PROGRESS IN DISEASE RESISTANCE AND YIELD POTENTIAL: AN ANALYSIS OF VEF - EP NURSERIES 1979 - 1986

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Paper presented at the Bean International Trials Workshop - New germplasm to serve Man s Needs ' CIAT, Cali, Colombia October 12-16, 1987

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CONTENT

Progress in disease resistance and yield potential
An analysis of VEF - EP Nurseries
(1979 - 1986)

1 INTRODUCTION

Internationally oriented plant breeding programs very often use as selection criteria varietal resistance to diseases considered of regional importance, and yield Advanced lines, product of crosses made using disease resistant parental material,or high yielder ones, are again evaluated for their disease resistance-under high disease pressure conditions - and for their yield capability-under disease protected conditions to allow the full expression of their yield potential-

Under the CIAT Bean Program scheme for evaluation of advanced lines, three stages are considered

1- VEF Nursery (Vivero Equipo de Frijol)
VEF is an observational nursery integrated by bean advanced lines generated by the plant breeders (F_6 - F_7), with specific disease resistance, adaptation and commercial grain attributes to satisfy the most diverse set of regional needs Lines are evaluated by their reaction to five limiting diseases - Rust Anthracnose, Angular Leaf Spot, Common Bacterial Blight and Bean Common Mosaic Virus - and by their yielding ability (although the latter not very accurately measured) Disease reaction evaluations are carried out under artificially controlled high disease pressure environments Rust and Common Bacterial Blight at CIAT, Anthracnose at Popayan, Angular Leaf Spot initially at Popayan and since 1985 at Quilichao, and Bean Common Mosaic Virus at the CIAT greenhouse

Yield evaluations are carried out at CIAT, for two semesters under a non-replicated trial, using a 4 8m² experimental plot

2- EP Nursery (Preliminary Yield Trial)

Those promising material selected from VEF are again evaluated in another trial - called EP Nursery - where disease reactions are verified and yield is properly measured during two semesters at two different locations under a three replications design, with check varieties, and a 9 6 m² experimental plot The testing locations are CIAT Palmira (1000 msnm, 24°C) and Popayán (1800 msnm, 17°C) Climbing beans - cold temperatures types, given their poor adaptation to Popayán, are evaluated at a higher altitude location La Selva, ICA Experimental Station (2120 msnm, 10°C)

3- IBYAN (International Bean Yield and Adaptation Nursery)

Promising material selected from VEF-EP then integrate the international multi-locational trial for bean yield and adaptation evaluation (IBYAN), distributed a l around the world

The purpose of this analysis is to describe - using the data generated by VEF and EP Nurseries during 1979-1986 -, the progress of the CIAT Bean Program during this eight-year period of plant breeding effort, in terms of the production of disease resistant lines and in the attainment of high-yield-pote tial lines with disease resistance attributes, that can satisfy the very diverse regional needs of the world bean community (*Phaseolus vulgaris*)

2 MATERIALS AND METHODS

2 1 Data Source

Disease reaction data of seven VEF Nurseries (VEF 1979, 80, 81, 83, 84, 85, 86) and their associated EP Nurseries (EP 1980, 81, 82, 84, 85, 86, - EP 1987 data was not available yet) were utilized to study the progress in disease resistance across time A total number of 7165 advanced lines was studied, whose distribution by year of evaluation and by bean type 1/ is shown in tables 1 and 2

Yield evaluation data from the last three EP Nurseries (EP 1984, 85, 86) were used to study the progress in terms of yield potential, yield data combined with EP disease reaction evaluations were used to study the progress in yield potential combined with disease resistance A total number of 1257 advanced lines was studied, whose distribution by year of evaluation and bean type is shown in tables 3 1 and 3 2

2 2 Analysis Methodology

Analysis of disease resistance evaluations

Disease resistance evaluations, originally measured in a 0-5 or 0-9 discrete scale, were transformed to R (resistant), I (intermediate) or S (susceptible) for each one of the five diseases considered rust anthracnose, angular leaf spot, common bacterial blight and bean common mosaic virus (only R or S apply for the latter)

1/ *From 1991 beans were classified according to their grain color, grain size and zone of adaptation, in the different bean types Table 1 shows the total number of bean lines tested at CIAT between 1980 and 1990 and their distribution by bean type*

In order to quantify the progress in terms of disease resistance in time, the total number of lines evaluated as R or I to a specific disease or to combinations of them - expressed as a percentage of the total number of lines produced by the breeders and evaluated at the VEF Nursery on each particular year - was plotted against time. This was done over all bean types as well as for each individual bean type. Disease combinations considered of regional importance were:

- Rust - Anthr - BCMV
- Rust - ALS - BCMV
- Rust - CBB - BCMV
- Rust - CBB - ALS
- Anthr - ALS - BCMV
- Anthr - CBB - BCMV
- All five diseases

In order to evaluate whether disease resistance was a criteria for selection of lines from the VEF Nursery to the EP Nursery, the trend in the number of EP lines evaluated as R or I to each disease or combination of diseases, expressed as a percentage of the total number of lines evaluated every year at EP, was compared to the corresponding trend in VEF. This was done for each bean type and over all bean types.

The actual contribution of the CIAT Bean Program in terms of sources of resistance on each bean type is here expressed as the total number of disease resistant lines (R or I) to each disease or combination, produced in the period 1981 - 1986. The data from 1979-1980 was not included as only from 1981 the actual bean classification - based on grain color, grain size or zone of adaptation - was put into practice for the various stages of bean germplasm evaluation.

Analysis of yield potential

Yield (kg/ha) evaluations used for this study correspond to three years of EP Nursery 1984, 1985 y 1986, with a total of 1257 lines evaluated, distributed by year and by bean type as previously shown in table 3 1 and 3 2 For each line, yield from two semesters in two locations (CIAT and Popayán, with the exception of climbing beans - cold temperatures which were evaluated at only one site - La Selva), under three replications per location x semester was available Experimental plot for yield at EP Nurseries was of 9 o m²

As yield EP Nurseries are artificially controlled for diseases, yield measurements are taken "under no stress', given the particular soil and climate limitations of the testing sites With this in mind, we have called this yield, a measurement of 'yield potential"

For the scope of this paper, a line is considered a high-yield-potential line, when its mean yield over semesters and reps on a particular year, is statistically greater than the corresponding check variety yield at any one of the testing sites By "statistically greater than" we mean that (line yield - check yield) $\geq$ LSD os for the corresponding year and bean type Table 5 presents the list of check varieties used for each bean type Table 6 shows the LSD os values (Waller - Least Significant Differences) utilized for the identification of high-yield-potential lines

High-yield-potential lines were identified for each bean type and over all bean types Those lines found superior at only one testing site (either at CIAT or at Popayan) were considered of 'specific environmental adaptation', while those found superior at both testing sites were considered of 'general adaptation'

Mean yield of superior lines and their mean increment in yield over the checks was calculated by bean type and over all bean types, for specific environmental adaptation lines as well as for more general adaptation ones

Analysis of yield potential combined with disease resistance

Using as our population the total number of lines identified as high-yield-potential lines, disease resistance attributes of them were quantified as percentages of resistant (R or I) lines to each individual disease or disease combination. This was done by bean type and over all bean types.
Mean yield of high-yield-potential-resistant (R or I) lines, vs high-yield-potential-susceptible lines to various diseases, were compared statistically in order to have an approximate test of the hypothesis of independence between the two attributes - disease resistance and yield - under no disease stress conditions.

As a conclusion of the analysis, the list of high yield-potential lines, adapted to both sites, CIAT and Popayán, and with some resistance attributes, was examined to see what proportion of them entered IBYAN and whether "released commercial varieties" were in it.

Finally the origin - in terms of the testing Nursery where they came from - of the 136 bean commercial varieties released (or with potential to be released by National Programs) between 1976 and 1986, was analyzed to quantify the capability of the VEF-EF-IBYAN process for germplasm evaluation to detect outstanding material.

3 RESULTS

3.1 Progress in disease resistance

Figures 1.1 to 1.5 illustrate the trend in time in both the number of resistant (R) lines and the number of resistant or intermediate (R-I) ones to each individual disease - Rust, Common Bacterial Blight, Angular Leaf Spot, Anthracnose and Bean Common Mosaic Virus - expressed as percentages from the total number of lines evaluated each year at VEF. Figures 2.1 to 2.5 show the trend by bean type, in the percentage of R-I lines.

Rust (Fig. 1.1, 2.1). An increasing trend in the percentage of R and R-I lines is observed until 1985, when more than 90% of the lines were R-I to the disease and about 50% were R. The decrease from 1985 on, reflects the Bean Program change in emphasis to the production of sources of resistance to Common Bacterial Blight, Web Blight and Bean Golden Mosaic Virus, as enough sources of resistance to rust already existed (M.A. Pastor-Corrales, personal communication). As an overall result there are now 2507 R and 5046 R-I lines to rust, representing 35% and 70% respectively of the total number of lines evaluated at VEF during the eight-year period 1979-1986. When observing the trend by bean type, it can be seen that Red Mottled, Brazilian types, and both climbing bean types exhibit the higher percentages of lines R or R-I to rust.

Common Bacterial Blight (Fig. 1.2, 2.2). The percentage of R-I lines shows an increase from below 20% in 1979 to about 50% in 1986, however, the percentage of R lines has remained constantly low (near 1%) through the years. This observation reflects the narrow base of existing resistant parental material. As an overall result there are now 71 lines R and 2271 R-I to the disease, representing respectively and 32

of the total production of advanced lines The most favored bean type in terms of disease resistance effort is the bush - Red Mottled, where 80/ of the lines evaluated at VEF 1986 are R-I to the disease (Fig 2 2)

Angular Leaf Spot (Fig 1 3, 2 3) The percentage of R-I lines has remained constant - at about 90/ between 1980 and 1986 - while the percentage of R lines shows a drastic reduction in the last four years This result reflects the emphasis placed on improving the evaluation system by increasing the level of disease pressure at the evaluation site In fact, from 1985 on, Quilichao - a higher disease pressure environment - instead of Popayán, was chosen as evaluation site for germplasm reaction to the disease As an overall result, 17/ of the lines evaluated at VEF (1171) are R to ALS and 75/ of them (5281) are R-I to the disease

Anthracnose (Fig 1 4, 2 4) An increasing trend in the percentages of R as well as in R-I lines is observed, with 2581 lines being R (36/) and 4818 being R-I (68/) to the disease All bean types have been favored, specially bush - Brazilian types and Climbing bean types

Bean Common Mosaic Virus (Fig 1 5, 2 5) The overall trend in the percentage of R lines (Fig 1 5) shows a decrease in 1983 - from around 90/ to below 70/ - This fact can be explained by two reasons the exclusion of climbing bean types from the BCMV project - as the clientele regions did not have this disease as a limiting factor - and the genetic link in bush Red Mottled types between susceptibility to BCMV and grain color (Morales, F personal communication) (see Fig 2 5) As an overall result, there are now 4990 bean lines R to BCMV, which represent 74/ of the total number of lines evaluated at VEF during the period 1979-1986

Tables 1 1 to 1 5 show the total contribution in sources of resistance to each individual disease, by bean type expressed in number of lines R or I to the disease The figures are presented in decreasing order according to number of presently available sources of resistance Only data from 1981 to 1986 is included, as from that year on beans were classified by their grain color, grain size and their zone of adaptation The results show that in general, Red Mottled, Small Red, Brazilian types, Climbing bean types and Small black exhibit the highest numbers of sources of disease resistance followed by Mexican types and Small White The total number of advanced lines available in Medium white and Pacific Coasts types is still low (100 and 165) in comparison to other bean types, so their contribution in sources of disease resistance is also low

Combined disease resistance

In a similar way as described for individual diseases, figures 3 1 to 3 6 and tables 2 1 to 2 7 illustrate the overall trend in the number of bean lines R or I to combinations of diseases and the actual number of sources of combined disease resistance by bean type The results show that out of the total number of lines evaluated at VEF between 1979 and 1986,

33/ are R-I to Rust - Anthr - BCMV
40/ are R-I to Rust - ALS - BCMV
16/ are R-I to Rust - CBB - BCMV
22/ are R-I to Rust - CBB - ALS
19/ are R-I to Anthr - CBB - ALS
27/ are R-I to Anthr - ALS - BCMV

and 9 1/ are R-I to all five diseases (Fig 3 1-3 7)

Results shown in tables 2 1 to 2 7 confirm what was previously stated, that Red Mottled, Small Red, Brazilian types Small

Black and climbing beans types exhibit the highest numbers of sources of combined disease resistance

Finally, Fig 3 7 shows a comparison between the trend in the percentage of lines R or I to all five diseases in VEF vs the corresponding trend in EP First of all, the percentage values of R-I line at EP were higher than those at VEF only up to 1983 but not afterwards, indicating that during the period 1979-1983 EP was selective by disease resistance but a lack of emphasis in the selection - of VEF lines to enter EP - by their disease resistance attributes existed between 1984 and 1986 As this was also observed by bean type (although not presented here), it can be thought that "disease resistance" has not been a major selection criteria from VEF lines to enter EP Nursery in the last three years On the other side it can be observed that the number of VEF lines R or I to all five diseases has increased from 1 in 1979 to 212 in 1986 (the later representing a 17 5% of the 1215 lines evaluated for all diseases at VEF 1986) indicating that in the process of selection of lines from VEF to EP, the condition of "no susceptibles" can now be imposed, which combined with commercially acceptable bean types, will make EP more selective and useful

As a conclusion of the previous analysis, it was shown that there are now enough sources of disease resistance to satisfy the most diverse regional needs 3 regions in Latin America are considered as representative examples of this For each region, the types of beans most widely consumed and particular disease problems for the region were taken in consideration As a contribution to each region, the number of present available sources of disease resistance to satisfy its specific needs is presented Those countries are Argentina, Brazil, Bolivia, Cuba, Dominican Republic and Ecuador, and Peru (see table 4)

As a general conclusion, it can be said that the breeding effort of this eight-year period has contributed to the availability of enough sources of combined disease resistance to satisfy specific regional needs of the world bean community

3.2 Progress in yield potential combined with disease resistance

Table 7 shows the total number of high-yield-potential lines identified by this analysis, classified by bean type and by their adaptation condition - of specific environmental adaptation to CIAT or to Popayan, or of general adaptation to both environments

317 lines were identified as high-yield-potential lines, representing the 25% of the total number of lines tested at EP during the three-year period 1984-1986. Out of these, 158 (13% of the lines tested) are of specific adaptation to CIAT, 117 (9% of the lines tested) are of specific adaptation to Popayán, and 42 (3% of the lines tested) show general adaptation to both testing sites. Bean types with the highest number of high-yield-potential lines were Red Mottled with 87 lines, and Small Red, with 67 lines, followed by Pacific Coast types and Small White, with 33 and 27 lines, respectively. Although the 87 Red Mottled type lines represent the highest number of high-yield-potential lines by bean type, they only correspond to the 22% of the total number of Red Mottled lines tested at EP during 1984-1986. Other bean types exhibit higher percentages of high-yield-potential lines (see table 7).

Table 8 shows the average yield increment over the checks of high-yield-potential lines: 724 kg/ha - for lines with specific adaptation to CIAT, 793 kg/ha - for lines with

specific adaptation to Popayán, and 1515 and 1342 kg/ha for lines of general adaptation to both environments. This observation suggests that lines with general adaptation are higher yielders than those with specific environmental adaptation.

Table 9 shows the mean yield of high-yield-potential lines by bean type, discriminated by their adaptation condition. It can be observed that the yield range for bush beans lines with general adaptation varies from 2016 kg/ha (6 Pacific Coast type lines) to 3074 kg/ha (4 Small White lines) at CIAT, and from 1873 (for the 6 Pacific Coast type lines) to 2724 (3 Mexican type lines) at Popayán.

Table 10 describes disease resistance attributes of the 317 high-yield-potential lines. 85% of them (269) are R to BCMV, 72% of them (229) are R-I to Anthracnose, 60% of them (189) are R-I to Rust, 53% of them (167) are R-I to ALS, and 21% of them (68) are R-I to Common Bacterial Blight. Also between 9% and 30% of them have combined disease resistance attributes, being 6% of them R-I to all five diseases.

With the intention to have an approximate test of the hypothesis of independence between the two criteria - disease resistance and yield potential-, statistical comparisons between yield of R-I vs S lines - out of those high-yield-potential lines - were performed and shown in table 11. It can be observed that none of the differences were found to be significant, so it can be said that there is not enough evidence to conclude that disease resistance - per se - affects the yield potential level of a bean line.

It was found that out of 22 high-yield-potential lines with general adaptation to both sites, CIAT and Popayán, and with combined disease resistance only 3 had entered IBYAN. This

observation might reflect the more stringent select or criterium for commercial grain types required for IBYAN
It was also found that out of the 136 released - or potentiallly released - commercial varieties, 8 had been tested at EP (see table 12) They satisfied the requirement of having a mean yield statistically greater or equal to the check and some disease resistance attributes

Finally, table 13 illustrates the power of the bean international network in identifying promising material as 72/ of the 136 released (or potentially released) commercial varieties, 98 have been identified from IBYAN, however only 3 varieties of them have followed the VEF-EP-IBYAN evaluation process 5 and 22 of the released commercial varieties came from EP and VEF Nurseries, respectively, so indicating that promising material are not necessarily given a full chance through the actual selection process The 11 released commercial varieties, non evaluated at VEF-EP-IBYAN correspond to outstanding varities from National Programs

4 CONCLUSIONS

Disease resistance

1 The analysis of disease reaction evaluations of VEF - EP Nurseries (1979-1986) shows an increasing trend in the production of disease resistant bean lines to the five diseases considered rust anthracnose angular leaf spot, common bacterial blight and bean common mosaic virus Emphasis was centered on the following bean types bush Red Mottled, Brazilian types, Small Red and Small Black, Climbing very temperatures and cold temperatures types

2 The analysis clearly shows that there are now enough sources of combined disease resistance to satisfy specific regional needs The total number of bean lines R or I to individual diseases varies from 2034, in the case of common bacterial Blight, to 4712 for rust The total number of bean lines, R or I to combinations of diseases varies from 637, that are R-I to all five diseases, to 2090 with combined resistance to Rust - Anthracnose - Bean common mosaic virus

3 The study shows that selection made from the VEF Nursery to the EP Nursery is not based on disease resistance The percentage of R-I lines - and that of S lines as a complement - are similar, from 1984 on, in both nurseries, over all bean types and for individual bean types

Yield potential combined with disease resistance

1 The analysis shows that 25/ of the 1257 lines tested at EP Nurseries in the three-year period 1984-1986 are high yield potential lines Their average yield increment over the checks was of 724 kg/ha and 793 kg/ha for lines with "specific environmental adaptation" to CIAT or Popayán respectively, and of 1042 and 1515 Kg/ha for those with "more general adaptation" at the same evaluation sites

Within this group of high-yield-potential lines, 53 to 85/ of them are R-I to single diseases, 11-39/ of them are R-I to combination of diseases and 6/ of them are R-I to all diseases considered

2 However, a high number of EP lines combining high-yield-potential and disease resistance attributes were not included in IBYAN This observation might reflect the more stringent selection criterium for commercial grain types required for IBYAN

- As a final conclusion, it is hoped that, if the EF Nursery were made more selective and more widely distributed, - selective, to include mostly disease-resistant lines with commercially-acceptable grain types - , this, combined with high-yielding attributes, could increase the chances of outstanding material to become "commercial varieties"

Important limitations of this analysis

After having gone through the conclusions drawn from this analysis it is very important to have in mind two limitations of it

a) The lack of information on specific constraints existing in the various areas where the different bean grain types are produced

b) The lack of information regarding commercial grain characteristics of the advanced lines that have been produced by the plant breeders during the period 1979-1986 and submitted to VEF-EF-IBYAN evaluation and selection process

The absence of this information makes impossible to clearly understand why disease resistant lines were not selected from VEF to EF while susceptible ones were, or why EF high-yield-potential lines with disease resistance attributes were not chosen to integrate the IBYAN International Nursery

Given the relevance of specific commercial grain characteristics for bean consumption - at least in Latinamerica countries -, and the importance of the identification of specific constraints of the various bean production areas in the world, it would be highly desirable to count with this extra information for a more realistic analysis in the future

TABLE 1: DATA SOURCE

— Disease resistance evaluations —

YEAR (VEF)	No of lines evaluated	%
1979	593	8
1980	557	8
1981	1109	15
1983	1385	19
1984	1036	15
1985	1203	17
1986	1282	18
TOTAL	7165	100%

TABLE 2: DATA SOURCE

— Disease resistance evaluations —
(Totals over VEF 1981 — 1986)

Bean Type	No of lines evaluated	%
Bush - Red Mottled	1535	24
Climbing - Cold Temperatures	1046	16
bush - Small Red	807	13
bush - Brazilian Types	675	11
bush - Small Black	536	9
bush - Mexican Types	498	8
bush - Small White	475	7
climbing - Warm temp	452	7
bush - Pacific Coasts	165	3
bush - Medium White	100	2
TOTAL	6289	100%

Table 3.1: DATA SOURCE

Year	No of lines evaluated
EP 1984	435
EP 1985	393
EP 1986	429
TOTAL	1257

Table 3.2 DATA SOURCE

Bean Types	No of lines evaluated	%
Bush		
Red Mottled	396	32
Small Red	141	11
Small Black	114	9
Small White	110	9
Pacific Coasts	72	6
Brazilian Types	57	4
Mexican Types	22	2
Medium White	18	1
Climbing		
Cold Temperatures	172	14
Warm Temperatures	155	12
TOTAL	1257	100

1. PROGRESS in

Disease resistance

FIG. 1.1

TREND IN THE NUMBER OF BEAN LINES WITH RESISTANCE TO

RUST

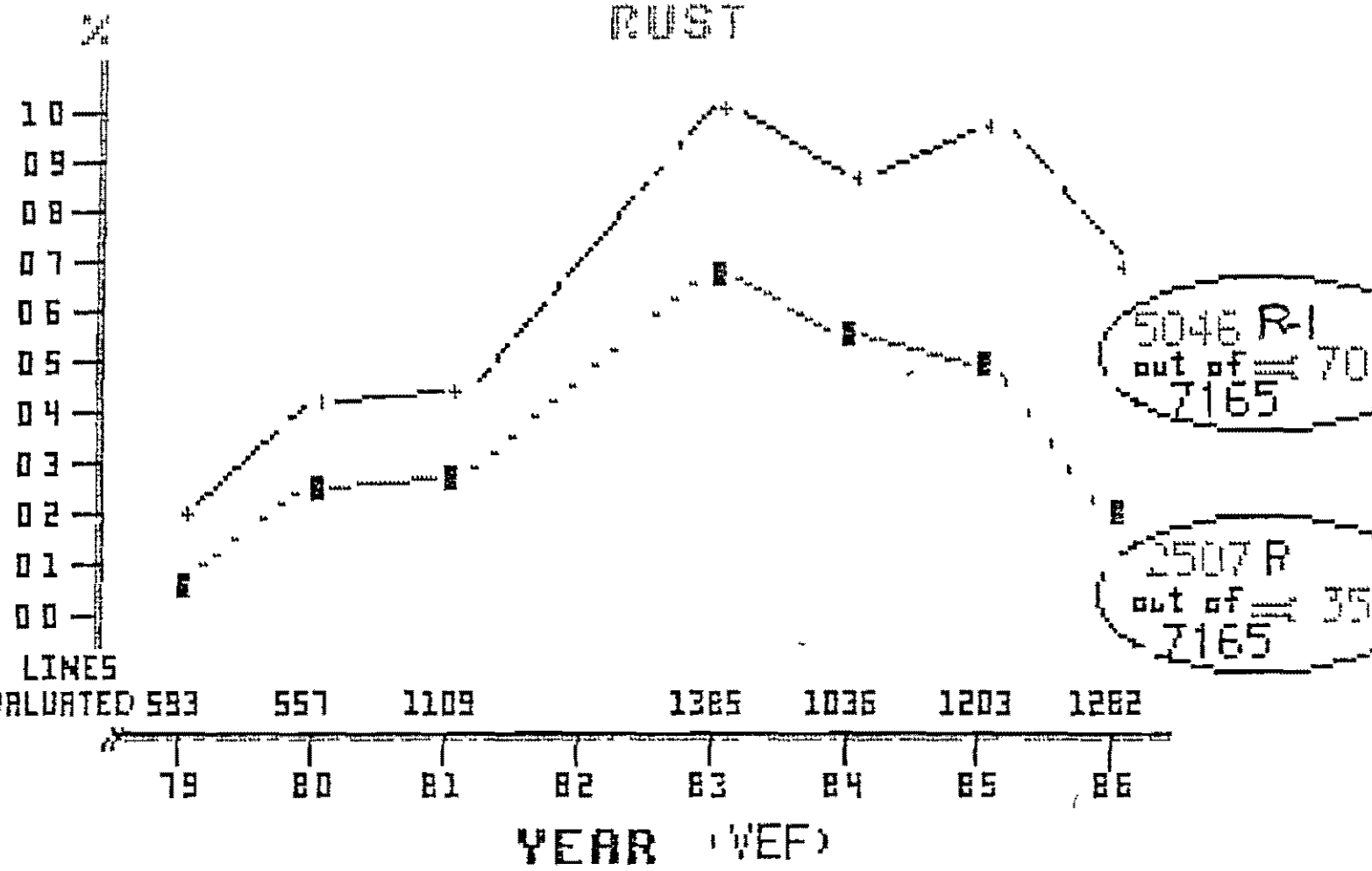


FIG. 1.2

TREND IN THE NUMBER OF BEAN LINES WITH RESISTANCE TO

BACTERIAL BLIGHT

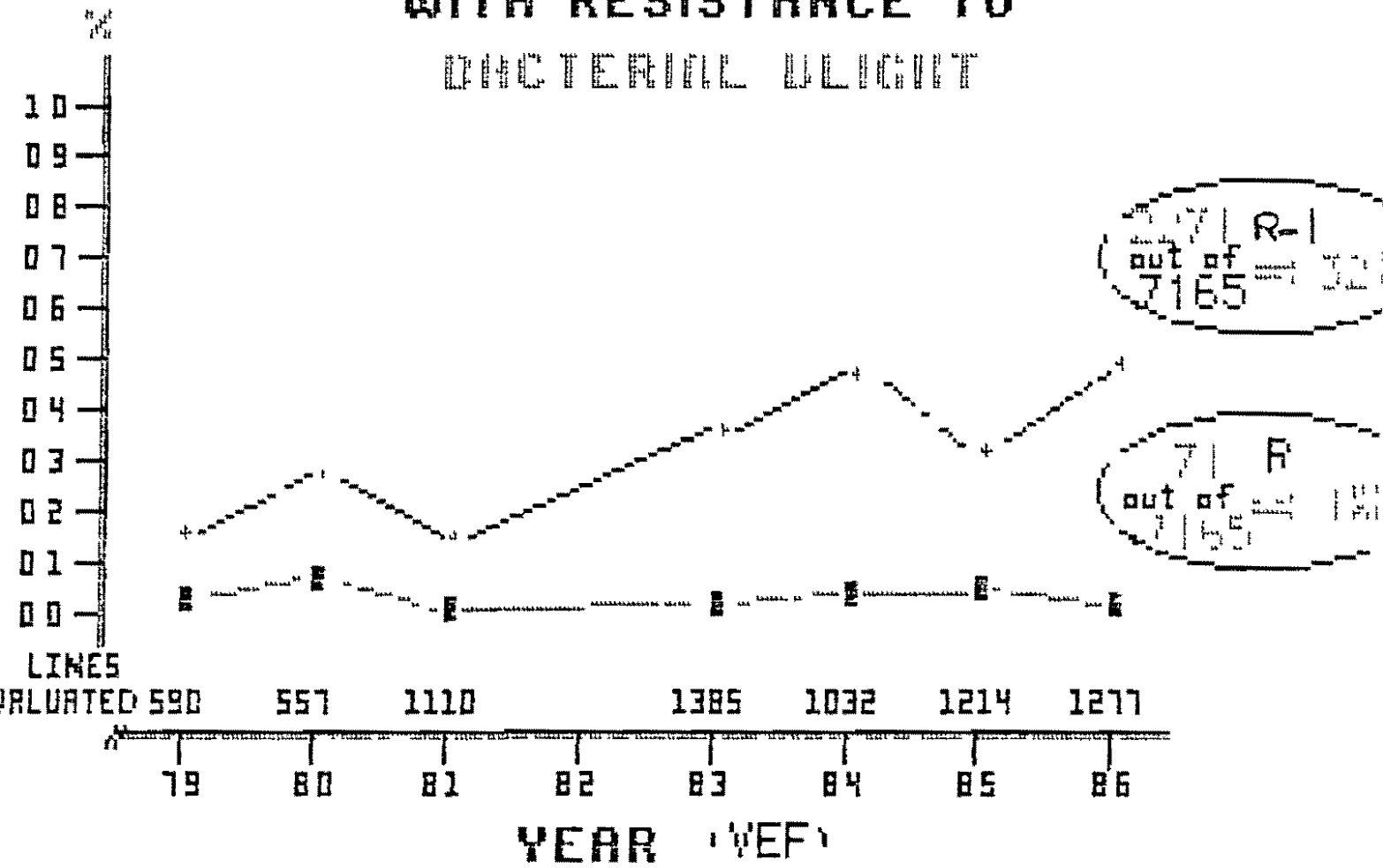


FIG. 1.3

TREND IN THE NUMBER OF BEAN LINES WITH RESISTANCE TO ANGULAR LEAF SPOT

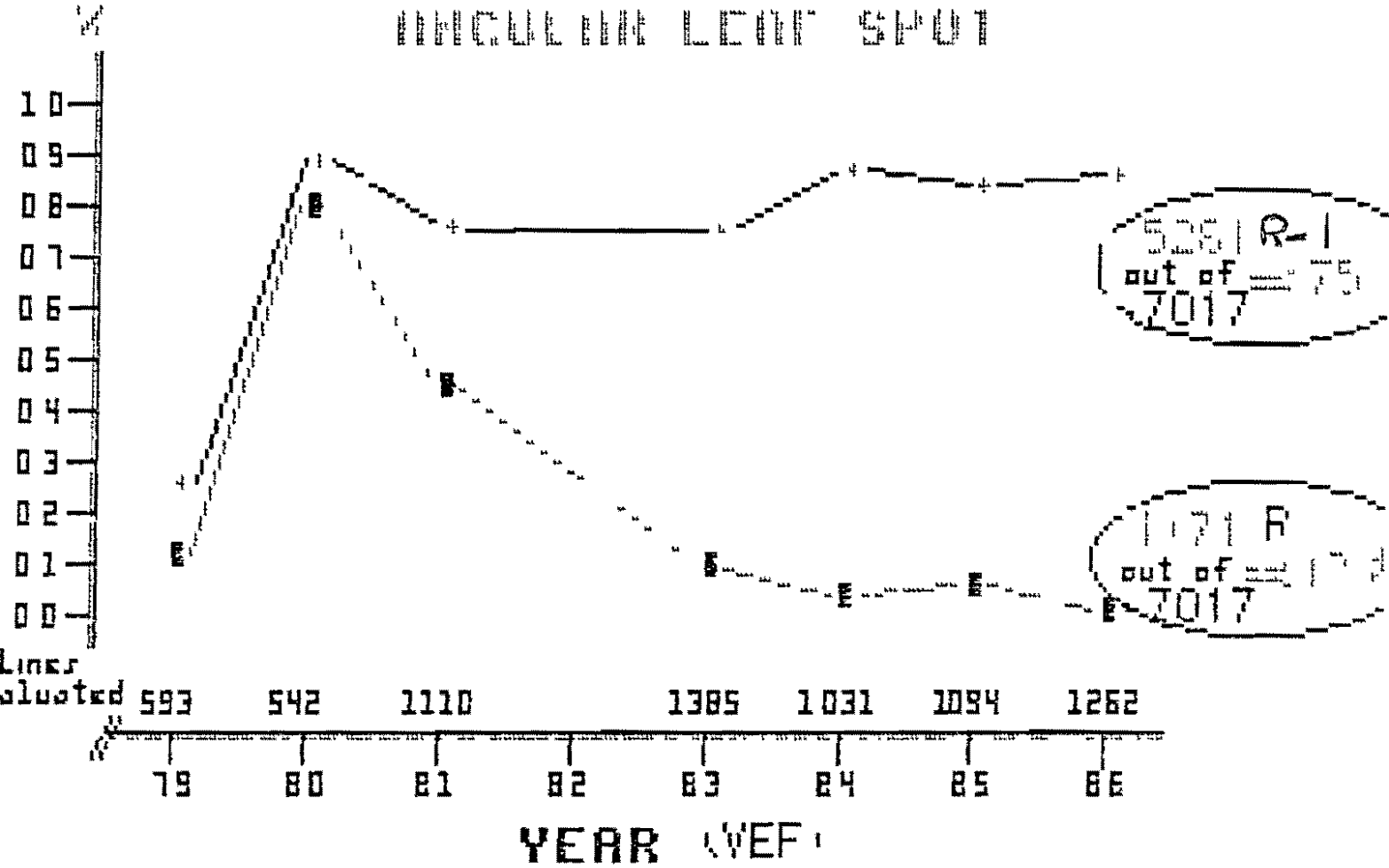


FIG. 1.4

TREND IN THE NUMBER OF BEAN LINES WITH RESISTANCE TO

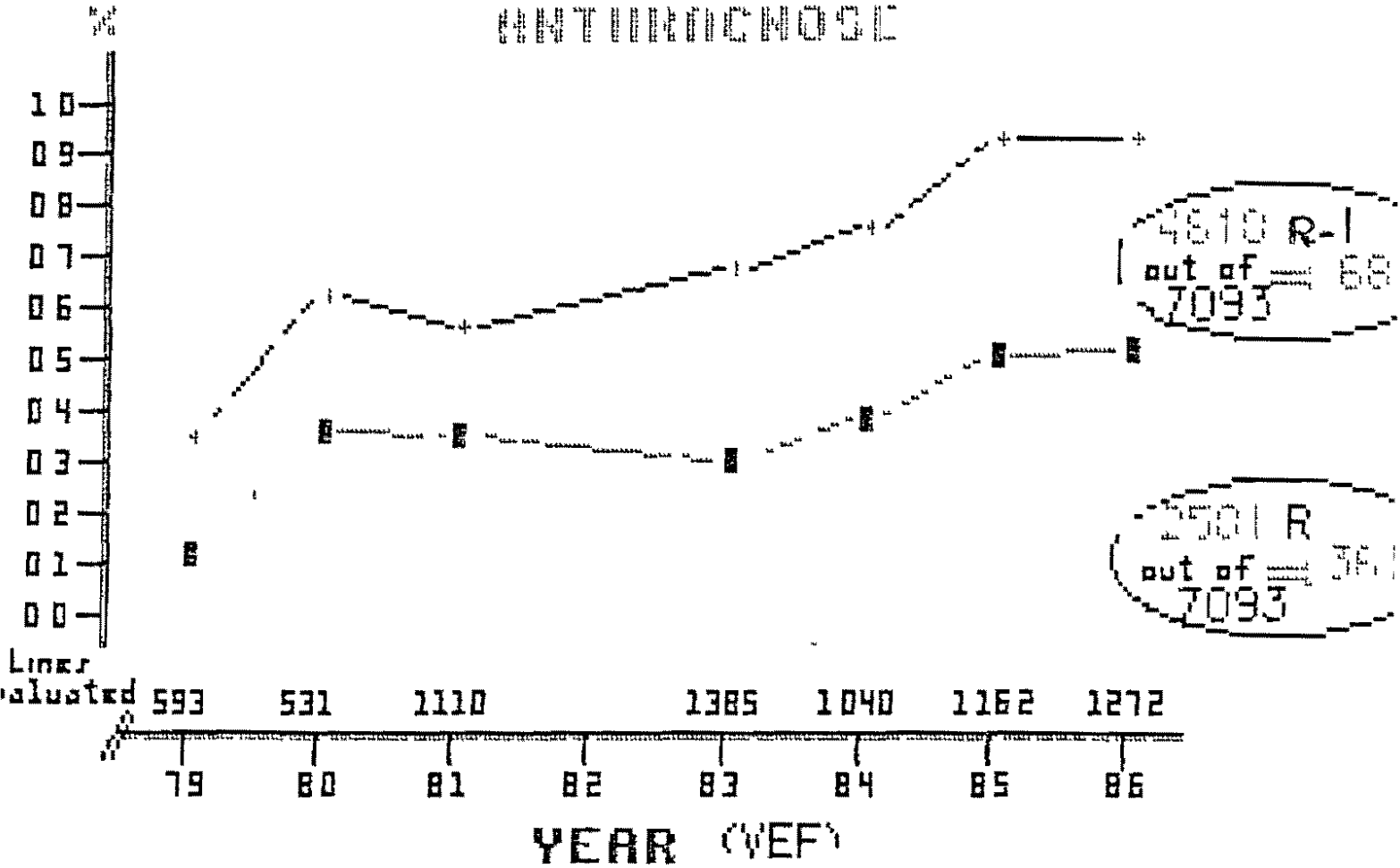


FIG. 1.5

TREND IN THE NUMBER OF BEAN LINES WITH RESISTANCE TO COMMON MOSAIC VIRUS

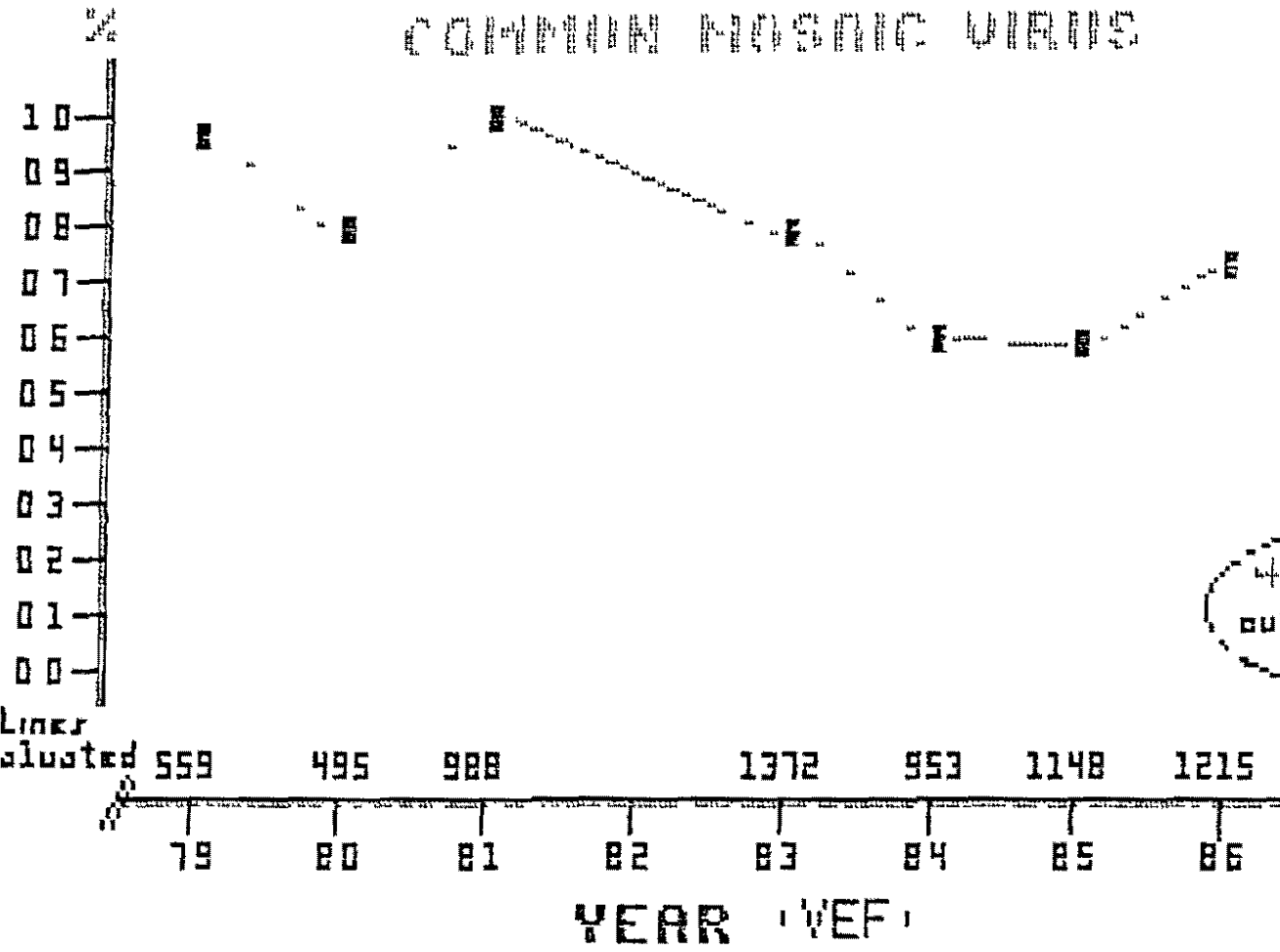


FIG. 2.1

Trend in the number of bean lines with resistance to RUST

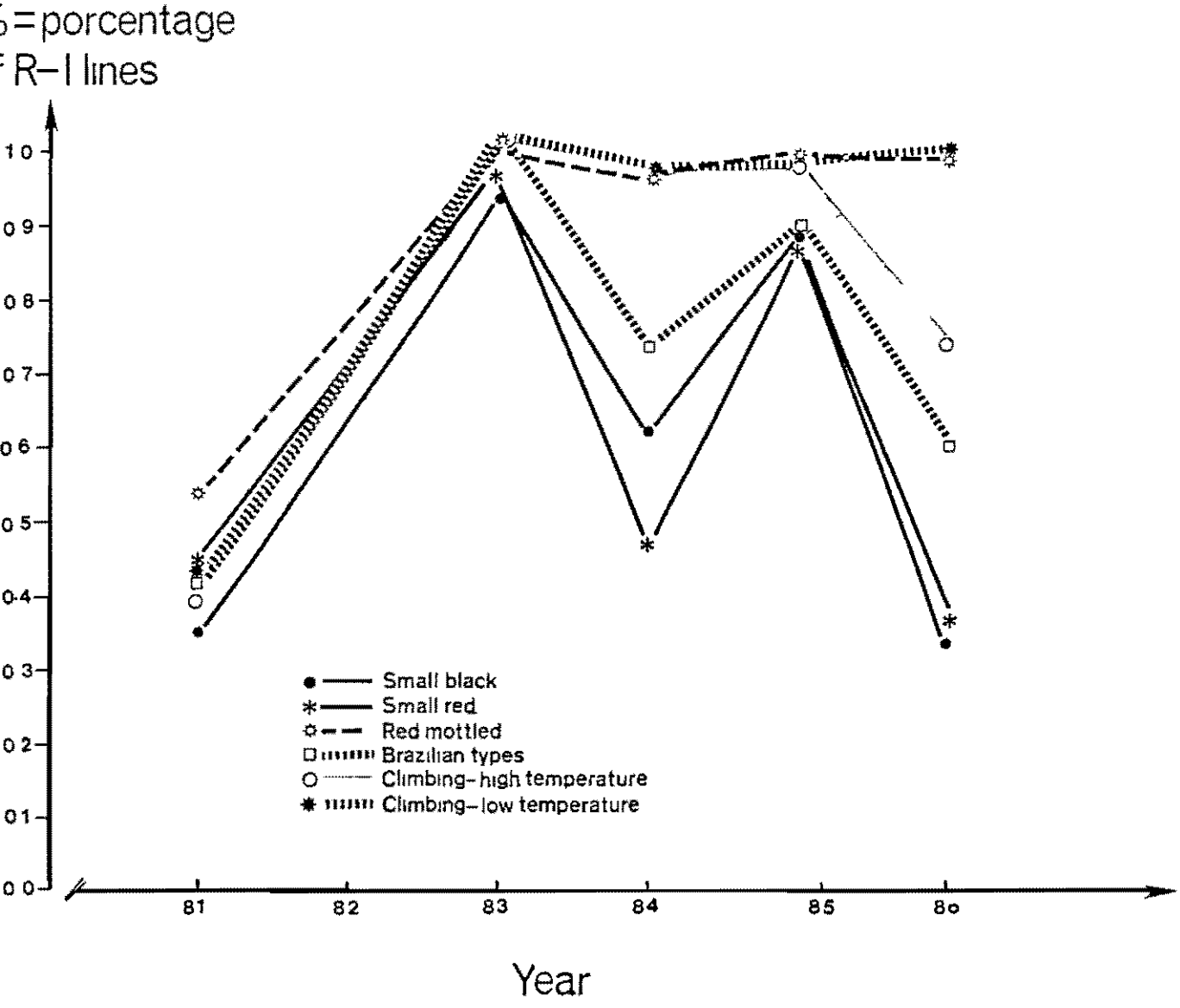
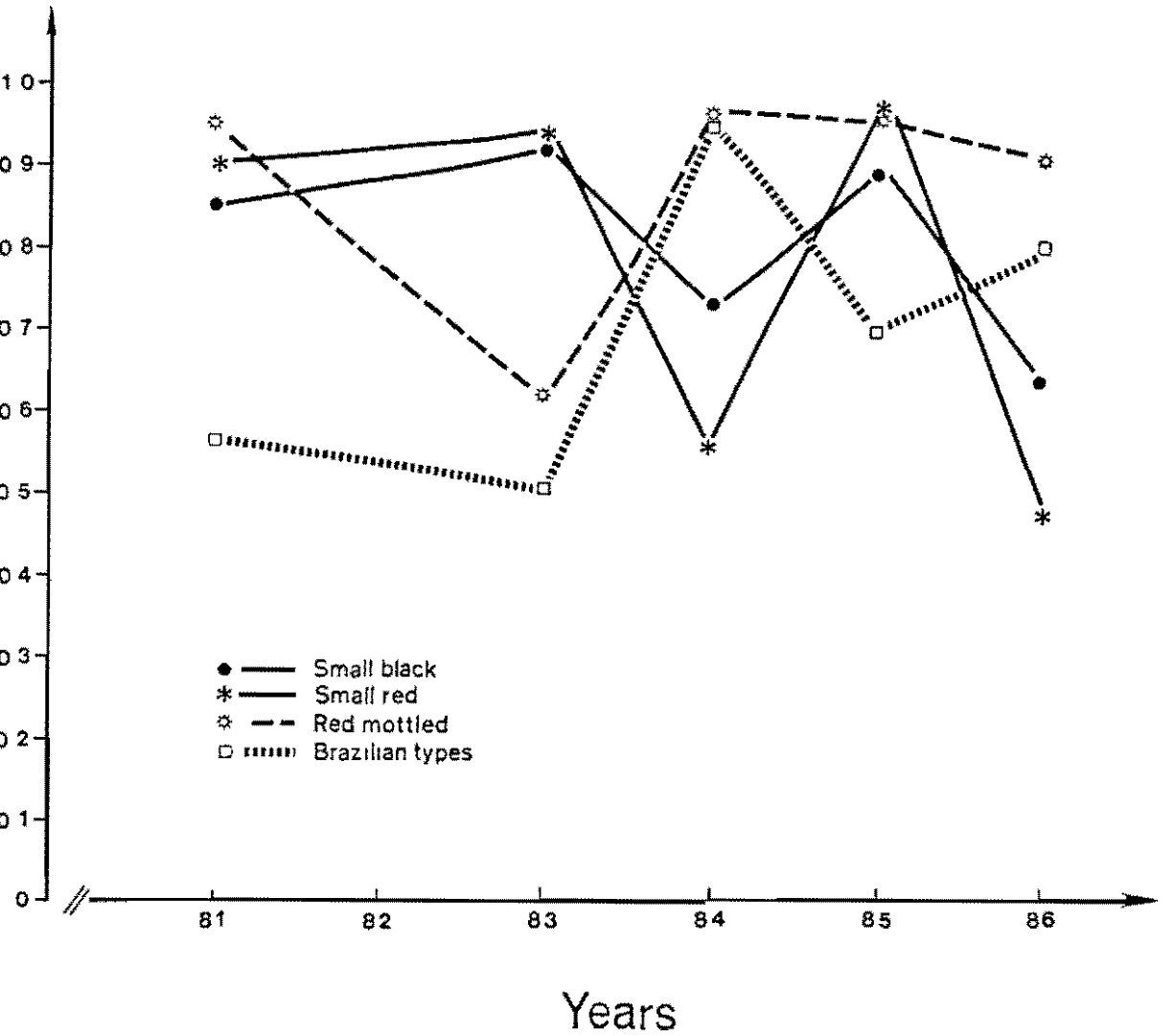


FIG. 2.3

Trend in the number of bean lines with resistance to ANGULAR LEAF SPOT

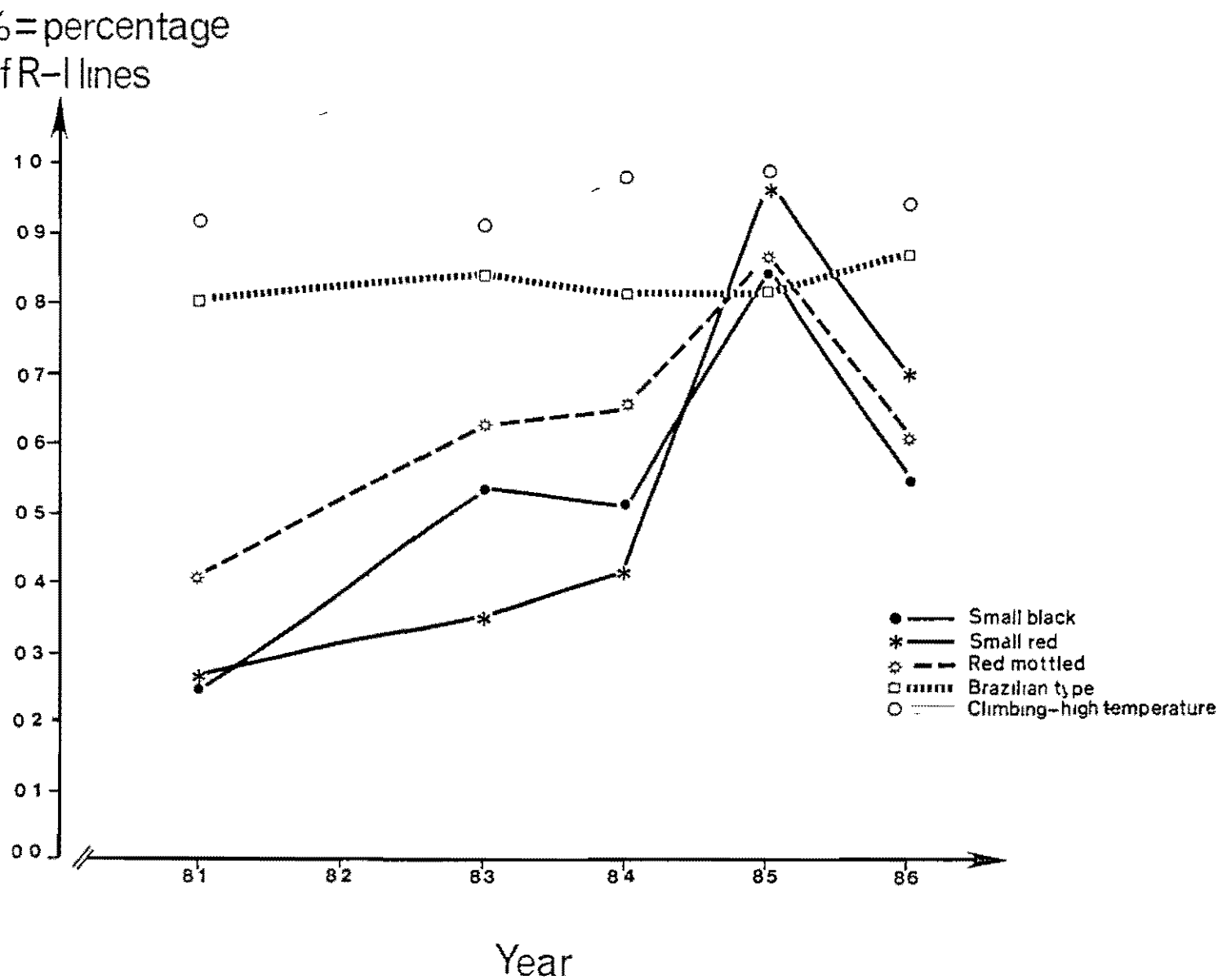
F percentage
R–I lines



Years

F I G . 2.4

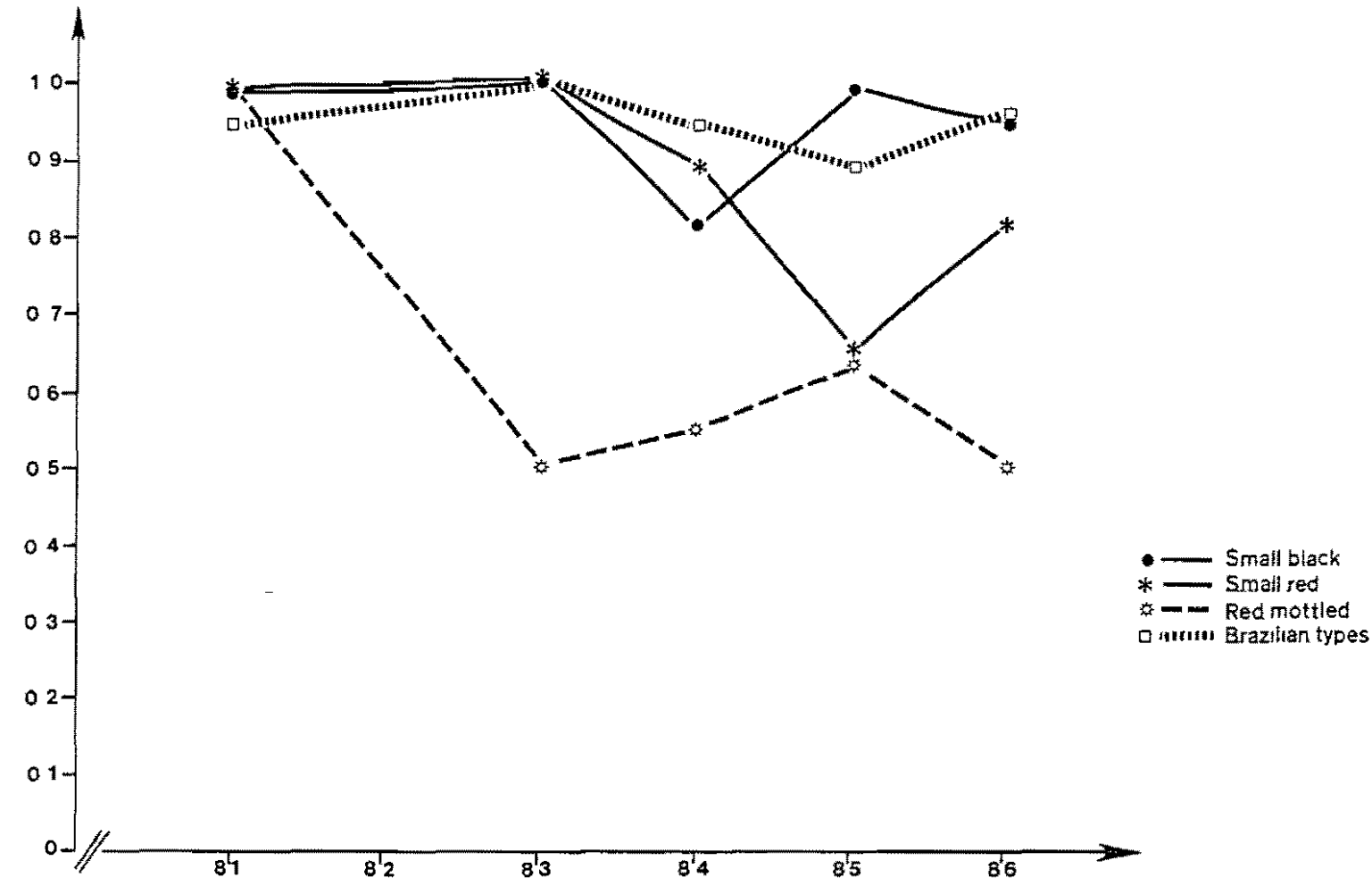
Trend in the number of bean lines with resistance to ANTRHACNOSE



IG. 2.5

rend in the number of bean lines with resistance
o COMMON MOSAIC VIRUS

=percentage
R–I lines



Years

Table 1 1 CONTRIBUTION IN SOURCES OF RESISTANCE — RUST — (1981 - 1986)

BEAN	TYPES	Total no of lines produced	no of R-I lines (and %)		% from Total 'R-I"
Habit	**Type**				
bush	Red Mottled	1535	1363	(89)	29
climbing	Low Temperatures	1046	956	(91)	20
bush	Small Red	807	523	(65)	11
bush	Brazilian Type	675	445	(66)	9
climbing	High Temperatures	452	369	(82)	8
bush	Small Black	536	313	(58)	7
bush	Small White	475	282	(60)	6
bush	Mexican Types	498	239	(48)	5
bush	Pacific Coasts	165	140	(85)	3
bush	Medium White	100	82	(82)	2
Total		6289	4712	(75%)	100%

Table 1 2 CONTRIBUTION IN SOURCES OF RESISTANCE — BACTERIAL BLIGHT — (1981 - 1986)

BEAN	TYPES	Total no of lines produced	no of R-I ' lines (and %)		% from Total ' R-I
Habit	**Type**				
bush	Red Mottled	1535	809	(53)	40
climbing	Low Temperatures	1046	451	(43)	22
bush	Small Red	807	152	(19)	8
bush	Brazilian Type	675	149	(22)	7
bush	Mexican Types	498	127	(26)	6
bush	Small Black	536	118	(22)	6
bush	Small White	475	112	(24)	6
climbing	High Temperatures	452	66	(15)	3
bush	Medium White	100	28	(28)	1
bush	Pacific Coasts	165	22	(13)	1
Total		6289	2034	(32%)	100%

Table 1 3 CONTRIBUTION IN SOURCES OF RESISTANCE — ANGULAR LEAF SPOT — (1981 - 1986)

BEAN	TYPES	Total no of lines produced	no of R-I lines (and %)		% from Total R-I '
Habit	**Type**				
bush	Red Mottled	1535	1160	(76)	25
climbing	Low Temperatures	1046	761	(73)	16
bush	Small Red	807	640	(73)	14
bush	Brazilian Types	675	455	(67)	10
bush	Small Black	536	440	(82)	10
bush	Small White	475	351	(74)	8
climbing	High Temperatures	452	335	(74)	7
bush	Mexican Types	498	220	(44)	5
bush	Pacific Coasts	165	153	(92)	3
bush	Medium White	100	86	(86)	2
Total		6289	4601	(73%)	100%

Table 1 4 CONTRIBUTION IN SOURCES OF RESISTANCE — ANTHRACNOSE — (1981 - 1986)

BEAN	TYPES	Total no of lines produced	no of R-I lines (and %)		% from Total R-I''
Habit	**Type**				
climbing	Low Temperatures	1046	975	(93)	23
bush	Red Mottled	1535	944	(62)	23
bush	Brazilian Types	675	524	(78)	13
climbing	High Temperatures	452	423	(94)	10
bush	Small Red	807	377	(47)	9
bush	Small Black	536	276	(51)	7
bush	Mexican Types	498	263	(53)	6
bush	Small White	475	245	(52)	6
bush	Pacific Coasts	165	71	(42)	2
bush	Medium White	100	56	(56)	1
Total		6289	4154	(66%)	100%

Table 1 5 CONTRIBUTION IN SOURCES OF RESISTANCE — COMMON MOSAIC VIRUS — (1981 - 1986)

BEAN	TYPES	Total no of lines produced	no of R lines (and %)		% from Total 'R'
Habit	**Type**				
bush	Red Mottled	1535	854	(56)	21
bush	Small Red	807	713	(89)	17
bush	Brazilian Types	675	642	(95)	16
bush	Small Black	536	521	(97)	13
bush	Small White	475	418	(88)	10
bush	Mexican Types	498	324	(65)	8
climbing	High Temperatures	452	248	(55)	6
climbing	Low Temperatures	1046	153	(15)	4
bush	Pacific Coasts	165	125	(76)	3
bush	Medium White	100	88	(88)	2
Total		6289	4086	(65%)	100%

FIG. 3.1

TREND IN THE NUMBER OF BEAN LINES WITH COMBINED RESISTANCE TO

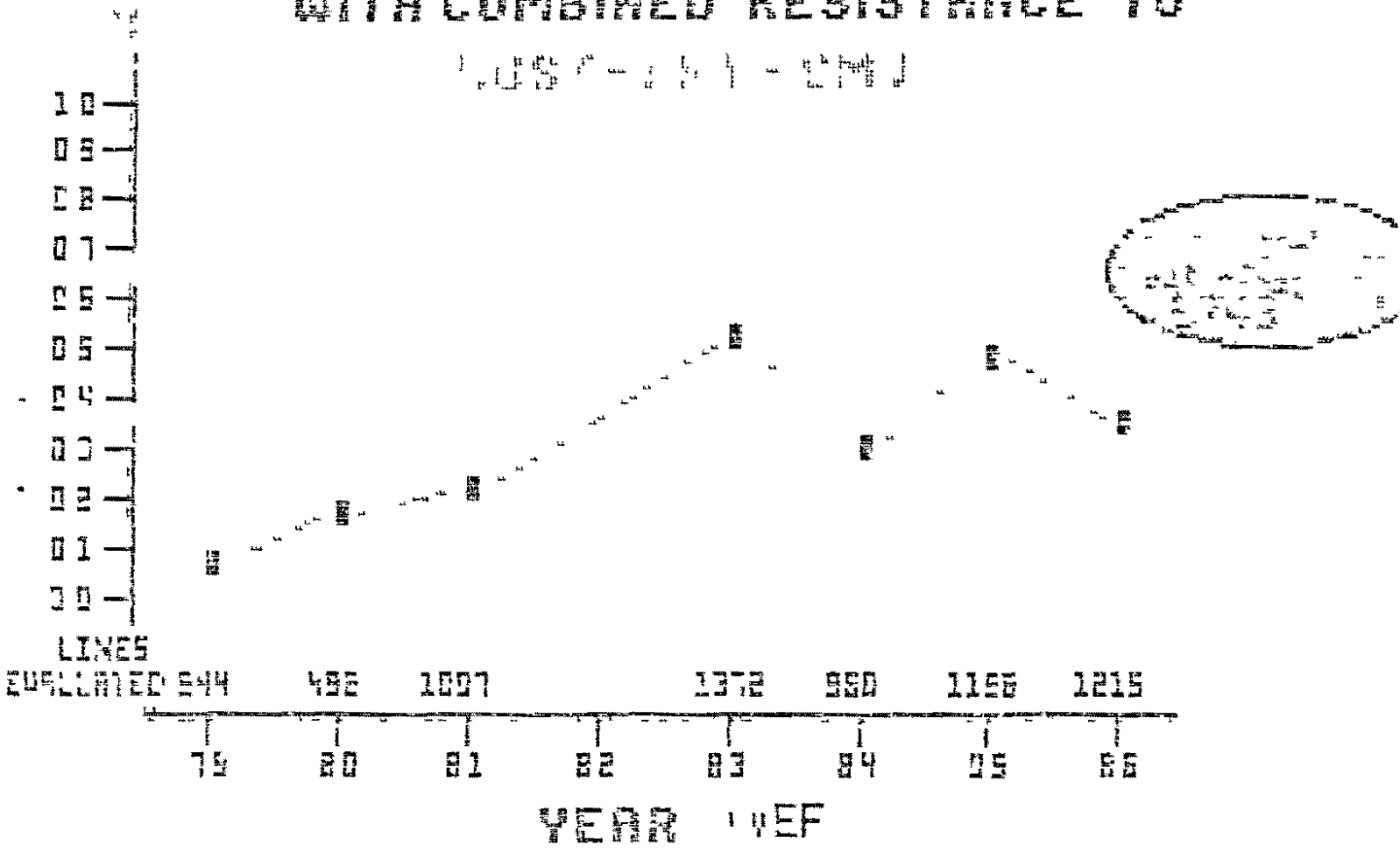


FIG. 3.2

TREND IN THE NUMBER OF BEAM LINES WITH COMBINED RESISTANCE TO

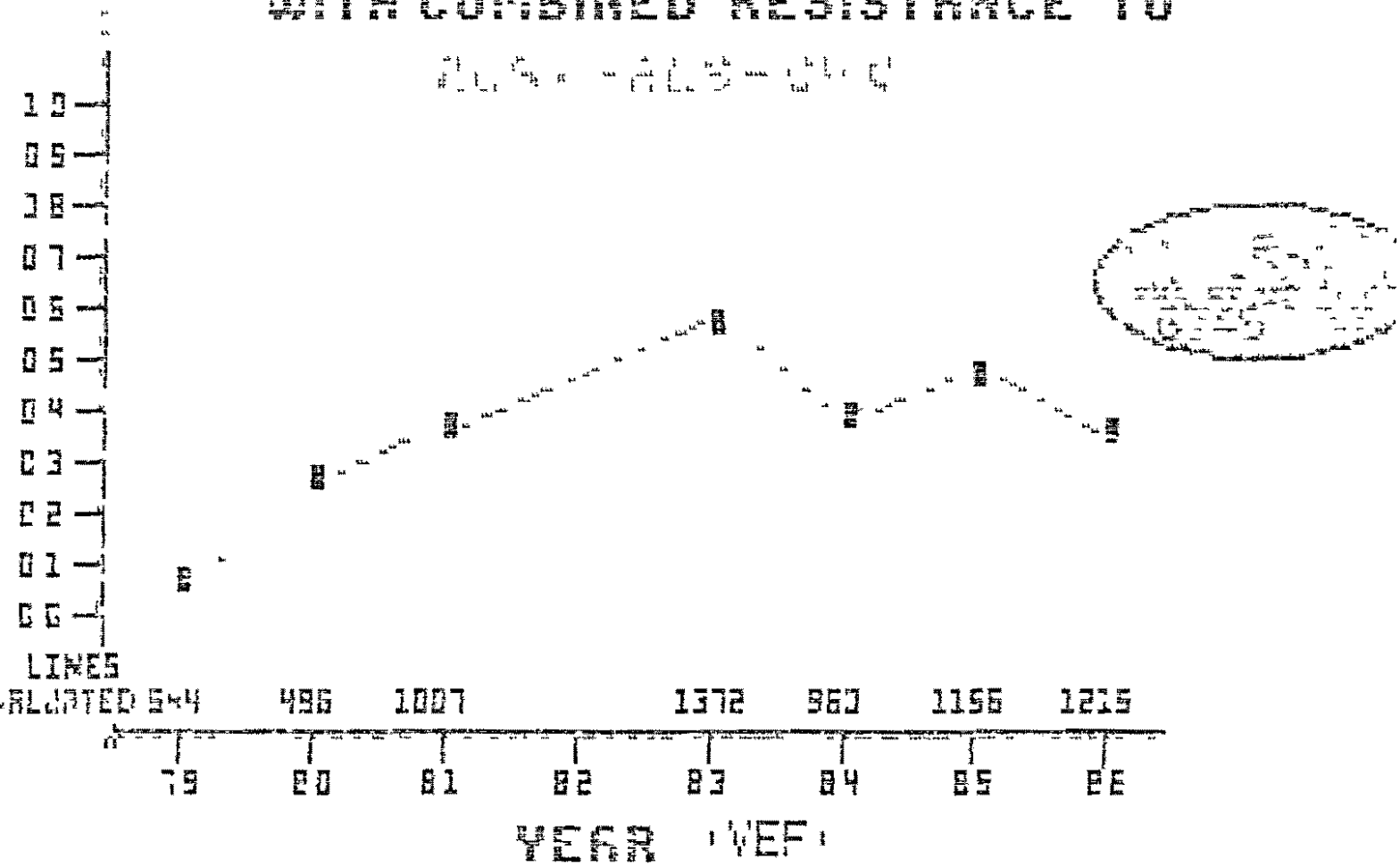


FIG. 3.3

TREND IN THE NUMBER OF BEAN LINES EXHIBITING RESISTANCE TO

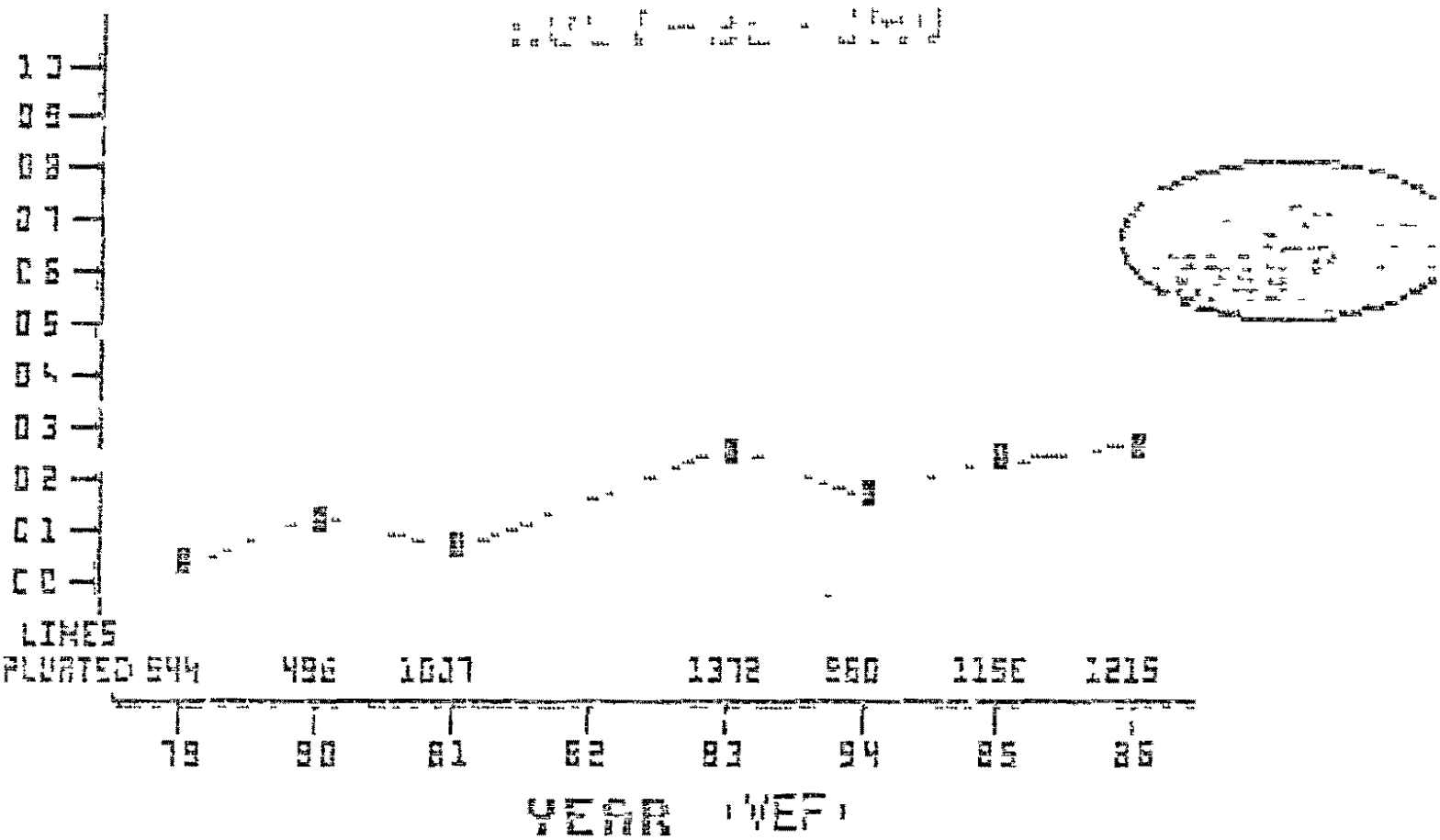


FIG. 3.4

TREND IN THE NUMBER OF BEAN LINES WITH COMBINED RESISTANCE TO

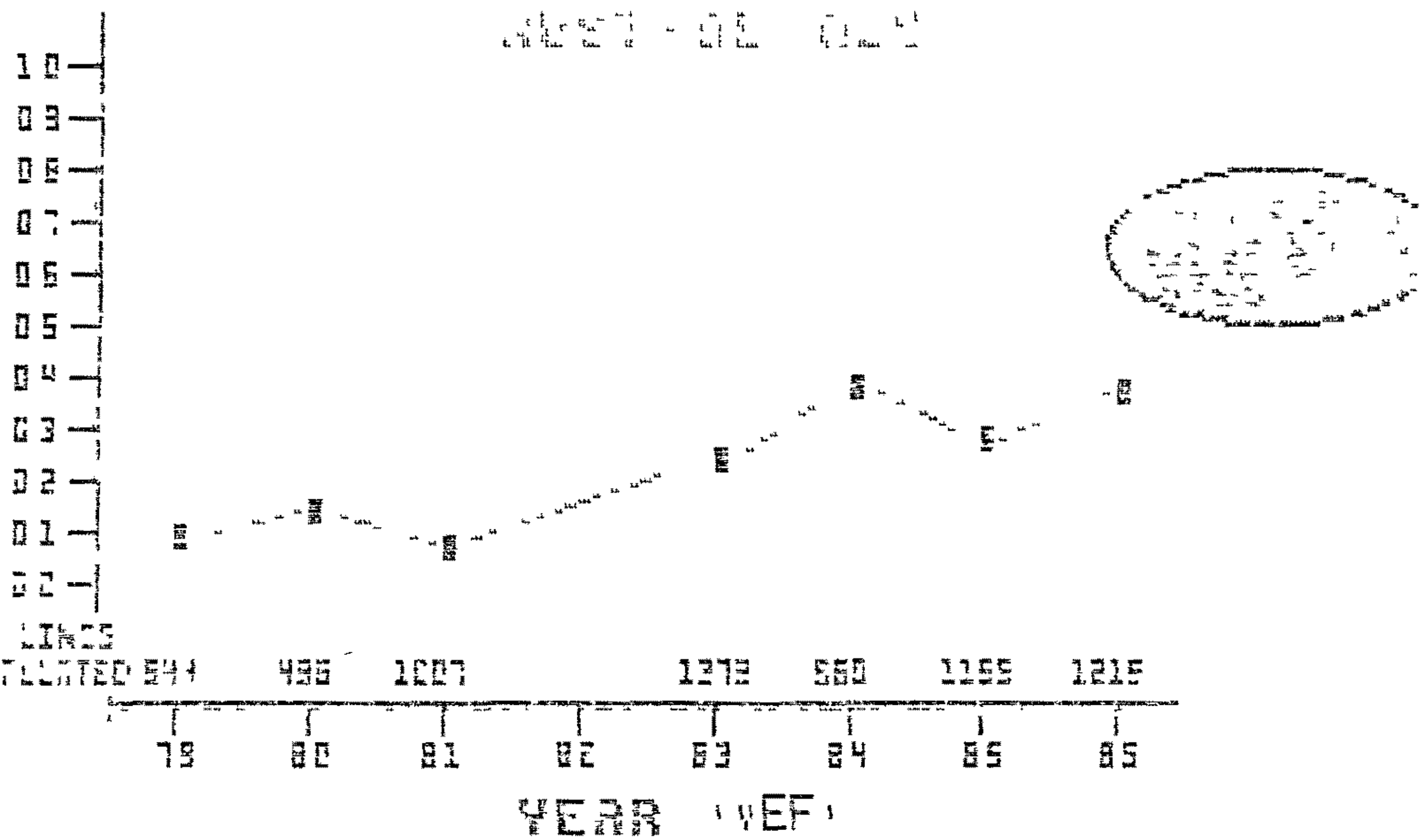


FIG. 3.5

TREND IN THE NUMBER OF BEAR LINES WITH COMBINED RESISTANCE TO

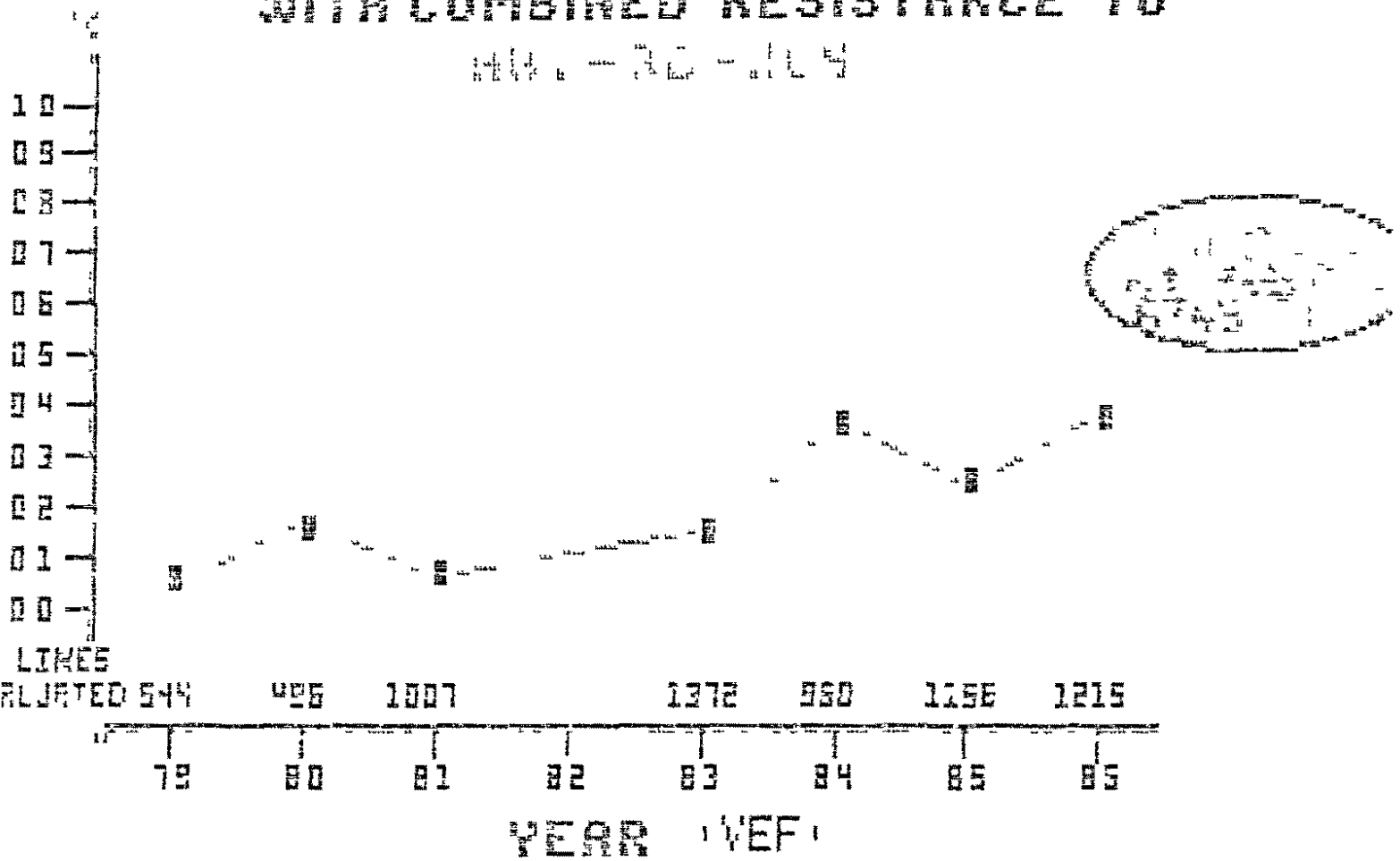


FIG. 3.6.

TREND IN THE NUMBER OF BEAN LINES WITH COMBINED RESISTANCE TO

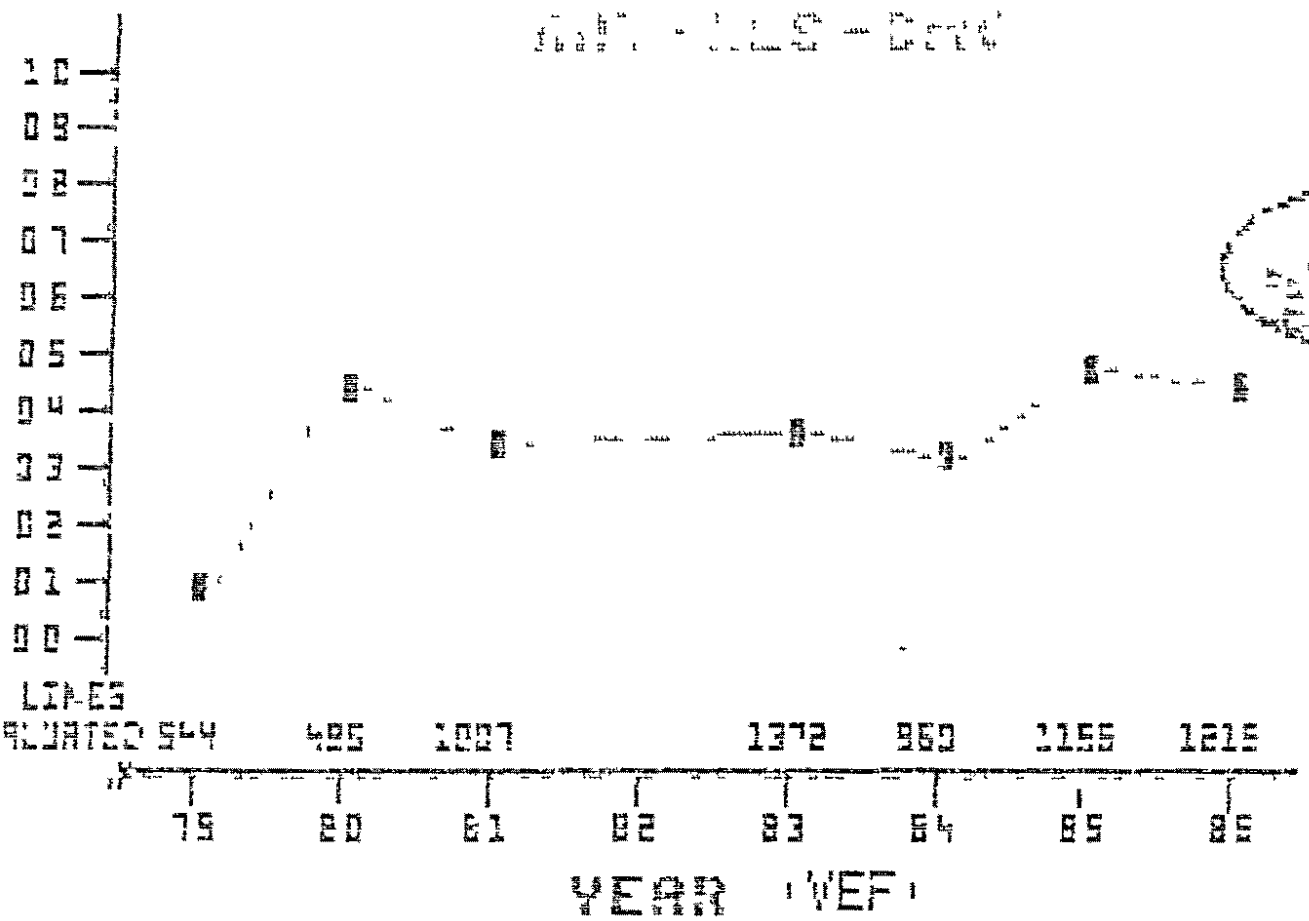


Table 2 1 CONTRIBUTION IN SOURCES OF COMBINED RESISTANCE RUST-Anthracnose - CMV (1981 - 1986)

BEAN	TYPES	Total no of lines produced	no of R-I lines (and %)		% from Total R-I
Habit	**Type**				
bush	Red Mottled	1535	573	(37)	28
bush	Brazilian Types	675	370	(55)	18
bush	Small Red	807	244	(30)	12
climbing	High Temperatures	452	194	(43)	9
bush	Small Black	536	192	(36)	9
bush	Mexican Types	498	183	(37)	9
bush	Small White	475	142	(30)	7
climbing	Low Temperatures	1046	99	(10)	5
bush	Pacific Coasts	165	49	(30)	2
bush	Medium White	100	44	(44)	2
Total		6289	2090	(33%)	100%

Table 2 2 CONTRIBUTION IN SOURCES OF COMBINED RESISTANCE RUST — ALS — CMV (1981 - 1986)

BEAN	TYPES	Total no of lines produced	no of R-I lines (and %)		% from Total R-I''
Habit	**Type**				
bush	Red Mottled	1535	649	(42)	27
bush	Small Red	807	406	(50)	17
bush	Brazilian Types	675	296	(44)	12
bush	Small Black	536	267	(50)	11
bush	Small White	475	217	(46)	9
climbing	High Temperatures	452	175	(39)	7
bush	Mexican Types	498	166	(33)	7
bush	Pacific Coasts	165	95	(58)	4
climbing	Low Temperature	1046	85	(8)	4
bush	Medium White	100	63	(63)	3
Total		6289	2419	(39%)	100%

Table 2 3 CONTRIBUTION IN SOURCES OF COMBINED RESISTANCE RUST — BB — CMV (1981 - 1986)

BEAN	TYPES	Total no of lines produced	no of ' R-I lines (and %)		% from Total "R-I
Habit	**Type**				
bush	Red Mottled	1535	457	(30)	45
bush	Brazilian Types	675	106	(16)	10
bush	Mexican Types	498	103	(21)	10
bush	Small Red	807	90	(11)	9
bush	Small Black	536	71	(13)	7
bush	Small White	475	68	(14)	7
climbing	Low Temperatures	1046	56	(5)	5
climbing	High Temperatures	452	39	(9)	4
bush	Medium White	100	24	(24)	2
bush	Pacific Coast	165	15	(9)	1
Total		6289	1029	(16%)	100%

Table 2 4 CONTRIBUTION IN SOURCES OF COMBINED RESISTANCE RUST — BB — ALS (1981 - 1986)

BEAN	TYPES	Total no of lines produced	no of R-I lines (and %)		% from Total ' R-I '
Habit	**Type**				
bush	Red Mottled	1535	627	(41)	38
climbing	Low Temperature	1046	440	(42)	27
bush	Mexican Types	498	143	(29)	9
climbing	High Temperature	452	130	(29)	8
bush	Small Red	807	87	(11)	5
bush	Brazilian Types	675	72	(11)	4
bush	Small White	475	60	(13)	4
bush	Small Black	536	57	(11)	3
bush	Medium White	100	37	(37)	2
bush	Pacific Coast	165	15	(9)	1
Total		6289	1631	(26%)	100%

Table 2 5 CONTRIBUTION IN SOURCES OF COMBINED RESISTANCE ANTHRACNOSE — BB — ALS (1981 - 1986)

BEAN	TYPES	Total no of lines produced	no of 'R-I lines (and %)		% from Total R-I'
Habit	**Type**				
bush	Red Mottled	1535	468	(31)	33
climbing	Low Temperatures	1046	448	(43)	32
climbing	High Temperatures	452	130	(29)	9
bush	Brazilian Types	675	88	(13)	6
bush	Mexican Types	498	75	(15)	5
bush	Small Red	807	62	(8)	4
bush	Small Black	536	46	(9)	3
bush	Small White	475	45	(10)	3
bush	Medium White	100	25	(25)	2
bush	Pacific Coasts	165	13	(8)	1
Total		6289	1400	(22%)	100%

Table 2 6 CONTRIBUTION IN SOURCES OF COMBINED RESISTANCE ANTHRACNOSE — ALS — CMV (1981 - 1986)

BEAN	TYPES	Total no of lines produced	no of R-I'' lines (and %)		% from Total ' R-I
Habit	**Type**				
bush	Red Mottled	1535	507	(33)	25
bush	Brazilian Types	675	345	(51)	17
bush	Small Red	807	271	(34)	13
bush	Small Black	536	209	(39)	10
climbing	High Temperatures	452	185	(41)	9
bush	Small White	475	178	(38)	9
bush	Mexican Types	498	166	(34)	8
climbing	Low Temperature	1046	100	(10)	5
bush	Pacific Coasts	165	50	(30)	2
bush	Medium White	100	40	(40)	2
Total		6289	2051	(33%)	100%

Table 2 7 CONTRIBUTION IN SOURCES OF COMBINED RESISTANCE — ALL FIVE DISEASES — (1981 - 1986)

BEAN	TYPES	Total no of lines produced	no of "R-I lines (and %)		% from Total R-I"
Habit	**Type**				
bush	Red Mottled	1535	301	(20)	50
bush	Brazilian Types	675	65	(10)	10
bush	Mexican Types	498	60	(37)	9
climbing	Low Temperatures	1046	50	(5)	8
bush	Small Red	807	46	(6)	7
bush	Small Black	536	37	(7)	6
climbing	High Temperature	452	32	(7)	5
bush	Small White	475	26	(6)	4
bush	Medium White	100	10	(10)	2
bush	Pacific Coasts	165	10	(6)	2
Total		6289	637	(10%)	100%

Table 4:

— NEEDS BY REGION[1] —
Available Sources of disease resistance
(some examples)

ARGENTINA

		R-I"
Small black	BB	118
	Ant - ALS	209
Large - Medium White	BB	28
	Ant - ALS	40

BRAZIL

		'R-I
Small Black	Rust - BB	71
	Ant - ALS	209
Brazilian Types	Rust - BB	106
	Ant - ALS	345

MEXICO

		"R-I'
Small Black	Rust-BB	71
	Ant-ALS	209
Mexican Types	Rust - BB	103
	Ant - ALS	166
Pacific Coasts	Rust - BB	15
	Ant - ALS	50

COLOMBIA — ECUADOR (Sierras)

		R-I '
Large Red	Rust-BB	457
Red Mottled	Ant-ALS	507

CUBA

		R-I
Small Red	Rust	523

BOLIVIA

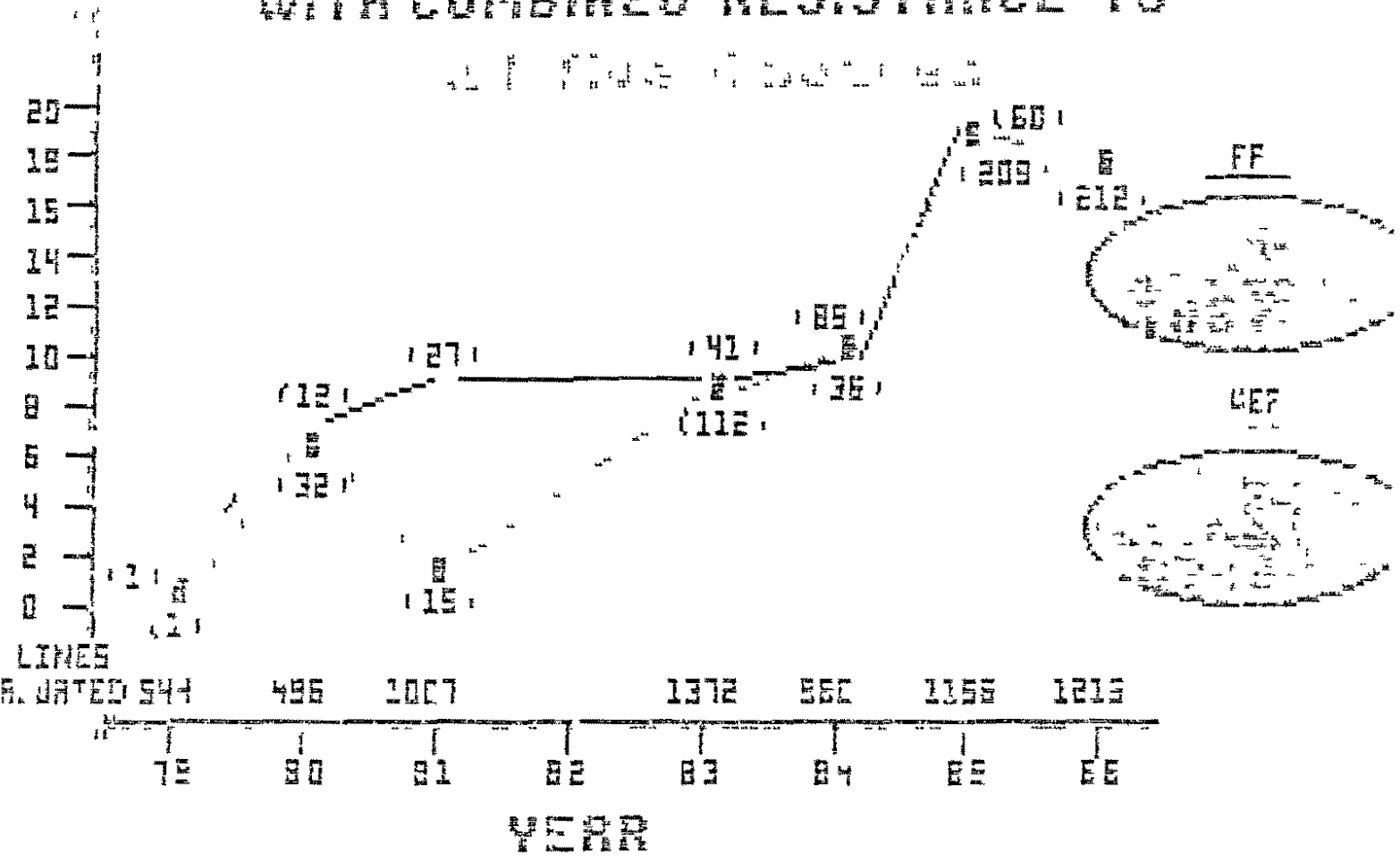
		'R-I
Small Black	Rust - ALS	267

[1] **Source** Voysest O 1983 Variedades de frijol en America Latina y su origen Pastor Corrales, M A /Morales F (personal communication)

- Resistance to BCMV needed in all cases

FIG. 3.7

TREND IN THE NUMBER OF BEAM LINES WITH COMBINED RESISTANCE TO



2. Progress in yield potential combined with disease resistance

HIGH YIELD POTENTIAL LINE

That whose mean yield is statistically **greater** than the check yield, at any one of the testing sites CIAT, Popayan, La Selva

Table 5 CHECK VARIETIES

Bean Types	Checks	Yield (kg/ha) CIAT	Yield (kg/ha) Popayán
Bush			
Small Black	ICA-Pijao/JAMAPA	2300	2447
Small Red	A-21/ZAMORANO	1518	2260
Small White	EX-RICO 23	1516	2157
Red Mottled	CALIMA	1706	1811
Medium White	ALUBIA CERILLOS	1637	1530
Pacific Coast	CANARIO 107/MAYOCOBA	1829	1218
Mexican Types	Ojo de Cabra/CANARIO 107	1677	2349
Brazilian Types	CARIOCA	1959	2533
Climbing			
Warm Temperatures	ROJO 70	1018	1907
Cold Temperatures	ICA-Viboral	—	3412[1]

1 Evaluated at La Selva exp station (2400 msnm)

Table 6 LSD values used for the identification of lines with high yield potential

Bean Types	Year of Evaluation (EP)							
	1984			1985			1986	
	LSD CIAT (kg/ha)	LSD Pop (kg/ha)		LSD CIAT (kg/ha)	LSD Pop (kg/ha)		LSD CIAT (kg/ha)	LSD Pop (kg/ha)
Bush Beans								
Small Black	194	466		417	522		783	386
Small Red	181	496		392	408		347	373
Small White	128	407		508	571*		276*	411
Red Mottled	159	512		415	431*		564	856*
Medium White	124	535		393	637*		—	—
Pacific Coasts	159	489		582	400*		383*	348
Mexican Types	116	507		287	306		—	—
Brazilian Types	152	587		544	800		366	286
Climbing Beans								
Warm in Temperatures	193	237	29	688	532*	67	933*	784
Cold Temperatures	-	—	99	—	728**	73	—	743**

(*) Figure correspondingh to semester B only
(**) Corresponds to the evaluation carried out at La Selva Experimental Station

Table 7 High yield potential lines produced on each bean type (Totals over the three years)

Bean Types	No of Lines tested	No of lines superior at CIAT	Popayan	Both	Total	(%)
Bush						
Red Mottled	396	53	32	2	87	(22)
Small Red	141	45	17	5	67	(48)
Pacific Coasts	72	4	23	6	33	(46)
Small White	110	23	5	4	32	(29)
Mexican Types	22	10	-	3	13	(59)
Brazilian Types	57	3	1	-	4	(7)
Medium White	18	3	1	-	4	(22)
Small Black	114	-	3	-	3	(3)
Climbing						
Warm temperatures	155	17	24	22	63	(41)
Cold temperatures	172	-	11[1]	-	11	(6)
TOTAL	1257	158	117	42	317	
%	100%	13%	9%	3%	25%	

[1] Evaluated at La Selva Experimental Station (2400 m s n m approx)

Table 8 **High yield potential lines:**
- Mean increment in yield over the checks -

Superior at	No of lines	Mean Yield (kg/ha)	Mean increament over the checks (kg/ha)
CIAT only	158	2334	724
Popayan	117	2433	793
Both sites	42	CIAT 2731	1515
		Pop 3327	1342
TOTAL	317		

[1] SE = Standard error of the mean

Table 9 HIGH YIELD POTENTIAL LINES — YIELD PER BEAN TYPE —

Bean Type	No of lines	Yield, when superior at			
		CIAT	Popayán	BOTH	
				CIAT	Popayán
Bush					
Red Mottled	87	2370	1949	2536	2372
Small Red	67	2222	2364	2219	2705
Pacific Coasts	33	2016	2100	2016	1873
Small White	32	2904	1923	3074	2625
Mexican Types	13	2096	—	2419	2724
Brazilian Types	4	3657	3134	—	—
Medium white	4	2391	1423	—	—
Small Black	3	—	2789	—	—
Climbing					
Warm Temperatures	63	1715	2126	3789	4162
Cold Temperatures	11	—	5479[1]	—	—
TOTAL	317	2334	2433	3123	3327

1 Evaluated at La Selva

Table 10 DISEASE RESISTANCE ATTRIBUTES OF HIGH YIELD POTENTIAL LINES

ATTRIBUTE		No of lines	%
High	Yield potential	317	100
R to	CMV	269	85
R-I to	Anthracnose	229	72
	Rust	189	60
	ALS	167	53
	R-Ant-CMV	125	39
	Ant-ALS-CMV	108	34
	R-ALS-CMV	102	32
	BB	68	21
	R-BB-CMV	36	11
	R-BB-ALS	36	11
	Ant-BB-ALS	28	9
	All diseases	19	6

Table 11 INDEPENDENCE BETWEEN YIELD[1] AND DISEASE RESISTANCE

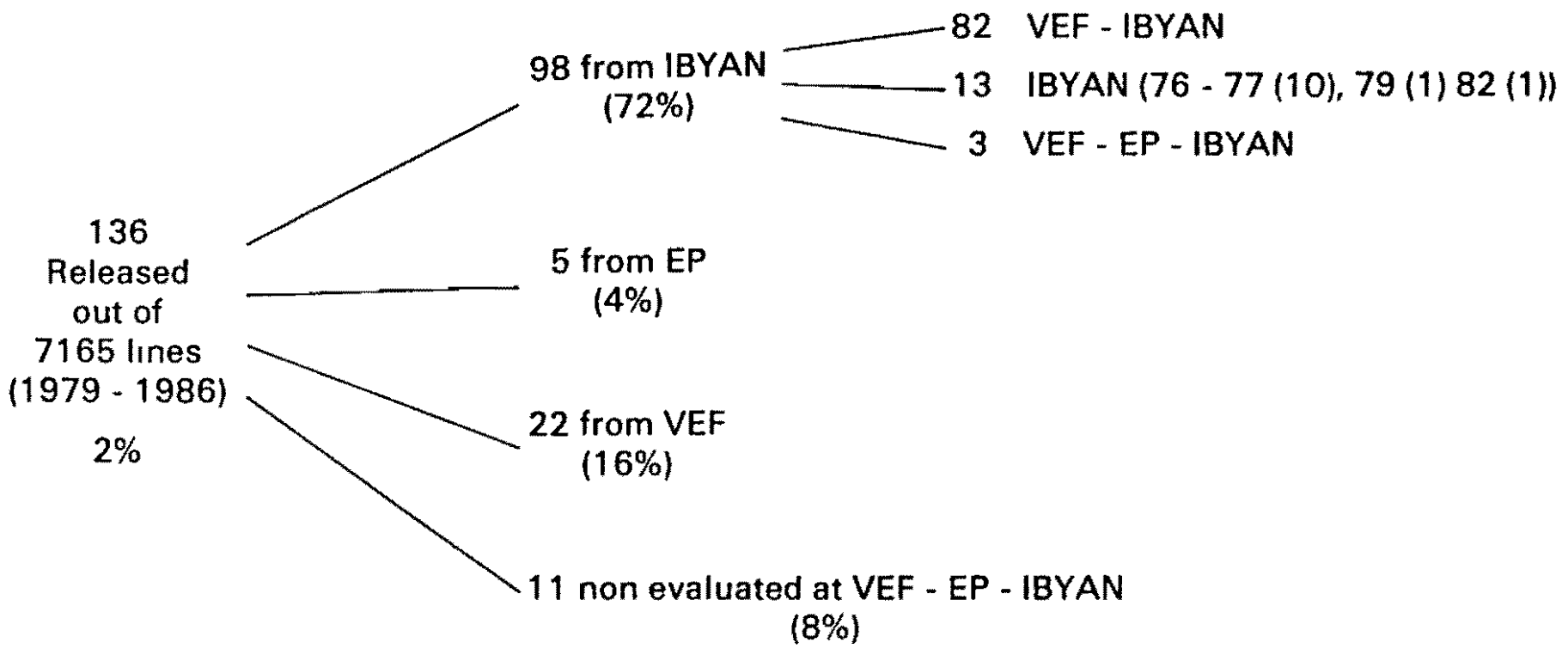
DISEASE	YIELD (kg/ha)		
	R-I	S	
RUST	2232	2175	NS
Anthracnose	2276	2058	NS
CMV	2221	2041	NS
ALS	2184	2231	NS
B Blight	1908	2305	NS
Rust-Ant-CMV	2346	2131	NS
All diseases	1890	2224	NS

1 Yield at CIAT

TABLE 12: EP LINES WITH HIGH YIELD POTENTIAL and COMBINED DISEASE RESISTANCE that have been RELEASED as VARIETIES

LINE	YIELD (kg/ha)		Disease resistance (all R to BCMV)			
	CIAT	Popayán	Rust	Anthr	ALS	CBB
Small Black						
1 NAG 20	2411	1282	R			I
Small Red						
2 RAB 142	2286	1564			I	
3 RAB 205 (Catrachita' - Honduras)	2216	2944		R		
4 MCD - 201 (Huetar 2 ' - C Rica)	1511	2037	I	I	I	
Small White						
5 2 W-33-2-MITA	2326	2576				R
Red Mottled						
6 PVAD 1111	1952	1262	I		I	I
7 PAI 29	1909	1089	I		I	I
Climbing-warm Temperatures						
8 ZAV 83044	1578	1130	I	R	I	

TABLE 13. ORIGIN of BEAN RELEASED VARIETIES (1976 - 1986)



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