyyden vuoksi ilman kerranteita. Koemaina oli Tikkurilasta otettu hiesuinen hietasavi AM 314 ja Ylistarosta otettu urpasavi AM 370 (ks. taul. 2). Käytetyt fosforilannoitteet olivat super-, renania-, kalkki- ja tomasfosfaatti, joista kaikista oli 2 eri määrää, nim. määrä 2 = 1 000 mg/ast. ja määrä 4 = 2 000 mg/ast. P_2O_5 (superfosf. vesiliukoinen, tomasfosf. sitruunahappoliukoinen ja renania- sekä kalkkifosf., erä I, ammoniumsitraattiliukoinen). Ne annettiin vain kokeen alkaessa keväällä 1960 Muut lannoitukset (1 000 mg/ast. N amm.nitr., 1 000 mg/ast. K_2O kaliumklor. sekä pieni erä hivenaineseosta) annettiin kaikkina koevuosina. Koeastiat olivat talvet ulkona. Koekasvina oli 1960 syysrapsi, mutta muulloin kaura (Pendek), josta 1961 otettiin tuleentunut sato ja muina vuosina maitotuleentunut sato. Kun urpasavessa kasvu liiallisen happamuuden vuoksi oli kovin huonoa, se kalkittiin kaikissa astioissa 1962 antaen 24 g/ast. kalsiumkarbonaattia.

Katsaus kokeessa saatuihin tuloksiin esitetään taulukoissa 3 ja 4. Niissä esitetään koko nelivuotiskauden summia, mutta fosforin, tutkimuksen keskeisimmän aineen, kohdalla esitetään myös kunakin vuotena saadut tulokset erikseen. Rikkimääritykset puuttuvat vuodelta 1960, joten luvut ovat liian pienet.

Kokeessa käytetyt kaksi eri maalajia, hietasavi ja urpasavi, eroavat toisistaan suuresti kalkki-

Taulukko 5. Astiakoe 1. Erilaisten fosforilannoitteiden aiheuttamat erot maan pH-luvuissa
Table 5. Pot trial 1. Differences in soil pH produced by the phosphate fertilizers

	Ilman fosforilannoitusta *Without phos. fert.*	Fosforilannoituksen aiheuttamat erotukset *Differences caused by phosphate fertilizers*							
		superfosf.		renaniaf.		kalkkif.		tomasfosf.	
		2	4	2	4	2	4	2	4
Hietasavi — *Clay loam*									
pH mitattu vedessä — *pH in water*	5.29	0.25	0.03	0.56	0.72	0.49	0.79	0.31	0.78
pH mitattu 1 n kaliumkloridissa — *pH in 1 N KCl*	4.06	0.15	0.05	0.38	0.61	0.38	0.64	0.35	0.59
Urpasavi — *Gyttja clay*									
pH mitattu vedessä — *pH in water*	5.03	— 0.03	— 0.11	0.08	0.36	0.25	0.66	0.07	0.37
pH mitattu 1 n kaliumkloridissa *pH in 1 N KCl*	4.58	0.02	0.00	0.02	0.20	0.14	0.39	— 0.01	0.21

pitoisuuden ja happamuuden puolesta, mikä voi antaa kiintoisaa lisävalaistusta verrattaessa toisiinsa maassa neutraalisti (superfosfaatti) ja emäksisesti (muut mukana olleet fosfaatit) vaikuttavia lannoitteita. Tätä kohtaa koskeva selvitys ei kuitenkaan voi olla tyydyttävä sen vuoksi, että urpasavi kesken koetta kalkittiin. Siitä huolimatta on eroja varsinkin kuiva-ainesatojen kohdalla. Hietasavessa superfosfaatti on ollut selvästi paras, mutta urpasavessa emäksiset fosfaatit ovat olleet parempia kuin superfosfaatti ja keskenään suunnilleen samanarvoisia. Jos vertailut tehdään satojen sisältämien fosforimäärien mukaan, erot vähenevät pysyen kuitenkin samansuuntaisina.

Annetusta fosforista ovat kasvit varsinkin hietasavessa ottaneet korkeat prosenttimäärät, sellaiset jotka ovat mahdollisia vain astioissa, joissa kasvien juuret täyttävät pienen tilavuuden hyvin tarkoin ja joissa maan kosteus pidetään kaiken aikaa optimaalisena.

Ensimmäisen koevuoden aikana on koko lannoitefosforista tullut hyväksikäytetyksi suunnilleen puolet. Urpasavessa tämä ensimmäisen vuoden osuus on suurempi kuin hietasavessa.

Muiden koesadoista selvitettyjen aineiden määriä tarkasteltaessa on huomattava, että ensimmäisenä koevuotena viljelty rapsi nostaa suuresti kalkin määriä. Urpasavesta kasvit ovat saaneet rikkiä paljon enemmän kuin hietasavesta. Näin ollen urpasavella saatujen satojen rikkimäärissä ei voi nähdä eri lannoitelajien aiheuttamia eroja. Sen sijaan hietasavella superfosfaatti on lisännyt kasvien rikin ottoa enemmän kuin muut lannoitteet. Natriummääritysten tuloksia ei esitetä, kun käytetty analyysimenetelmä ei ole tyydyttävä. Kuitenkin voidaan mainita, että renaniafosfaatti aiheutti sadoissa selvästi suuremman natriumpitoisuuden kuin muut koelannoitteet.

Kun koelannoitteilla voi olla erilainen vaikutus maan happamuuteen, tehtiin koeastioista syksyisin sadonkorjuun jälkeen pH-mittauksia. Niiden keskiarvot esitetään taulukossa 5. Superfosfaatti ei ole aiheuttanut muutoksia maan pH-lukuihin, mutta muut fosfaatit ovat kaikki nostaneet sitä jokseenkin yhtä paljon.

A s t i a k o e 2 järjestettiin vuosina 1961—63 kolmin kerrantein, joten tulokset ovat varmempia kuin astiakokeessa 1 ja erojen merkitsevyyksiä voidaan selvitellä yksityiskohtaisemmin (SNEDECOR 1950). Koemaaksi otettiin Tikkurilasta peräisin oleva, muokkauskerroksen alta otettu liejusavi AM 313 (taul. 2), josta tiedettiin etukäteen, että siinä on sekä kalkituksella että fosforilannoituksella selvä vaikutus. Koelannoitteina olivat super-, kalkki- ja tomasfosfaatti. Fosforihappomäärät 1 ja 2 olivat 500 ja 1 000 mg/ast. P_2O_5 (superf. veteen, kalkkifosf., erä II, ja tomasfosf. sitruunahappoon liukeneva). Ne annettiin tässä kokeessa samoin kuin astiakoe 1:ssäkin vain kokeen alkaessa. Vuotuislannoitukset muilla kasvinravinteilla olivat samat kuin astiakoe 1:ssä (s. 14). Kun erityyppisten fosforilannoitteiden vaikutukset voivat olla erilaiset maan kalkkitilan ja happamuuden mukaan,

Taulukko 6. Astiakoe 2. Liejusavella AM 313 saadut tulokset
Table 6. Pot trial 2. Results with gyttja clay AM 313

		Ilman fosforilannoitusta *Without phos. fert.*	Fosforilann. aiheuttamat erot *Diff. caused by phos. fert.*						Merkitsevyysasteet *Significance*			
			superfosf.		kalkkif.		tomasfosf.		kalkitus *liming*	fosf.-laji *type of phos.*	fosf.-määrä *rate of phos.*	kalkitus × fosf.-laji *liming × type of phos.*
			1	2	1	2	1	2				
Sato kuiva-ainetta yht. 3 vuoden aikana g/ast. — *Dry matter yield total in 3 years g/pot*	ilman kalkkia *without lime*	75.3	97.8	165.6	81.4	113.7	65.2	109.1	***	***	***	*
	kalkittuna — *limed*	153.9	104.0	143.5	54.2	82.2	43.9	76.7				
Kuiva-ainesadosta jyviä % — % *of grain in yield*	ilman kalkkia	43	7	8	7	8	7	8	***			
	kalkittuna	50	1	1	2	2	2	2				
Koko sadon (jyvät + oljet) kuiva-aine-% korjuuhetkellä 16/8 —63 *Dry matter % of total yield (grain + straw) at harvest, Aug. 16, 1963*	ilman kalkkia	32.6	0.3	5.4	1.3	2.2	3.4	4.7	***	**	*	**
	kalkittuna	39.0	6.0	6.9	1.1	2.3	—0.4	1.8				
Sadoissa kasvinravinteita mg/astia — *Plant nutrients in harvest, mg/pot:*												
Fosforia, P_2O_5 — *Phosphorus* 1961	ilman kalkkia	110	133	239	156	221	161	217	**		***	
	kalkittuna	260	50	140	61	122	82	122				
1962	ilman kalkkia	104	64	80	78	112	111	98	*			
	kalkittuna	255	29	35	37	45	21	53				
1963	ilman kalkkia	129	29	51	5	12	—5	28	**	*		
	kalkittuna	207	36	34	—1	5	2	17				
Yht. 3 vuotena — *Total in 3 years*	ilman kalkkia	343	226	370	239	345	267	343	***		***	
	kalkittuna	722	115	209	97	172	105	192				
Lannoituksessa annetusta fosforista sadoissa % — % *of applied phosphate recovered in harvest*	ilman kalkkia		45	37	48	35	53	34				
	kalkittuna		23	21	19	17	21	19				
1. v:na osuus koko käytetystä lannoitefosforista % — *1st year % of total fertilizer phosphate utilised by plants*	ilman kalkkia		59	65	65	64	60	63				
	kalkittuna		43	67	63	71	78	64				
Rikkiä, S, yht. 1962—63 — *Sulphur*	ilman kalkkia	50	87	107	—6	—6	—8	—5	***	***	*	
	kalkittuna	62	79	109	8	±0	—2	8				
Kalia, K_2O, yht. 1961—63 — *Potassium*	ilman kalkkia	2 255	1 494	1 964	582	568	437	727	***	***		
	kalkittuna	3 046	1 352	1 769	479	613	435	638				
Kalkkia, CaO, yht. 1961—63 — *Calcium*	ilman kalkkia	141	89	187	80	148	60	128	***	*	**	
	kalkittuna	318	183	251	97	140	81	124				
Magnesiaa, MgO, yht. 1961—63 — *Magnesium*	ilman kalkkia	179	127	237	109	160	87	159	***	*	***	
	kalkittuna	317	128	184	62	103	67	130				

astiakoe 2:n kaikki erilaiset lannoitukset järjestettiin sekä kalkitsemattomalle että kalkitulle (24 g/ast. kalsiumkarbonaattia) maalle. Koekasvina oli kaikkina vuosina kaura (Pendek), josta otettiin tuleentunut sato.

Taulukossa 6 esitetään astiakoe 2:sta saadut tärkeimmät tulokset. Kuiva-ainesatoihin on sekä kalkituksen että fosforilannoituksen vaikutus ollut suuri ja tilastollisesti erittäin merkitsevä. Parhaimman vaikutuksen on aiheuttanut sekä kalkitsemattomassa että kalkitussa maassa superfosfaatti. Kalkkifosfaatti ja tomasfosfaatti jäävät siitä jälkeen kalkitsemattomassakin, mutta vielä enemmän kalkitussa maassa. Kalkitus on selvästi nostanut jyvien osuutta kuiva-ainesadossa. Samoin on vaikuttanut fosforilannoitus kalkitsemattomassa maassa, mutta kalkitussa enää niin vähän, että erotuksille ei tule tilastollisia merkitsevyyksiä. Fosforilannoitelajien välillä ei tässä kohdin ole eroja.

Vuonna 1963 tehtiin sadoista (= jyvät + oljet) kuiva-ainepitoisuuden määritykset korjuuhetkellä. Voidaan sanoa, että tämä kuiva-ainepitoisuus kuvastaa kasvien tuleentuneisuutta. Varsinkin kalkitus on selvästi jouduttanut tuleentumista. Fosforilannoituskin on sitä tehnyt, mutta eri lajien vaikutuksessa näyttää olevan eroja. Lukujen mukaan superfosfaatti on edistänyt tuleentumista parhaiten kalkitussa, muut fosfaatit kalkitsemattomassa maassa. Kun on kysymyksessä jo kolmas sato fosforilannoituksen antamisen jälkeen, ei suuria eroja voi enää odottaa.

Jos kokeessa mukana olleita lannoitteita vertaillaan satojen sisältämien fosforimäärien mukaan, vähenevät erot siitä, mitä ne ovat kuiva-ainesatojen perusteella vertaillen. Ainoastaan viimeisenä koevuotena ovat erot satojen fosforimäärissä tilastollisesti merkitseviä. Odottamatonta on, että superfosfaatin vaikutus on jatkunut selvänä kaikkein kauimmin. Vertailtaessa toisiinsa eri lannoitteiden vaikutusta kuiva-ainesatoihin ja satojen fosforimääriin voidaan tulla sellaiseen päätelmään, että kokeessa olleiden emäksisten fosfaattien fosfori olisi kasveille lähes yhtä käyttökelpoista kuin superfosfaatin, mutta syystä tai toisesta ei saisi aikaan yhtä runsasta kuiva-ainesadon lisäystä.

Muista satojen sisältämistä aineista voidaan todeta, että kalkitus on yleensä lisännyt niiden määriä. Rikkiluvuista puuttuvat tiedot v:lta 1961. Käytettävissä olevien lukujen mukaan superfosfaatti on selvästi nostanut satojen rikkimääriä.

Kuten astiakoe 1:ssä myös astiakoe 2:ssa tehtiin syksyisin sadonkorjuun jälkeen maasta pH-mittaukset. Tulosten keskiarvot nähdään taulukossa 7. Kalkkifosfaatin maan happamuutta vähentävä vaikutus näyttää olevan samantapainen kuin tomasfosfaatin. Kun koe lopetettiin syksyllä 1963, otettiin astioista maanäytteet, joista tehtiin kasvinravinneanalyysit ammoniumasetaattimenetelmällä (Vuorinen ja Mäkitie 1955; Kurki ym. 1965). Eri koelannoitteiden aiheuttamat erot olivat kuitenkin niin vähäiset ja sattumanvaraisen tuntuiset, ettei lukuja tässä esitetä.

T i i v i s t e l m ä n ä astiakokeiden tuloksista voidaan sanoa, että ns. kalkkifosfaatti fosforilannoitteena näyttää olevan verrattavissa lähinnä

Taulukko 7. Astiakoe 2. Erilaisten fosforilannoitteiden aiheuttamat erot maan pH-luvuissa
Table 7. Pot trial 2. Differences in soil pH produced by the phosphate fertilizers

		Ilman fosforilannoitusta *Without phos. fert.*	Fosforilann. aiheuttamat muutokset *Diff. caused by phos. fert.*					
			superfosf.		kalkkif.		tomasfosf.	
			1	2	1	2	1	2
pH mitattu vedessä — *pH in water*	ilman kalkitusta *without lime*	4.89	0.18	0.03	0.31	0.58	0.35	0.48
	kalkittuna —*limed*	6.58	— 0.11	0.01	0.15	0.28	0.20	0.23
pH mitattu 1 n kaliumkloridissa — *pH in 1 N KCl*	ilman kalkitusta *without lime*	3.64	0.02	0.00	0.04	0.36	0.07	0.23
	kalkittuna —*limed*	5.27	— 0.01	0.15	0.23	0.51	0.35	0.34

Taulukko 8. Kenttäkoesarja 1. Renaniafosfaatin ja superfosfaatin vertailevat
Table 8. Field trial series 1. Comparative trials between Rhenania phosphate and super

Kokeen N:o *Trial No.*	Koepaikka *Locality*	Maalaji *Soil type*	Viljelyskasvit *Crops*			pH
1.	Itä-Hämeen koetila, Hartola	hieta *fine sand*	kaura *oats*	1. n. *ley*	2. n. *ley*	5.0
2.	V. Ijäs, Nakkila	liejusavi *gyttja clay*	ohra *barley*	1. n. *ley*	2. n. *ley*	5.5
3.	Etelä-Pohjanmaan koeasema, Ylistaro	liejusavi *gyttja clay*	kev.v. *spr.wheat*	1. n. *ley*	2. n. *ley*	5.1
4.	Pohjois-Pohjanmaan koeasema, Revonlahti	saraturve *carex peat*	kaura *oats*	1. n. *ley*	2. n. *ley*	5.7

Keskim. 4 kokeessa — *Av. (4 trials)* ... 1 kev.v., 1 ohra, 2 kauraa, 4 1. n., 4 2. n.
1 kg P_2O_5 antanut sadonlisäystä ry — *Yield increase (f.u.) caused by 1 kg* P_2O_5

[1]) *f.u. = Scandinavian fodder unit.*

Taulukko 9. Kenttäkoesarja 2. Kalkkifosfaatin ja superfosfaatin vertailevat
Table 9. Field trial series 2. Comparative trials between sintered phosphate and

Kokeen N:o *Trial No.*	Koepaikka *Locality*	Viljelyskasvit *Crops*			pH
	Hietamaat — *Finesand soils*				
1.	Itä-Hämeen koetila, Hartola	kaura — *oats*	kaura — *oats*	1. nurmi - *ley*	6.5
2.	Peltotalo, Laukaa	kaura — *oats*	1. n. — *ley*	2. n. — *ley*	6.2
3.	Sirkka, Laukaa	ohra — *barley*	1. n. — *ley*	2. n. — *ley*	6.1
4.	Pienviljelijäkoulu, Ilomantsi	ohra — *barley*	kaura — *oats*	1. n. — *ley*	6.4
5.	Keski-Pohjanmaan koeasema, Tohola-mpi	ohra — *barley*	1. n. — *ley*	2. n. — *ley*	6.0

Keskim. hietamaat 5 koetta, — *Av. finesand soils*, 3 ohraa, 4 kauraa, 5 1. n., 3 2. n.
1 kg P_2O_5 antanut sadonlisäystä ry — *Yield increase f.u. caused by 1 kg* P_2O_5

	Savimaat — *Clay soils*				
6.	Lounais-Suomen koeasema, Mietoinen	kaura	1. n.	2. n.	4.6
7.	Mustiala, Tammela	kev.v.	ohra	1. n.	6.3
8.	Satakunnan koeasema, Kokemäki ...	ohra	1. n.	2. n.	5.5
9.	M. Naukkarinen, Nakkila	kaura	1. n.	2. n.	5.2

Keskim. savimaat, 4 koetta — *Av. clay soils* 1 kev.v., 2 ohraa, 2 kauraa, 4 1. n., 3 2. n.
1 kg P_2O_5 antanut sadonlisäystä ry — *Yield increased f.u. caused by 1 kg* P_2O_5

	Multa- ja turvemaat — *Humus- and peat soils*				
10.	Uusi-Peltotalo, Laukaa	kaura	1. n.	2. n.	5.1
11.	Maamieskoulu, Alajärvi	ohra	1. n.	2. n.	6.0
12.	M. Turpeinen, Pihtipudas	kaura	1. n.	2. n.	5.2
13.	Pohjois-Pohjanmaan koeasema, Revonlahti	kaura	1. n.	2. n.	5.7
14.	Peräpohjolan koeasema, Rovaniemi ..	1. n.	2. n.	3. n.	4.4

Keskim. multa- ja turvemaat, 5 koetta — *Av. humus- and peat soils* 1 ohra, 3 kauraa, 5 1. n., 5 2. n., 1 3. n.
1 kg P_2O_5 antanut sadonlisäystä ry — *Yield increase f.u. caused by 1 kg* P_2O_5

Keskim. kaikissa 14 kokeessa — *Av. from all 14 trials*
1 kg P_2O_5 antanut sadonlisäystä ry — *Yield increase f.u. caused by 1 kg* P_2O_5

kokeet, koemaiden ominaisuudet ja satotulokset ry/ha yht. 3 v:n aikana
phosphate. Soil characteristics mg/l soil and yield results f.u./ha[1]*), total in 3 years*

Amm. aset. menetelmällä *By amm. acetate method*			Sato ilman fosf.-lann. *Yield without phos. fert.*	Fosforilann. saadut erotukset *Diff. caused by phos. fertilizers*				Merkitsevyysasteet *Significance*			
				superfosf.		renaniaf.		lannoitettu lannoittam. *fert. no fert.*	lann.-laji *type of fert.*	lann.-määrä *rate of fert.*	lann.-laji × -määrä *fert. type × rate*
vaiht. Ca	kali K	fosf. P		1	2	1	2				
660	159	5.7	7 780	180	450	310	320				
800	153	4.8	6 540	650	760	760	800	**			
1 400	196	5.7	10 300	— 50	230	170	340		*	*	
2 060	75	4.4	8 070	— 50	360	160	300				
			8 173	183	450	350	440	**		**	*
				4.8	5.9	9.2	5.8				

kokeet, koemaiden ominaisuudet ja satotulokset ry/ha yht. 3 v:n aikana
superphosphate. Soil characteristics mg/l soil and yield results f.u./ha total in 3 years

Amm. aset. menetelmällä *By amm. acetate method*			Sato ilman fosf.-lann. *Yield without phos. fert.*	Fosforilann. saadut erotukset *Diff. caused by phos. fertilizers*				Merkitsevyysasteet *Significance*			
				superfosf.		kalkkif.		lannoitettu lannoittam. *fert. no fert.*	lann.-laji *type of fert.*	lann.-määrä *rate of fert.*	lann.-laji × -määrä *fert. type × rate*
vaiht. Ca	kali K	fosf. P		1	2	1	2				
960	158	3.9	4 190	730	1 050	690	740	**			
480	116	2.2	4 560	1 280	1 740	1 600	2 570	***			
1 080	106	1.3	5 810	1 560	2 220	1 640	2 450	***		*	
790	212	4.8	7 320	720	270	110	720	(*)			
800	73	2.2	6 150	720	1 490	780	1 450	**		*	
			5 606	1 002	1 354	964	1 586	**		*	
				26.4	17.8	25.4	20.8				
480	249	4.8	7 800	330	580	630	910	(*)			
3 310	445	13.0	6 990	390	280	60	80				
1 260	171	7.4	8 950	950	430	1 300	1 100	(*)			
1 110	76	2.2	7 390	50	510	— 50	360			(*)	
			7 783	430	450	485	613	*			
				11.3	5.9	12.8	8.1				
1 220	138	3.1	4 330	840	430	— 60	540	***	*		**
1 210	148	8.3	5 390	340	—160	— 10	210				
610	136	5.2	5 730	1 130	1 110	530	1 080	**	*		
1 800	139	5.7	7 580	— 30	330	320	220	**			
400	55	3.1	4 970	60	650	230	530			*	
			5 600	468	472	202	516	**			
				12.3	6.2	5.3	6.8				
			6 226	648	781	555	926	***		***	
				17.1	10.3	14.6	12.2				

tomasfosfaattiin. Renaniafosfaattia koskevat tiedot ovat riittämättömät, mutta se näyttäisi olevan samanveroista kuin kalkkifosfaatti.

Kenttäkokeet

Siilinjärveltä saadusta apatiittirikasteesta valmistettujen emäksisten fosforilannoitteiden tutkimiseksi järjestettiin myös kenttäkokeita kaksi pientä sarjaa eri puolilla Suomea.

Kenttäkoesarja 1:ssä vertailtiin renaniafosfaattia superfosfaattiin. Kokeet olivat käynnissä vuosina 1960—62. Renaniafosfaatti oli samaa erää, jota käytettiin astiakoe 1:ssä (taul. 1). Fosforimääriä oli kokeissa 2, määrä 1 oli 200 kg/ha superfosfaattia (38 kg veteen liukenevaa P_2O_5) ja määrä 2 400 kg/ha (76 kg P_2O_5). Renaniafosfaattia otettiin erät, joissa tuli samat määrät P_2O_5 (ammoniumsitraattiin liuk.). Fosforilannoitukset annettiin vain kerran, kokeen alkaessa. Typpi- (200 kg/ha oulunsalp.) ja kalilannoitukset (200 kg/ha 50 % kalis.) sen sijaan uusittiin kaikkina koevuosina. Yhtäjaksoiset kolmen vuoden tulokset kokeista, joissa fosforilla on yleensä ollut vaikutusta, saatiin vain neljästä kentästä. Katsaus niihin esitetään taulukossa 8. Kokeiden vähäinen lukumäärä ei oikeuta pitkälle meneviä päätelmiä, mutta voidaan panna merkille, että renaniafosfaatti on keskimäärin ollut samanveroista kuin superfosfaatti.

Kenttäkoesarja 2:ssa verrattiin ns. kalkkifosfaattia (erä II, taul. 1) superfosfaattiin. Fosforimäärät 1 ja 2 olivat samat kuin kenttäkoesarjassa 1:ssä. Kalkkifosfaatin määrät laskettiin sitruunahappoon liukenevan P_2O_5:n mukaan. Kokeet järjestettiin samaan tapaan kuin sarjassa 1. Fosforilannoitukset annettiin vain kokeen alkaessa, ja vuosittain annettavat typpi- ja kalilannoitukset olivat niin ikään samat. Yhtäjaksoiset kolmen vuoden tulokset kentistä, joissa fosforilannoituksella oli vaikutusta, saatiin kaikkiaan 14:stä kokeesta (taul. 9).

Fosforilannoituksen vaikutus on näissä kokeissa ollut hyvä (vrt. esim. SALONEN ja TAINIO 1957; TENNBERG 1960, 1964). Lähes ennätysmäiset ovat sadonlisäykset olleet hietamaissa, mutta savimaissa pienemmät ja, odottamatonta kyllä, multa- ja turvemaissa kaikkein pienimmät.

Fosforilannoituksen vaikutuksen yleensä ja eri lajien vaikutuksissa esiintyvien erojen vertailemiseen maan kemiallisiin ominaisuuksiin aineisto on kovin pieni. Jokseenkin selvänä tulee kuitenkin näkyviin, että fosforilannoituksen vaikutus on ollut suurin fosforiköyhässä maassa ja kääntäen. Tutkimuksen pääkysymykseen, superfosfaatin ja kalkkifosfaatin vaikutuksen mahdolliseen eroon ja sen riippuvuuteen maan kemiallisista ominaisuuksista, koetulokset eivät anna selvää vastausta. Ei esim. voi todeta mitään johdonmukaisuutta maan happamuuden tai kalkipitoisuuden ja erityyppisten fosforilannoitteiden vaikutusten välillä. Voidaan kylläkin väittää, että koekenttien maat kalkkitilan ja happamuuden puolesta ovatkin, lukuun ottamatta yhtä tapausta (koe 7), sellaisia, joilla nimenomaan

Taulukko 10. Eri koevuosina saadut satotulokset kaikissa kokeissa (14 kpl) keskimäärin ry/ha/v
Table 10. Average annual yields, f.u./ha, in the different years from all 14 trials

	Sato ilman fosf.-lann. *Yield without phos. fert.*	Fosf. lann. saadut erotukset *Diff. caused by phos. fert.*			
		superfosf.		kalkkifosf.	
		1	2	1	2
1. vuosi = fosf.lannoitteiden antamisvuosi — *1st year = phosphate applied*	2 115	245	321	191	276
2. vuosi = 1. jälkivaikutusvuosi — *2nd year = 1st year residual effect*	1 963	159	188	156	245
3. vuosi = 2. jälkivaikutusvuosi — *3rd year = 2nd year residual effect*	2 148	244	271	209	404
Koko koeaikana keskim. vuodessa — *3-year average*	2 075	216	260	185	309

emäksiset fosforilannoitteet ovat edullisia. Kokeessa 7 todellakin kalkkifosfaatti jää keskiarvoissa selvästi huonommaksi kuin superfosfaatti, mutta vuotuisvaihtelun takia siinä ei tule tilastollisia merkitsevyyksiä.

Kolmivuotisen koekauden eri vuosina saaduista keskimääräisistä tuloksista antaa käsityksen taulukko 10. Fosforilannoituksen antamat sadonlisäykset ovat kolmantena vuotena olleet vielä samaa luokkaa kuin ensimmäisenä, eikä eri lannoitelajien välillä ole tässä kohden eroja. Verraten pienen fosforilannoituksen vaikutus on siten jatkunut samanlaisena pitkään, siis päinvastoin kuin astiakokeissa 1 ja 2 (taul. 3, 4 ja 6), joissa todettiin ensimmäisenä vuotena suuri ja myöhempinä vuosina melkoisen vähäinen vaikutus.

Taulukko 11. Eri kasvilajeilla saadut tulokset keskim. vuodessa koko koeaikana ry/ha
Table 11. Average annual yields, f.u./ha, during all trial years for different types of crops

	Sato ilman fosf.-lann. *Yield without phos. fert.*	Fosf.lann. saadut erotukset *Diff. caused by phos. fert.*			
		superfosf.		kalkkifosf.	
		1	2	1	2
Korsiviljat, keskiarvot 16 koesadosta — *Cereals, average from 16 harvests*	1 994	225	290	159	268
Nurmet, keskiarvot 26 koesadosta — *Leys, average from 26 harvests*	2 125	210	242	201	333
Kaikki kasvilajit keskim. — *Average for all crops*	2 075	216	260	185	309

Taulukko 12. Eri ikäisillä nurmilla saadut tulokset keskim. ry/ha/v
Table 12. Average annual yields, f.u./ha, from leys of different ages

	Sato ilman fosf.-lann. *Yield without phos. fert.*	Fosf.lann. saadut erotukset *Diff. caused by phos. fert.*			
		superfosf.		kalkkifosf.	
		1	2	1	2
1. v:n nurmet, 14 koesatoa — *1st-year leys, 14 harvests*	2 169	206	217	196	256
2. v:n nurmet, 11 koesatoa — *2nd-year leys, 11 harvests*	2 155	226	252	214	418
3. v:n nurmet, 1 koesato — *3rd-year leys, 1 harvest*	1 200	100	480	140	490
Keskim. kaikki nurmet, 26 koesatoa — *Average, 26 harvests*	2 125	210	242	201	333

Taulukko 13. Nurmisatojen kasvilajikoostumus kg ja % keskim. 20 koesadossa
Table 13. Botanical composition of leys, kg and %, average from 20 harvests

	kg/ha					%				
	tulos ilman fosf. *without phos. fert.*	fosf.lann. saatu ero *diff. caused by phos. fert.*				tulos ilman fosf. *without phos. fert.*	fosf.lann. saatu ero *diff. caused by phos. fert.*			
		superfosf.		kalkkifosf.			superfosf.		kalkkifosf.	
		1	2	1	2		1	2	1	2
Apilaa — *Clover*	803	68	112	64	149	15	—1	±0	±0	±0
Timoteita — *Timothy*	3 799	466	563	423	775	70	1	1	±0	2
Muita heinäkasveja — *Other grasses*	594	83	— 28	42	— 24	11	±0	—2	±0	—2
Rikkaruohoja — *Weeds*	248	— 22	54	— 13	— 14	4	±0	1	±0	±0
Yhteensä — *Total*	5 444	595	701	516	886					

Viljelykasvina on näissä kokeissa ollut vain kevätviljoja (1 kevätvehnä, 6 ohraa ja 9 kauraa) ja nurmia (14 1. v:n ja 11 2. v:n nurmea ja 1 3. v:n nurmi). Eri kasvilajien antamiin tuloksiin esitetään katsaus taulukossa 11. Rehuyksiköissä ilmaistuna sekä ilman lannoitusta saadut sadot että eri fosforilannoitteiden vaikutukset ovat olleet molemmissa kasvilajiryhmissä suunnilleen samanlaiset.

Eri-ikäisiltä nurmilta saadut tulokset esitetään taulukossa 12 (yksi 3. v:n nurmi johtuu siitä, että koe 14 oli koko ajan nurmena, joka oli kylvetty ilman suojaviljaa). Ilman fosforilannoitusta saatu sato on ollut hyvin samaa luokkaa

Taulukko 14. Satotuotteiden kasvinravinnepitoisuuksia g/kg kuiva-ainetta
Table 14. Plant nutrient content of harvested crops, g/kg dry matter

			Anal. lukum. *No. of analyses*	Ilman fosforilannoitusta *Without phos. fert.*	Superfosf. 1	Superfosf. 2	Kalkkifosf. 1	Kalkkifosf. 2
Ohra — *Barley*	jyvät — *grain*	N	3	17.8	19.1	18.6	18.6	19.0
		P_2O_5	3	8.3	8.6	8.9	8.6	8.5
		S	3	1.2	1.5	1.4	1.5	1.4
		K_2O	3	8.3	8.7	8.3	8.5	8.4
		CaO	3	0.7	0.6	0.7	0.6	0.6
		MgO	3	2.0	2.3	2.2	2.2	2.1
» »	oljet — *straw*	N	3	8.6	9.5	8.5	9.0	8.2
		P_2O_5	3	2.6	3.0	2.8	2.6	2.7
		S	3	1.6	1.6	1.6	1.5	1.2
		K_2O	3	23.1	24.8	21.7	24.6	23.0
		CaO	3	4.0	4.0	3.9	4.0	3.8
		MgO	3	1.8	1.7	1.5	1.5	1.7
Kaura — *Oats*	jyvät — *grain*	N	7	22.4	22.3	21.9	22.9	22.0
		P_2O_5	7	9.4	9.4	9.5	9.3	9.4
		S	7	1.6	1.7	1.9	1.7	1.6
		K_2O	7	6.7	6.4	6.5	6.5	6.7
		CaO	7	1.0	1.1	1.1	1.1	1.1
		MgO	7	2.3	2.3	2.3	2.3	2.3
» »	oljet — *straw*	N	3	10.2	9.4	10.0	10.3	11.1
		P_2O_5	3	3.2	3.2	3.0	3.3	3.3
		S	3	1.9	1.9	1.9	1.8	1.8
		K_2O	3	31.7	33.7	30.8	30.8	30.7
		CaO	3	3.6	3.8	4.3	3.2	3.7
		MgO	3	2.3	2.4	2.5	2.0	2.2
Heinät — *Hay*	pelkkä apila — *clover only*	N	12	21.9	21.2	20.4	20.7	21.2
		P_2O_5	12	3.9	4.0	3.7	3.8	4.0
		S	12	1.3	1.4	1.2	1.2	1.2
		K_2O	12	30.5	30.8	29.4	30.3	31.0
		CaO	12	21.9	21.7	21.1	21.6	20.2
		MgO	12	5.2	5.2	5.3	5.9	5.3
» »	pelkkä timotei — *timothy only*	N	16	10.1	10.4	9.9	10.4	10.0
		P_2O_5	16	3.5	3.6	3.6	3.5	3.6
		S	16	1.0	1.0	0.9	1.0	1.0
		K_2O	16	21.5	21.1	21.1	21.4	21.4
		CaO	16	3.7	3.7	3.6	3.7	3.7
		MgO	16	1.4	1.5	1.5	1.5	1.5
» »	sekanäyte — *mixed*	N	6	14.3	14.0	14.3	14.5	13.7
		P_2O_5	6	4.0	4.0	4.1	4.0	4.0
		S	6	1.4	1.4	1.4	1.4	1.4
		K_2O	6	21.5	21.1	19.9	20.7	20.6
		CaO	6	5.2	5.1	5.2	5.7	5.2
		MgO	6	2.4	2.3	2.5	2.5	2.4

sekä 1. että 2. vuoden nurmissa, mutta fosforilannoitusten vaikutukset ovat olleet toisen vuoden nurmissa hieman suuremmat siitä huolimatta, että aikaa lannoituksen antamisesta oli kulunut vuosi enemmän.

Nurmien kasvilajikoostumuksesta esitetään tiedot taulukossa 13. Kasvilajianalyysit on saatu 10:stä sekä 1. vuoden että 2. vuoden nurmen sadosta. Fosforilannoituksen vaikutus nurmien kasvilajikoostumukseen on ollut pieni. Voidaan kuitenkin panna merkille, että runsaampi fosforimäärä on hieman lisännyt apilan ja timotein kilomääriä, mutta lannoitelajien välillä ei voi nähdä selviä eroja.

Osasta koesatoja tehtiin kemiallisia analyyseja, jotta saataisiin tietoja siitä, onko koelannoitteilla erilaista vaikutusta satotuotteiden kivennäisainepitoisuuksiin. Kun analyysien tulosten yksityiskohtaisessa tarkastelussa ei voitu löytää johdonmukaisia eroja, esitetään kivennäispitoisuudet vain suppeasti taulukossa 14. Ainoat kohdat, missä näyttäisi olevan johdonmukaisia, lannoitelajista riippuvia eroja, ovat ohran olkien rikki- ja fosforipitoisuudet. Huomautettakoon, että olkien korkeat typpipitoisuudet johtuvat siitä, ettei vilja ole aina ollut täysin tuleentunutta ja että sen seassa on voinut olla rikkaruohoja.

Kenttäkoesarja 2:n kentistä, lukuun ottamatta kokeita 11 ja 14, otettiin kolmivuotisen koekauden lopussa maanäytteet ruuduittain. Niistä tehtiin paitsi pH-määritykset (sekä vesi- että kaliumkloridiliuoslietoksesta) myös ravinneanalyysit ammoniumasetaattimenetelmällä. Eri käsittelyjen väliset erot olivat kuitenkin vähäiset, mikä tietenkin johtuu siitä, että koelannoitemäärätkin olivat pienet (0, 38 ja 76 kg/ha P_2O_5 kolmen vuoden ajaksi). Niinpä tyydytäänkin esittämään vain keskiarvoja maalajiryhmittäin (taul. 15). Vesilietoksessa mitatuissa pH-luvuissa on vain vähäisiä ja täysin satunnaisilta näyttäviä eroja, mutta kaliumkloridilietoksesta saatujen lukujen mukaan olisi hietamaiden ryhmässä

Taulukko 15. Maa-analyysien tuloksia kokeiden loppuessa
Table 15. Results of soil analyses at the end of trials

		Koekenttiä *No. of trials fields*	Ilman fosforilannoitusta *Without phos. fert.*	Superfosf.		Kalkkifosf.	
				1	2	1	2
pH vesilietoksesta— *pH in water*	hieta — *finesand*	5	6.2	6.3	6.2	6.3	6.3
	savi — *clay*	4	5.4	5.5	5.5	5.4	5.5
	multa ja turve — *humus and peat*	3	5.2	5.5	5.5	5.5	5.5
	kaikki maalajit — *all soil types*	12	5.7	5.8	5.8	5.8	5.8
pH KCl-lietoksesta — *pH in 1 N KCl*	hieta	5	4.8	4.8	4.8	4.9	4.9
	savi	4	4.4	4.4	4.4	4.4	4.5
	multa ja turve	3	4.2	4.2	4.2	4.2	4.2
	kaikki maalajit	12	4.5	4.6	4.5	4.6	4.6
Ammoniumasetaattimenetelmän mukaan mg/l maata — *By amm. acetate method mg/l soil*							
Vaihtuva kalkki, Ca — *Exch. Ca*	hieta	5	820	900	900	880	980
	savi	4	1 600	1 590	1 740	1 510	1 680
	multa ja turve	3	1 210	1 360	1 280	1 260	1 200
	kaikki maalajit	12	1 190	1 240	1 280	1 180	1 280
Vaihtuva kali, K — *Exch. K*	hieta	5	133	121	115	116	120
	savi	4	235	242	251	235	257
	multa ja turve	3	118	118	119	130	143
	kaikki maalajit	12	163	161	162	159	171
Helposti liukeneva fosfori, P — *Readily soluble P*	hieta	5	2.8	3.0	3.2	2.8	3.3
	savi	4	6.8	7.1	6.9	5.9	7.2
	multa ja turve	3	4.5	4.9	5.8	5.1	6.3
	kaikki maalajit	12	4.6	4.8	5.1	4.4	5.3

kalkkifosfaatti hiukan nostanut pH-arvoja. Vaihtuvan kalkin luvuissa ilmenevässä samaten satunnaiselta tuntuvassa vaihtelussa lienee lannoitteiden kipsipitoisuudella osuutta. Vaihtuvan kalin kohdalla ei eroja tässä ole odotettavissa, mutta sitäkin enemmän helposti liukenevan fosforin pitoisuuksissa. Niissäkin ilmenee jotakin tähän viittaavaa vain multa- ja turvemaiden ryhmässä.

T i i v i s t e l m ä n ä kenttäkokeiden tuloksista voidaan sanoa, että vaikka kalkkifosfaatti näyttääkin jäävän hieman jälkeen superfosfaatista, se on kuitenkin kelvollinen lannoite ainakin kalkkiköyhillä ja happamilla mailla. Renaniafosfaatin osalta tulokset ovat edulliset, mutta kokeiden vähäisen lukumäärän vuoksi on varminta vain todeta, että harvalukuiset koetulokset ovat samansuuntaiset kuin ulkomailla vastaavalla tuotteella saadut.

Kalkkifosfaatin ja renaniafosfaatin käytön mahdollisuuksista Suomen peltoviljelyksessä

Tutkittuja Suomen oloissa uusia fosforilannoitteita, kalkkifosfaattia ja renaniafosfaattia, voidaan pitää suunnilleen samanarvoisina. Sekä astia- että kenttäkokeissa niistä tuli sikäli myönteiset tulokset, että ne sopivat hyvin ainakin kalkkiköyhille ja happamille maille.

Kalkki- ja renaniafosfaatin käyttökelpoisuudesta riittävän kalkkipitoisilla, lähes neutraaleilla mailla on kylläkin saatu vain verraten puutteellinen selvitys, mutta näyttää siltä, että sellaisissa tapauksissa nämä emäksiset fosfaatit eivät kykene täysin kilpailemaan superfosfaatin kanssa. Meillä on kuitenkin nykyisin viljelysmaiden peruskalkitus sellaisessa vauhdissa, että sen jatkuessa samanlaisena on muutamassa vuodessa kaikki pahasti happamat maat korjattu. Siten erityisten happaman maan lannoitteiden merkitys todennäköisesti vastaisuudessa vähenee.

Väkilannoitteiden käyttömäärät ovat nykyisin siksi suuret, että niiden kuljetuskustannukset ja levitystyö merkitsevät aika paljon. Niiden vähentämiseksi on hyvä, että lannoitteiden tehoaineiden prosentit ovat korkeat. Esim. kalkkifosfaatin pitoisuus, 15—16 % P_2O_5, tuntuu nykyoloissa kovin pieneltä. Alhaisen prosentin vastapainona ei siinä ole edes muita hyödyllisiä aineita, ja maata neutraloiva vaikutuskin on vähäinen.

Kokeilluissa fosforilannoitteissa ei ole sivuaineena rikkiä, jota esiintyy monissa fosforilannoitteissa. Tällä kertaa saattaa rikin puuttuminen tuntua vähemmän tärkeältä, mutta asia voi muuttua, jos rikittömien lannoitteiden käyttö yleistyy.

Alhainen fosforipitoisuus ja emäksisyys aiheuttavat sen, että ko. lannoitteet eivät voi tulla kysymykseen moniravinteisten lannoitteiden aineosina. Tämäkin näkökohta vähentää näiden koelannoitteiden mahdollisuuksia, sillä jo nyt seoslannoitteet ovat vallitsevia ja niiden osuus näyttää yhä lisääntyvän.

Kun kaiken todennäköisyyden mukaan kokeissa olleiden fosforilannoitteiden tapaiset tuotteet eivät voi saada niin laajaa käyttöä kuin olisi välttämätöntä, on tarpeen tutkia muita mahdollisuuksia karbonaattipitoisen apatiitin käyttämiseksi lannoiteteollisuudessa. Omavaraisuus niin tärkeän kasvinravinteen kuin fosforin kohdalla on arvokas kaikissa oloissa, mutta erityisesti silloin, kun tuonti syystä tai toisesta estyy.

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SUMMARY

Studies on the value of alkaline phosphate fertilizers prepared from calcite-containing apatite

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In the phosphate deposit found in Finland, apatite occurs with calcite. At present no sufficiently cheap method is known for separating the apatite from this mixture in such pure form that it could be used in the manufacture of superphosphate, for example. Therefore, experiments were carried out with two types of calcareous phosphate fertilizers prepared from enriched apatite, the first called Rhenania phosphate, indicated in the tables »renaniaf.» (HONCAMP 1931, p. 345—349), and the second prepared by melting apatite with quartz sand, known as sintered phosphate and indicated in the tables »kalkkifosf.» (WAGGAMAN 1953, p. 394; COOKE 1956, p. 42—43).

The most important characteristics of these phosphates are given in Table 1.

The effect of these fertilizers on crops in pot trials was compared with the effects of superphosphate and basic slag (indicated as »superf.» and »tomasfosf.» respectively), Tables 3—7, and in field trials they were compared with superphosphate, Tables 8—15.

Although both Rhenania phosphate (few trial results) and sintered phosphate (many results) were slightly inferior to superphosphate and to basic slag, they can nevertheless be considered satisfactory forms of phosphate fertilizer. They would be best for use on lime-deficient and acid soils.

For a fertilizer to be both practical and economical, it must have other qualities besides merely a satisfactory plant nutrient effect. The content of the effective component in the two fertilizers tested, 15—16 % P_2O_5, must be regarded as too low. This fact, as well as the alkalinity of the two products, hinders their use as ingredients in multi-nutrient fertilizers. Such fertilizers, however, make up the bulk of the market in Finland and will become increasingly important in the future. The soil-neutralizing effect of the two products tested — although rather weak — would be advantageous in a country such as Finland, where soils are generally too acid, but at present this fact is no longer wery significant, since basal lime application is rapidly increasing and will soon be carried out on virtually all fields. The conclusion from these trials is therefore that the two fertilizers tested do not fulfil the requirements and that other methods should be developed for utilizing calcite-containing apatite for the manufacture of phosphate fertilizers.

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RED SPOT OF AMARYLLIS CAUSED BY FUNGI

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Various factors, both biotic and abiotic, may produce injuries to amaryllis [*Hippeastrum vittatum* L'Herit (Herb.)] [1]) resulting in a reddish colouration of the tissues due to diffusion of anthocyanin pigments. In most cases such reddening in amaryllis in the form of spots or blotches is a consequence of fungal infection. This phenomenon has been termed 'red spot'.

In the years 1958—63 studies were carried out at the Department of Plant Pathology on fungal-induced red spot of amaryllis. Symptoms of this disease were watery, red or reddish-brown lesions on the bulbs, leaves and scapes (Fig. 1), reddish scabs in the outer scales of the bulb, red spotting of the leaves or red discolouration of the roots.

The principal causal agent of this disease is *Stagonospora curtisii* (Berk) Sacc. The disease produced by it has been given the names »red leaf spot», »rust» (WEISS 1934), »leaf scorch» (MILLIKAN 1940), »red blotch» (LASKARIS and DODGE 1941), »red fire», »red fire disease» (DODGE and RICKETT 1948), as well as in German

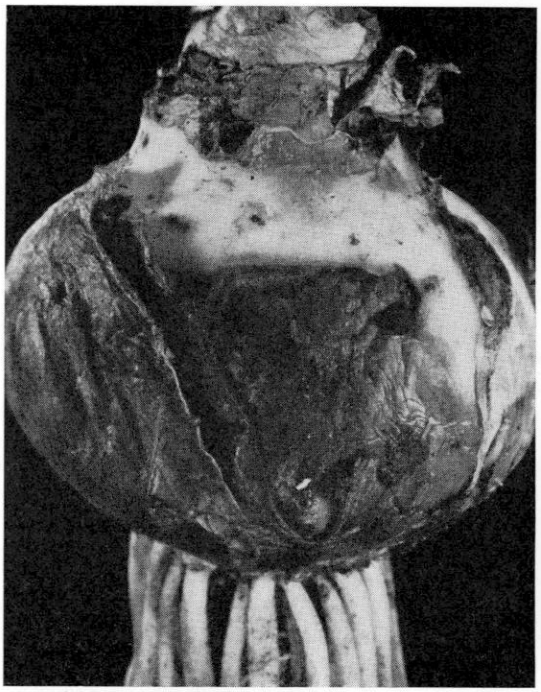


Fig. 1. Lesion of red fire in bulb of amaryllis caused by *Stagonospora curtisii*.

»Roter Brenner» (KOTTHOF and FRIEDRICHS 1929, KOTTHOF 1942, PAPE 1955), in Swedish »rödbränna» (INGELSTRÖM 1950) and in Finnish »punalaikkutauti» (JAMALAINEN and KANERVO 1956, TAPIO and MÄKINEN 1959). Some species of fungi isolated at the Department of Plant Pathology may also be responsible for red spot

[1]) Most cultivated *Hippeastrum* plants are hybrids. For this reason certain workers (cf. PAG 1964) consider the names *H. hybridum* and *H. x hortorum* more correct than *H. vittatum*. In practice, however, cultivated *Hippeastrum* plants are generally called amaryllis. At one time, *Hippeastrum* plants were regarded as belonging to the genus *Amaryllis*, but this has been subdivided into several genera, and is now a monotypic genus, according to certain authorities (cf. HIITONEN 1958), consisting of only one species, *Amaryllis belladonna* L.

of amaryllis, but they are not so important as *S. curtisii* (cf. PAG 1964, p. 30).

Red spotting of amaryllis leaves and scapes may furthermore be brought about by infestation with the amaryllis mite *(Tarsonemus laticeps* Hallbert), and this phenomenon has been called »red disease» in English (DODGE and RICKETT 1948, BAKER and WHARTON 1952) and »Roter Brenner» in German (PAPE 1955). The mites feed on flower and leaf primordia, and as a result reddish, ragged streaks arise in the leaves and scapes. Besides the amaryllis mite, the bulb mite *(Rhizoglyphus echinopus* Murr.) may likewise be found in diseased amaryllis plants; it occurs as a secondary pathogen in the decay lesions produced by fungi.

Occurrence of red spot in Finland

In order to determine incidence of red spot in cultivated amaryllis in Finland, detailed inspections were made in the years 1958—61 in the stocks of the six largest bulb-importing firms in the country. These inspections comprised about 10 % of the 10 000 to 15 000 amaryllis bulbs imported annually. The bulk of the bulbs came from Holland, while small quantities were obtained from Denmark. In February 1961 examinations were made of all the amaryllis bulbs in three market gardens where only imported stock was grown. In addition, in March of the same year inspections were made of about one-fourth of the amaryllis bulbs in a market garden specializing in this plant; in this case most of the bulbs had been obtained from seed, by division of sets or from lateral bulbs, while only a small quantity had been imported.

Table 1 gives the results of the above analyses of amaryllis bulbs and shows the severity of red spot and infestation by the bulb mite. In judging the severity of red spot the following scale of 0—5 was used:

0 = healthy

1 = a few red scabs on the surface of the bulb.

2 = numerous red scabs, partly coalescing into dry lesions in the outer bulb scales.

3 = watery red or reddish-brown lesions, 1—2 cm in diameter, on the bulb surface, or the entire surface covered by reddish scabs.

4 = large watery, reddish-brown lesions extending to a depth of 1—3 bulb scales or penetrating to the interior of the bulb via its neck.

5 = extensive decayed areas in the interior of the bulb; bulb rotted.

The figures indicating the percentage of red spot have been computed according to the formula

$n_1 + 2n_2 + \cdots + 5n_5 \times \frac{100}{5}$, in which n = total number of bulbs examined, n_1 = number of bulbs having a disease severity of 1, and so on.

Table 1. Severity of red spot of amaryllis bulbs and their infestation by mites. Inspections made in the years 1958—61

Years	No. of bulbs inspected	Severity of red spot (0—5), per cent							Infestation by bulb mites (0—3), per cent				
		0	1	2	3	4	5	%	0	1	2	3	%
Import firms													
1958—59	268	10.1	49.3	30.2	9.3	1.1	0	28.4	35.8	33.6	19.0	11.6	35.4
1959—60	698	12.2	47.6	30.2	9.4	0.6	0	27.7	92.0	6.0	2.0	0	3.3
1960—61	530	6.6	31.7	43.6	18.1	0	0	34.6	79.8	17.4	2.1	0.8	7.9
Total	1 496	—	—	—	—	—	—	—	—	—	—	—	—
Average	—	11.6	46.3	31.8	9.9	0.5	0	28.0	83.2	11.8	4.8	1.2	7.7
Commercial gardens 1961													
Garden No.													
I—III	658	0	3.0	42.7	46.4	7.0	0.9	55.0	36.8	54.4	7.1	1.7	24.6
IV	468	23.5	43.0	26.3	6.6	0.6	0	23.6	0	0	0	0	0

The infestation of the bulbs by mites was judged by using the following scale of 0—3:

0 = no mites

1 = a few scattered mites

2 = a few colonies of mites

3 = large colonies of mites.

The percentage of bulb infestation by mites was calculated from the formula $\frac{n_1 + \cdots + 3n_3}{n} \times \frac{100}{3}$

The percentage of healthy amaryllis bulbs in the various import lots ranged from 0 to 28.8 %, averaging 11.6 %. The proportion of bulbs completely free from mites ranged from 23.9 to 100.0 %, averaging 83.2 %. The disease percentage, calculated as described above, was found to average 28.0 and the mite infestation averaged 7.7 %. Fungi causing red spot had infected the imported bulbs to such an extent that under favourable growing conditions they could multiply, thus increasing the degree of bulb infection and impairing the quality of the bulbs. This is confirmed by the data given at the bottom of Table 1, showing the observations made in three market gardens where imported bulbs were cultivated. Out of 658 bulbs examined, not a single one was completely free of the disease, and only 36.8 % were without mites. The average severity of the disease was 55.0 % and the average mite infestation 24.6 %, indicating a definite increase in both the disease and the mite attack during the time of cultivation in this country. On the other hand, market garden No. IV (lowermost entry in the table), which principally used self-produced stock, had considerably healthier bulbs: out of 468 amaryllis bulbs examined, 23.5 % were without disease, and the average severity of the disease was 23.6 %. Furthermore, no mites at all were found in the bulbs.

Fungi isolated from red spotted amaryllis bulbs

Attempts were made to obtain representative fungal samples from the different kinds of lesions. During the bulb examinations made in the winter of 1959—60, the following fungi were found in 143 samples:

Stagonospora curtisii (Berk.) Sacc.	53 %
Colletotrichum crassipes (Speg.) v. Arx ..	31 %
Fusarium bulbigenum Cke. & Mass.	11 %
Botrytis cinerea Pers., *Rhizoctonia tuliparum* (Kleb.) Whetz. & Arthur, *Papularia sphaerosperma* (Pers.) Fr., *Chaetomium* sp. Kunze & Schmidt, *Trichothecium roseum* Link., *Penicillum nigricans* (Bain.) Thom.	5 %

In addition, in 1960 an amaryllis bulb infected with red spot was found to be infected with *Melanospora fallax* Zukal and *Fusarium moniliforme* Sheld.

Stagonospora curtisii (Berk.) Sacc.

The chief causal agent of the red spot disease complex is considered to be *S. curtisii*, originally isolated as a pathogen of narcissi; synonyms according CREAGER 1933 and SMITH 1935: *Hendersonia curtisii* Berk., *Phoma amaryllidis* Kotth. & Friedr., *Phyllosticta gemmipara* Zondag, *P. hymenocallidis* Seaver, *P. narcissi* Aderh., *P. ondermannii* Sacc. & Syd., *Stagonospora crini* Bub. & Kab. and *S. narcissi* Hollos. DOUGHERTY (1916) was apparently the first to report this fungus as a pathogen of amaryllis; he regarded it as belonging to the genus *Phyllosticta*.

The following data have been presented by some workers on the size of the pycnidia and pycnidiospores of *S. curtisii* and its synonyms: pycnidia 40—100—110—120—128—140—160—180—220—225—330 μ, average 165 μ, and pycnidiospores: 0-sept. 5—6—7—12 × 3.0—3.5—5.0 μ, 1-sept. 8—13 × 5—6 μ, 2-sept. 12—

18—19—27 × 4.5—6—8 μ (ADERHOLD 1900, KOTTHOF and FRIEDRICHS 1929, ZONDAG 1929, PETRAK 1930, GROVE 1935, SMITH 1935).

The many names given to this fungus are chiefly due to the variations in size of the pycnidia and pycnidiospores under different growth conditions as well as the large number of its host plants in the family *Amaryllidaceae*, 11 species according to SMITH (1935) and a further two according to WEISS (1947).

From about 200 amaryllis bulbs studied, isolations were made of a fungus which was determined to be *S. curtisii*. The isolations were made in the following four ways: 1) from red or reddish-brown lesions in both fleshy and dry bulb scales, 2) from grey mycelium growing in fleshy scales, 3) from black pycnidia in dry scales and 4) from red spotted bulb scales which had been stored dry for five years. *S. curtisii* was also isolated from bulbs of *Eucharis grandiflora* and *Sprekelia* sp. All the isolates produced a dense, tough, dark grey mycelium when cultured on nutrient agar. In studying the isolates from different sources, it was found that when cultured on agar media containing oats, potato dextrose, malt or glucose the mycelium was sterile and produced no pycnidia. In contrast, the mycelium was fertile on agar containing fresh or autoclaved pieces of amaryllis leaves, scapes or bulb scales. On such media various kinds of swellings were initially formed in the mycelium: roundish, terminal and intercalary chlamydospores with dimensions of 6.7 × 10.7 μ (2—20 μ), or irregularly-shaped protuberances (cf. ZONDAG 1929). From both these kinds of mycelial swellings, bulbils were later formed. From 3 to 4 weeks after isolation pycnidia developed in the thick, greyish-coloured mycelium (Fig. 2).

The following average measurements were obtained from three samples of *S. curtisii* growing in fresh, sterilized leaves and scapes on amaryllis, pycnidia: 235 × 228 μ (140—280 × 140—280 μ) and pycnidiospores: 0-sept. 53.9 % 6.9 × 2.2 μ, 1-sept. 28.4 % 9.1 × 2.6 μ, 2-sept. 11.8 % 8.9 × 3.3 μ, 3-sept. 4.9 % 13.6 × 3.0 μ and 4-sept. 1.0 % 12.0 × 4.0 μ.

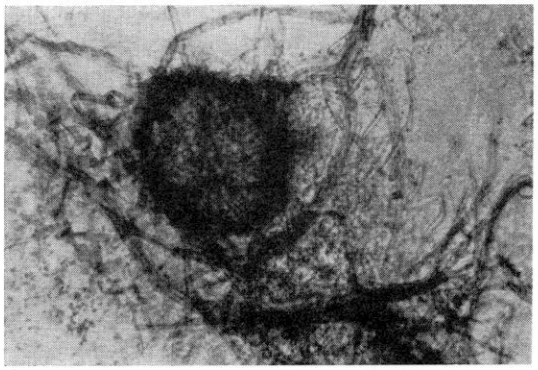


Fig. 2. Pycnidium of *Stagonospora curtisii*. × 100.

Two samples growing on agar medium containing autoclaved amaryllis leaves produced pycnidia: 129 × 114 μ (62—208 × 62—166 μ) and pycnidiospores: 0-sept. 87.3 % 6.1 × 2.6 μ. 1-sept. 7.8 % 6.4 × 2.9 μ, 2-sept. 3.9 % 8.5 × 3.3 μ and 3-sept. 1.0 % 10.0 × 3.0 μ.

Five samples obtained from dry, diseased amaryllis bulb scales showed pycnidia 77.5 × 62.6 μ and pycnidiospores: 0-sept. 71.1 % 8.0 × 3.2 μ, 1-sept. 27.7 % 10.2 × 3.9 μ and 2-sept. 1.2 % 8.0 × 3.0 μ.

The data given above for the fungi isolated from red spotted amaryllis bulbs correspond to the information on *S. curtisii* reported in the literature.

Colletotrichum crassipes (Speg.) v. Arx

Besides *Stagonospora curtisii* *C. crassipes* occurred abundantly in the amaryllis bulbs examined, being found in 31 % of the fungal isolations. These two fungi were often encountered in the same bulbs.

C. crassipes produces reddish, scabby spots 0.5—2.0 mm in size on the surface of the bulb. The spots may enlarge and coalesce, in which case the infected scale dries and becomes paper-like. In the epidermal layer of the underlying fleshy bulb scales, dark grey-brownish acervuli may be seen with the naked eye. When the fungus grows naturally in the bulb scales, these acervuli are roundish, have an average diameter

of 103 μ (57—200 μ), and produce superficial hyphae in which develop brownish, irregularly shaped appresoria with a diameter of 16.5 μ (10—18 μ). When cultured on oat agar medium, the acervuli are generally larger than those in the bulb scales, averaging 256 μ in diameter (100—664 μ). The conidia are colourless, oblong 23.0 × 6.3 μ (16—38 × 5—8 μ), contain crystalline inclusions and often have 1 or 2 vacuoles.

C. crassipes has been encountered on several plant species, such as *Agave* sp., *Sansiviera zeylanica*, *Solanum lycopersicum* (v. ARX 1957), and recently *Hippeastrum vittatum* (PAG 1964).

Fusarium bulbigenum Cke. & Mass.

The red colouration of the roots was found in most cases to be caused by *F. bulbigenum*. It was isolated from the bulb surface, roots, leaves, and scapes, and once even from the stamens of infected plants. The fungus could be found in most of the amaryllis specimens studied, provided that the plant surface was not disinfected before being transferred to the agar medium. As disinfectant 0.3 % oxyquinoline sulphate-ethanol was used (3 g oxyquinoline sulphate + 200 ml distilled water + 800 ml ethyl alcohol). Conidia of *F. bulbigenum* are evidently quite common on the surface of amaryllis but the fungus is unable, under normal conditions, to penetrate into the internal tissues of the plant. Only through injuries in the epidermis does the fungus enter the plant (cf. HELLMERS 1958). The average dimensions of the *F. bulbigenum* conidia isolated from amaryllis and cultured on oat-agar medium were as follows: 0-sept. 29.3 % 8.8 × 2.0 μ, 1-sept. 19.0 % 9.3 × 2.1 μ, 2-sept. 24.4 % 10.4 × 2.3 μ, 3-sept. 19.0 % 21.5 × 3.0 μ, 4-sept. 3.4 % 20.0 × 3.5 μ and 5-sept. 5.2 % 29.7 × 4.0 μ.

The fungus produces large numbers of both terminal and intercalary chlamydospores with average dimensions of 7.7 × 7.0 μ (4—10 × 4—10 μ). On oat agar the stroma is light pink in colour (cf. WOLLENWEBER and REINKING 1935).

Fusarium moniliforme Sheld.

When perithecia of *Melanospora fallax* were transferred from the surface of infected amaryllis bulbs to oat agar, a second fungus grew in addition; it was determined to be *F. moniliforme* Sheld. (GORDON 1952) [syn. *F. moniliforme* v. *subglutinans* Wr. & Rg. (WOLLENWEBER and REINKING 1935)]. The two fungi were separated by single-spore cultures. Measurements made on three *F. moniliforme* cultures on oat agar gave the following average dimensions of its conidia: 0-sept. 41.5 % 14.7 × 2.6 μ, 1-sept. 13.1 % 22.3 × 3.1 μ, 2-sept. 10.2 % 28.4 × 3.2 μ, 3-sept. 15.3 % 31.3 × 3.3 μ, 4-sept. 5.9 % 37.9 × 3.8 μ and 5-sept. 14.0 % 43.4 × 4.5 μ. No chlamydospores were produced. The stroma on oat agar was pale salmon pink with occasional tinges of pale violet. According to SAUTHOFF and GERLACH (1955), *F. moniliforme* v. *subglutinans* causes reddish brown lesions in *Haemanthus* species belonging to the family *Amaryllidaceae* and in addition infected *Hippeastrum* × *hortorum* in tests carried out by these workers.

Melanospora fallax Zukal (syn. *M. anomala* Hotson)

Dark-coloured fruiting bodies were found on the surface of both dry and fleshy scales of an amaryllis bulb infected with red spot. These structures resembled the pycnidia of *Stagonospora* curtisii but were considerably larger. A fungus was isolated from them and was sent to the »Centraalbureau voor Schimmelculture» in Holland, where it was identified as *Melanospora fallax* (cf. DOGUET 1955). The same fungus had previously been isolated at the Department of Plant Pathology in 1958 from lily bulbs imported from Japan. When cultured on oat agar the mycelium of *M. fallax* is pale tan and the stroma faintly pink. Large numbers of clustered, reddish brown bulbils 40—150 μ in size are produced in the mycelium (cf. Fig. 3). The smallest bulbils, evidently young, were paler than the larger ones. Perithecia, which were

formed both in living bulb scales and on oat agar, were tan, globose and 364 μ in size (238—546 μ). The ascospores produced in the perithecia (Fig. 3) were dark brown, bilaterally symmetrical, and binucleate, and had average dimensions of 21.8 × 11.0 μ (10—32 × 8—14 μ) from 50 measurements.

GLYNNE and MOORE (1961) have found that *Melanospora damnosa* often occurs together with *Fusarium culmorum* (w.b.Sm.) Sacc., and similarly it was found in the present studies that *M. fallax* occurred together with *F. moniliforme*.

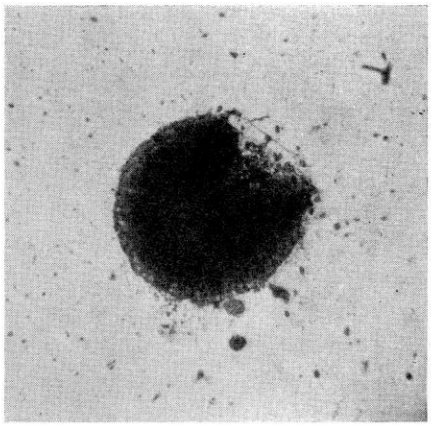


Fig. 3. Perithecium and spores of *Melanospora fallax;* at the lower edge are two bulbils. × 80.

Other fungi isolated from amaryllis bulbs

In some of the bulbs *Chaetomium* sp. Kunze & Schmidt (GILMAN 1945) was found, as well as *Papularia sphaerosperma* (Pers.) v. Höhn (GILMAN 1945). Both these fungi, particularly *Chaetomium* sp., were furthermore isolated from the leaves of many amaryllis plants infected with red leaf spot. The lesions caused by these fungi are superficial and red-coloured, and occur as a dense mottling of numerous spots 1—2 mm in size. The fungi do not penetrate into the deeper tissues of the leaves, like *Stagonospora curtisii*. Instead they remain in the epidermal layer, causing the leaves to wither somewhat earlier than usual and consequently resulting in a slight weakening in the growth of the bulb. The culture of *Chaetomium* sp. isolated from amaryllis was generally similar to the description given by GILMAN (1945) of *C. cochlioides* Palliser. The only difference was that the mycelium was olive green in colour, a feature which GILMAN claims to be characteristic of *C. globosa* Kunze.

In addition to the above, the following fungi were isolated from amaryllis bulbs: *Botrytis cinerea* Pers. and *Rhizoctonia tuliparum* (Kleb.) Whetz. & Arthur, *Penicillium nigricans* (Bain.) Thom. and *Trichothecium roseum* Link. (syn. *Cephalosporium roseum* Cda). The latter has a mild antibiotic influence on pathogenic fungi (WOLLENWEBER (SORAUER) 1932, MAKKONEN and POHJAKALLIO 1960; cf. Table 4 and pp. 34 and 36).

The isolated fungi were cultivated in numerous trials on both fresh and autoclaved pieces of amaryllis leaf, scape and bulb in 2 % aqueous agar. The results showed that *Botrytis cinerea*, *Rhizoctonia tuliparum*, *Stagonospora curtisii*, *Melanospora fallax* and *Chaetomium* sp. were able to grow on living plant tissue, and are parasites of amaryllis. Fungi of the genera *Fusarium* and *Colletotrichum* are weaker parasites, while *Trichothecium roseum*, *Papularia sphaerosperma* and *Penicillium nigricans* are apparently only saprophytes of amaryllis.

Examination of tissue preparations made from bulb scales, leaves and scapes of amaryllis infected by *Stagonospora curtisii* revealed that the fungal hyphae grew intercellularly, producing haustoria which penetrated through the cell wall into the interior of the cell. The tissue consequently decayed into a soft pulpy mass.

Infection trials with fungi isolated from amaryllis diseased with red spot

There are numerous reports in the literature of trials in which the leaves and scapes of amaryllis and other plants of the *Amaryllidaceae* family were infected by means of mycelial and spore suspensions of *Stagonospora curtisii* (ZONDAG 1929, SMITH 1929, 1935, LASKARIS and DODGE 1941).

The pathogenicity of the various fungi isolated from amaryllis was studied by infecting *Hippeastrum vittatum* plants of different ages. Completely healthy, mature amaryllis plants were not available in sufficient amounts for all the trials. Therefore the infection trials were made principally with seeds and seedlings, and only some of the isolated fungi were used to infect the bulbs and leaves of older plants.

Infection of amaryllis bulbs

The plant material consisted of two-year-old, healthy amaryllis bulbs which had been grown from seed. Inoculation was performed by pouring 25 ml of the fungal-glucose suspension on the bulbs and on the soil, into which it was mixed to a depth of 1—2 cm. The trial comprised 5 × 5 bulbs.

Of the fungi tested in the above experiments (table 2), only *Stagonospora curtisii* caused appreciable red spotting in the leaves and bulbs of amaryllis. Bulbs infected with *Fusarium bulbigenum* had a slight amount of red spotting. Red colouration of the roots, which did not impair the growth of the plant, was also caused by other fungi.

Infection of amaryllis leaves

The amaryllis plants used in the trial were 3—4 years old. Their leaves showed no symptoms of red spot, and only a few of the bulbs were slightly red-spotted. The leaves were inoculated with a fungal-glucose suspension to which had been added 2.5 % methyl cellulose as a binding agent. Each fungus under study was tested on 5 plants; in addition, there were 5 uninoculated control plants. Each group of 5 plants was placed in a glass enclosure in order to prevent contamination. Furthermore, two plants in each such group were covered with a plastic bag in order to maintain high humidity.

Stagonospora curtisii completely destroyed the leaves covered with a plastic bag within two weeks; the uncovered leaves were likewise badly damaged. The bulbs produced new leaves, on which appeared red, watery lesions.

Botrytis cinerea and *Rhizoctonia tuliparum* caused the leaves in the plastic bags to rot, but they did not infect the newly emerging leaves or the uncovered leaves.

Colletotrichum crassipes produced brownish red lesions in diameter 2—3 cm on the covered leaves as well as red spots 1—5 mm in diameter on both the covered and uncovered leaves.

The leaves infected with *Melanospora fallax* had several large lesions 5—10 cm in size as well as many small red spots 1—5 mm in diameter.

In the plants infected with *Chaetomium* sp. both the upper and lower surfaces of the leaves

Table 2. Infection trial on 3—4-year old amaryllis plants

Fungus	Extent of red spot infection 0—5 Months after inoculation				
	½	1 ½	4		
	leaves + bulbs	leaves + bulbs	leaves	bulbs	roots
Control	0	0	0	0	0.1
Stagnospora curtisii	0	2.5	2.6	2.4	0.7
Fusarium bulbigenum	0	0	0	0.6	0.8
Fusarium moniliforme	0	0	0	0	0.5
Melanospora fallax	0	0	0	0	0.2

Table 3. Infection trials on amaryllis seeds, 1960—63

Fungus	Emergence % 60 days after sowing	
	Trial I—III	IV
Control	51	39
Stagnospora curtisii	0	0
Melanospora fallax	13	37
Fusarium bulbigenum	20	33
Colletotrichum crassipes	47	27
Botrytis cinerea	49	—
Rhizoctonia tuliparum	55	—
Papularia sphaerosperma	57	—
	(I—II)	
S. curtisii + *T. roseum*	(27)	—
Fusarium moniliforme	(50)	27
Penicillium nigricans	(48)	—
Chaetomium sp.	(55)	—
Trichothecium roseum	(57)	—
F value	4.3*	28.8***
L.S.D.	22.5%	1.6%

were covered with small, superficial red spots ½—1 mm in diameter. About two months after inoculation some of these spots had become depressed and contained dark-coloured pycnidia of the fungus.

Fusarium bulbigenum produced several large, dark red lesions in the leaves as well as many small red spots which were more numerous in the exposed leaves than in those covered with a plastic bag.

In the covered plants inoculated with *Fusarium moniliforme* the leaf epidermis showed reddening in some places. The uncovered leaves were apparently completely healthy.

The mycelium of *Papularia sphaerosperma* grew on the surface of the leaves in the plastic bag but not on the leaves which were exposed.

The leaves inoculated with *Penicillium nigricans* and *Trichothecium roseum* remained green and apparently uninfected with red leaf spot.

Infection of amaryllis seeds

The seeds of amaryllis which were used in these trials were partly produced at the Department of Plant Pathology and partly supplied by the Danish firm Ohlsens Enke. The seeds were sown in a mixture consisting of 2 parts sand and 1 part peat moss. Four trials were carried out. A seed rate of 20 seeds per pot was used; in Table 3, in trials I—III there was one pot per fungus and in trials IV five pots of each fungal species.

Trials I—III were conducted in the laboratory at a temperature of 20—22°C. In trial IV the pots were initially kept for 20 days in the laboratory at 20—22° and thereafter in the greenhouse at an average temperature of about 15°C (12—17°). At 5-day intervals the numbers of germinated seeds were counted. The results (Table 3) are based on counts made 60 days after sowing. Only those seeds which had produced green seedlings were counted as having germinated, since seedlings lacking in pigment were infected with red spot disease and incapable of further development.

The seeds began to germinate about 20 days after sowing. In trials I—III emergence was at a maximum about 50 days after sowing, after which the number of seedlings decreased somewhat as a consequence of fungal damage under the conditions of weak illumination. In trial IV the largest number of seedlings were counted 65 days after sowing. In this case the plants had received adequate illumination in the greenhouse,

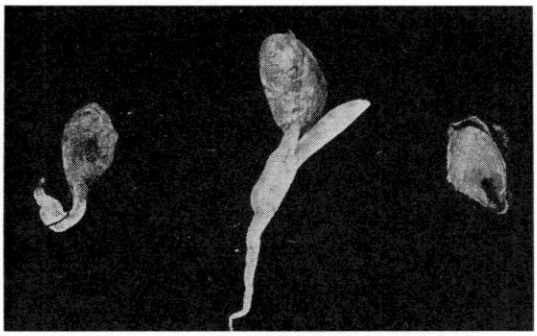


Fig. 4. Amaryllis seeds infected by *Fusarium bulbigenum* (left) and *Stagonospora curtisii* (right) 3 weeks after inoculation. In the centre control seed.

and consequently they were not damaged by fungi after they had attained maximum emergence.

In all the trials the control seeds germinated rather poorly. Successful emergence averaged only 48 %, a result at least partly due to contamination of the seeds by fungi, principally *Rhizopus* sp. (cf. the seed dressing trials p. 40).

In all the trials *Stagonospora curtisii* completely prevented germination (Fig. 4).

Fusarium bulbigenum considerably depressed germination in the three laboratory trials, suppressing it completely in trials I. In trial IV, carried out in the greenhouse, this fungus caused a germination only 6 % lower than that of the control (Fig. 4); the difference was significant.

In the laboratory trials at a temperature of 20—22°C *Melanospora fallax* considerably reduced germination of the amaryllis seeds, causing complete inhibition in trial III. Under greenhouse conditions, where the lower temperature (12—17°C) resulted in improved seedling vigour and slower fungal growth, the adverse effect of this fungus on germination was only slight, although nevertheless significant (Fig. 5).

In the laboratory trials the other fungi tested did not cause any appreciable decrease in seed germination. A noteworthy observation in trial I is that the presence of *Trichothecium roseum* reduced the inhibitory effect of *S. curtisii* from 100 to 49 %. This can apparently be attributed to

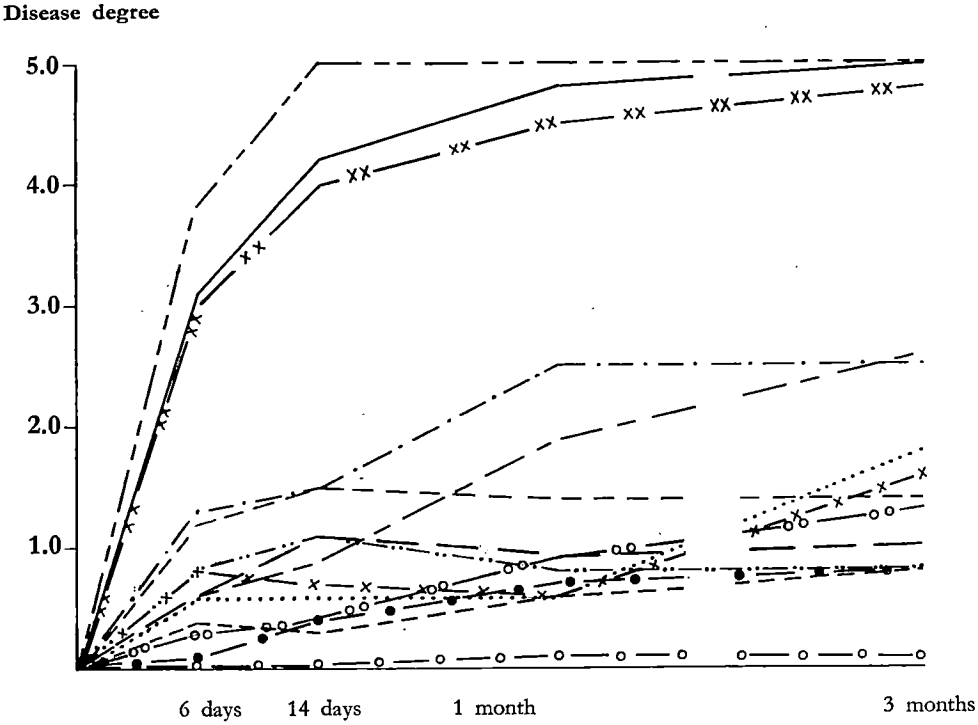
Fig. 5. Amaryllis seedlings 60 days after inoculation and sowing. From left to right: control, infected with *Fusarium moniliforme*, *Colletotrichum crassipes*, and *Melanospora fallax*.

the antibiotic influence of *T. roseum* (cf. pp. 31 and 36).

In the greenhouset trial *C. crassipes* and *F. moniliforme* also caused a significant reduction in amaryllis seed germination (Fig. 5).

Infection of amaryllis seedlings

Amaryllis seeds of the same origin as those in the previously described trials were sown in a sand-peat moss mixture (2:1) and the seedlings subsequently transplanted to autoclaved soil. About 2 months after sowing, when the seedlings had reached the 2—3 leaf stage, they were inoculated with various fungi. Owing to the somewhat different inoculation methods used in the different years (1959—62), the results are not entirely comparable.



Fungus	Trial No.	Significance X^2 — %
S. curtisii + *C. crassipes*	II	15.6***
Stagonospora curtisii	I—IV	37.4***
S. curtisii + *T. roseum*	I II	26.5***
Colletotrichum crassipes	I II IV	15.5***
Melanospora fallax	III IV	7.2***
Chaetomium sp.	II	18.8***
Trichothecium roseum		3.1*
Botrytis cinerea	I II IV	4.6*
Fusarium bulbigenum	I—IV	5.1**
Fusarium moniliforme	III—IV	1.1*
Papularia sphaerosperma	I II	20.1***
Rhizoctonia tuliparum	I II IV	4.6*
Penicillium nigricans	I II	1.4*

Fig. 6. Results of infection trials on amaryllis seedlings, 1959—62.

Prior to inoculation the fungi were cultivated for two weeks on nutrient media; in 1959 they were cultivated on oat agar in Petri dishes, in 1960 on a mixture of 1 part by weight ground oat and 4 parts sand and in 1961 and 1962 in a glucose solution.

The results are presented diagrammatically in Fig. 6. The degree of seedling infection was estimated on a scale of 0—5 (cf. p. 27) at intervals of 6 days, 14 days, 1 month and 3 months after inoculation. The significance of the results was calculated by the X^2 test, in which the numbers

of healthy and diseased + dead seedlings in the inoculated groups were compared with the corresponding numbers in the controls.

In all the trials *Stagonospora curtisii* was a very powerful pathogen, killing all the seedlings within 2 to 4 weeks.

Melanospora fallax was likewise pathogenic to the amaryllis seedlings. In 1962 it caused the death of all the plants within two weeks. In 1961, however, it had a weaker effect, with the average degree of infection only 1.5.

Colletotrichum crassipes killed fewer seedlings than *M. fallax*, but nevertheless it damaged most of the plants and weakened their growth. In 1960 a combined infection trial was carried out with both *S. curtisii* and *C. crassipes*. Under natural conditions these two fungi often occur together in amaryllis bulbs. The trial demostrated that all the inoculated seedlings died about one week earlier than those which had only been inoculated with *S. curtisii*. The pathogenic effect of these two fungi together is thus especially severe.

Chaetomium sp. caused red spotting in the leaves of the seedlings. The spots were superficial, about 1 mm in diameter and did not contain conidia. Such infected leaves withered earlier than normal ones. The bulb, however, was apparently undamaged, and new, healthy leaves grew from it.

Papularia sphaerosperma produced mild red spotting on the leaves.

The mortality of the seedlings infected with *Trichothecium roseum* was 20 %. When inoculated with both *T. roseum* and *S. curtisii* together, the plants showed disease symptoms and died more slowly than when they were inoculated with *S. curtisii* alone. This was further evidence of the antibiotic effect of *T. roseum*, described earlier (p. 34).

Fusarium bulbigenum and *F. moniliforme* had only a minor effect on the seedlings. The plants infected with the former grew slightly less well than the control plants. Otherwise there were no actual symptoms of disease in the aerial parts of the plants. In contrast, the roots were affected with red spotting, which resulted in the death of 8 % of the seedlings.

Many of the fungi tested, including *Botrytis cinerea* and *Chaetomium* sp., were capable of interfering somewhat with the growth of the seedlings, causing withering of the leaves, for instance. This did not have an adverse effect on the bulbs, however, since new, healthy leaves arose.

Control trials against red spot of amaryllis

Many different methods are recommended for controlling red spot of amaryllis. The hot water treatment (LORENZ 1934, ZACHER 1949, VIENNOT and BOURGIN 1952, SCHENK 1954) and dipping bulbs in various chemical solutions (copper and mercury compounds; WEISS 1934, MILLIKAN 1940, SCHENK 1954, PAPE 1955) are the methods generally used. Spraying the plants during the growing season also prevents damage to amaryllis from red spot (GILL 1959).

The following section deals with trials on the effect of various fungicides on amaryllis plants naturally infected with red spot. In the seed dressing trials, studies were made on the efficacy of certain fungicides on all of the fungi which had been isolated from amaryllis. The efficacy of the fungicides in controlling the causal agent of the disease, *Stagonospora curtisii*, was investigated by various methods in the laboratory as well as by treating infected amaryllis plants in the greenhouse.

The fungicides used in the trials were:

Preparation	Active ingredient	Manufacturer
Inorganic		
Mercuric compounds		
Aretan	6 % alkoxyalkylmercury (Hg 3 %)	Plant Protection Ltd, England
Ceresan liquid seed-dressing	3.7 % methoxyethylmercury chloride (Hg 2.5 %)	Farbenfabriken Bayer, Germany
Farsan cereal dressing	2.37 % methoxyethylmercury acetate (Hg 1.5 %)	Tehomyrkkylaboratoriot, Finland
Verdasan	5 % phenylmercury acetate (Hg 2.5 %)	Plant Protection Ltd, England
Copper compounds		
Copper powder	85 % copper oxychloride	Rikkihappo Oy, Finland
Tin compounds		
Brestan	60 % triphenyl stannic acetate	Farbwerke Hoechst, Germany
Organic		
Formaldehyde		
Formalin	40 % formaldehyde	S.G. Nieminen Oy, Finland
Captan		
Orthocide 75	75 % N-(trichloromethylthio)-tetrahydrophthalimide	California Spray Chemical Co, USA
Orthocide 10	10 % N-(trichloromethylthio)-tetrahydrophthalimide	»
Nitrobenzene		
Brassicol	20 % quintozene (PCNB)	Farbwerke Hoechst, Germany
Brassicol wettable powder	50 % »	»
Folosan	5 % tecnazene (TCNB)	Plant Protection Ltd.
Thiocarbamate		
Dithane dust	6.5 % zinc ethylbisdithiocarbamate (zineb)	N.V. Philips-Roxane »Duphar», Holland
Dithane Z-78	65 % »	»
Dithane M-22	70 % manganese dithiocarbamate (maneb)	»
Duphar ferbam	95 % ferric dimethyldithiocarbamate (ferbam)	»
Thiram		
Duphar TMTD root seed dressing	50 % tetramethylthiuram disulphide	»
Pomarsol forte	50 % »	Farbenfabriken Bayer, Germany
Pomarsol dust	10 % »	»
Antibiotics		
Actidione	cycloheximide	The Upjohn Co., USA
Agrimycin	15 % streptomycin + 1.5 % oxytetracycline	Pfizer & Co, USA
Griseofulvin	griseofulvin	Merck & Co, USA
Kojic Acid	5-hydroxy-2-hydroxine-ethyl-4-pyrone	»
Sorbistat	sorbic acid	»
U-4527	cycloheximide	The Upjohn Co, USA
U-7413	cycloheximide oxime	»
U-7414	» acetate	»
U-7415	» semicarbazone	»
Usno	usnic acid	Lääke Oy, Finland

Trials with mature amaryllis bulbs

In the autumn of 1957 80 amaryllis bulbs (60 white and 20 red-white »Paradise amaryllis van Meeven's superiora») were obtained from Holland through the agency of the Finnish Commercial Horticultural Association. All the bulbs were diseased with red spot.

The trial was begun in December 1957 and terminated on May 29, 1961, at which time the final analyses were made. The bulbs were treated annually in December after 3—4 months' rest. The badly decayed areas in all the bulbs were cut way and the bulbs treated with the fungicides; in the case of the sprays, they were immersed for one hour in the solution, and for the dusts they were covered with a measured amount of the compound (cf. Table 4). In addition, the bulbs were immersed for one hour in 1957 in water at 40—44°C, in 1959 in a 0.15 % malathion solution and in 1960 in 0.5 % malathion solution in order to kill bulb mites *Rhizoglyphus echinopus* (cf. TAPIO and MÄKINEN 1959). In order to get more fungal infection, the bulbs were inoculated in December 1959 with *S. curtisii* by mixing 30 g of fungus-oat-sand mixture in each pot, these being kept moist for 12 days before the fungicide treatments.

Examination and comparison is somewhat difficult owing to the presence of mites in the bulbs. The degree of infection with red spot was estimated on the bulbs 6 times and on the leaves 5 times on a scale of 0—5 (cf. p. 27). Similar observations were made on all the scapes that emerged; on the roots the estimates were made only once, at the termination of the trial. The figures in Table 4 are averages of these evaluations.

The degree of infection varied considerably at the different times of examination. The plants treated with captan and thiram were the only ones which showed significantly less infection of scapes, leaves and bulbs than the control plants. The other fungicides, except Ceresan liquid seed dressing and Verdasan, gave a slight reduction in the extent of disease in the scapes, leaves and bulbs.

Only the bulbs treated with captan and ferbam produced significantly more scapes than the control bulbs in the trial. An increase in the number of scapes was also noted for Ceresan, thiram, TCNB and PCNB. With the exception of Ceresan, all the inorganic fungicides tested caused a reduction in the number of scapes. The differences between the fungicides were most distinct in the final trial year 1961, since by this time the bulbs had been treated for four consecutive years. Then the bulbs treated with formalin produced fewer scapes than the control bulbs.

The numbers of flowers per scape varied appreciably from year to year, and there were no significant differences between the treatments in this characteristic.

The size of the bulbs showed no great changes during the course of the trial. The bulbs treated with thiram were significantly larger at the end of the trial than the control bulbs, while those treated with formalin, Aretan, copper powder and Folosan were somewhat smaller.

The fungicides also had an effect on the flowering time of the bulbs. On a average, the bulbs treated with ferbam and thiram flowered 2—3 weeks earlier than the control plants. TCNB, captan and copper powder hastened flowering by about one week, while formalin and Ceresan retarded the formation of flowers by 2—3 weeks.

In the trials captan and thiram proved to be the best fungicides for controlling red spot (cf. GILL 1959). Ferbam was moderately effective, while mercury and copper preparations, which have been widely used for combatting *Stagonospora curtisii* in amaryllis (MILLIKAN 1940, SCHENK 1954, PAPE 1955), did not offer such good control as the former compounds.

Seed dressing trials

Three seed dressing compounds — captan, thiram and mercury — were used to disinfect amaryllis seeds (cf. p. 33). Treatment was given both to uninfected seeds and to seeds which

Table 4. Control trial of red spot with mature amaryllis bulbs, 1957—61

Treatment	Concentration used %	No. of plants	Degree of infection 0—5				Scapes			Flowers av. no. per scape	Flowering time av. 1957—61		Growth vigour 29. May 1961 0—3		Size of bulbs Ø cm	Mite infestation at end of trial 0—3
			average 1957—61			1961 roots	no./bulb		av. length cm		date	dev. from control	leaves	roots		
			scapes	leaves	bulbs		1961	av. 1957—61								
Control	—	7	0.8	1.2	2.1	1.5	0.3	1.0	38	2.8	25.2	0	2.1	2.0	6.3	1.9
Aretan	0.3	6	0.1	1.1	1.7	1.0	0.7	0.9	45	2.9	19.2	— 6	2.1	2.6	6.2	1.0
Aretan + sticker	0.3	7	0.2	0.9	1.9	0.7	0.3	0.9	42	2.7	27.2	+ 2	2.1	2.2	5.7	1.1
Ceresan liquid	0.3	7	0.3	0.7	2.2	0.7	1.1	1.3	42	2.6	14.3	+17	2.5	2.5	6.4	1.9
Verdasan	0.3	7	0.3	0.6	2.1	1.2	0.7	0.8	43	2.9	23.2	— 2	2.1	1.4	6.3	2.1
Copper powder	0.6	7	0.6	1.0	1.8	1.2	0.7	0.9	42	2.6	15.2	—10	1.9	1.6	5.9	2.1
Formalin	0.4	6	0.4	1.1	2.0	1.5	0.2	0.8	38	2.7	11.3	+14	2.4	2.2	5.9	1.8
Duphar ferbam w.p.	0.25	6	0.7	0.7	1.8	1.2	1.0	1.4	44	2.9	5.2	—20	2.8	2.3	6.2	1.2
Orthocide 75 (captan)	0.25	7	0.2	0.4	1.2	1.3	1.2	1.5	47	2.8	13.2	—12	2.9	2.3	6.2	0.8
Brassicol w.p. (PCNB)	0.25	7	0.8	1.1	2.0	1.6	0.6	1.2	41	2.7	25.2	0	2.9	2.2	6.3	1.4
Folosan (TCNB)	1 g/ bulb	6	0.8	0.9	1.8	1.5	0.7	1.2	41	2.6	14.2	—11	2.3	1.8	5.9	1.8
Duphar TMTD (thiram)	1.2 g/ bulb	7	0.1	0.1	1.6	1.3	0.9	1.3	48	2.7	31.1	—25	3.0	2.3	6.9	1.3
F value			2.7*	2.4*	6.7***	—	—	2.6*	0.9	8.3***	—	—	—	—	—	3.2*
L.S.D.			0.5	0.6	0.5	—	—	0.4	9.8	0.4	—	—	—	—	—	0.5

had been infected with the fungi isolated from diseased amaryllis bulbs (Table 5). The dusts — captan (Orthocide 75) and thiram (Duphar root dressing) — were used in sufficient amounts to coat the seeds when were shaken together with the compound in small paper bags. The liquid mercury compounds (Ceresan and Farsan) were used in the form of 0.25 % solutions, in which the seeds were immersed for ten minutes. Ceresan was tested in 1961 and 1962 and Farsan in 1963. Both the control and the treated seeds were placed on the surface of a sand-peat-moss mixture in germination trays, inoculated with fungi and covered with sand, as described on p. 33. In 1961 and 1962 the trials were performed in the laboratory at a temperature of 20—22°C. In 1963 the trays were first kept for 20 days at a temperature of 20—22°C, during which time they began to germinate, and thereafter in the greenhouse at a temperature of about 15°C. The greenhouse had more adequate illumination than the laboratory, in which the seedlings suffered slightly from insufficient light.

The effect of seed dressing on the germination of the healthy and infected seeds is presented in Table 5. The data indicate that seed dressing improved the germination of the seeds infected with pathogenic fungi by an average of 35 % in the laboratory (temp. 20—22°C) and an average of 10 % in the greenhouse (15°C). Captan and thiram were more effective than the mercury products; the former also increased the germination percentage of the uninfected seeds by some 20 % in the laboratory and 14 % in the greenhouse. The negligible effects of mercury treatment in reducing germination in the laboratory trials (by only 3 %) and improving it in the greenhouse (2 %) were not statistically significant.

In the laboratory trials (20—22°C) carried out in 1961—1962, captan was very effective against *Stagonospora curtisii*, raising the germination of infected seeds from 0 to 75 %. At a temperature of 15° in the later greenhouse trial, however, the increase was only 18 %. The improvement in germination provided by thiram was 52 % and 36 % respectively and that by mercury 22 % in the laboratory trials and none at all in the greenhouse trial.

As for the fungi that were non-pathogenic to amaryllis seeds, captan and thiram generally

Table 5. Effect of seed dressing on germination of amaryllis seeds infected with pathogenic and non-pathogenic fungi

Fungus	Germination-%				Significance X^2-%	
	untreated	captan	thiram	mercury	all treatments	(capt. + thiram)
Laboratory trials 1961—62 (20—22)°C)						
Control	44	63	65	41	1.3	(3.7*)
Pathogenic fungi:						
Stagnospora curtisii	0	75	52	22	27.0***	
Melanospora fallax	10	61	57	(25)	15.7***	
Fusarium bulbigenum	31	55	67	60	8.9***	
Colletotrichum crassipes	38	63	48	59	3.7*	
Fusarium moniliforme	(50)	(75)	(37)	(63)	(0.2)	
Average	20	64	56	—	41.0***	
Non-pathogenic fungi:						
Penicillium nigricans	48	40	55	—	0.1	
Chaetomium sp.	55	43	54	—	0.6	
Trichothecium roseum	57	45	40	—	2.6	
Botrytis cinerea	62	67	47	(56)	0.8	
Rhizoctonia tuliparum	63	53	34	(50)	4.3*	
Papularia sphaerosperma	65	38	65	—	2.7*	
Average	58	48	49	—	8.9*	
Greenhouse trials 1963 (15°C)						
Control	35	46	51	37	2.9*	(4.8*)
Pathogenic fungi:						
Stagonospora curtisii	0	18	36	0	20.8***	
Colletotrichum crassipes	27	46	46	31	6.3**	
Fusarium moniliforme	27	37	37	30	1.7	
Fusarium bulbigenum	32	39	47	32	1.8	
Melanospora fallax	35	38	38	45	0.8	
Average	24	36	40	28	21.0***	

reduced the germination of infected seeds, the former chemical by 11 % and the latter by 9 % (Table 5). It is possible that these fungi which improved the germination of the untreated seeds had an antibiotic influence on the pathogenic fungi normally occurring on the seeds. Of the 200 seeds tested, 88 % were infected with *Rhizopus* sp. and 7 % with *Penicillium* sp. When amaryllis seeds inoculated with the non-pathogenic fungi were disinfected with fungicides, any antibiotic effects would have been suppressed, a phenomenon which has already been discussed in the case of *Trichothecium roseum* (pp. 34 and 36).

The experiments show that since captan and thiram seed-dressing fungicides are effective in controlling those species of fungi which are the most important causes of red spot of amaryllis and since they furthermore lead to a substantial improvement in the germination of normal commercial seed, these compounds should be recommended for general use. On the other hand, mercuric seed-dressing products are not to be recommended, since their effect is weak. Moreover, they may even decrease germination. This was shown particularly in the 1961 trial, in which the germination of seed dressed with a mercury compound was 25 % lower than that of untreated seed.

Effect of various fungicides on Stagonospora curtisii in vitro

The effects of various fungicides on pathogenic fungi grown on a nutrient medium were tested in laboratory experiments by the diffusion method, the vapour method and the solution method. The methods were developed by Mr. A. Ylimäki, senior Plant Pathologist, and the writer.

In the diffusion method (Fig. 7 and 8) an inoculum of fungus was transferred to the centre of a Petri dish containing glucose agar. At the

Table 6. Effect of various fungicides on *S. curtisii* in laboratory trials

Treatment	mg/dish or flash	Mycelial growth after 12 days			
		Diam. of colony mm		Solution method	
		diffusion method	vapour method	mg	rel.
Control	—	100	100	8 267	100
Inorganic compounds					
Aretan (mercury)	10	28	28	0	0
Ceresan (mercury)	15	53	79	783	10
Verdasan (mercury)	10	43	83	0	0
Copper powder	10	92	90	9 550	116
Brestan (Sn-acetate)	20	81	99	0	0
Organic compounds					
Orthocide 75 (captan)	5	97	95	117	1
Brassicol wet. powd. (PCNB 50)	10	33	94	1 067	13
Brassicol (PCNB 20)	20	39	99	167	2
Folosan (TCNB)	80	7	26	650	8
Pomarsol forte (thiram)	5	79	98	0	0
Dithane Z-78 (zineb)	10	91	97	0	0
Duphar ferbam	5	90	97	1 883	23
F value		25.8***	50.2***	70.0***	
L.S.D.		10.6 mm	3.2 mm	347 mg	
Antibiotic compounds					
Control	—	100	—	7 950	100
Actidione	2	18	—	0	0
U-4527	2	19	—	0	0
U-7413	2	55	—	2 075	26
U-7414	2	58	—	—	—
U-7415	2	54	—	—	—
Agrimycin	2	83	—	7 175	91
Griseofulvin	2	86	—	2 750	35
Kojic Acid	2	87	—	7 425	93
Sorbistat	2	95	—	6 600	83
Usno	2	84	—	0	0
F value		16.0***		46.7***	
L.S.D.		6.4 mm		470 mg	

edges of the medium four 10 mm pieces of filter paper were placed at regular intervals and upon them was placed a definite weighed amount of the fungicide to be tested. The chemical partially diffused through the paper into the agar medium and subsequently came into contact with the growing fungus. The diameter of the colony was measured 2, 6, and 12 days after inoculation.

In the vapour method a Petri dish with glucose agar was inoculated in the same way as above. Inside the cover of the dish, at its centre, the cap of a medicinal tube 10 mm in diameter was fastened with wax and filled with a weighed amount of the fungicide. The dish with the fungus was then inverted over the cover, and consequently only the vapour from the chemical acted upon the fungus. The size of the colony was measured as in the first method.

In the solution method the fungal inoculum was put into an Erlenmeyer flask containing 50 ml of glucose nutrient solution, and a definite weighed amount of the fungicide was added. The flasks were kept on the shaker for two weeks, after which the formation of conidia was observed and the mycelial growth weighed.

The tests (Table 6) showed that TCNB was the most effective of the compounds tested. In the diffusion method it almost completely inhibited the growth of the fungus (Fig. 7 B). Likewise it effectively controlled the fungus in the vapour method, restricting the diameter

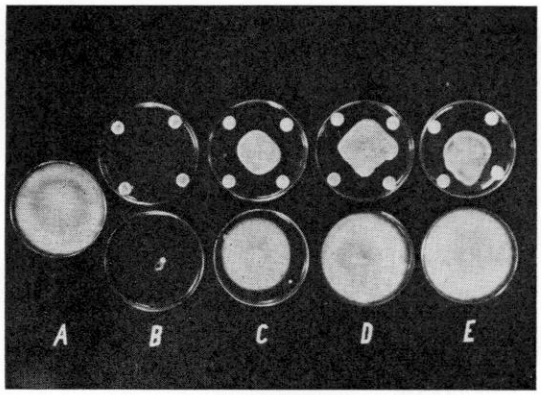


Fig. 7. Effect of various fungicides on the growth of *S. curtisii* on glucose agar. Upper row diffusion method, lower row vapour method. A) control, B) TCNB, C) captan, D) methoxyethyl mercury chloride, E) thiram.

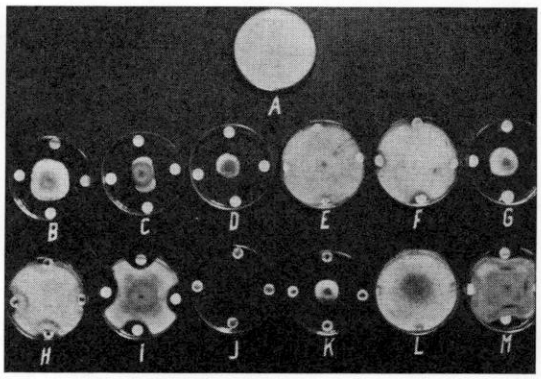


Fig. 8. Effect of various fungicides on the growth of *S. curtisii* on glucose agar, using the diffusion method. A) control, B) alkoxyalkylmercury, C) phenylmercury acetate, D) PCNB wettable powder, E) zineb wettable powder, F) copper oxychloride, G) PCNB dust, H) ferbam wettable powder, I) stannic acetate, J) TCNB dust, K) methoxyethyl acetate, L) captan wettable powder, M) thiram wettable powder.

of the colony to as little as 26 mm (Fig. 7 B). In the solution method, this compound reduced the growth of the organism to only 8 % of the untreated control. PCNB proved to be distinctly poorer than TCNB in the present trials. Brassicol wettable powder and dust (Fig. 8 D, G) decreased the growth of. *S. curtisii* by approximately 64 % in the diffusion method, 92 % in the solution method and only 3.2 % in the vapour method. The effectivity of both TCNB and PCNB declined considerably account for the experiment performed (Table 7) if the chemicals were exposed to the air outdoors for two weeks and could thus vapourize.

The mercuric fungicides (Aretan, Ceresan, Verdasan) provided good control of the fungus (Figs. 7 D, 8 B, C, K), particularly the former, which even in the vapour method depressed the growth of *S. curtisii* by 72 %. In the solution method, Aretan and Verdasan completely suppressed the fungus, while there was slight growth with Ceresan.

The solutions of thiram, stannic acetate and zineb inhibited the fungus completely. With captan there was a slight growth of mycelia, and somewhat more with ferbam. In the diffusion method, stannic acetate (Brestan) and thiram (Pomarsol forte) were moderately effective, reducing the growth of the fungus by about 20 % (Figs. 7 E, 8 I, M). A poorer fungicidal control was given by Dithane Z—78 (Fig. 8 E), Duphar ferbam (Fig. 8 H) and Orthocide 75 (Fig. 7 C, 8 L). All these compounds had only

Table 7. Fungicidal effect on *S. curtisii* of TCNB and PCNB before and after exposure to air for 2 weeks in laboratory trials

Treatment	Diam. of colony mm after 12 days	
	diffusion method	vapour method
Control	100.0	100.0
TCNB before exposure	4.2	22.5
» after »	34.0	71.3
PCNB before exposure	36.5	100.0
» after »	51.3	100.0
F value	53.8***	48.8***
L.S.D.	14.4	11.3

Table 8. Fungicide trial for control of *S. curtisii* on amaryllis seedlings, 1959—60

Treatment	Conc. %	Amount per plant	Degree of infection (0—5) two months after inoculation					
			in 1959		in 1960			
			I	II	I	II	III	Average
Control, uninoculated	—	—	0.1	0.3	0	0.2	0.3	0.2
» , inoculated	—	—	5.0	5.0	5.0	5.0	5.0	5.0
Orthocide 75 (captan)	0.25	0.5 dl	3.9	—	5.0	3.7	0.5	2.5
Orthocide dust (captan)	—	1.0 g	—	1.7	5.0	5.0	0.3	2.6
Brassicol w.p. (PCNB)	0.25	0.5 dl	3.5	—	4.8	1.9	2.5	2.8
Brassicol (PCNB)	—	0.5 g	—	3.3	5.0	4.3	1.0	2.9
Folosan (TCNB)	—	1.0 g	—	3.3	5.0	3.8	2.3	3.4
Pomarsol forte (thiram)	0.25	0.5 dl	4.3	—	5.0	3.2	1.8	2.8
Pomarsol dust (thiram)	—	1.0 g	—	0.3	5.0	0	2.3	2.4
Dithane Z-78 (zineb)	0.25	0.5 dl	—	—	4.8	5.0	1.5	3.1
Dithane dust (zineb)	—	1.0 g	—	0.3	5.0	0	0	1.6
Duphar ferbam	0.25	0.5 dl	2.8	—	5.0	3.4	1.8	2.8
Copper powder	0.6	0.5 dl	2.6	5.0	5.0	5.0	5.0	5.0
Aretan (mercury)	0.25	0.5 dl	3.0	3.7	5.0	5.0	4.8	4.9
Verdasan (mercury)	0.25	0.5 dl	3.6	—	5.0	5.0	4.5	4.8
Ceresan (mercury)	0.25	0.5 dl	3.8	—	—	—	—	—
F value			4.02***	2.7°	—	—	—	6.02***
L.S.D.			1.8	3.3	—	—	—	1.5

a weak effect in the vapour method, depressing the growth of the fungus by only 1—3 %. Copper powder was quite ineffective in all three methods (Fig. 8 F).

Various antibiotic chemicals were tested, using the diffusion and solution methods. Cycloheximide (Actidione and U—4527) was very good, completely inhibiting the fungus in the solution method and reducing its growth by about 82 % in the diffusion method. Likewise, the derivatives of cycloheximide, U—7413 (oxime), U—7414 (acetate) and U—7415 (semicarbazone), retarded the growth of the organism by an average of 44 % as compered with the untreated control. Of these, only U—7413 was tested in the solution method, and here it depressed mycelial growth by 74 %. The other antibiotics in the trials were less effective. In the solution method, Usno inhibited the fungus, Griseofulvin retarded its growth moderately and Sorbistat to a small extent. In the diffusion method the decrease in fungal growth provided by the compounds were about 17 % for Usno and Agrimycin, 13 % for Kojic acid, 11 % for Griseofulvin and 5 % for Sorbistat.

The results of laboratory trials give an indication of the fungicidal effect of different compounds, but a chemical which is unable to inhibit the fungus on artificial growth media may nevertheless weaken it under natural conditions so that the organism cannot penetrate into the host plant. This can be seen by comparing the above-described trials carried out in vitro with those conducted on living plants (pp. 38—40, and following section).

Effect of various fungicides on Stagonospora curtisii in vivo

The trials were carried out on two groups of amaryllis plants: 2-month-old seedlings and 2-year-old plants, both of which had been grown from seed as described on p. 33. The plants were inoculated with *S. curtisii* in the same way as in the seedling infection trials (p. 34). In the 1959 trials the mycelium of one half of a Petri dish was mixed into the soil per seedling, and in 1960 the amounts of fungus-oats-sand mixture added to the soil was 10 g per seedling and 35 g per 2-year-old plant.

The results of the trials (Tables 8 and 9) reveal that the degree of infection with *S. curtisii* varied considerably according to the times of setting, inoculation and fungicidal treatment. If the fungus had succeeded in penetrating the plant before treatment, the effect of the fungicide was obviously weaker (cf. trial N:o 1960/I,

Table 9. Fungicide trial for control of *S. curtisii* on 2-year old amaryllis plants, in 1959 and 1960
The concentration and amounts of fungicides are the same as in Table 8.

Treatment	Degree of infection (0—5)					
	in bulbs				in roots	in leaves
	in 1959		in 1960		in 1960	
	4	7	3	6	6	6
	months after inoculation					
Control, uninoculated	0.2	0.3	0	1.0	1.0	0.2
» , inoculated	1.3	2.9	3.3	3.5	2.5	1.7
Orthocide 75 (captan)	0.5	1.1	2.2	2.2	2.0	0.3
Orthocide dust (captan)	—	—	1.8	2.2	2.0	0
Brassicol w.p. (PCNB)	0.3	0.7	1.3	1.8	1.3	0
Brassicol (PCNB)	—	—	2.2	1.8	1.7	0
Folosan	0.6	1.4	1.3	2.2	2.3	0
Pomarsol forte (thiram)	0.8	1.7	1.2	1.8	1.8	0.9
Pomarsol dust (thiram)	—	—	1.0	2.7	1.8	0.2
Dithane Z-78 (zineb)	—	—	1.3	1.7	2.3	0
Dithane dust (zineb)	—	—	1.2	2.3	1.7	0
Duphar ferbam w.p.	—	—	2.3	2.8	2.8	0.6
Copper powder	—	—	2.2	2.2	2.5	0.2
Aretan (mercury)	0.7	1.2	2.0	2.2	2.0	0.4
Verdasan (mercury)	—	—	2.0	2.8	1.8	0.2
Ceresan (mercury)	0.5	1.0	1.7	2.5	1.8	0.9
F value	—	4.8***	1.4°	1.4°	1.2°	—
L.D.S.	—	1.0	1.5	1.4	1.2	—

Table 8) than if the fungicide had been applied prior to penetration.

In the trials performed on seedlings the best compounds proved to be zineb, thiram and captan. Ferbam and PCNB also suppressed the growth of *S. curtisii* rather well. On the other hand, TCNB gave poor control, even though it almost completely inhibited the fungus in vitro (cf. p. 41); this phenomenon is evidently due to its strong tendency to vapourize. The mercuric fungicides, furthermore, were considerably less effective in these trials on seedlings than they were in the experiments on an artificial nutrient medium (cf. p. 42). Copper powder generally had no inhibitory effect at all on the fungus (Table 8). The only exception was in trial 1959/I, in which infection was uneven: half the seedlings died, while half were healthy.

In the trials on 2-year-old amaryllis plants (Table 9) a significant reduction in the degree of red spot disease was achieved with PCNB, zineb and thiram. The efficacy of captan, TCNB, maneb, Aretan and copper powder was at the limit of significance. PCNB and maneb were the only compounds which significantly reduced the amount of root infection. No appreciable differences in growth vigour were noted between the different treatments.

Summary

These studies concern the red spot disease of amaryllis (*Hippeastrum vittatum* (L'Herit) Herb.) caused by several fungi but primarily by *Stagonospora curtisii* (Berk.) Sacc.

Inspections of imported amaryllis bulbs (1496 in number) made in 1958—61 revealed that 71—100 % (av. 88.4 %) of the bulbs were infected with the red spot disease. In market gardens all the 658 imported bulbs inspected were infected, while only 76.5 % of the 468 bulbs produced from seed were diseased. The severity of infection was respectively 28 %, 55 % and 24 %.

Eleven fungus species were isolated from diseased amaryllis bulbs. The most prevalent were *Stagonospora curtisii* (Berk.) Sacc. (53 % of the 143 isolations), *Colletotrichum crassipes* (Speg.) v. Arx (31 %) and *Fusarium bulbigenum* Cke. & Mass. (11 %). The remaining species made up 5 %.

S. curtisii produced red or brownish-red watery lesions on the bulbs, roots, leaves and scapes

of amaryllis. In infection trials the fungus was strongly pathogenic, completely preventing germination of seed, and killing all seedlings within 2—4 weeks after inoculation. It was capable of significantly infecting mature amaryllis bulbs within 1½ months, and retained its infective capacity in dried bulb scales for at least 5 years.

C. crassipes caused superficial red scabbiness in amaryllis bulbs. It slightly impaired seed germination, caused mild infection of seedlings and together with *S. curtisii* increased the pathogenic effect of the latter.

F. bulbigenum was weakly parasitic, being responsible mainly for reddening and slight weakening of the roots. The fungus caused a significant decrease in seed germination but infected seedlings only to a minor extent and mature seedlings not at all.

Fusarium moniliforme Sheld., isolated from one red-spotted amaryllis bulb, caused slight reddening of roots. *Melanospora fallax* Zukal isolated from the same bulb, depressed seed germination and in the seedling infection trial was the most serious pathogen next to *S. curtisii*.

Chaetomium sp. Kunze & Schmidt and *Papularia sphaerosperma* (Pers.) v. Hühn were leaf parasites, producing superficial red spotting in amaryllis leaves as well as slightly hastening their withering. The latter species was a very weak pathogen.

Botrytis cinerea Pers. and *Rhizoctonia tuliparum* (Kleb.) Whetz. & Arthur infected seedlings and leaves only under extremely wet conditions.

The germination of amaryllis seeds was improved by inoculation with *Chaetomium* sp., *Papularia sphaerosperma*, *Botrytis cinerea*, *Rhizoctonia tuliparum*, *Trichothecium roseum* Link. and *Penicillium nigricans* (Bain.) Thom., evidently due to the antibiotic effect of these fungi against *Rhizopus* sp. (in 88 % of 200 seeds examined) and *Penicillium* sp. (in 7 % of 200 seeds). The antibiotic influence of. *T. roseum* against *S. curtisii* was also observed in the infection trials with seeds and seedlings.

Captan and thiram significantly reduced bulb and leaf infection in mature amaryllis. Furthermore, bulbs treated with captan and ferbam produced significantly more scapes than the control bulbs. The organic products tested in these bulb trials were all more effective than the inorganic ones.

In seed dressing trials, captan and thiram distinctly improved the germination of both uninfected amaryllis seeds and seeds which had been infected with pathogenic fungi. Mercuric compounds gave rather good control of pathogenic fungi, but in some trials they impaired the germination of the control seeds.

In the laboratory experiments in vitro TCNB almost completely inhibited the growth of *S. curtisii*. PCNB and mercury compounds also considerably delayed the growth of the fungus. The other organic products tested (thiram, zineb, ferbam, captan) had a weak effect. Of the antibiotics cycloheximide and its derivaties were the most effective and usnic acid moderately good in suppressing the development of the fungus.

In greenhouse trials, infection of seedlings with *S. curtisii* was significantly decreased by zineb, captan and thiram. Infection of 2-year-old plants was reduced by PCNB, captan and thiram. Many of the organic fungicides only weaken the ability of the fungus to penetrate into a resistant host plant and do not appreciably retard its growth. The inorganic compounds somewhat impaired the germination of the seeds and the development of the plants.

Captan and thiram are the best while the thiocarbamates (ferbam, maneb and zineb) are also good fungicides for seed dressing and bulb treatment of amaryllis. They greatly reduce the extent of red spot, thus improving seed germination as well as the growth and flowering of the plant.

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SELOSTUS

Sienten aiheuttama amarylliksen punalaikkuisuus

EEVA TAPIO

Maatalouden tutkimuskeskus, Kasvitautien tutkimuslaitos, Tikkurila

Tutkimus käsittelee sienten, pääasiallisesti *Stagonospora curtisii*n aiheuttamaa punalaikkuisuutta amarylliksessä [*Hippeastrum vittatum* (L'Herit) Herb.].

Tuontiliikkeissä v. 1958—1961 suoritetuissa amarylliksen sipulien (1 496 kpl) tarkastuksissa todettiin punalaikkuisia sipuleita olevan 71—100 %, keskimäärin 88.4 %. Kauppapuutarhoissa olivat kaikki viljellyt tuontisipulit (658 kpl) punalaikkuisia ja siemenistä kasvatetuista sipuleista (468 kpl) 76.5 %. Tautisuusprosentit olivat vastaavasti 28, 55 ja 24.

Punalaikkuisista amarylliksistä eristettiin 11 sienilajia, joista yleisimmät olivat *Stagonospora curtisii* (Berk.) Sacc. (53 % 143:sta sienieristyksestä), *Colletotrichum crassipes* (Speg.) v. Arx (31 %) sekä *Fusarium bulbigenum* Cke. & Mass. (11 %). Muita sieniä oli 5 %.

S. curtisii aiheuttaa punaisia tai punaruskeita, vetisiä laikkuja amarylliksen sipuliin, juuriin, lehtiin ja kukkavanoihin. Sieni oli infektiokokeissa voimakkaasti patogeeninen estäen kokonaan siementen itämisen, tappaen kaikki siementaimet 2—4 viikon kuluessa inokuloinnista ja pystyen ainoana tutkittavana olleista sienistä saastuttamaan täysikasvuisia amarylliksen sipuleita merkitsevästi 1.5 kk:ssa. Sienen todettiin säilyvän saastutuskykyisenä kuivissa sipulinlehdissä ainakin 5 vuotta.

C. crassipes aiheutti sipuleihin pinnallista punarupisuutta. Se haittasi vähäisessä määrin siementen itävyyttä, saastutti heikosti siementaimia ja lisäsi sekainfektiossa *S. curtisii*n patogeenista vaikutusta.

F. bulbigenum oli heikko parasiitti aiheuttaen pääasiassa juurten punertumista ja niiden vähäistä heikkenemistä. Sieni alensi siementen itävyyttä merkitsevästi, mutta kykeni vain heikosti saastuttamaan siementaimia eikä lainkaan täysikasvuisia sipuleita.

Yhdestä punarupisesta ja -laikkuisesta amarylliksen sipulista eristetty *Fusarium moniliforme* Sheld. aiheutti infektiokokeissa juurten lievää punertumista. Samasta sipulista eristetty *Melanospora fallax* Zukal alensi siementen itävyyttä ja oli siementaimien infektiokokeissa *S. curtisii*n jälkeen voimakkain patogeeni.

Chaetomium sp. Kunze & Schmidt ja *Papularia sphaerosperma* (Pers.) v. Hühn olivat lehtiparasiitteja aiheuttaen lehtiin pinnallista punapilkkuisuutta sekä lehtien hieman tavallista aikaisempaa kuihtumista. Viimeksi mainitun patogeenisuus oli hyvin heikko.

Botrytis cinera Pers. ja *Rhizoctonia tuliparum* (Kleb.) Whetz. & Arthur infektoivat siementaimia ja lehtiä vain erittäin kosteissa oloissa.

Chaetomium sp., *Papularia sphaerosperma*, *Botrytis cinerea*, *Rhizoctonia tuliparum*, *Trichothecium roseum* Link. ja *Penicillium nigricans* (Bain.) Thom. paransivat niillä infektoitujen siementen itävyyttä vaikuttaen ilmeisesti antibioottisesti siemenissä olleisiin *Rhizopus* sp. (joita oli 88 %:ssa tutkituista 200 siemenestä) ja *Penicillium* sp. (7 %:ssa) -sieniin. *T. roseum*in antibioottinen vaikutus *S. curtisii*hin todettiin lisäksi siemenien ja siementaimien sekainfektiokokeissa.

Punalaikkuisten amarylliksen sipulien nelivuotisessa fungisidikäsittelykokeessa kaptaani ja tiram vähensivät merkitsevästi sipulien ja lehtien punalaikkuisuutta, ja kaptaanilla ja ferbamilla käsitellyt sipulit kehittivät merkitsevästi enemmän kukkavanoja kuin kontrollisipulit. Kaikki sipulien käsittelykokeessa ollet orgaaniset valmisteet olivat tehokkaampia kuin epäorgaaniset.

Amarylliksen siementen peittauskokeissa kaptaani ja tiram kohottivat merkitsevästi sekä patogeenisilla sienillä infektoitujen että infektoimattomien siementen itävyyttä. Myös elohopeavalmisteet tehosivat melko hyvin patogeenisiin sieniin, mutta haittasivat eräissä kokeissa infektoimattomien (kontrollin) siementen itävyyttä.

Fungisidien vaikutusta *Stagonospora curtisii*hin tutkittiin laboratoriossa keinoravintoalustalla eri koemenetelmin sekä kasvihuoneessa käsittelemällä sienellä infektoituja siementaimia ja nuoria amarylliksiä. Keinoravintoalustakokeissa ehkäisi TCNB lähes kokonaan *S. curtisii*n kasvun. Myös PCNB ja elohopeavalmisteet hidastivat huomattavasti sienen kasvua. Muut kokeessa olleet orgaaniset valmisteet (tiram, zineb, ferbam ja kaptaani) olivat heikkotehoisia. Antibioottivalmisteista ehkäisivät sykloheksimidi ja sen johdannaiset tehokkaimmin ja usniinihappo melko hyvin sienen kasvua.

Kasveilla suoritetuissa *S. curtisii* -infektio- ja torjuntakokeissa zineb, kaptaani ja tiram vähensivät merkitsevästi siementaimien saastuntaa (infektoitumista) sekä PCNB, kaptaani ja tiram nuorten amaryllisten saastuntaa. Ilmeisesti useat orgaaniset aineet heikentävät vain sienen kykyä tunkeutua vastustuskykyä omaavaan isäntäkasviin hidastamatta sanottavasti sienen kasvua. TCNB:n melko heikko teho kasveihin johtui aineen voimakkaasta haihtumisesta. Epäorgaaniset valmisteet haittasivat jossain määrin siementen itämistä ja kasvien kasvua.

Kaptaani ja tiram soveltuvat parhaiten sekä tiokarbamaatit (ferbam, maneb ja zineb) sangen hyvin amarylliksen siementen peittaukseen ja sipulien käsittelyyn vähentäen punalaikkuisuutta ja edistäen siementen itämistä sekä kasvien kasvua ja kukintaa.

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Seria ANIMALIA DOMESTICA N. 14 — Sarja KOTIELÄIMET n:o 14

REPEATABILITIES AND CORRELATIONS OF ECONOMIC TRAITS IN THE FINNISH RANDOM SAMPLE EGG-LAYING TEST

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An essential part of the changes made in the Finnish poultry - breeding programme in 1962, was the establishment of a Random Sample Test for comparisons of commercial strains or crosses of poultry. At the same time, the progeny-testing station for cockerels was suspended. By focusing attention to the end-results of breeding work, the Random Sample Test leaves the hands of breeders free as to the choice of breeding methods. This is an important point, because there are certainly many alternative ways of obtaining good results, and new ways may be found in an atmosphere of free competition.

The purpose of the present study was to investigate the repeatability of various economic traits of entries in the R.S. tests from year to year, and the correlations among the same traits, in order to find the most suitable measure of the economic value of different stocks. This analysis has been made necessary by the fact that the most successful stocks or crossbreeding combinations are to be »registered» or authorized for general selling on the basis of three years' results.

It is true that repeatabilities of measures of various traits in R.S. egg-laying tests have previously been studied by several workers (e.g. KING 1954, DICKERSON and ABPLANALP 1956, A.R.S. 1961), but it appears that there is considerable variation between estimates obtained in different circumstances. Thus, estimates obtained elsewhere obviously cannot be applied in evaluating the reliability of different measurements in the Finnish test. On the other hand, the results of this test might contribute something to the general knowledge of the usefulness of R.S. tests.

The importance of different traits in determining or predicting the net income has been studied by NORDSKOG (1960) and by ROBERTS and DELAND (1964), but again it is necessary to analyse the Finnish data before inferences can be drawn regarding the most valuable measurements in these particular conditions.

As a side-issue there is a comparison of different statistical procedures for analysing correlations among various traits.

The Finnish Random Sample Test, the source of data

The test is being run by the Finnish Poultry Breeders' Association at Urjala, ca. 140 km northwest of Helsinki. There is space for 40 pens of 50 pullets each or for a total of 2 000 hens in the poultry-house. Each pen is used for a different entry, so that there are no replicates within years and the sample size at housing time is 50 birds. It has not yet been possible to take

the samples as hatching eggs, but 100 one-day old female chicks have been sampled simultaneously from each participating stock. For the present, they have been taken directly from the particular breeders, but only pullet dams have been accepted, and there must have been at least two cockerels in the breeding pen. In the first three years, the marking of the chicks was done on the breeding farms with special wingtags sent from the test station. Intermingled rearing on a separate farm has been applied until the age of 150 days (about 60 days in a brooder-house and 90 days on range). Fifty birds per entry have then been picked out at random for the actual test and marked with legbands showing the entry number.

In the laying-house, the location of each entry has been chosen partly at random and partly so that it will be different for the same stock from year to year. All-mash feed is supplied ad libitum from self-feeders, and records of its consumption are kept as accurately as possible. In addition, a fixed amount of grain per pullet is given daily from the floor.

The eggs collected from each particular pen are sent weekly as a separate consignment to an egg-marketing co-operative, where they are evaluated as regards total weight, quality and market value. Thus the price obtained for the eggs of each entry corresponds exactly to their actual market value in the Finnish egg market.

The hens are tested up to the age of 500 days, so the actual test period is ca. 350 days. In the first year, however, the test period was only 290 days. At the end of the test the slaughter value of the surviving hens is determined.

On the basis of the records kept in the tests it has been possible to include the following traits in the present study:

(1) Rearing mortality = percent mortality to 150 days.

(2) Adult mortality = percent laying-house mortality computed from 150 days to 500 days of age.

(3) Age at maturity = days of age to 50 % production calculated from the first day of the first three consecutive days of 50 % production.

(4) Body weight = the total weight of the entry at the age of 1 year divided by the number of hens.

(5) Egg weight = the total weight of eggs given by the entry in the test period, divided by the total number of eggs.

(6) Hen-housed egg number = number of eggs per pullet housed to 500 days of age.

(7) Hen-day egg number = the total number of eggs given by the entry divided by the total number of hen-feeding days during the test period.

(8) Hen-housed egg mass = the total weight of eggs from the entry per pullet housed.

(9) Hen-day egg mass = item (7) multiplied by item (5) = eggs g/day.

(10) Income from eggs = the total account paid by the marketing co-operative for the eggs of the entry during the test, per pullet housed.

(11) Feed consumption = the total amount of feed eaten by the entry during the test, per pullet housed.

(12) Feed conversion = the total amount of feed divided by the total weight of eggs given by the entry.

(13) Net income = income from eggs + slaughter value at the end of test — feed costs, per pullet housed.

The means, standard deviations and coefficients of variation of these 13 measurements in each of the three tests are shown in Table 1.

The table reveals some changes from year to year in some traits, especially in the rearing mortality. The values for egg weights are unusually low, but this is obviously due to the fact that all eggs are included in the averages. In the first year the egg weight was also determined by weighing the eggs only once a month, and then the average was 61.1 grams, that is 5.9 grams more than the mean of all eggs. The correction factor used for transforming the results of the

Table 1. Means, standard deviations and coefficients of variation of different traits in the Finnish Random Sample Test in the first three years. Each year 40 × 50 = 2 000 pullets

Trait		Means			Stand. deviat.			Coeff. of variat. %		
		I	II	III	I	II	III	I	II	III
Rearing mortality	%	18.9	6.5	9.9	11.9	5.1	6.5	62.9	78.0	65.8
Adult mortality	%	19.6	22.7	17.7	9.6	10.3	8.1	49.2	45.4	45.6
Age at maturity	days	186[1])	173	166	6.2	8.3	10.3	3.33	4.82	6.21
Body weight	kg	2.10	2.11	2.13	.188	.181	.129	8.98	8.57	6.03
Egg weight	g	55.2[3])	54.9[3])	55.1[3])	1.54	2.12	1.60	2.80	3.87	2.91
Hen-housed egg number		209[2])	210	220	27.2[2])	23.1	24.0	13.0	11.0	10.9
Hen-day egg number	%	65.7[2])	66.3	68.5	5.24[2])	5.18	5.66	7.98	7.81	8.26
Hen-housed egg mass,	kg	11.5[2])	11.5	12.1	1.56[2])	1.43	1.32	13.6	12.4	10.9
Hen-day egg mass	g/day	36.3[2])	36.4	37.8	3.22[2])	3.36	3.15	8.89	9.23	8.33
Income from eggs	Fmks	27.8[2])	28.0	31.4	3.81[2])	3.60	3.39	13.7	12.8	10.8
Feed consumption	kg	45.1[2])	44.5	46.4	5.02[2])	3.89	3.15	11.1	8.7	6.8
Feed conversion	kg/egg-kg	3.92	3.88	3.85	.313	.309	.322	7.98	7.97	8.36
Net income	Fmks	10.3[2])	11.6	11.1	2.48[2])	2.80	2.96	24.1	24.0	26.7

[1]) The birds hatched on May 9 or ca. 5 weeks later than in other years.
[2]) Corrected to correspond to a 350-day test period.
[3]) Owing to the small-egg period, the figures are ca. 6 g smaller than March egg weights.

first year to correspond to the 350-day test period was based on the monthly hen-day egg numbers of the third year, presented in Table 2.

The intensity of egg-laying in the last two months appears to be about 87 % of the average of the preceding 10 months. The actual intensity in the first year (290 days) was 66.7 % and the hen-housed egg yield 174 eggs. According to the lowered intensity (87 % × 66.7 % = 58 %), the expected addition during the extra 60 days would have been ca. 35 eggs, and the corrected yield would be 209 eggs, or 1.2 times the actual yield. The same factor has been applied to the means and standard deviations of traits Nos. 6, 8, 10, 11 and 13 of the first year in Table 1. A corresponding correction has been made in the case of trait No. 7.

Returning now to Table 1, one can observe that there has been some improvement in the yields, and simultaneously a decrease in the variability, obviously caused by elimination of the poorest entries.

In the first year there were 10 pure strains represented in the test, but only one of them was left in the last two years. About 3/4 of the entries were of the White Leghorn breed, while the remaining 1/4 have been of either New Hampshire, Rhode Island Red or Brown Leghorn or their crosses to White Leghorn. A total of 22, 19 and 17 different breeders were represented in the different years, respectively, the average number of entries per breeder being 1.82, 2.11 and 2.35.

According to the pooled results of the three test years, there were highly significant differences between breeders in all the egg-production traits, the proportion of the variance due to breeders within years being at least 40 %. In the rearing mortality this proportion was close to 62 % ($P < 0.001$), and in the adult mortality ca. 33 % ($P < 0.01$). With regard to feed consumption per bullet housed it was 12.5 % ($P < 0.2$) and in the body weight only 5.2 % (NS), owing to the fact that both heavy and light breeds or their crosses were sent to the tests by the same

Table 2. Means, standard deviations and coefficients of variation of monthly hen-day egg yields in the third test year

Statistical parameter	Value of the parameter in different months, %											
	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII
Mean	52.1	67.8	74.5	76.3	75.3	71.6	72.3	71.0	68.0	65.6	61.8	59.1
Standard deviation	14.2	8.2	5.7	5.2	5.5	5.9	5.9	4.9	5.7	6.3	6.8	6.3
Coeff. of variation	27.2	12.0	7.6	6.8	7.3	8.3	8.2	6.9	8.4	9.6	11.0	10.6

breeders. It is not possible to determine how large a part of the breeder differences is due to environment, but on the basis of analyses concerning the progeny testing station for cockerels this cannot be large as compared with the genetic differences between stocks within breeders (MAIJALA 1965).

Statistical analyses

Two kinds of correlation analyses were performed on the data. The first one concerned the »phenotypic» correlations between traits within test years. Here the whole data, that is 3 × 40 samples, could be utilized. In regard to the mortality, the actual percentage figures were used, because the use of arcsin transformation (SNEDECOR 1957) proved to change the pooled correlation between adult mortality and net income only from 0.613 to 0.627.

The second type of analysis consisted of comparing samples drawn from the same stock in successive years. Eighteen such pairs were available from the first two years, and 23 pairs from the last two years, a total of 41 pairs. Every possible comparison was made. For example, trait No. 1 from the year 1963 was compared to traits Nos. 1—13 from the year 1964, and trait No. 1 from the year 1964 to all traits in the year 1963. The same was done with regard to the pairs of the years 1964 and 1965. Four different correlation coefficients ($n = 82$) were thus available for estimating the correlation between every pair of traits, and two values ($n = 41$) for the correlations concerning the same trait from year to year. In computing the average correlations, each coefficient was first transformed to a z-value, and these were weighted according to the degrees of freedom. These correlations can be considered »genetic» ones, of which those concerning the same trait in both years are in fact estimates of the repeatability of the test from year to year.

The two types of correlation matrices were submitted to a type of multivariate analysis called factor analysis (HARMAN 1960, VAHERVUO and AHMAVAARA 1958). Biological applications of this method have previously been made by, for example, BURT and BANKS (1947), TOUCHBERRY (1951), TANNER and BURT (1954), BAILEY (1956), WEBER (1957), DE GROOT (1961 a, 1961 b), SMITH et al. (1962 and 1965), VARO (1962, 1965 a, 1965 b), TAYLOR and ROLLINS (1963), and ROUVIER and RICARD (1965). The size studies of WRIGHT (1932) can, in fact, be considered the forerunners of these applications.

The principal factor (or component) method of HOTELLING (1933) was employed in the present study for the initial factorization, using an IBM 1620 computer and a standard programme. In order to facilitate the interpretation of the results, the orthogonal rotation method »Varimax» (KAISER 1956) was applied to the factor matrix. In the initial factorization, the highest correlation of each variable was used as its communality estimate.

Finally, some stepwise multiple regression analyses were performed for comparison and to find the most practical predictions of the net income in a test on the basis of results obtained in the preceding test. This analysis was done in two different ways: (1) entirely on the basis of the »genetic» correlation matrix, and (2) taking the intercorrelations of the X's or independent variables from the »phenotypic» matrix. In the first alternative it was not possible to use the net income itself as an independent variable, so there were 12 X's, while in the second alternative there were 13 X's. Two different models were tried in both analyses, namely: (a) a model where all the X's were available as independent variables, and (b) a model where only variables Nos. 1—10 were available, that is only the variables not requiring the recording of feed consumption. Unities were used on the diagonal of the correlation matrix, and the machine used here was Elliot 803.

Repeatabilities

The estimates of repeatability obtained from the two sets of data as well as the pooled estimates are shown in Table 3. To see the differences more clearly, the pooled estimates are shown graphically in Fig. 1.

As was to be expected, the age at sexual maturity, body weight and egg weight gave significant and uniform correlations in both comparisons. Equally good results were obtained, however, with regard to the feed conversion.

Table 3. Estimates of the repeatability of test results with regard to different traits in the first two pairs of years

Trait	Correlation between successive years		
	I × II	II × III	Pooled
1. Rearing mortality	.425	.241	.325*
2. Adult mortality	—.117	.034	—.003
3. Age at maturity	.636**	.572**	.601**
4. Body weight	.646**	.668**	.658**
5. Egg weight	.573*	.615**	.596**
6. Hen-housed egg number	.441	.183	.312
7. Hen day egg number	.744**	.398	.577**
8. Hen-housed egg mass	.552*	.168	.352*
9. Hen-day egg mass	.757**	.326	.554**
10. Income from eggs	.489*	.218	.344*
11. Feed consumption	.252	.040	.134
12. Feed conversion	.688**	.576**	.629**
13. Net income	.586*	.456*	.516**
No. of pairs	18	23	41

** $P < 0.01$;; * $P < 0.05$

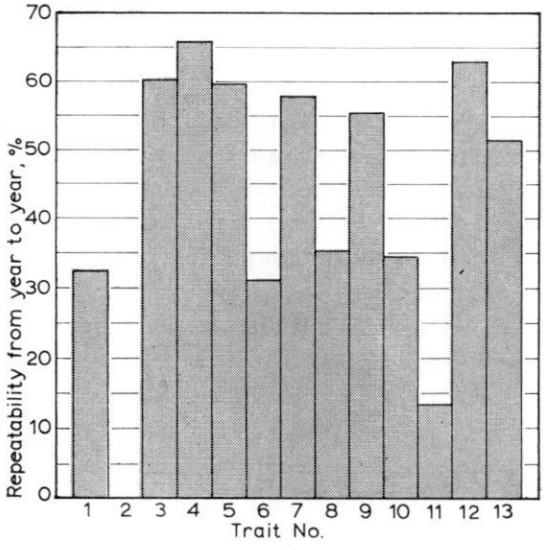

Fig. 1. Repeatability of different traits from year to year in the first three years of the Finnish Random Sample Test.

The pooled estimates concerning hen-day egg number and mass are also rather high, but here the agreement between the two primary estimates is not so good. The net income, which for the present has been used as the official judging basis, has given reasonable estimates of repeatability, but on the other hand it can be observed that these are at a lower level than those concerning feed conversion.

The three hen-housed measures of egg production (traits 6, 8 and 10) gave especially low values in the last pair of years, and hence the pooled values are on the border of significance. The poorest repeatability seems to be presented by the adult mortality and the feed consumption per pullet housed, while that concerning the rearing mortality just reaches statistical significance in the pooled results.

Correlations among the traits

Both the »genetic» and »phenotypic» correlations are shown in Table 4, where the repeatabilities are also included in order to facilitate comparisons. Traits Nos. 1, 2, 3 and 12 have been changed to their counternumbers or reciprocals, in order to avoid negative values and to make the traits positive.

In general, there are higher values in the »phenotypic» matrix than in the »genetic» one. For example, the correlation between hen-housed egg mass and income from eggs is almost unity in the »phenotypic» matrix, but only .35 in the »genetic» one. The most striking differences are to be seen in the values concerning the adult viability, but the values concerning the hen-housed egg production do not lag far behind them in this respect. In the correlations of egg weight the differences are very small, while for the rearing viability the »genetic» correlations are in many cases higher than the »phenotypic» ones.

A comparison of the last row to the rightmost column shows that the adult viability is of decisive importance ($r = .61$) in the determination of the net income in the same test, but that its value in predicting the net income in another year is smaller than that of rearing viability. Similarly, the hen-housed egg number is more important on the »phenotypic» level than the hen-day number, but the reverse is the case on the »genetic» level. The same applies to the hen-housed egg mass as compared to the hen-day egg mass. The feed consumption per pullet housed seems to have no predictive value with regard to the net income of another year, although it is important with regard to the current test. The most obvious explanation of these relations appears to be the non-repeatability of the adult viability.

The total egg mass per kg of feed, which in fact includes most of the economic traits considered, is less dependent on the adult viability of the current year than is the net income, but on the basis of the »genetic» correlations it appears to be at least as efficient, in a selection for viability, as is the net income. Its »genetic» correlations with most other traits are at the same level or higher than those of the net income. Trivial exceptions are formed by the correlations concerning body weight and egg weight. It appears possible on the basis of these data, that a use of feed conversion figures might

Table 4. Correlations among the 13 traits in the first three years. »Genetic» values above and »phenotypic» ones below the diagonal. Repeatabilities on the diagonal

Trait		Correlation coefficient (× 100) to different traits												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Rearing viability	1	**33**	01	12	01	01	21	**24**	21	22	19	07	**26**	21
Adult viability	2	—02	**00**	01	21	22	03	11	10	17	10	—07	22	15
Earliness of maturity	3	03	**18**	**60**	00	—13	**26**	**36**	11	**23**	16	02	**31**	22
Body weight	4	—01	01	05	**66**	**39**	10	02	17	16	18	**41**	—12	03
Egg weight	5	14	12	—11	**54**	**60**	11	08	**30**	**33**	**29**	**29**	20	**24**
Hen-housed egg number	6	18	**69**	**55**	**24**	11	**31**	**43**	**30**	**39**	**30**	03	**44**	**37**
Hen-day egg number	7	12	**36**	**66**	**24**	05	**85**	**58**	**41**	**51**	**40**	11	**52**	**47**
Hen-housed egg mass	8	**20**	**66**	**51**	**36**	**35**	**97**	**81**	**35**	**44**	**35**	11	**45**	**40**
Hen-day egg mass	9	16	**37**	**57**	**40**	**41**	**81**	**93**	**87**	**55**	**44**	20	**51**	**48**
Income from eggs	10	**20**	**68**	**47**	**35**	**36**	**97**	**80**	**99**	**86**	**34**	10	**45**	**40**
Feed consumption	11	13	**56**	**29**	**53**	**36**	**73**	**49**	**78**	**57**	**77**	**13**	05	03
Feed conversion	12	17	**40**	**50**	—02	13	**72**	**74**	**72**	**73**	**71**	11	**63**	**58**
Net income	13	17	**61**	**46**	16	**27**	**88**	**79**	**90**	**82**	**91**	**44**	**91**	**52**

Bold face type: $P < 0.05$

favour smaller animals than a use of net income. In spite of this, the correlations in the right lower corner of the table are in favour of feed conversion instead of net income as a judging basis. For the net income was predictable with an accuracy of 58 % from the feed conversion of another year, while the accuracy was only 52 % when the net income itself was used. In the repeatabilities of these two measurements there was a difference of 63—52 = 11 %-units.

Factor analyses

Seven factors were extracted from the »genetic» correlation matrix and five factors from the »phenotypic» one, but only four common factors from each analysis are included in Table 5, where the results are shown.

In the upper part of the table, there are significant loadings only in the first two factors. The highest loading of the first factor in both the initial and rotated factor matrix concerns feed conversion, so the rotation would not have

Table 5. Results of factor analyses concerning the »genetic» and »phenotypic» correlations among the economic traits of entries in the first three tests

Trait	Initial loadings				Rotated loadings			
	I	II	III	IV	I	II	III	IV
A. Based on the »genetic» correlation matrix:								
1. Rearing viability	.33	—.10	—.14	—.18	.36	.04	—.18	.07
2. Adult viability	.22	.16	.31	.28	.12	.06	.48	—.00
3. Earliness of maturity	.36	—.28	—.30	.26	.26	—.04	—.03	.54
4. Body weight	.19	.63	—.13	.18	—.01	.66	.23	.03
5. Egg weight	.36	.54	.21	—.05	.28	.46	.32	—.26
6. Hen-housed egg number	.56	—.14	—.13	.07	.51	.06	.03	.31
7. Hen-day egg number	.69	—.19	—.15	.06	.63	.05	.02	.37
8. Hen-housed egg mass	.61	.08	.02	—.05	.57	.20	.12	.07
9. Hen-day egg mass	.72	.08	—.01	—.01	.65	.24	.15	.14
10. Income from eggs	.60	.08	.06	—.08	.57	.18	.13	.03
11. Feed consumption	.20	.49	—.35	—.12	.09	.62	—.15	.01
12. Feed conversion	.75	—.23	.14	—.04	.76	—.10	.15	.15
13. Net income	.69	—.12	.19	—.07	.71	—.03	.18	.05
Eigenvalue	3.56	1.19	.49	.25	—	—	—	—
» , % of total commun.	63.6	21.2	8.7	4.5	—	—	—	—
B. Based on the »phenotypic» correlation matrix:								
1. Rearing vialibity	.18	—.05	—.02	—.10	.20	.03	.06	.05
2. Adult viability	.61	.04	.57	—.10	.29	—.03	.79	.01
3. Earliness of maturity	.56	—.34	—.19	.38	.22	—.08	.14	.73
4. Body weight	.32	.63	—.30	.09	—.07	.74	.11	.16
5. Egg weight	.30	.58	—.24	—.36	.25	.72	.07	—.17
6. Hen-housed egg number	.96	—.08	.21	.13	.45	.11	.71	.53
7. Hen-day egg number	.88	—.24	—.24	.24	.48	.14	.28	.79
8. Hen-housed egg mass	.99	.11	.08	—.02	.52	.35	.65	.44
9. Hen-day egg mass	.92	.03	—.35	.01	.57	.45	.25	.61
10. Income from eggs	.99	.12	.13	—.05	.53	.34	.68	.39
11. Feed consumption	.69	.52	.22	.27	—.03	.51	.71	.30
12. Feed conversion	.77	—.47	—.16	—.35	.89	—.06	.16	.36
13. Net income	.92	—.18	.02	—.28	.79	.13	.46	.32
Eigenvalue	7.32	1.46	.83	.65	—	—	—	—
» , % of total commun.	72.7	14.5	8.2	6.4	—	—	—	—

Bold face type = significant value (HARMAN 1960).

Table 6. The loadings of the first two »genetic» common factors, when the rotation is performed with only two factors

Common factor	Loadings of the different traits in the two rotated factors												
	1	2	3	4	5	6	7	8	9	10	11	12	13
I.....	.34	.15	.43	—.05	.14	.58	.71	.54	.64	.53	.00	.78	.69
II.....	.02	.22	—.13	.66	.63	.07	.07	.30	.34	.29	.53	.05	.14

been necessary for the interpretation. The other significant loadings in this factor concern various measures of egg production, and hence this factor can be considered as a general »production efficiency»- factor, the best measure of which is the amount of feed consumed per kg eggs, or its reciprocal, the egg mass obtained per kg feed. The initial and rotated factor matrices do not agree absolutely with regard to the second best measure, but in any case it is either the hen-day egg number, hen-day egg mass or net income. The remaining traits also have positive loadings on the first factor, so no component trait should be seriously embarrassed if selection were for this factor. However, one then has to accept a high feed consumption per pullet as a desirable trait.

The second factor in the »genetic» matrix seems to be associated with the size of both the hen and her eggs, and with the feed consumption. So it can be called a »size factor», which is best measured by the body weight.

Table 6 gives the results of rotation, when this was performed only with the first two factors in the »genetic» matrix.

These results do not differ essentially from those in Table 5, but some further clarification can be seen, which better differentiates trait No. 12 from the other traits. At the same time, trait No. 7 has become the trait having the second highest loading in this factor, and the negative loading of body size has become more apparent. In the second factor, the loading of egg size increased a little. It thus appears that this rotation lays greater emphasis on egg-laying intensity in the first factor and egg size in the second factor than the rotation performed with four factors. However, feed conversion seems to have the highest loading in each solution, thus supporting the conclusions drawn from the correlation matrix.

In the »phenotypic» part of Table 5 the interpretation of the first factor will depend a little on whether it is done on the basis of the initial loadings or of the rotated ones. Obviously, it is a question of »production efficiency» here, too, but owing to the great influence of adult mortality the hen-housed measures of egg production are emphasized relatively more in the initial factor loadings. However, in the rotated matrix feed conversion again had the highest loading. The second highest value concerned net income, and so the rotated matrix is in reasonable accord with the »genetic» matrix. The small negative loading of body weight in the rotated factor gives additional support to the similarity of the rotated »phenotypic» matrix and the »genetic» matrices.

The same name can be given to the second factor as in the upper part of the table, although there are higher loadings on the traits Nos. 8—10 in the rotated »phenotypic» factor.

There are also significant loadings in the third and fourth factor in the lower part, but these are rather difficult to interpret. The nearest interpretation to the third factor would obviously be the »viability factor», since its highest loading is on the adult viability and the other high loadings on the traits measured on a hen-housed basis. However, it could also be considered a chancefactor, because its best measure proved to have no repeatability in Table 3.

The fourth factor seems to be associated with the pure egg-laying intensity and with the age at sexual maturity, so it could be called the »intensity» factor. The main thing, however, is that the first two factors were also interpretable in the lower part of the table.

Regression analyses

A free choice model was used in the selective multiple regression analysis, so that the programme could choose at each step as a new explainer (argument) that independent variable which would best improve the multiple correlation. Before the final choice of the new variable, the programme examined whether there were any explainers in the model so poor that they should be removed from it. As a critical F-value 2.0 was used.

The results of the four regression analyses are shown in Table 7.

The overwhelmingly most important variable among the 12 traits in the first model based on the »genetic» correlation matrix was feed conversion. An addition of the hen-day egg mass to the model increased the multiple correlation only from .583 to .619. It is curious that the third variable to be added was the hen-day egg number, although it is included in the hen-day egg mass measurement. The most interesting point to observe is that the same three traits were the best measures of the first common factor in Table 5. No essential increase in the multiple correlation can be seen when additional traits are included in the equation, and the data on mortality do not occur at all in the equations obtained in the first model. The same applies to the age at sexual maturity.

Table 7. The relative value of different traits or of their combinations in predicting the net income of another year

Step No.	R	Standard partial regression coefficients of different traits in the multiple regression equation							
1. a. »Genetic» matrix, traits Nos. 1—12 as X's:									
		X_{12}	X_9	X_7	X_5	X_{11}	X_{10}	X_8	
1	.583	$.58^3$	—	—	—	—	—	—	—
2	.619	$.46^3$	$.24^3$	—	—	—	—	—	—
3	.633	$.40^3$	$.19^3$	$.16^3$	—	—	—	—	—
4	.639	$.39^3$	$.16^3$	$.18^3$	$.10^3$	—	—	—	—
5	.642	$.39^3$	$.16^3$	$.18^3$	$.12^3$	$-.07^3$	—	—	—
6	.645	$.37^3$	$.15^3$	$.17^3$	$.10^3$	$-.07^2$	$.08^2$	—	—
7	.648	$.35^3$	$.14^3$	$.16^3$	$.09^2$	$-.07^2$	$.08^1$	$.07^1$	—
1. b. »Genetic» matrix, traits Nos. 1—10 as X's:									
		X_9	X_7	X_{10}	X_8	X_6	X_4	X_5	X_2
1	.479	$.48^3$	—	—	—	—	—	—	—
2	.546	$.33^3$	$.30^3$	—	—	—	—	—	—
3	.567	$.27^3$	$.26^3$	$.18^3$	—	—	—	—	—
4	.581	$.23^3$	$.23^3$	$.16^3$	$.15^3$	—	—	—	—
5	.591	$.20^3$	$.20^3$	$.15^3$	$.14^3$	$.12^3$	—	—	—
6	.596	$.21^3$	$.18^3$	$.16^3$	$.15^3$	$.13^3$	$-.08^2$	—	—
7	.603	$.18^3$	$.20^3$	$.14^3$	$.14^3$	$.13^3$	$-.12^3$	$.11^3$	—
8	.607	$.18^3$	$.19^3$	$.15^3$	$.14^3$	$.14^3$	$-.13^3$	$.10^3$	$.07^2$
2. a. »Phenotypic» intercorrelations among X's, traits Nos. 1—13 as X's:									
		X_{12}	X_5						
1	.578	$.58^3$	—	—	—	—	—	—	—
2	.596	$.56^3$	$.17^1$	—	—	—	—	—	—
2. b. »Phenotypic» intercorrelations among X's, traits Nos. 1—10 as X's:									
		X_9	X_1	X_5					
1	.472	$.48^3$	—	—	—	—	—	—	—
2	.498	$.56^3$	$-.20^1$	—	—	—	—	—	—
3	.512	$.52^3$	$-.28^2$	$.18^0$	—	—	—	—	—

Traits Nos. 1—3 and 12 considered as positive traits.
Significance of t-values: $3 = P < 0.001$; $2 = P < 0.01$; $1 = P < 0.05$; $0 = P < 0.2$

After elimination of traits Nos. 11 and 12 from the independent variables, traits Nos. 9 and 7 retained their position before the other traits, as can be seen in the second part of the table. The rank order of the remaining traits changed a little, however, and traits Nos. 1—3 were taken into account, too, although they did not increase the correlation noticeably.

From the practical point of view, the two owest parts of Table 7 are obviously the most important ones, since they show the predictability of the net income from the preceding year's results. One sees from the third part that the prediction based on feed conversion alone can be improved a little by taking egg weight into account, but that further improvement seems to be difficult. The fourth part shows that exclusion of the measurement of feed consumption and conversion impairs the judging accuracy decisively. Of the remaining measures hen-day egg mass appears to be the most important, and the other traits to be included in the model are body weight and egg weight. It thus appears that relatively few measurements are actually needed to predict the future economic value of stocks in R.S. tests. Unfortunately, however, the few necessary measures include the feed conversion, the measurement of which requires some extra labour and carefulness.

Feed conversion as a selection basis

The correlation analyses performed in the preceding paragraphs (subjective study of correlation matrices, factor analyses and regression analyses) as well as the repeatability estimates seem to speak in favour of the feed conversion instead of the net income as a basis of assesment in the Finnish Random Sample Test. Although the amount of data does not warrant far-reaching conclusions, it might be of interest to make a more practical trial on its usefulness as a selection criterion. This is possible with the same data as were used for the »genetic» correlation matrix in Table 4. The stocks which were represented in the test in two successive years were grouped into the better and poorer halves on the basis of both feed conversion and net income in one year, and the success of these groups in the other year was examined. All the four possible comparisons were made for both grouping bases, and the difference between the top and bottom groups in regard to each trait was computed in terms of percentages of the standard deviations of the same traits from Table 1. The signs of these differences were determined by the desirability of the difference as in Tables 4—7. The average results are shown graphically in Fig. 2.

Feed conversion appears to give the best differentiation between the groups with regard to most of the traits, including net income. The only trivial exception is body weight, and even this may be due to chance alone. Another

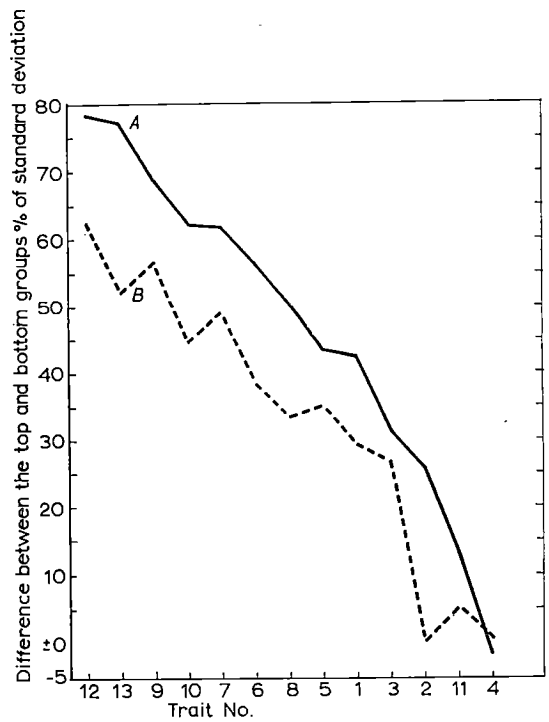

Fig. 2. The superiority of the better half as compared to the poorer half with regard to different traits in another year, when selection is based on the feed conversion (A) or on the net income (B) of one year.

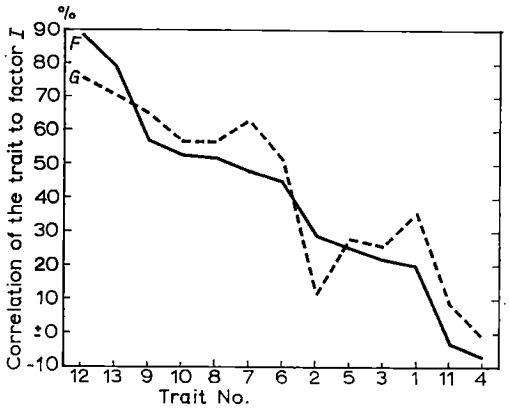

Fig. 3. The loadings of various traits in the first common factor of the rotated »genetic» (G) and »phenotypic» (F) factor matrices.

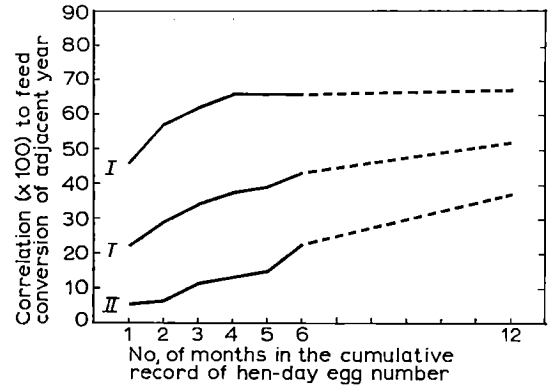

Fig. 4. Predictability of the feed conversion of one year from the cumulative monthly hen-day egg numbers of an adjacent test year (I = first pair of years, II = second pair of years, T = pooled results).

important feature is that the differences between the better and poorer halves were in the desired directions, excepting the small loss in body weight, when selection was based on feed conversion. As was to be seen from Table 4, this negative deviation is far from statistically significant. Thirdly, it is of interest to notice that the rank order of the differences in Fig. 2 is about the same as that of the rotated loadings of the first common factor in Table 5, shown graphically in Fig. 3.

On the other hand, it is of interest to know whether the yearly feed conversion could be predicted by part records of varying lengths. The cumulative monthly hen-day egg numbers of the first six months of each test year were available to elucidate this question. These were correlated to the feed conversion rates of the same stocks in adjacent years. The computations were performed in both possible directions. The results are shown in Fig. 4, separately for the two pairs of years and for the pooled estimates.

In the first pair of years the predictability was rather good from the very first month, then rising very rapidly and reaching practically its maximum as early as the end of the fourth month. In the latter pair of years the correlations rose very slowly, as was to be expected on the basis of the second column in Table 3. It thus becomes still more obvious that there had been a special disturbing factor in the test in the third year. For this reason, the curve showing the pooled results is not very encouraging. It may be added that in the latter pair of years the hen-day egg numbers of some individual months from February to June gave better predictions than the yearly record.

Discussion

The most important p r a c t i c a l result of the present study is obviously the demonstration of the usefulness of feed conversion as a measure of the economic value of egg-laying poultry stocks. Its essential advantage, as compared to net income, appears to be its lesser dependence on adult mortality, which, in the small samples of 50 birds tested in only one location, proved to be determined mainly by chance. Another favourable side is its independence of fluctuations in the market prices of both feeds and products, although it has to be admitted that the feed conversion rate may lose its value as an economic measure if the ratio between feed and product

prices changes essentially. To facilitate international comparisons of poultry stocks with regard to feed efficiency it might also be reasonable to express feed consumption in terms of digestible nutrients and proteins rather than in kilograms.

The low repeatability of mortality is in reasonable accord with some heritability estimates concerning viability (LUSH et al. 1948, ROBERTSON and LERNER 1949) and with the first results obtained from the Californian R.S. test (DICKERSON and LAMOREUX 1953). On the other hand, higher repeatabilities have been reported from more recent American tests (KING 1954, A.R.S. 1961, HILL and NORDSKOG 1956). The variations in the estimates are easy to understand, when account is taken of the great variation in the prevailing causes of deaths in different circumstances and the varying incidence levels. The main causes of death in the Finnish test may have changed from year to year, thus lowering the repeatability. For example, special mortality problems occurred in the third test year, when the chicks were reared on two different farms in equal numbers. At one farm 12.0 % died and 7.5 % had to be slaughtered because of sickness at the end of rearing, while the respective figures at the other farm were only 6.9 % and 2.7 %. The greatest known source of variance in this rearing mortality was the interaction between rearing farms and poultry stocks (2.68 % ***), while the differences between breeding farms accounted for 2.02 %**, between rearing farms 1.86 % *** and between stocks within breeding farms 1.70 % *** of the total variance. This variation in the rearing mortality seemed to affect the laying-time mortality, and, being due to a special cause, it lowered the correlations between the second and third tests. In view of the fact that variety x year interactions in mortality have been reported from other tests (e.g. HILL and NORDSKOG 1956), it seems questionable whether serious attention should be paid to the mortality figures before there is an essential increase of sample size and an extension of the test to different locations.

The low repeatability of mortality also explains the low estimates concerning the hen-housed measures of egg production as compared with the hen-day measures. It is true that the rank order was the reverse in the American tests, but even here the feed conversion had a higher repeatability than the net income, namely .48 vs. .35 (A.R.S. 1961). An exceptionally high repeatability (.68) for the hen-housed egg number has been obtained by DICKERSON and ABPLANALP (1956).

From the repeatability estimates it is possible to calculate the accuracy of judging on the basis of three years' averages, by using the formula $b = \frac{n\,r}{1 + (n-1)\,r}$, where n = the number of records (years) and r = the estimate of repeatability (LUSH 1945). When based on the pooled values of Table 3 these accuracies are 59, 0, 82, 85, 82, 82, 55, 80, 62, 79, 61, 32, 84, and 76 % for the traits studied. Thus the difference between feed conversion and net income is about 8 %-units.

It may appear curious to some readers that the »genetic» correlations of mortality to feed conversion are on at least the same level as those to net income. The most obvious explanation of this is the fact that dying hens often do not lay any eggs for a variable period preceding their death (HARRIS 1926, MAIJALA 1957). So they can be considered as »feed-thieves», lowering the feed efficiency of their groups. It can be further assumed that this would apply especially to such causes of death as the leucosis complex, which are known to be hereditary, while many accidental causes may lead to rather abrupt death.

It is difficult to find reports concerning the prediction of net income from various traits measured in previous tests. The studies of NORDSKOG (1960), CAWLEY et al. (1963) and ROBERTS & DELAND (1964) refer to the »phenotypic» relations within a certain test, and hence they overemphasize the importance of hen-housed egg yields and mortality in the determination of net income. The estimates of »genetic» determination obtained in the present

study seem to indicate that the only measurements needed in predicting future success would be feed conversion on a hen-day basis and egg weight. An exclusion of the measurement of feed consumption decreased the accuracy of prediction noticeably, but the results obtained by KING (1956) should encourage a new search for a good way of predicting feed consumption on the basis of egg production, egg weight and body weight.

The importance of body weight and egg weight may have been underestimated in the present study, because a linear correlation was assumed. No tests on linearity were performed, but ocular examination indicated no obvious deviation from linearity in the mutual dependence of egg weight and hen-day egg production.

It has to be admitted that there were too few data available to enable a final evaluation of the usefulness of feed conversion as an economic measure. Another reason for caution in drawing conclusions is the fact that it is not known how large a part of the similarity of successive samples from the same stock is due to similarity in prehatching environment. A covariance analysis performed on those groups which occurred in the tests in two successive years and of which there were at least two stocks representing the same breeder, showed that the repeatability of feed conversion was fairly evenly distributed among breeder differences and between stocks within breeders $r = 0.48$ vs. 0.35), while with regard to adult mortality the only positive covariance was between breeders ($r = 0.13$ vs. -0.19). Although there were only 23 pairs available representing 8 breeders, these results seem to indicate that the breeder differences in adult mortality are due to environmental differences, whereas the differences in feed conversion may be partly hereditary.

From the methodical viewpoint it is interesting to notice that about the same conclusions could be drawn from a simple grouping of variables or from a subjective study of correlation matrices as from more sophisticated analyses of correlation matrices. It thus appears that complicated multivariate analysis methods are not necessary in this type of study, although they may help in creating a clear picture of the interrelationships between various variables and safeguard the conclusions to be drawn from the simpler analyses. However, factor analysis, with a suitable rotation, seemed to be of special value in that it made it possible to extract the same results from a »phenotypic» correlation matrix as from the corresponding »genetic» one. If this were to apply to the real phenotypic and genetic correlations computed on the basis of individuals rather than groups, it would be valuable, because the phenotypic correlations are easier to estimate with reasonable accuracy.

On the basis of experience obtained in the present study, it appears that factor analysis may be useful in mapping out a network of intercorrelated traits concerning which there exists comparatively little previous knowledge and where it is not known which traits are essential in describing the whole network. In most situations concerning animal breeding problems, however, the economic value of the animals to be produced is a definite objective, and it is only a question of predicting this from the various observable characters of the animals available for selection. In these cases, the multiple regression methods applied over generations seem to be more likely to give the required answers, where both the heritabilities and the intercorrelations of the various traits are taken into account.

The grouping of the population into a few classes on the basis of various criteria and computing of the differences of these classes in standard values of different traits in the next sample or generation is obviously useful, not only for demonstration purposes but also for more scientific investigations.

Summary

Data from the first three years of the Finnish Random Sample Test were analysed in order to gain an impression of the reliability of these tests and to find the most useful measure of the economic value of egg-laying stocks. As a side-issue there was a comparison of methods of analysing correlations among traits. The intercorrelations among various traits within test years were called »phenotypic» correlations, while those computed from year to year were called »genetic» ones. The former values were based on $3 \times 40 = 120$ samples (à 50 pullets) and the latter on 41 pairs of samples, in which the correlations were computed in both directions.

A subjective study of the correlation matrices as well as the factor analyses, multiple regression analyses and a simple paper selection trial spoke in favour of feed conversion instead of net income as a measure of the future economic value of stocks. The main reason for this appeared to be the non-existent repeatability of adult mortality in the small samples, which also made the hen-housed measures of egg production less repeatable than the hen-day measures. The repeatabilities of feed conversion and net income were .63 and .52, respectively. On the »genetic» level, feed conversion was as much dependent on mortality as was net income.

A factor analysis with a rotation made it possible to extract the same results from a »phenotypic» correlation matrix as from the corresponding »genetic» one. A stepwise multiple regression analysis, where »phenotypic» intercorrelations among X's and »genetic» correlations between X's and Y were used, appeared to be useful for finding a practical selection index. The only trait which increased the prediction accuracy from that obtainable with feed conversion alone was egg weight, and even then the accuracy increased only from .58 to .60. The weights to be given to the standard values of feed conversion and egg weight in the corresponding equation were related as 3.3 to 1.

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SELOSTUS

Taloudellisten ominaisuuksien toistuvuuksista ja vuorosuhteista Kanatalouskoeasemalla

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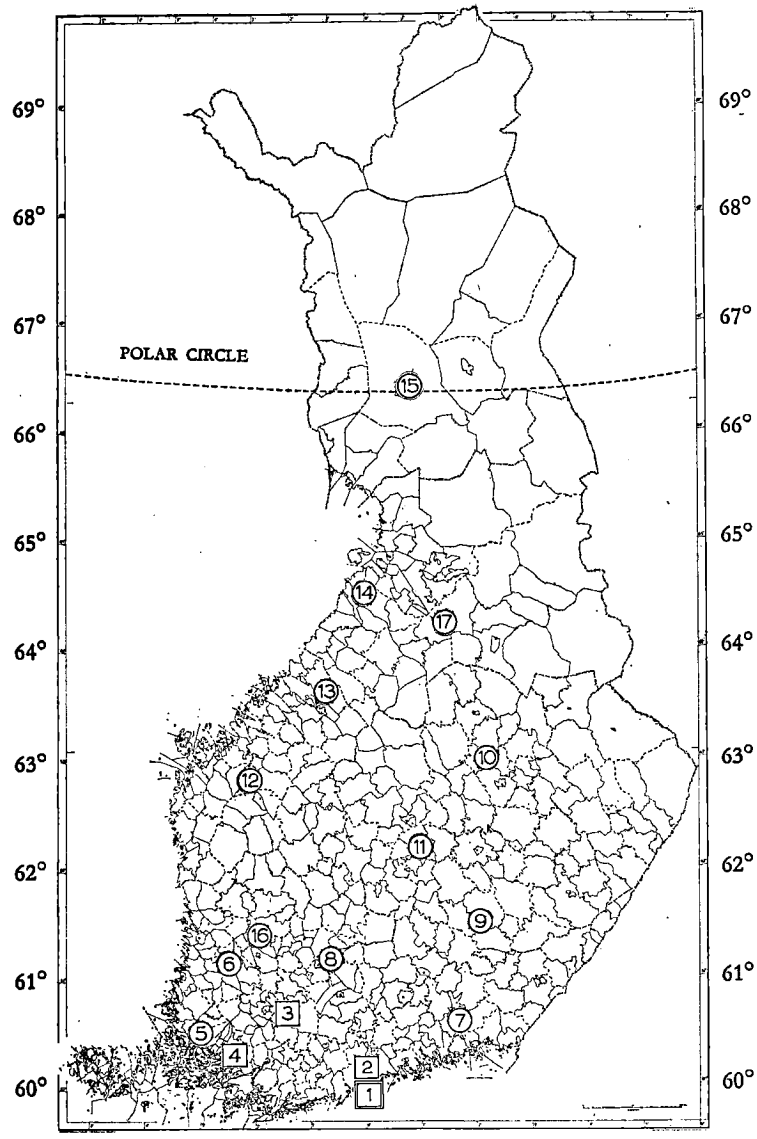
Siipikarjanhoitajain Liiton v. 1962 Urjalaan perustaman Kanatalouskoeaseman kolmen ensimmäisen vuoden kokeiden tuloksia analysoitiin näiden kokeiden luotettavuuden arvioimiseksi sekä sopivimman mitan löytämiseksi kanakantojen taloudellisuuden arvostelua varten. Tutkimuksen sivutarkoituksena oli eräiden menetelmien vertailu ominaisuuksien välisiä vuorosuhteita tutkittaessa. Eri ominaisuuksien välisiä vuosien sisäisiä vuorosuhteita kutsuttiin »fenotyyppisiksi», kun taas eri vuosina mitattujen ominaisuuksien välisiä vuorosuhteita kutsuttiin »perinnöllisiksi». Edelliset arvot perustuivat 3 × 40 = 120 eläinnäytteeseen (à 50 nuorikkoa) ja jälkimmäiset 41 näytepariin, joissa vuorosuhteet oli laskettu molempiin mahdollisiin suuntiin.

Sekä vuorosuhteiden silmävarainen tarkastelu että niiden nojalla suoritetut faktori- ja regressioanalyysit samoin kuin yksinkertainen ryhmittelykin antoivat tulokseksi, että kanakantojen taloudellisen arvon mitaksi sopisi paremmin rehuhyötysuhde (rehunkulutus kg/muna-kg) kuin markkamääräinen nettotulo. Pääasiallisena syynä tähän tulokseen näytti olevan munintakauden kuolleisuuden sattumanvaraisuus koeaseman pienissä eläinnäytteissä. Nettotulo oli nimittäin enemmän kuin rehuhyötysuhde riippuvainen tästä kuolleisuudesta. Sa-

masta syystä olivat kokeen alussa ollutta kanaa kohti lasketut munatuotokset sattumanvaraisempia kuin ruokintapäivää kohti lasketut. Rehuhyötysuhteesta voitiin seuraavan vuoden nettotulo ennustaa 58 %:n varmuudella, kun itse nettotulo antoi vain 52 %:n varmuuden. Rehuhyötysuhteen oma toistuvuus oli n. 63 %. »Perinnöllisellä» tasolla oli kuolleisuuden vaikutus rehuhyötysuhteeseen vähintään yhtä suuri kuin nettotuloonkin.

Faktorianalyysi sopivan rotaation kera teki mahdolliseksi johtaa »fenotyyppisestä» vuorosuhdematriisista suunnilleen samat tulokset kuin »perinnöllisestäkin» matriisista, vaikka nämä matriisit sellaisenaan olivat huomattavasti toisistaan poikkeavia. Asteittainen kerrannaisregressioanalyysi, jossa selittävien muuntelijoiden välisinä vuorosuhteina käytettiin »fenotyyppisiä» kertoimia sekä selittäjien ja selitettävän muuntelijan välisinä vuorosuhteina »perinnöllisiä» arvoja, näytti käyttökelpoiselta menetelmältä käytännöllisen valintaindeksin etsimisessä. Ainoa piirre, joka pystyi lisäämään rehuhyötysuhteen avulla yksistään saavutettavaa ennustusvarmuutta, oli munien paino, ja tällöinkin nousi varmuus vain 58 %:sta 60 %:iin. Rehuhyötysuhteen ja munien painon standardiarvoille annettavat painot olivat vastaavassa yhtälössä toisiinsa suhteessa 3.3 :1.



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