Genetic Study on Post-Harvest Root Deterioration in Cassava[1]

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ABSTRACT

Post-harvest root deterioration (vascular streaking) of cassava *(Manihot esculenta* Crantz) clones (accessions and breeding lines) was evaluated with harvests from different ages, seasons and locations to assess the effect of environmental factors on cassava genotypes. Vascular streaking was sensitive to any of these environmental factors. Genotype x location interaction was highly significant suggesting that final cultivar selection should be carried out in each location.

Genetic analysis carried out in one location suggested that inheritance of vascular streaking was, at least partly, controlled by additive factors and quantitative rather than qualitative. Narrow sense heritability of 0.64 was obtained. Vascular streaking was highly significantly correlated with root dry matter content in all the trials conducted during seven years.

Since free recombination between resistance to vascular streaking and high root dry matter content may not be possible, the most acceptable balance between these two traits should be defined according to the use of product and edafo-climatic condition of production area prior to selection program.

INTRODUCTION

Cassava *(Manihot esculenta* Crantz) is one of the basic crops in the lowland tropics. The potential of this crop as an efficient calorie producer has long been recognized and has recently drawn wide attention (de Vries et al, 1967; Martin, 1970; Nestel and Cock, 1976; Nojima and Hirose, 1977). The high productivity under a wide range of environmental conditions and the vast potential of genetic improvement of the crop have been demonstrated (CIAT, 1974, 1975, 1976, Kawano et al 1978).

One of the factors limiting the usefulness of cassava is post-harvest root perishability. Post-harvest root deterioration consists of primary and the later secondary deteriorations (Booth, 1976; CIAT, 1976; Lozano et al, 1978). The primary deterioration can appear within 2 days after harvest taking a shape of vascular streaking. Vascular streaking is divided into two types which appear to occur independently (Taniguchi, 1982). The first type is characterized by discoloring into gray-brown of soft tissues inside cortex which appears in a ring shape and the second one is characterized by blue-black lines along xylem vessel (Hirose, 1982). The first type seems to be independent of microbial activity while the second type appears to be related to microbial activity. The first type tends to appear more when the roots are not damaged by harvest and the second type appears more when the roots are much damaged.

Secondary deterioration, which is microbial and can also produce similar blue-black vessel pigmentation (but without any pattern) and leads eventually to a general and complete root decay, occurs 5 days or more after harvest. Most roots become unacceptable for fresh human consumption when vascular streaking appears (Wheatley, 1982). Roots become totally unaccep-

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table for any use when secondary deterioration takes place. Varietal resistance to post-harvest root deterioration has been reported (Montaldo, 1973; CIAT, 1976; Marriott, 1979).

It is this rapid root perishability after harvest which has prevented cassava from becoming a highly commercialized crop for human consumption and which also imposes difficulty for large scale industrialization of the crop for both animal feeding and other industrial uses.

We observed post-harvest root deterioration of cassava clones under different environmental conditions and its genetic behavior. The objective of this article was to study nature of post-harvest root deterioration and to assess the possibility of selection for less deterioration.

MATERIALS AND METHODS

Experiment sites

CIAT Experiment Station is located in the medium altitude plateau (Department of Valle) of Colombia. The climate in Valle is characterized by two short dry seasons with relatively well distributed rainfall. The soils are generally fertile. Carimagua Experiment Station of Instituto Colombiano Agropecuario (ICA) and CIAT is located in the middle of the Llanos Orientales (Dept. of Meta), Colombia. The soils are extremely poor and the climate is characterized by pronounced dry and wet seasons. Caribia Experiment Station of ICA is located on the northern coast of (Dept. of Magdalena) Colombia. The soils are medium to high in fertility and the climate is characterized by a long dry season and a wet season. Detailed climatic and edaphic data for these three locations are presented elsewhere (Kawano et al, 1978). In general, CIAT, Carimagua and Caribia represent high, low and medium yielding environments for cassava production, respectively. All the field experiments except for a genotype x environment experiment were carried out at the CIAT station.

Planting of genotype x environment experiment

Eight cassava clones (germplasm accessions and breeding lines) with different growth habits and origins; 'Llanera', M col 22, M Col 1468, M Col 1684, CM 342-170, CM 507-37, CM 523-7 and CM 728-2, were planted in yield trials at the three experimental sites following the method established by the CIAT cassava breeding program (Kawano et al, 1978). The plantings and harvestings were adjusted in such a way that harvests at eight and twelve months after plantings corresponded to the beginning of wet season (Season A) and the end of wet season (Season B) at each site. Dates of plantings and harvests and rainfall data are presented elsewhere (Kavano et al, unpublished data). No irrigation or application of fungicide or pesticide was made in all experimental sites. Five hundred kg/ha of dolomitic lime, 75 kg/ha of N, 150 kg/ha each of P_2O_5 and K_2O, and 10 kg/ha of Zn were applied only to the experiments at Carimagua. Each yield trial had two replication and root samples for determination of vascular streaking were taken from each replication, age, season and location.

Genetic study

One hundred and thirty three unselected F_1 clones from a cross M Col 22 x M Mex 59 and 56 F_1 clones from a cross M Col 22 x M Ven 270 were planted in a single-row trial in May 1975. Twelve rows each of the parental clones were also planted. Five 20-cm stem cuttings per clone were planted on each row. The planting distance was 1 m between plants and 2 m between rows. A year later, three inside plants per row were harvested and evaluated for vascular streaking.

A total of 853 unselected F_1 hybrid clones derived from 43 crosses and 988 clones from 55 crosses were planted in the same manner as the single-row trial described previously.

The parental clones for these crosses were also planted in three rows each. The former population was evaluated for vascular streaking and the latter for field deterioration rating.

A series of replicated yield trials have been conducted beginning with the planting of 218 germplasm accessions in Oct 1974 and ending with that of 270 breeding lines in Oct, 1980 following the same procedure described earlier (Kawano et al, 1978). In each harvest of these trials, all the entries were measured for root dry matter content and root deterioration.

Measurement of root deterioration

Eight well formed roots without mechanical damage at harvest from each plot were kept under shade and a week later chopped and evaluated for vascular streaking using the following rating scale.

0 : No deterioration
1 : Deterioration in less than 25% of the area of sections.
2 : Deterioration between 25 and 50% area.
3 : Deterioration between 50 and 75%
4 : Deterioration in more than 75%

The data were taken from average of eight individual roots per plot. Care was taken to include only deterioration which were in the form of vascular streaking and to exclude the secondary deteriorations which were in the shape of general, patternless decay although the later was rare at the moment of this evaluation.

Twelve well formed roots from each plot were kept in the field and two weeks later chopped and evaluated for deterioration following the same method as described above including both vascular streaking and general decay (field rating).

RESULTS

Typical symptoms of vascular streaking a week after harvest and general decay three weeks after harvest are presented in Fig. 1 and 2, respectively.

Genotype x environment interaction

No consistent effect of location, age of plant (month of harvest), or season (beginning or end of wet season) on vascular streaking rating was observed (Table 1 and 2). The highly significant interaction among location, age of plant, and season suggested that vascular streaking was sensitive to any of these factors. Highly significant interaction between clone and location suggested that cultivar selection was highly important, however, the selection had to be done in each location.

Genetic study at CIAT

The majority of F_1 clones from the cross M Col 22 x M ven 270 (susceptible x susceptible) were susceptible to vascular streaking while the F_1 clones from the cross M Col 22 x M Mex 59 (susceptible x moderately resistant) showed a wide variation (Fig. 3). The regression of F_1 average on the mid-parent value for primary rating was highly significant (Fig. 4). It was also significant for field rating (Fig. 5). Parent-offspring regression coefficient gives an estimate for heritability based on relative effect of additive genetic factor similar to narrow sense heritability in self-pollinated crops. Heritability estimates thus calculated were 0.64 for the vascular streaking rating and 0.54 for the field rating. These suggest that inheritance of post-harvest root deterioration is, at least partly, controlled by additive factors and quantitative rather than qualitative under the CIAT environment.

Vascular streaking rating was highly significantly correlated with root dry matter content (Fig. 6) and this relationship was consistent throughout all the nine trials conducted during seven years (Table 3).

DISCUSSION

Since we started observation on post-harvest root deterioration in 1974, significant

findings have been added to the nature of this phenomenon (Booth, 1976; CIAT, 1976; Lozano et al, 1978; Taniguchi, 1982; Hirose, 1982). Yet, the relationship between the second type of vascular streaking and the later general decay has to be clarified. We have not been able to incorporate all these findings into our evaluation scheme. Our evaluation method for vascular streaking could not distinguish between the two types of vascular streaking and our field evaluation two weeks after harvest included all types of post-harvest root deterioration, thus giving little, if any, new dimension to understanding of the phenomenon itself. For future study, separate genetic analyses on each step of post-harvest deterioration are highly desirable.

From a practical point of view, however, the result suggests a certain possibility for reducing post-harvest root deterioration by breeding.

Progress by breeding can be readily expected if the selection goal is merely a better resistance to post-harvest root deterioration at each location. However, the real question is whether it can be done without sacrificing other important characteristics and if not, what the acceptable balance would be between post-harvest deterioration and other characters such as root dry matter content and eating quality.

Given the relatively large statistical error associated with the vascular streaking rating on great number of clones, the correlation between vascular streaking rating and root dry matter content is expected to be much tighter in biological nature than would be interpreted from the actual correlation coefficients presented in Table 3. Thus, combination of high root dry matter with low vascular streaking must be difficult if not imposible.

Eating quality for fresh consumption is a subjective matter. It is generally believed to be positively related to root dry matter content. In medium-altitude tropics such as Valle or Quindio provinces of Colombia, cassava generally produces roots of high dry matter content (CIAT, 1980). Thus, under this environment, cultivars with genotypically low dry matter content such as "Chiroza Gallinaza" can have reasonably high root dry matter content and good eating quality combined with resistance to vascular streaking.

In lowland tropics where the temperature is high and root dry matter contents are generally low, only genotypes with high root dry matter can survive as good eating cultivars. Under this environment, vascular streaking is much less severe, possibly due to generally low root dry matter content (CIAT, 1980, Wheatley 1982). Thus, cultivars with high root dry matter content and good eating quality can maintain some resistance to vascular streaking.

As for animal feed or industrial use the most important criterion may be root dry matter yield, in which an alternative between high root dry matter content with low resistance to vascular streaking and low dry matter with high resistance should be carefully examined. Resistance to secondary deterioration may be sought to the maximum if it proves to be independent from root dry matter content.

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Table 1 Vascular streaking rating of eight clones harvested at different ages, seasons and locations.

Location	Caribia				Carimagua				CIAT–Palmira				
Month of Harvest	8		12		8		12		8		12		
Season*	A	B	A	B	A	B	A	B	A	B	A	B	Average
Clone													
Lianera	3.7	0.3	1.7	3.0	1.2	2.7	2.5	0.6	1.2	3.0	1.7	1.6	1.9
M Col 22	3.8	1.0	1.5	2.8	1.4	0.7	1.3	0.7	1.8	2.7	1.1	3.0	1.8
M Col 1468	2.2	2.0	3.0	1.6	0.6	1.1	2.7	1.6	0.2	2.1	1.0	1.3	1.6
M Col 1684	2.2	0.8	1.5	2.9	0.1	0.5	0.9	0.3	0.7	2.6	0.6	0.8	1.2
CM 342-170	1.1	0.5	1.8	2.7	2.1	2.6	2.4	1.7	1.8	3.3	3.2	2.1	2.1
CM 507-37	1.2	0.4	1.7	1.8	0.4	1.6	2.0	0.5	1.1	3.5	1.4	1.8	1.5
CM 523-7	1.3	0.3	1.6	1.4	2.2	0.7	1.1	0.6	2.3	3.1	2.2	3.1	1.7
CM 728-2	0.9	0.1	0.5	3.3	0.2	0.5	0.8	0.6	0.4	2.5	0.5	1.0	0.9
Average	2.1	0.7	1.7	2.4	1.0	1.3	1.7	0.8	1.2	2.9	1.5	1.8	1.6

* A : Beginning of wet season, B : End of wet season or beginning of dry season.

Table 2 Analysis of variance for vascular streaking.

Source of variance	Degree of freedom	Mean square
Clone (V)	7	1.833
Location (L)	2	3.413
Month of harvest (M)	1	0.482
Season (S)	1	0.454
V × L	14	1.052**
V × M	7	0.201
V × S	7	0.317
L × M	2	2.239
L × S	2	4.660
M × S	1	0.060
V × L × M	14	0.323
V × L × S	14	0.202
V × M × S	7	0.853
L × M × S	2	7.602**
Error	14	0.507

** Significant at 1% level

Table 3 Relationship between primary deterioration rating and root dry matter content in replicated yield trials at CIAT.

Planting date	No. cassava genotypes evaluated	Correlation coefficient between primary deterioration rating and root dry matter content.
Oct. 1974	218	0.53**
Sept. 1976	225	0.58**
Sept. 1977	327	0.50**
Apr. 1978	225	0.37**
Jan. 1979	291	0.73**
Jun. 1979	249	0.61**
Oct. 1979	201	0.80**
Apr. 1980	286	0.33**
Oct. 1980	270	0.43**

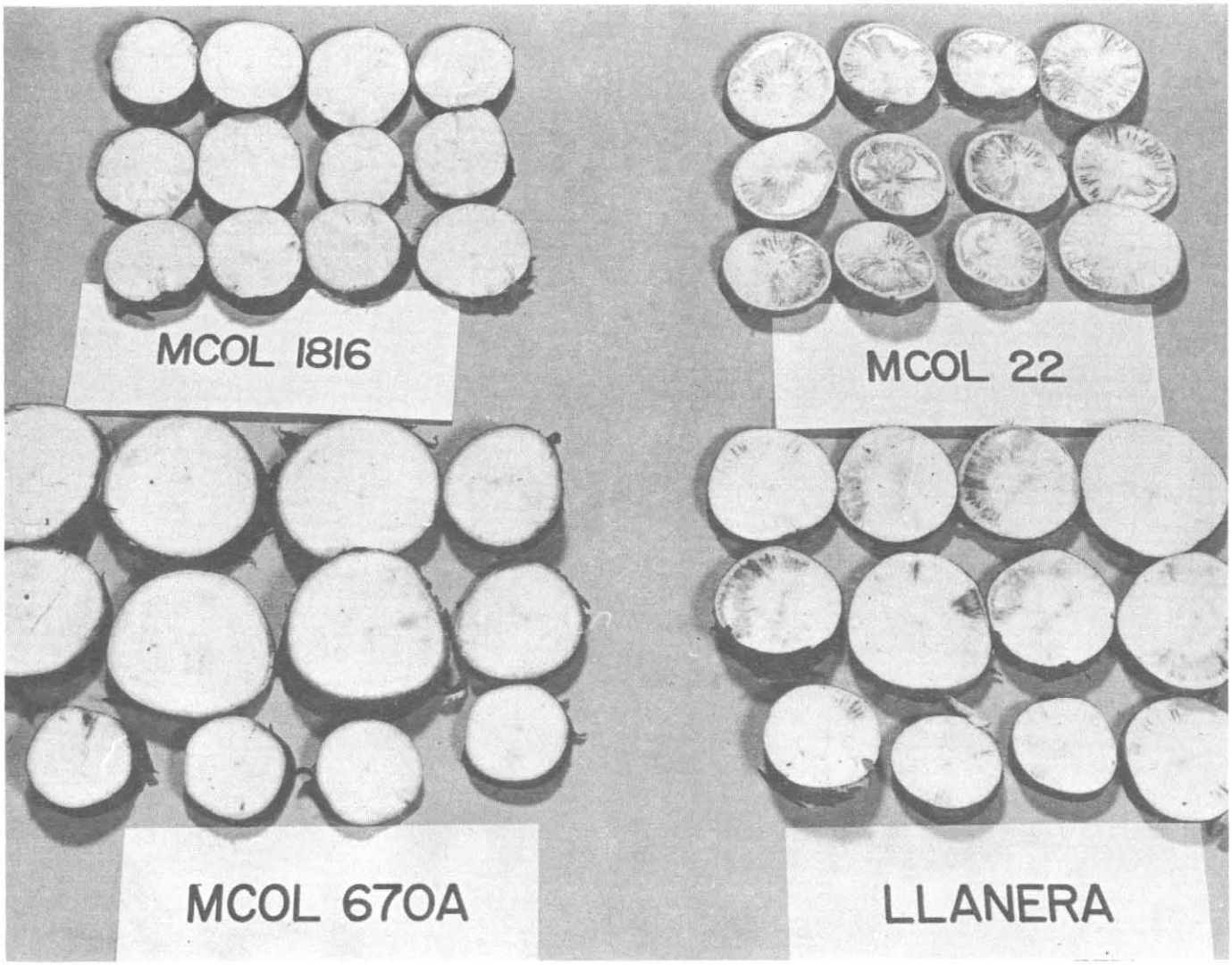

Fig. 1 Roots of four accessions with distinct susceptibilities to post-harvest root deterioration one week after harvest.

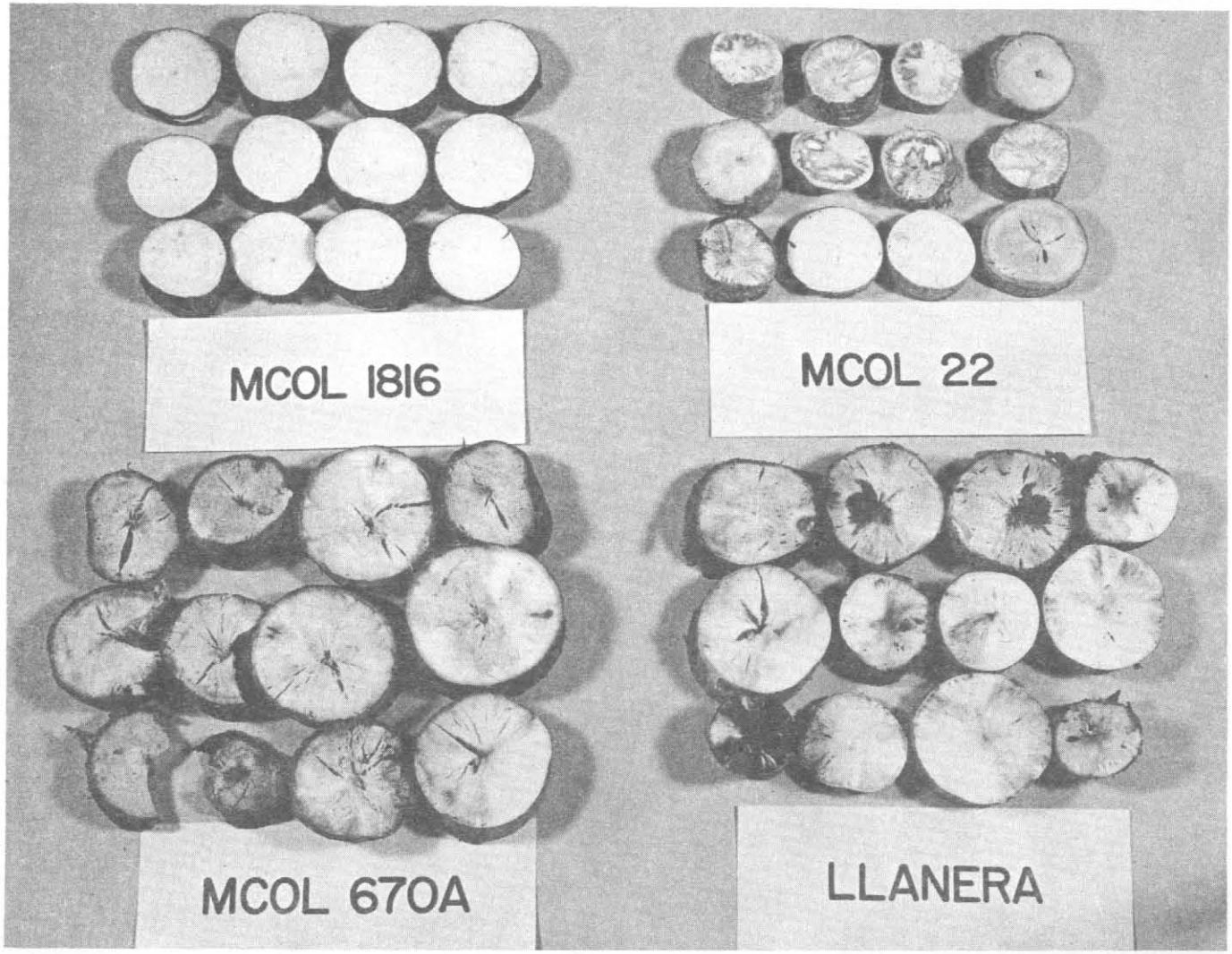

Fig. 2 Roots of four accesions with distinct susceptibilities to post—harvest root deterioration three weeks after harvest.

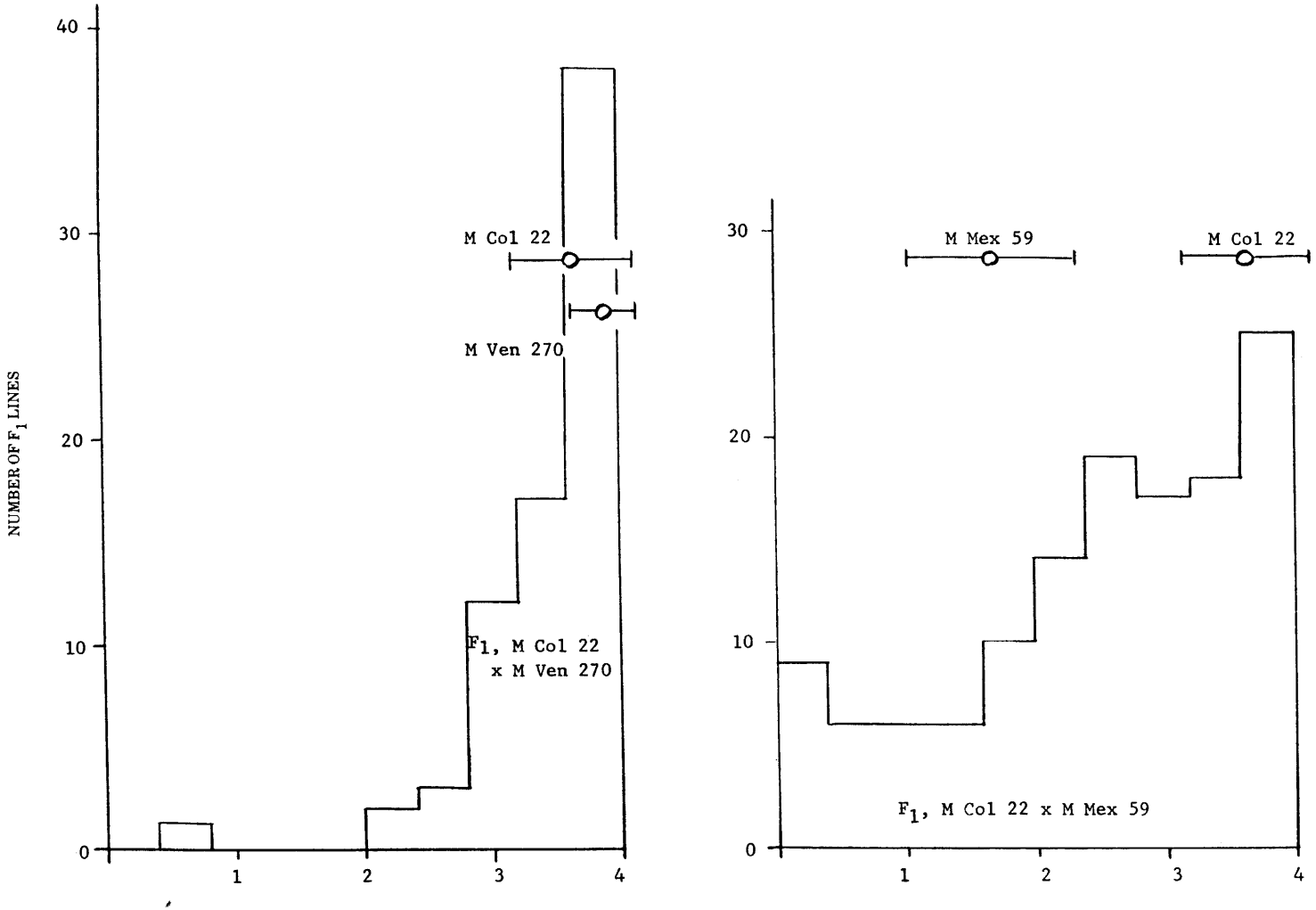

Fig. 3 Segregation in primary deterioration rating of two F_1 populations (parental values are shown with standard error).

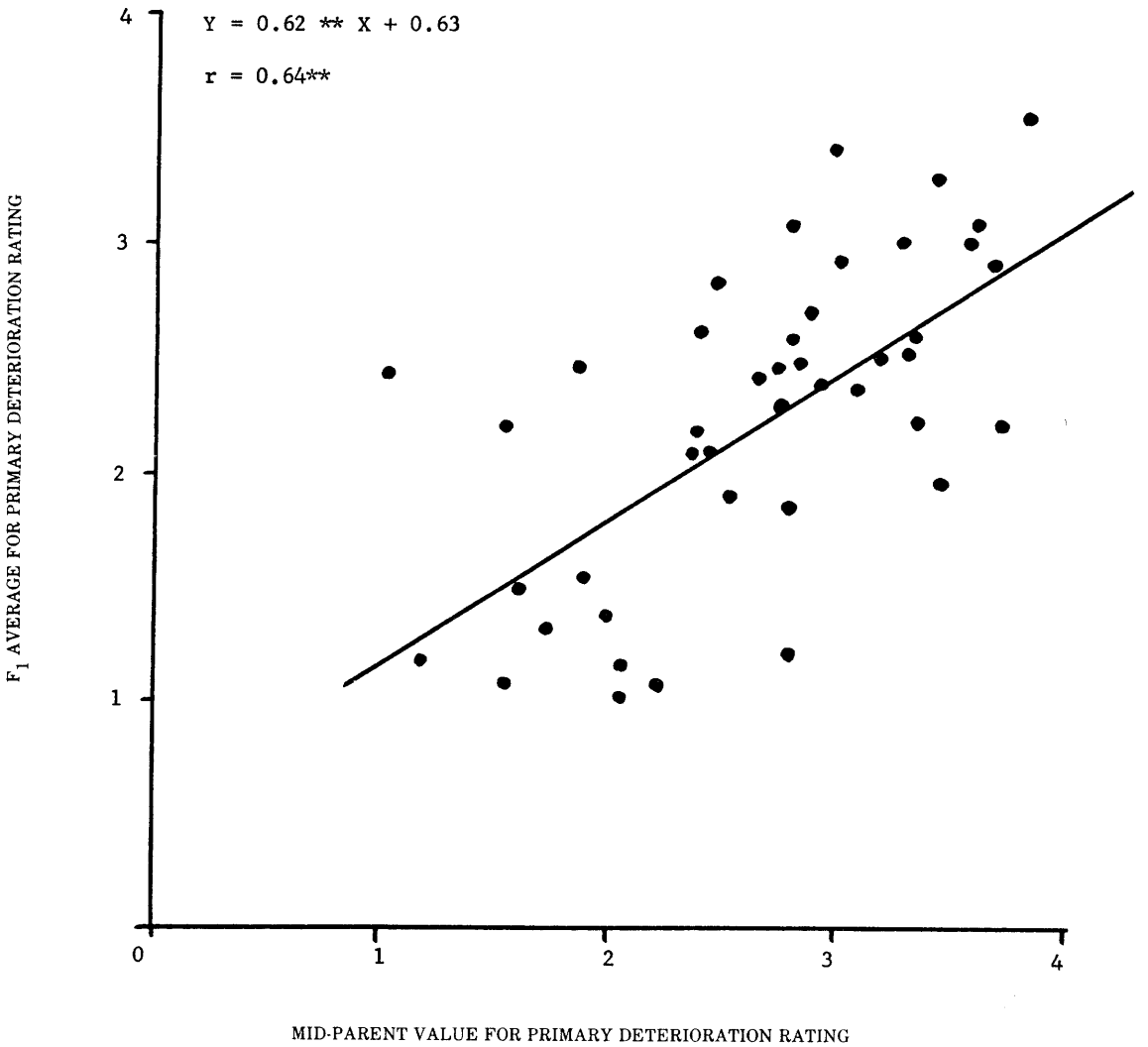

Fig. 4 Regression of F_1 average on the mid-parent value for primary root deterioration rating.

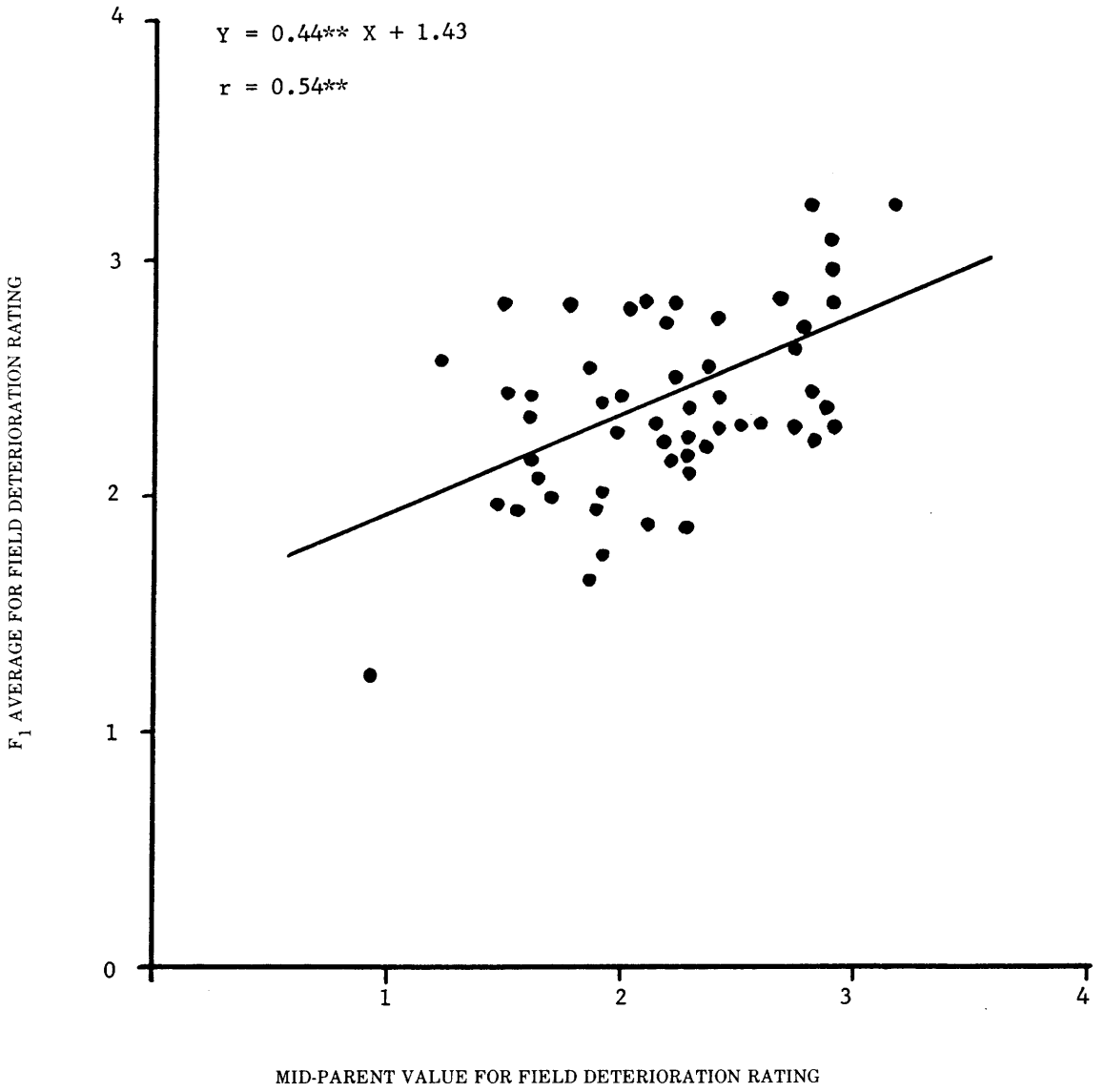

Fig. 5 Regression of F_1 average on the mid-parent value for field deterioration rating.

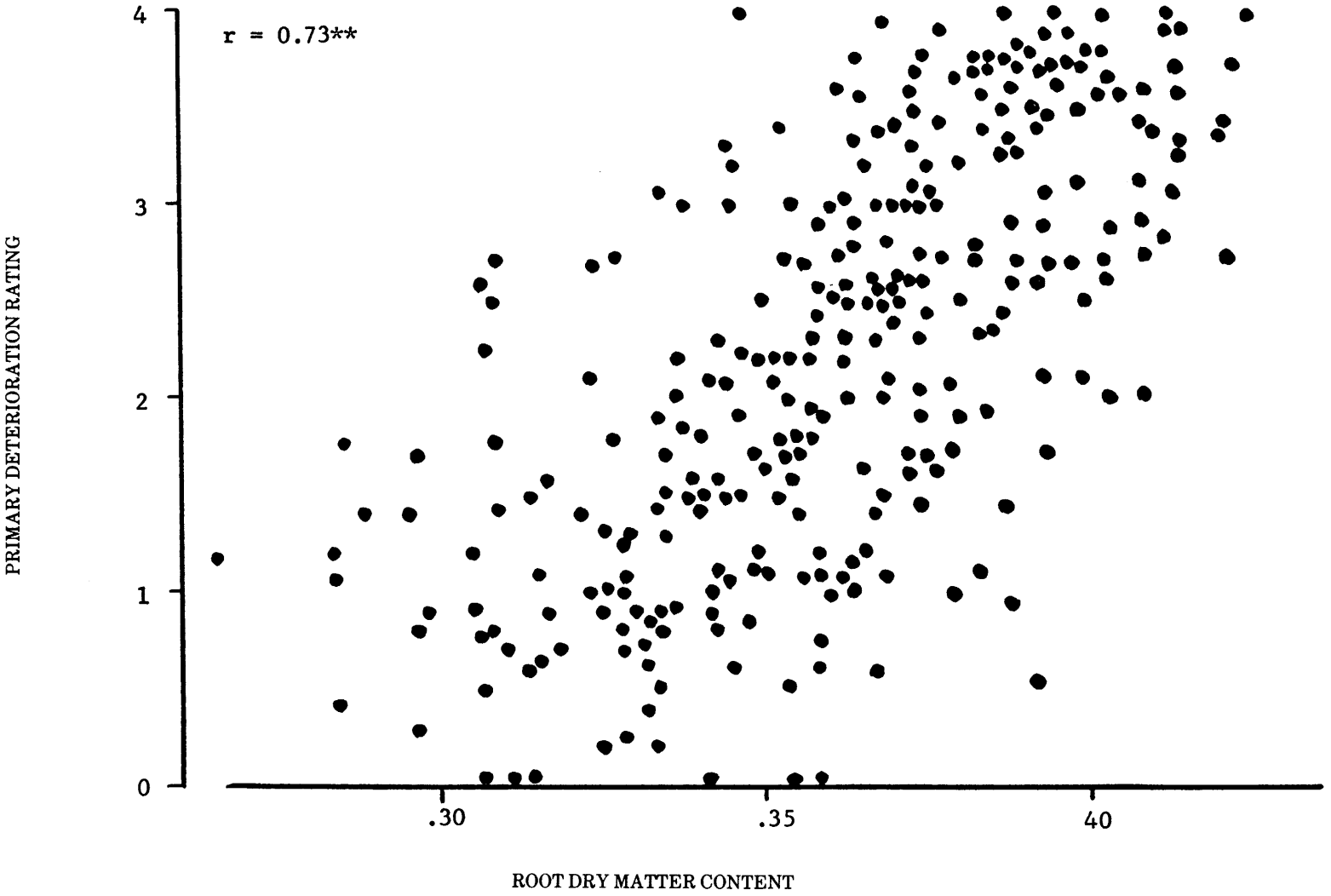

Fig. 6 Relationship between root dry matter content and primary deterioration rating (Data from yield trial planted in January, 1979).