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Selection for resistance to coffee berry disease in arabica coffee in Ethiopia. Evaluation of selection methods

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Abstract

Seedling tests and field inoculations used to measure levels of resistance to coffee berry disease (CBD) in visually selected trees are evaluated against disease levels under natural conditions (field score).

A scale for disease levels in the field is provided. The seedling test is improved to make it amenable for statistical analysis.

Generalized results for field score and both test methods are given together with the relationships between the tests and field scores and among the tests themselves.

A difference in seedling and field resistance to the disease was observed. Results of other tests to study this difference, together with the quantitative nature of the results obtained in the tests, support the hypothesis that the resistance is of a horizontal nature.

The results of the application of selection criteria based on the correlations between seedling tests, field inoculations and field score are given together with their evaluation after one year. It is concluded that visual selection combined with seedling tests and field inoculations is highly effective in identifying that part of the arabica coffee population with a high level of resistance to CBD.

Introduction

Ethiopia is the primary gene centre for arabica coffee (*Coffea arabica* L.) (Zeven and Zhukovsky, 1975) and coffee is the main agricultural export product of that country. The species is partly growing under semi-wild conditions and is partly grown by small holders. Under these conditions, pest and disease problems were always of minor importance. In 1971 this situation changed drastically with the discovery of coffee berry disease (CBD) in Ethiopia (Anonymous, 1972). Reported first from Kenya (McDonald, 1926), the disease spread gradually throughout East Africa. In Ethiopia it spread rapidly through the main coffee growing areas of the south-western provinces. In certain areas high losses with nearly total crop destruction resulted.

Coffee berry disease is a typical anthracnose, attacking and destroying green coffee berries. The fungus, *Colletotrichum coffeanum* Noack sensu Hindorf, (Hindorf, 1973), lives on the maturing bark of coffee trees (Nutman and Roberts, 1960) probably as a micro-epiphyte (Robinson, 1976). When green berries are infected, a purplish brown lesion can develop and ultimately the whole berry might be destroyed. Conidia of the fungus are water borne and splash distributed. Susceptibility of the berries depends on their development and is highest at the expanding and ripening stages (Mulinge, 1970; Mogk, 1973). At ripening stage the bean is no longer destroyed and the disease is of low economic importance.

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Due to the age-old coffee growing system in Ethiopia, there is a large genetic variation among individual trees, even at a single farm. Although the population as a whole is susceptible to the disease, among trees there may be a variation from highly susceptible to highly resistant. Robinson (1974, 1976) started a program in 1973 to select highly resistant trees in areas heavily affected by the disease. On the basis of circumstantial evidence he concluded that the resistance is of a horizontal nature. The present author joined the program in 1974 and assumed full responsibility in 1975. Up to 1976, 650 trees had been selected visually in various severely affected areas of the country. They were propagated immediately after selection by the coffee agronomy section of Jimma Research Station. To facilitate an early decision on planting of seedlings, the mother trees were tested while seedlings were still growing in the nurseries. This paper describes the tests used to measure the level of resistance of visually selected trees and evaluates them.

Material and methods

The field work was conducted in two different areas: Jimma and Gera.
The Jimma Research Station is located 7°46′N and 36°E. Its altitude is 1730 m, with an average yearly rainfall of 1535 mm. Here the disease is of medium severity. The work at the station was conducted on coffee trees planted in 1968 from seeds collected in Ethiopia by a French coffee mission during 1966, and on trees of a few other Ethiopian collections and of some introduced coffee lines. The material collected from Ethiopia consists of single tree progenies (lines). A number of trees showing a wide variation in disease levels in 1975 were chosen for testing.

Gera is an area where the disease is severe. It is located 40 km west-north-west of Jimma. Its altitude is between 1800–1900 m with an average yearly rainfall probably over 1800 mm. Coffee trees without the disease were selected in 1975 from a plantation of 280 hectares belonging to the Institute of Agricultural Research.

Preparation and sources of inoculum used in the tests. 'Natural inoculum' was obtained from infected berries collected in the field, washed with distilled water and incubated over-night in a damp atmosphere in a closed container. Thereafter a conidial suspension was prepared by washing the berries in distilled water. Inoculum was also prepared from cultures of *C. coffeanum* actively growing on 2% malt extract agar (7–15 days old). Before each experiment the fungus was grown on detached green coffee berries to ensure maximal pathogenicity, reisolated and recultured, with the number of transfers after reisolation limited to three. Conidial suspensions were prepared in distilled water and concentrations measured with a haemocytometer.

Isolates used were: standard (isolated September 1975 from the Harrar plot at Jimma Research Station); Sidamo (isolated March 1976 from Wondo Genet.); F 58 (isolated June 1976 from tree 8/105, line F 58 from the French collection, Jimma Research Station).

Observations on natural infection (Field score). Trees used in the tests were scored for percentage of berries infected with the disease in October 1975 (Jimma), October 1976 (Jimma and Gera) and August 1977 (Gera). Scoring was according to the disease classes of Table 1. As the epidemic on an individual tree will be a compound interest

Table 1. Disease classes for CBD assessment of individual trees in the field (Field score classes).

Disease class	Percentage of infected berries
0	0
1	$0 < x \leqslant 1$
2	$1 < x \leqslant 10$
3	$10 < x \leqslant 50$
4	$50 < x \leqslant 90$
5	$90 < x \leqslant 99$
6	$99 < x \leqslant 100$

Tabel 1. Ziekteklassen gebruikt voor classificatie van aantasting van individuele bomen door koffiebesziekte in het veld (Veldbeoordelingsklassen).

disease this scale is based on the values of $\log_{10} x/1\text{-}x$.

In 1976, 19 trees were chosen at random from the selected trees at Gera. Around each of these trees four rows of ten trees were scored to assess variation of disease damage in the area. In 1977 this procedure was repeated for areas around 15 trees.

For Jimma, being an intermediate disease area, the highest field score obtained in two consecutive years was used for calculation of correlation with the tests. For Gera the field score of 1976 was used.

Field inoculation. Branches of trees to be tested were marked and the number of berries per branch recorded. These berries were sprayed, by means of an insecticide handsprayer, with 'natural inoculum' with a conidial concentration of 2×10^6. Each branch was then kept in a plastic 'sleeve' overnight to retain sufficient moisture for infection (Nutman and Roberts, 1960). The plastic sleeve was covered with paper to avoid high temperatures due to isolation. Each inoculation was replicated three times at Jimma and four times at Gera. Records were taken after three weeks. Inoculations were made during berry expansion when the berries were most susceptible (Mulinge, 1970; Mogk, 1973). In Gera, trees chosen randomly in the vicinity of selected trees were inoculated as controls. The treatment was repeated three times at three week intervals.

Seedling test. This test has been used for two experiments, a main selection experiment in which the standard isolate inoculum was used and a second experiment in which individual trees were tested against the three isolates and the 'natural inoculum'.

The test was an adaptation to local requirements from the one used at Ruiru Coffee Research Station, Kenya (Van der Vossen et al., 1976). The parchment was removed from 100 seeds obtained from a single coffee tree and the seeds were sown in heat sterilized wet sand in a plastic box. Seedlings were inoculated before or just after unfolding of cotyledons. Prior to inoculation boxes were closed for 48 hours to precondition seedlings at 100% relative humidity. Seedlings were sprayed with a suspension of 2×10^6 conidia per ml, maintained at 100% relative humidity for 48 hours, reinoculated and kept again under the same conditions for an additional 48 hours. The main selection experiment was replicated three, but in a few cases two times and the second experiment was replicated twice. Seedlings were scored three

weeks after inoculation using a scale developed by Cook (Van der Vossen et al., 1976). For statistical analysis, the scale had to be changed to obtain additivity in the results. This was done on the assumption that the individual scores within a test of genetically homozygous material are binominally distributed. Arabica coffee is an inbreeder with a low percentage of cross pollination (Person, 1974; Van der Vossen, 1973) and in most cases genetic variation between seedlings from the same mother tree should be low. Classes 2 + 3 and classes 5 to 11 were taken together leaving an assessment scale with 5 classes. P of the observed distribution in each test was calculated, angularly transformed and, for statistical analysis, treated as a normally distributed variate. The method was checked for 83 tests of individual trees by comparing the angular transformation of the observed proportion of seedlings with no symptoms with the angular transformation of that proportion expected from the distribution with the observed P. The correlation coefficient between observed and expected values was 0.957. A slight under-estimation of the proportion with no symptoms over the whole range of tests was observed.

Results of the tests in the main experiment were grouped according to the date of inoculation. Results of each of the two varieties used as a standard per 'inoculation date' were added and for each of those varieties P was calculated per 'inoculation date' and angularly transformed. The mean of the two varieties varied considerably between 'inoculation dates'. Results of tests for each date were corrected using the means obtained from the standard varieties per 'inoculation date'.

The second experiment was made during the main rainy season when climatological circumstances vary little. No correction was needed in this experiment.

Detached berry test. Berries at the hard green stage were picked and surface-sterilized by commercial laundry bleach (5.25% hypochlorite, 1 : 5) for five minutes, washed in sterile water and put on heat-sterilized damp sand in plastic boxes. Berries were inoculated with a drop of a suspension containing 250 000 conidia per ml. Berries from a number of coffee lines were tested with the three isolates and the 'natural inoculum'. Each test consisted of 50 berries and was replicated three times. Boxes were kept closed after inoculation to maintain the high relative humidity needed for infection. Numbers of diseased berries were recorded 10 days after inoculation.

Results

Assessment of levels of natural infection (Field score). Field scores for individual trees varied from no infection to complete loss. Among the 19 areas scored at Gera in 1976 statistically significant differences were found. Disease frequencies based on observations in these 19 areas and disease frequencies in the group of selected trees in 1976, one year after initial selection on the basis of field score, are presented in Table 2.

Field inoculations. Results of three consecutive inoculations at Gera and two consecutive inoculations at Jimma[2] showed that under circumstances highly favourable for infection as existing under artificial inoculation, it was possible to obtain disease

[2] A number of highly susceptible trees in Jimma could not be used any more at the third inoculation.

Table 2. Distribution of CBD over individual trees in Gera in 1976, one year after initial selection, indicated as percentage of trees of the unselected population or visually selected trees per field score class.

Field score class	0	1	2	3	4	5	6
Unselected population (%)	2	16	21	26	30	5	0.4
Visually selected trees (%)	39	34	20	5	2	–	–

Tabel 2. Verdeling van koffiebesziekte over individuele bomen in Gera in 1976, een jaar na de oorspronkelijke selectie. Aantal bomen per veld beoordelingsklasse als percentage van het totale aantal bomen van de ongeselecteerde of van de geselecteerde bomen die beoordeeld werden.

on all inoculated trees. Statistically significant differences between trees as a result of a given inoculation were present. Significant interactions between dates of inoculation and trees showed that susceptibility of the berries of a tree varied with inoculation date and that the date of maximum susceptibility varied among trees.

Based on these results it was concluded that the highest mean value of the consecutive inoculations had to be used for further analysis.

The relation between field inoculations and field score is given in Table 3. Means per field score class were compared by t-tests with pooled s^2 of the two means that were under comparison. From Table 3 it can be concluded that there is a good correlation between field score and field inoculation.

Table 3. Relation between the results of field scores and field inoculations for Jimma and the selected trees at Gera. The mean result of field inoculations at Gera for randomly chosen control trees is included. Values marked with the same letter do not differ significantly at the 5% level.

Field score class	Jimma		Gera	
	number of trees tested	mean field inoculation	number of trees tested	mean field inoculation
0	10	34 a	33	38 a
1	6	40 a	27	43 ab
>1	17	67 b	18	48 b
control trees			22	73 c

Tabel 3. Relatie tussen veldbeoordeling en veldinoculatie te Jimma en voor de geselecteerde bomen te Gera. Het resultaat van de veldinoculaties op willekeurig gekozen bomen te Gera is ook gegeven. Waarden gemerkt met dezelfde letter verschillen statistisch niet significant op het 5% niveau.

Seedling tests. In the main selection experiment mean score values of trees varied between 2.1 and 49.9. Differences between seedlings obtained from the different trees were highly significant.

The relation between the seedling test and the field score is given in Table 4. Means per field score level and significance between means at the 5% level are shown. Means were tested by t-tests with unequal variances according to Cochran (In: Snedecor and Cochran, 1967). Table 4 suggests that there is a correlation between seedling test and field score. It was observed that trees scoring low in the seedling test were relatively common among trees with a field score higher than 1. Therefore, a linear relation between seedling test and field inoculation was unlikely. The correlation coefficients between them were not significant (Table 7).

Table 4. Relation between field score and seedling test. Values marked with the same letter do not differ significantly at the 5% level.

Field score class	Jimma		Gera	
	number of trees tested	mean seedling test	number of trees tested	mean seedling test
0	15	14.9 a	31	16.0 a
1	9	19.6 ab	28	21.0 b
>1	26	23.5 b	24	20.8 b

Tabel 4. Relatie tussen veldbeoordeling en zaailingentoets. Waarden gemerkt met dezelfde letter verschillen niet significant op het 5% niveau.

Table 5. Seedling tests with different sources of inoculum: Means of seedling tests, ranking of outcomes per inoculum (between brackets), analysis of variance and Least Significant Differences (L.S.D).

Coffee trees	Sources of inoculum				Mean with Sidamo	Mean without Sidamo
	F 58	Standard	Sidamo	natural inoculum		
4/5	18.0 (1)	25.1 (1)	26.2 (2)	40.1 (2)	27.8	28.4
8/78 (S952)	22.9 (2)	28.4 (2)	21.9 (1)	38.1 (1)	27.8	29.8
7466	38.1 (5)	31.3 (3)	51.9 (4)	41.3 (3)	40.6	36.9
7429	36.0 (3)	36.3 (4)	38.1 (3)	46.2 (4)	39.1	39.5
6/331 (F 58)	41.2 (5/6)[1]	35.0 (3/4)[1]	–	59.6 (5/6)[1]	–	45.3
6/407 (F 60)	38.0 (4)	47.1 (5)	56.1 (5)	58.8 (5)	50.0	47.9
7587	56.2 (6)	61.2 (6)	57.8 (6)	77.1 (7)	63.1	64.9
Unknown	70.5 (7)	71.7 (7)	73.0 (7)	64.9 (6)	70.0	69.0
Mean – 6/331	39.9	43.3	46.2	52.3	–	–
Mean + 6/331	40.1	42.3	–	53.3		

Analysis of variance:	D.F.	F.
Coffee trees	6 (7)[1]	39.0** (19.1**)
Sources of inoculum	3 (2)	7.0** (11.2**)
Interactions	18 (14)	1.4 (1.0)
Error	28 (24)	

L.S.D.'s	5%	1%
Coffee trees	7.6 (10.0)[1]	10.3 (13.6)
Sources of inoculum	5.8 (6.1)	7.7 (8.3)
Within table	15.3 (17.4)	20.5 (23.6)

[1] From tree number 6/331 (line F 58) not enough seed was available to perform the tests with the Sidamo isolate. In ranking in the main table the figures for 6/331 are given as those between which they score. The analysis of variance and the L.S.D.'s are given without 6/331 with Sidamo isolate and (in brackets) without Sidamo isolate with 6/331. *Niet voldoende zaad van boomnummer 6/331 (Lijn F 58) was beschikbaar om de testen met het Sidamo-isolaat uit te voeren. In de rangvolgorde zijn de waarden van 6/331 gegeven als rangen waartussen de uitkomst ligt. De variantie-analyse en de waarden van de L.S.D.'s zijn gegeven zonder 6/331 met het Sidamo-isolaat en met 6/331 zonder het Sidamo-isolaat (tussen haakjes).*

Tabel 5. Zaailingentoetsen met verschillende isolaties. Gemiddelden van zaailingentoetsen, rangnummer van de uitkomsten (tussen haakjes), variantie-analyse en kleinste significante verschil (L.S.D.).

Seedling tests with different sources of inoculum. Results and statistical analysis are given in Table 5. Unfortunately not enough seed from line F 58 tree 6/331 was available to perform all tests. Therefore 6/331 was not tested against Sidamo isolate. A statistical analysis was conducted with Sidamo isolate without 6/331 and without Sidamo isolate with 6/331. Differences between sources of inoculum and between individual trees were highly significant, but the interactions were not significant. To show the lack of interactions, the individual trees were also ranked in Table 5 for disease severity according to sources of inoculum. Line F 58 was one in which there was a poor correlation between seedling test and field score. Tree 6/331 did not react differently when tested against the isolate obtained from its line.

Table 6. Detached berry tests: means of angular transformations of percentages of disease, ranking of outcome per inoculum (between brackets), analysis of variance and Least Significant Differences (L.S.D.).

Coffee lines	Sources of inoculum				
	Standard	F 58	Sidamo	natural inoculum	mean
S 952	29.3 (1)	34.3 (1)	35.2 (1)	44.1 (3)	36.9
4/5	36.2 (2)	40.8 (3)	38.8 (2)	40.3 (2)	39.0
F 60	37.5 (3)	40.8 (2)	41.5 (3)	39.6 (1)	39.8
F 59	41.2 (4)	43.5 (5)	53.5 (5)	49.2 (5)	46.8
69/70	42.7 (5)	42.7 (4)	51.0 (4)	53.6 (6)	47.5
F 54	53.2 (6)	59.0 (7)	60.7 (6)	47.4 (4)	55.1
F 58	65.8 (8)	52.5 (6)	64.0 (7)	66.8 (8)	62.3
F 18	63.2 (7)	70.1 (8)	72.5 (8)	63.5 (7)	67.3
Mean	46.1	48.0	53.6	50.5	–

Analysis of variance:	D.F.	F.
Coffee lines	7	20.64**
Sources of inoculum	3	4.66**
Interactions	21	1.23
Error	64	

L.S.D.'s	5%	1%
Coffee lines	6.0	8.0
Sources of inoculum	4.3	5.7
Within table	12.0	16.0

Tabel 6. Experimenten met afgeplukte bessen: Gemiddelde van angulaire transformaties van ziekteprercentages, rangnummers van de uitkomsten (tussen haakjes), variantie-analyse en kleinste significante verschillen.

Detached berry tests. An experiment comparable to the testing of sources of inoculum against seedlings from individual coffee trees was made by means of detached berry tests. Individual coffee lines were tested against sources of inoculum. Results and statistical analysis are shown in Table 6. Differences between sources of inoculum and coffee lines were highly significant. Interactions were not significant. The disease severity ranking for coffee lines is also given in Table 6 as a further illustration of the lack of interactions. Line F 58 did not react differently with its own isolate.

Discussion

Artificial tests for the selection of resistant material must represent its behaviour in

the field. The results of field inoculations showed a clear correlation with the natural infection observed. This can be explained partly by the fact that environmental conditions had the same influence on field inoculations as on natural infection. The greater part of the variation among field inoculations in a certain area was not due to environmental conditions since control trees in the direct vicinity of trees selected for resistance scored completely differently (Table 3).

In the seedling test it was observed that trees with a high score were relatively rare amongst trees with no disease under field circumstances, but trees with low scores in the seedling tests were relatively common among trees with more than 1% disease in the field. This was probably the reason for the absence of a simple correlation between field inoculations and seedling tests. The existence of a group of trees with a high level of susceptibility in the field but a low score in the seedling test suggests a more complex relation between seedling test and field inoculation. The material tested can be divided into two subgroups, one consisting of trees with a field score of 0 and 1 and a second comprising trees with a field score higher than 1. The first group will include only a minimal number of trees scoring low in the seedling test in spite of high susceptibility. In this group a correlation between seedling test and field inoculation can be expected. The second sub-group will consist of material that shows a correlation between seedling tests and field inoculations and material in which there is no correlation at all. Correlation coefficients between seedling tests and field inoculations were calculated for both sub-groups and compared with the overall correlation coefficients (Table 7). These coefficients were, as expected, only significant in the sub-group with field score 0 and 1. It is interesting that the correlation coefficient for this sub-group is better in Jimma than in Gera material. This may be due to microclimatical differences; Gera is a large farm with varying disease conditions whilst the collections in Jimma are located on two terraces facing the same direction.

Tests as reported here have also been made by Van der Vossen et al. (1976). They found a good correlation between seedling test (hypocotyl test) and maximum field score, a combination of field inoculation and natural level of infection. In only two cases did a variety show a higher susceptibility in the field than expected from the seedling test. However, the validity of the correlation coefficients they found is questionable. The distribution of results in the seedling tests used for their calculations is bimodal which is probably due to a scaling effect. The standard error within the seedling tests probably varied with the mean grade found (see Figure 2 in their publication). Both these phenomena give an upward bias to the correlation coefficient found and render it impossible to compare their results directly with results presented here.

The discrepancy observed between the results of seedling tests and field inoculations and field score could be due to differences in sources of inoculum used. In the main experiment of the seedling test only one isolate was used while in the field inoculation and also under natural circumstances inoculum was derived from many sources. A weak vertical gene (Van der Plank, 1968) present in the mixed natural pathogen population might have been absent from the isolate used in the seedling test. Only main effects and no interactions could be found in seedling tests and detached berry tests where host genotypes were tested by means of three isolates and the 'natural inoculum' (Table 5 and 6). One of the genotypes with an abberent

Table 7. Correlation coefficients between field inoculations and seedling tests.

Field score class	Jimma		Gera	
	r	degrees of freedom	r	degrees of freedom
0 and 1	0.635**	14	0.368*	44
>1	−0.155	15	−0.323	13
Total	0.256	31	0.241	59

Tabel 7. Correlatiecoëfficiënten tussen veldinoculaties en zaailingentoetsen.

reaction was tested with its own isolate. It is concluded that the resistance expressed in the seedling stage is part of the resistance of the berry but that, at least in a number of cases, additional factors are needed.

The lack of interactions in experiments, in which the reaction of host genotypes was tested by means of different sources of inoculum, and the quantitative results in all tests are strong indications for the horizontal nature of the resistance to the disease (Van der Plank, 1968). This makes long term control of the disease with resistant varieties possible.

Table 8. Trees that pass the respective tests as percentage of trees tested per field score class.

Field score class	0	1	>1
1. Seedling test (%)	62	45	33
2. Field inoculations (%)	77	60	27
3. Seedling + Field (%)	58	40	7

Tabel 8. Bomen die voldeden in de respectievelijke toetsen als percentage van het totale aantal getoetste bomen in die klasse.

Table 9. Evaluation of selection and testing procedures. Distribution of the disease at Gera in 1977 over individual trees of the unselected population (15 areas), visually selected trees (sub-population 1) and trees of this sub-population that passed the tests (sub-population 2). Numbers of trees per field score class as percentage of total number of trees scored in the population or sub-population.

Field score class	0	1	2	3	4	5	6
Unselected population	3	2	12	19	29	14	21
Sub-population 1	56	21	16	5	2	–	–
Sub-population 2	68	26	5	–	–	–	–

Tabel 9. Beoordeling van de selectie- en toetsprocedures. Verdeling van de ziekte in 1977 te Gera over individuele bomen van de ongeselecteerde populatie, visueel geselecteerde bomen (subpopulatie 1) en bomen van deze subpopulatie die in de toetsen voldeden (subpopulatie 2). Aantallen bomen per veldbeoordelingsklasse als percentage van het totale aantal bomen dat beoordeeld werd in de populatie of subpopulatie.

The practical application of the test results is shown for the Gera area. Selection criteria were established on the basis of field performance in 1976 of the visually selected trees tested. The combination of field inoculation and seedling test resulted in a very sharp drop in percentage of trees that passed the tests but scored in the field in classes with more than 1% disease (Table 8). Most of the susceptible trees with a low score in the seedling test were eliminated by the field inoculation test.

The effect of the application of the selecting and testing procedures was evaluated one year later. Results are shown in Table 9. Figures from Table 9 and Table 2

show that the visual selection produced a sub-population with a dramatically lower disease incidence than the original unselected population. Losses to CBD would already be very low if the coffee population consisted of a mixture of this planting material. It is impossible, however, to isolate from this sub-population individual resistant lines without further testing of parents and progenies. The combination of seedling test (a test not biased by environmental conditions) and field inoculation allows strict selection within the sub-population of visually selected trees. In this way a second sub-population is created which, in comparison with the first one, shows a considerably reduced number of susceptible individuals. It is concluded that the selection and testing program has been very successful in identifying the part of an arabica coffee population with a high level of resistance to coffee berry disease.

Samenvatting

Resistentieselectie tegen koffiebesziekte in arabica koffie in Ethiopië. Toetsmethoden en hun praktische waarde

Twee toetsmethoden, te weten inoculatie van respectievelijk zaailingen en van in het veld staande bomen, werden beoordeeld op hun waarde voor verificatie van resistentie tegen koffiebesziekte in arabica koffie.

Voor ziektewaarneming in het veld (veldbeoordeling) werd een schaal ontwikkeld (Tabel 1). De zaailingentoets (Van der Vossen et al., 1976) werd ten behoeve van statistische verwerkbaarheid gewijzigd.

Toetsen en veldbeoordelingen werden uitgevoerd op bomen met een ver uiteenlopende gevoeligheid (Jimma) en bomen die visueel geselecteerd waren voor resistentie tegen koffiebesziekte (Gera). In Gera werden bovendien in de veldinoculatie een aantal niet geselecteerde bomen getoetst en werd de ziekte over de ongeselecteerde populatie beoordeeld. In Tabel 2 zijn de veldbeoordeling van ongeselecteerde en geselecteerde koffie met elkaar vergeleken.

Aan de hand van de veldbeoordelingen en de resultaten van toetsen werden de volgende relaties opgesteld: veldinoculaties en veldbeoordeling (Tabel 3); zaailingentoets en veldbeoordeling (Tabel 4) en zaailingentoets en veldinoculatie.

De in de zaailingentoets waargenomen resistenties waren niet altijd direct gecorreleerd met de resistentieniveaus waargenomen bij natuurlijke infectie en na veldinoculaties. Of deze discrepantie veroorzaakt werd door het in de zaailingentoetsen gebruikte isolaat werd nader onderzocht. In zaailingentoetsen en toetsen met afgeplukte bessen werd de aantasting van een aantal genotypen door drie isolaten en inoculum verkregen van natuurlijk geïnfecteerde bessen, vergeleken (Tabel 5 en 6). In beide gevallen waren hoofdeffecten hoog significant. Interacties waren daarentegen niet aantoonbaar.

De relatie tussen de resistentie in het zaailingenstadium en die in het veld, kon beschreven worden door het materiaal te splitsen in twee groepen. In de eerste groep was een directe correlatie aanwezig terwijl deze in de tweede groep ontbrak (Tabel 7).

Het kwantitatieve karakter van de resultaten van de toetsen en de veldbeoordelingen samen met het ontbreken van interacties tussen inocula en koffiegenotypen wordt beschouwd als een zeer sterke aanwijzing voor het horizontale karakter van de resistentie.

Aan de hand van de relatie tussen veldbeoordelingen en de toetsen werden selectiecriteria bepaald. Het resultaat van de toepassing van deze criteria op de visueel geselecteerde bomen in Gera is gegeven in Tabel 8.

Na een jaar werd aan de hand van nieuwe ziektewaarnémingen in het veld, de selectieprocedure beoordeeld (Tabel 9). De conclusie wordt getrokken dat een combinatie van visuele selectie in het veld, zaailingentoetsen en veldinoculaties zeer effectief is om dat gedeelte van een arabica koffiepopulatie op te sporen dat een hoog niveau van resistentie tegen koffiebesziekte bezit.

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