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WHITEFLY (T. vaporarium, West.) PREFERENCE ON THREE BEAN GENERA OF THE FAMILY LEGUMINOSAE.

presented by

FREDDY R. ALONZO-PADILLA

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James A. Webster
Major professor

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WHITEFLY (*T. vaporarium*, West.) PREFERENCE ON THREE BEAN GENERA OF THE FAMILY LEGUMINOSAE

By

FREDDY R. ALONZO-PADILLA

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ABSTRACT

WHITEFLY (Trialeurodes vaporarium Westw.) PREFERENCE OF THREE BEAN GENERA OF THE FAMILY LEGUMINOSAE

By

Freddy R. Alonzo-Padilla

Whitefly (Trialeurodes vaporarium Westw.) prolificacy and high survival attributes enable it to fully infest the leaf underside of the host plants. As a sucking insect, it stunts the growth of bean plants due to the enormous losses of plant sap. The adult mobility and habit of feeding in the phloem enables it to be an efficient vector of several virus diseases.

The purpose of this research was to evaluate 118 bean cultivars of four species of Phaseolus, two species of Vigna, and one species of Dolichos lablab, for shelter and oviposition preferences to the greenhouse whitefly in free-choice greenhouse conditions. A second purpose of this research was to study leaf-part preferences exhibited by adult whiteflies when confined to selected cultivars of the three genera with varying degrees of resistance.

A satisfactory method for testing bean germplasm for whitefly resistance was developed, as suggested by the highly significant (P=0.01) correlation coefficient found between cultivar plant responses recorded in the free-choice germplasm test versus those plant responses recorded in the experiment of plant part and adult preferences.

The highest resistance for whitefly adult attraction and/or for oviposition was found in genera other than Phaseolus. Within the Phaseolus this resistance was also higher in species other than Ph. vulgaris. Both Vigna radiata, Dolichos lablab and V. repens in decreasing order of preference, were the least preferred. In the Phaseolus germ plasm, the degree of attractiveness was in general shown in the following ascending order: first, Ph. coccineus and Ph. lunatus, second, Ph. accutifolius, and third, Ph. vulgaris.

In all these genera and species, the highest level of resistance was associated with low attractiveness shown by the first well expanded leaf blade of the upper plant part, and with the almost non-attractiveness of the shoot. Shoot non-attractiveness was a fairly common phenomena except in the preferred and very preferred cultivars.

In the Ph. vulgaris group, wild types seemed to be the best source of breeding material for resistance to this insect, although Ph. lunatus and Ph. coccineus were sources of resistance, and successful crosses of these with Ph. vulgaris have been reported in the literature.

Seed coat color of Ph. vulgaris was suggested to be related with whitefly adult attraction and with oviposition preference. The plants of some black and red seeded types were least preferred for shelter and/or for oviposition, but plants of the striped seeded types were the most preferred. Somewhat intermediate in attractiveness were some brown and white seeded cultivars.

Whitefly adults confined to the most resistant cultivars were observed to greater extent on leaf parts such as the petiole and stem, as well as on the chamber wall, which are unusual parts selected by the whitefly adult in normal conditions.

The highest resistance for whitefly adult attraction and/or for oviposition was found in genera other than *Phaseolus*. Within the *Phaseolus* this resistance was also higher in species other than *Ph. vulgaris*. Both *Vigna radiata*, *Dolichos lablab* and *V. repens* in decreasing order of preference, were the least preferred. In the *Phaseolus* germ plasm, the degree of attractiveness was in general [illegible] in the following ascending order: first, *Ph. coccineus* and [illegible]

Short flights, as part of the normal whitefly behavior were also taken less often in the most resistant cultivars. The shoot, the petiole and the stem exhibited only 18, 16 and 2 percent, respectively, of the adult attraction shown by the first well expanded leaf blade alone.

Confining conditions of the whitefly adult leaf-part preference study allowed identification of cultivars exhibiting non-preferred responses even under greater infesting pressure.

Short flights, as part of the normal whitefly behavior were also taken less often in the most resistant cultivars. The [illegible], the petiole and the stem exhibiting only 18, 11 and 2 percent, respectively, of the adult attraction shown by the first fully expanded leaf blade alone.

Confinied conditions of the whitefly adult leaf-part preference study allowed identification of cultivars exhibiting non-preferred [illegible] infesting [illegible].

The author would like to dedicate this thesis to the following persons.

The small bean-peasants of the world.

Mr. Manuel Alonzo and Mrs. Victoria Padilla de Alonzo.
(Love and deepest gratitude to their multiple efforts).

Nolandth Elizabeth, Itze Victoria, and Freddy Rolando (Jr.).
(My lovely children)

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The author would like to express gratitude to Dr. J. A. Webster, his major professor, first for allowing him to continue working on this project he had started in the Institute of Science and Agriculture Technology of Guatemala where he worked as entomologist of the bean program. Indebted is also the author to him for the greenhouse space, some material facilities and for computer time received, through his person, as a grant from the USDA-Cereal Leaf Beetle Program. Without these valuable facilities this research would not have been possible.

Special thanks are due the members of comittee Dr. J. A. Webster, Dr. R. Ruppel, Dr. E. Grafius, and Dr. M. W. Adams for their valuable criticism in the writting of this thesis.

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Sincere appreciation is extended to his better half, Sonia, who has been at his side throughout this rewarding period.

Thanks are due also to all those persons that in any way contributed to complete this thesis, and the author studies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The importance of the greenhouse whitefly, *Trialeurodes vaporarium* (Westw.), as a greenhouse pest is well known. Its importance as a vector of virus diseases is also well documented (15, 52, 37).

Breeding bean cultivars for genetic resistance against either the greenhouse whitefly (*Trialeurodes vaporarium* Westw.) or the more tropical bean whitefly (*Bemisia tabaci* Gen.) provides an ideal way of controlling or suppressing their physical damage. Breeding for genetic resistance probably greatly reduces the frequency with which bean plants show virus diseases. There are several supporting facts for this author's hypothesis: (1) virus disease transmission is confined to the adult life stage, the only non-sedentary whitefly life stage; (2) the adult whitefly's specificity as a phloem-feeder enables this to be the only stage efficiently transmitting virus diseases; (3) adult whiteflies take a relatively long time (15 minutes or more) to reach the phloem in *Ph. lunatus* (53); (4) viruses in the whitefly adult require a relatively long incubation period (more than 8 hours) for the adult to become a positive vector; and (5) congenital virus transmission has not been demonstrated (53).

Genetic recombination of either resistance or tolerance against whitefly transmitted diseases and to the vector would certainly decrease the genetic vulnerability of bean cultivars to insect transmitted diseases.

The intrinsic advantages of studing whitefly-host resistance as a method of control revolve around a minimum production cost and a minimum disturbance caused to the balance between destructive insects and their natural enemies in contrast to pesticide dependent systems. Another advantage is that no environmental or food contamination would result from using such a method of control for whiteflies. It should also be emphasized that this method is exceptionally compatible with all other control measures.

This research was conducted in greenhouse and laboratory conditions. The purpose was to: (1) detect sources of resistance against the whitefly in three bean genera (Phaseolus, Vigma, and Dolichos), all members of the family Leguminosae; and (2) to discover possible adult behavior preferences when exposed to different genera or cultivars with varying degrees of resistance.

LITERATURE REVIEW

Family Leguminosae

Characteristics:

About 12,000 species are reported to be members of the leguminosae (11). Leguminosae members are dicotyledoneous plants with hypogynous or perigynous flowers. The androecium has 3 to 10 stamens that may be united or free. The corolla either zygomorphic or actinomorphic, has 4 to 5 petals united or free, but 5 united or free or 2 united and 3 free are also common. Also the calyx is of 4 to 5 petals, and also united or free. The fruit is a typical bibalved legume (8, 11, 44, 49).

Plant genera used in this thesis as experimental units are all members of the Papilionatae sub-family. They are identified by their papilionaceous flowers, that is, with the upper petal or standard exterior (44, 49). _Phaseolus_, _Vigna_ and _Dolichos_, the genera tested, are all members of the section Phaseoleae having leaflets pinnately 3 foliolate and not stipellate, but, they are differentiated by some flower, pod and seed features.

Genus _Phaseolus_:

This genus is botanically distinguished from _Vigna_ by having a spirally twisted keel, and from _Dolichos_ by the stigma being oblique instead of terminal (44, 49). The calyx of _Phaseolus_ is campanulated or short and tubular, with the upper segments united or free holding

an orbicular standard. Wings of the flower are erect and ovate shaped, rarely oblong, but add to the keel beyond the claw. The keel has a long, obtuse, spirally twisted beak. The upper stamen is free and thickened at the base or with appendages. The style is long, thickened within the beak of the keel and twisted with the latter. Both annual and perennial plant types are winding or postrate, rarely somewhat erect herbs, with a ligneous base and tri-foliate leaves. The flowers are disposed in axillary racemes of white, yellow, violet, red, or purple color (11, 42, 44). Features that differentiate species of Phaseolus are also related with flower and pod characteristics.

Phaseolus vulgaris (L) - the flowers, 1.5 to 2 cm long, are pale purple or pink, and white, and the pods are swollen and less than 1.4 cm wide (8, 11, 42, 44).

Phaseolus lunatus (L) - the flowers, less than 1 cm long, are a greenish-yellow color, and the pods, 1.5 to 2 cm wide, are broad and flat (8, 11, 44).

Phaseolus coccineus (L) - the racemes are 15 to 20 cm long or longer. The flowers, about 2 cm long, are red or white. The pods are distinctively thicker, with seeds that are larger than Ph. vulgaris in nearly all their dimensions. In contrast to Ph. vulgaris and Ph. lunatus, the cotyledons are hypogeous in germination (11, 42, 44).

Phaseolus accutifolius (L) - the flowers are white or pale purple. The pods are compressed and cylindrical, containing up to six seeds that are particularly elliptic or oval. The seeds are small, usually less than 0.5 cm in diameter and without radial nervure (11).

an orbicular standard. Wings of the flower are erect and ovate shaped, rarely oblong, but and to the keel beyond the claw. The keel has a long, obtuse, spirally twisted beak. The upper stamen is free and thickened at the base or with appendages. The style is long, thickened within the beak of the keel and twisted with the latter. Both annual and perennial plant types are winding or prostrate, rarely somewhat erect herbs, with a [illegible] leaves. [illegible]

Genus Vigna:

The calyx is campanulate or somewhat tubular, and the upper two segments may be free or united. The keel, almost as long as the wings, is truncated, or beaked, at the tip but not spiral. The flowers are greenish-yellow, rarely purple, and disposed in axillary racemes. The pod is characteristically linear, straight or slightly recurved, 2-valved and filled between the seeds. The seeds are reniform or quadrate. The plant type is either postrate and twining, and sometimes, though rarely erect. The leaves are pinnate bearing three leaflets with stipules usually more persistent (42).

V. repens - the flowers, 12 to 20 in number, are disposed in a conical raceme on a glabrous peduncle 5 to 10 cm long. The corolla is pale yellow and 11 to 13 mm long. The pods are fairly glabrous, 3.7 to 5 cm long, 6 mm broad, and thinly silky containing 8 to 10 seeds of shiny brown color with a white hilum (42, 44).

V. radiata - the flowers are about 1 cm long, yellow and racemosely arranged near the end of the short pubescent pedunculus. The pods are pubescent and linear, 6 to 8 cm long and about 6 mm wide, bearing seeds 4 to 6 mm long. It is an erect or climbing annual herb, branched from the base, and clothed with brownish hairs. Leaflets are acuminate and 8 to 15 cm long (11, 44).

Genus Dolichos:

Dolichos lablab (L) - the calyx is campanulate with short segments, and a united upper part. The wings are curved, but the keel is very much incurved. The flowers are white, yellowish or pale purple, usually disposed in small racemes. The pod is linear, very much compressed,

straight or curved, and usually with thickened margins. The seeds are thick and compressed with a linear, fleshy arillus (11, 42, 44).

GREENHOUSE WHITEFLY

Origin and significance:

The insect, popularly known as the greenhouse whitefly or snowfly (Trialeurodes vaporarium, West. Aleyrodidae: Homoptera), is native of Brazil, but found throughout the world (30). According to Russel (1963), 144 genera of plants are hosts of this whitefly, which is predominately found on hosts having rather thick sappy leaves, such as the french and runner beans (29, 30, 47).

Although the so called greenhouse whitefly and larvae are very small, they occur in such immense numbers that the plants become impoverished and the quality of the fruits decrease. The entire undersides of leaves are often completely covered with the scale-like larvae and pupae (21, 47). Hussey et al (25), pointed out that up to 20 scales per cm^2 may be tolerated on tomatoes before whiteflies adversely affect yield. However, in ornamentals, a much lower density is tolerated (22).

The potential of the greenhouse whitefly to cause damage is also related to its ability to transmit virus diseases (15, 52, 23). T. vaporarium was reported by Duffes (15) as being the vector of the beet pseudoyellows virus in California. The same species has been reported by Trasversi (52) as being the vector of a sunflower virus in Argentina. T. abutilonea was identified in Maryland as the vector of sweet potato yellow-dwarf virus (23).

Life cycle:

Whitefly metamorphosis, is somewhat intermediate between complete and incomplete: four larva or scale-like instars and the adult stage. All larval instars, except the first one which is temporarily a crawler, are sedentaries, wingless, and resemble scales (13, 21, 29, 47). On a susceptible pinto bean cultivar, 12 to 18 hours after the early fourth larva instar, it undergoes changes that resemble a pupa stage (author's observations). When these changes take place, its dorsal skin becomes chitinized and leathery in appearance. Considerable growth in depth as well as adult differentiation takes place at this time (10, 12, 21, 29, 37, 53).

The developmental history of whiteflies, as in other insects, is influenced by several factors, among which host and temperature are perhaps the most important (author's experience). In a greenhouse test with young bean plants at 23.3^{o}C, hatching time took between 8 to 10 days. The duration of the first stage was 5 days, the second 2 days, the third 3 days, and the fourth stage 8 days (30). Unfortunately the adult life span was not recorded, but the life of both male and female on tomato plants was 34 and 39 days, respectively.

Adult:

The adults are very small sucking insects. When reared on a susceptible pinto dry bean cultivar, the males measured 1 to 1.2 mm long and 0.4 to 5 mm wide; the females measured 1.3 to 1.8 mm long and 0.5 to 0.7 mm wide (measurements done by author).

Mating of the adults takes place soon after emergence from the pupa, usually on the same leaf on which they emerge (21, 29). The male

generally rests quietly by the side of the female and mates repeatedly. Although repetition of coitus appears unnecessary, it has been observed to occur between the same pair up to five times (21). Parthenogenesis has been observed to be a common phenomena in whiteflies (21, 30, 36).

Oviposition:

Oviposition generally begins on the second to the fifth day after adult emergence. The undersides of young leaves are preferred for oviposition, though occasionally other green plant parts may be used (21, 30). Eggs are generally laid in incomplete circles of about 1.5 mm diameter. The female inserts her stylet into the leaf tissue and using that point as the center and the body as radius, deposits each egg into a small cut porperly made (21, 30). The average number of eggs reported by Lloyd was 130, but the largest observed was 534 on Lamium purpureum (a kind of weed), one of the 18 plant hosts studied (30).

Egg:

Greenhouse whitefly eggs are stalked, the stalk being short and partly imbedded in the tissue of the leaf (21, 30). The length of the stalk measures about 0.02 mm, with the total length of the egg being about 0.24 mm (21). Eggs are greenish when first deposited and are covered with wax produced by the adult. After two to four days they begin to darken, turning from the original yellowish green to brown, and finally to black (21, 22). Just prior to hatching (ten to thirteen days after oviposition), a crack appears near the unattached end of the egg on its concave side, and the larvae emerge about seven minutes later (21).

Scale or larvae:

All four larval instars, except the first one, are totally sedentary. The first larva stage shows a kind of movement that is considered non-migratory movement. It is usually confined to the first hours of life and is usually only a sufficient distance for the scale to grow without coming in contact with others from the same batch (21, 30, 37, 53).

All larval stages are distinctively flat after the molt. Since the dorsal skin of the fourth larval stage becomes heavily chitinized and leathery in appearance, it is nearly always referred in the literature as being the pupa. But, at the beginning of the instar it is similar to the larva of the preceding instar (10, 21, 22, 37). When the adult emerges from the mature scale, the empty shell is left attached to the leaf (21, 22, 37).

Host plant resistance:

Insect host plant resistance, according to Beck (7), is defined as the heritable characteristics by which a plant species, race, clone, or individual may reduce probability of successful utilization of that plant as a host by an insect, species, race, biotype, or individual. This kind of resistance is usually made up of varying degrees of one or more components: non-preference and preference, antibiosis, and tolerance (40).

In the consulted literature for the last 30 years, no paper related to the screening of bean-cultivars for whitefly damage and possible mechanisms of resistance was found.

Scale or larvae:

All four larval instars, except the first one, are totally sedentary. The first larva stage shows a kind of movement that is considered non-migratory movement. It is usually confined to the first hours of life and is usually only a sufficient distance for the scale to grow without coming in contact with others from the same batch (21, 3[illegible], 37, 5[illegible]).

[illegible]

Preference or non-preference:

Leafhopper preference for different plant colors for feeding or for oviposition has been reported in alfalfa, clover, soybeans and in several species of Phaseolus (6, 38, 43, 46, 54, 55). Physical characteristics, mainly those related to leaf pubescence density and/or its characteristics, have most often been associated with such insect preference or non-preference. Preference of the whitefly for less hairy tomato and poinsettia plants has also been observed (9, 16, 19, 26).

Though other factors may be more important at close range, vision, phototaxis, geotaxis, and hydrotaxis are the most often reported clues directing insects to the proper environment for feeding and for oviposition (2, 14, 17, 34, 35).

Whitefly preference for feeding and oviposition on yellow, yellow-green and white substrates, as well as the undersides of young leaves, and especially for those of thick sappy hosts are phenomena often reported in the literature (3, 9, 20, 21, 22, 32, 37, 47, 51).

Resistance of certain plant tissues to puncturing has also been reported as a resistance mechanism to sucking insects for certain legume varieties (46).

Antibiosis:

All adverse effects on the normal biology of the insect when it uses a resistant host plant variety as host are included in this category of resistance (17, 39). This kind of resistance is often due to toxins or other antibiotic agents, to the absence of some nutritional materials, and to the imbalance of available nutrients (31, 35, 41). Saponins,

sugar:nitrogen ratio, and the differential presence or absence of specific carbohydrates have been found to have detrimental effects on several insect pests of legumes (4, 5, 18, 24, 31, 33).

Tolerance:

Tolerance is a sometimes disputable category of resistance that was originally introduced by Painter (39). Tolerance, stands for the ability of a plant cultivar to reproduce itself or repair injury to a marked degree in spite of supporting a population equivalent to that damaging a susceptible host (40). This kind of response has been shown by some legume cultivars when exposed to damaging sucking insects. Alfalfa cultivars that are susceptible to the pea aphid have shown more pronounced stunting than tolerant varieties (40). Some cowpea strains have also exhibited such reactions against the hopperburn injury caused by leafhoppers (55).

SELECTION OF BEAN CULTIVARS FOR RESISTANCE AGAINST THE GREENHOUSE WHITEFLY (Trialeurodes vaporarium WESTW.) IN GREENHOUSE CONDITIONS

Introduction

Despite the wide number of insecticides available to horticulturists and farmers, whiteflies continue to be one of the major economic pests for greenhouse and crop production around the world. Many of the affected plants are succulents, and like beans, are used as food crops. Since good persistent chemical control of the whitefly (T. vaporarium or of B. tabaci), has not been found in beans with the broad number of insecticides tested, it would be desirable to have resistant cultivars, and thus lower whitefly population levels.

Failure to find specific literature about bean-screening experiments against whitefly damage and/or its possible mechanisms of resistance, indicates that information about these topics is scarce or lacking.

The purpose of this research was to evaluate 118 bean cultivars (four species of Phaseolus, two species of Vigna, and one of Dolichos lablab) for shelter and oviposition preference by the greenhouse whitefly.

Materials And Methods

Screening of the cultivars was done in greenhouse conditions from July to September, 1978, at a mean temperature of 26^{o}C and a 12 hour

photoperiod. The experimental bean plants consisted of 109 Phaseolus vulgaris (L), two Ph. lunatus (L), three Ph. coccineus (L), one Ph. accutifolius, one Vigna repens, one Vigna radiata (=Ph. aureus), and one Dolichos lablab.

Most of the common dry bean entries were selected from the 2,200 entries evaluated in Guatemala for resistance to the whitefly, Bemisia tabaci (Genn), and to the leafhopper, Empoasca sp. The entries were selected based on either their high preference on non-preference ratings. The ratings were based on the number of nymphs and adults under natural and artificial infestations when the plants were 30 and 45 days old (1).

Similarly, the other species, except Dolichos lablab, were selected on the basis of the author's criteria that different plant and leaf characteristics could cause different whitefly response. Though the same criteria were followed in the addition of Dolichos lablab, it was received from Dr. S. Wellso, (U.S.D.A., Michigan State University), who found it in Honduras, C.A. Cultivars previously evaluated in Guatemala were obtained from the International Institute of Tropical Agriculture, in Colombia. A few Ph. vulgaris were brought by the author from the College of Agriculture of Mayaguez in Puerto Rico. Three Ph. vulgaris entries were also received from Dr. W. Adams, (Dept. of Crop and Soil Science, Michigan State University), as being very susceptible to the leafhopper.

A complete randomized design (3 reps per cultivar) was used. Each experimental unit was a bean plant in a 13 cm diameter clay pot in the soil mixture (1 sand:1 peat:1 topsoil) used in the Michigan State University plant science greenhouse.

photoperiod. The experimental bean plants consisted of 109 *Phaseolus vulgaris* (L.), two *Ph. lunatus* (L.), three *Ph. coccineus* (L.), one *Ph. acutifolius*, one *Vigna sinensis*, one *Vigna radiata* (*Ph. aureus*), and one *Dolichos lablab*.

The bean accessions were selected from the 2,000

To avoid differences in attraction mainly due to plant differences in color caused by soil fertility differences, the soil in each pot was fertilized twice, 2 and 30 days after germination, with one gram of 12-12-12 fertilizer. Two seeds per pot were sown in order to guarantee a uniform population of one plant per pot.

There were three artificial infestations, 15, 25 and 35 days after planting (Figures 1 and 2). Different arrangements of plant varieties within each replicate before each release time was done to expose each plant cultivar to a different plant neighbor effect. Whiteflies, reared for at least five generations on a susceptible pinto-bean cultivar, were used for infesting purposes.

The whitefly adults were collected with an aspirator and a collector assay tube (Figure 3). Insects were inactivated by exposure for 15 minutes in a refrigerator at $0^{o}C$. Plastic cylinders, with a foam ring in the opening of the tube, were used to confine the whiteflies prior to infesting each experimental unit. The whiteflies, in the plastic cylinders, were carefully transported in a cold ice box (Figure 4) to prevent re-activation before the cylinders were distributed between the pots on the grenhouse bench. This prevented infestation of the cultivars without a previous whitefly orientation, probably toward the cultivars more preferred. To avoid bias, care was taken in placing a single cylinder of whiteflies at the same distance from each plant.

Mean infestation rates per plant for first, second and third releases were 35, 45, and 55 insects in the first replicate, and 34, 35, and 158 in the second and third replications.

Data relative to adult preference were taken 60 hours after each infestation. The total whitefly population on each cultivar was recorded.

A

B

Figure 1. Growing stages of bean-plants at (A) first release (15 days old), and (B) second release (25 days old).

Figure 2. Growing stage of bean-plants at third release (35 days old).

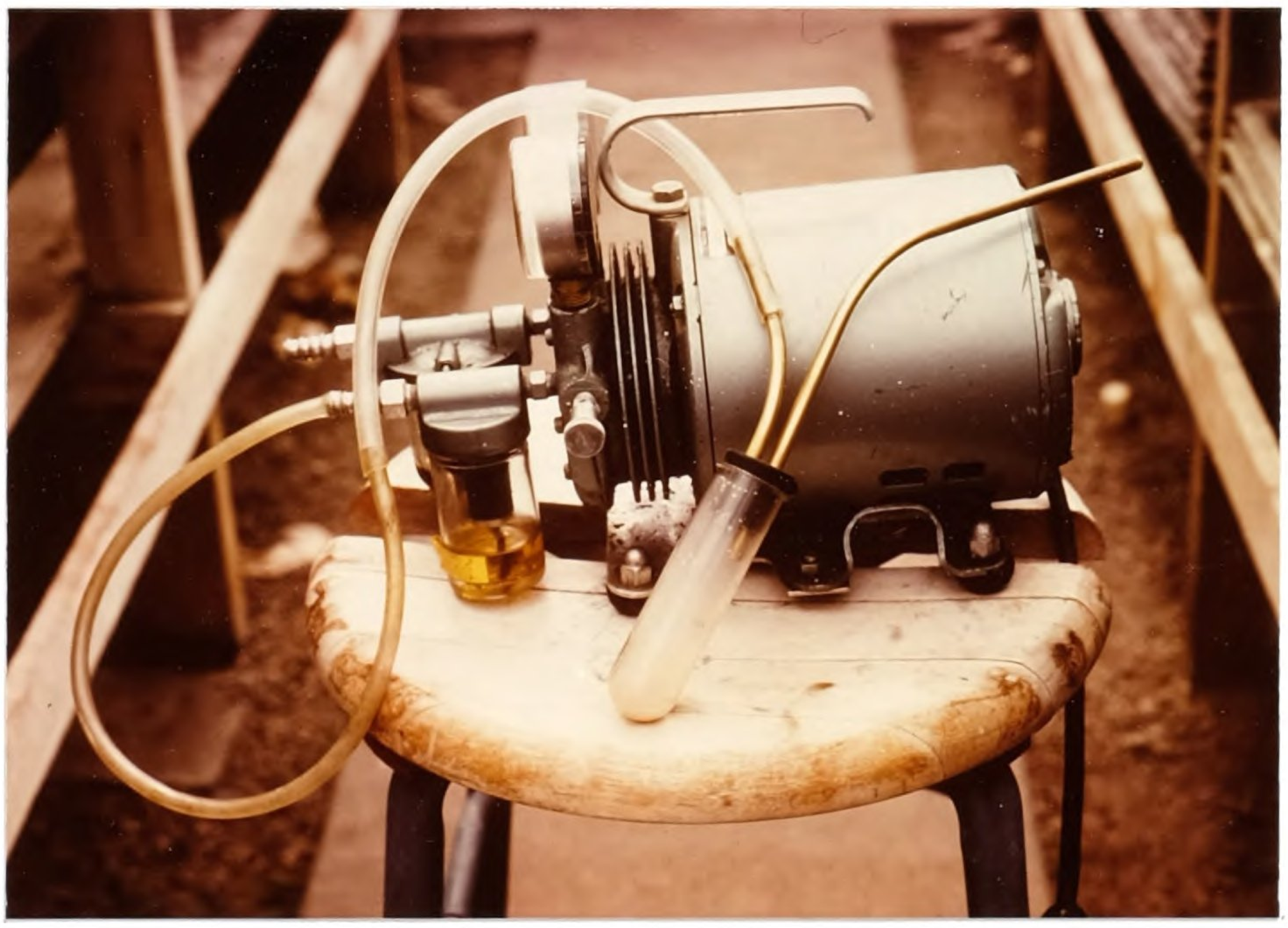


Figure 3. Aspirator apparatus used to collect whitefly adults.

Figure 4. Cold box used for transporting whitefly adults in plastic cylinders.

Recapture of the adults was done during counting by using the aspirator. Much of the work was done during the night when the adults were relatively immobile.

Data relative to oviposition preference were taken twenty days after each infestation time; a visual rating scale of: (1) non-preferred, (2) moderately non-preferred, (3) intermediately preferred, (4) preferred, and (5) very preferred was used for this purpose. Oviposition readings were based on the relative abundance of the scale numbers all over the entire plant. Counting the number of scales per cultivar from the first release in the first and second replicates was done to know numerical values as a reference for the classes. The same rating scale from 1 (non-preferred) to 5 (very preferred) was also followed to categorize germplasm for adult preference. The five resistance classes for adult preference were defined as follows: (1) non-preferred (lowest transformed mean value + 1 hsd-value), (2) moderately non-preferred (lowest transformed mean value + 2 hsd-values), (3) intermediately preferred (lowest transformed mean value + 3 hsd-values), (4) preferred (lowest transformed mean value + 4 hsd-values), and (5) very preferred (lowest transformed mean values + 5 or more hsd-values).

Analysis of variance, simple correlations, statistics describing populations, and graphic techniques were used to discriminate varietal effects, and to present results relative to adult and oviposition preferences.

RESULTS AND DISCUSSION

To determine the statistical significance of both adult and oviposition preferences, analysis of variance of the mean number of adults (square root transformation) attracted by each cultivar and of the mean oviposition values were calculated (Table 1). There were highly significant differences (P=0.01) among cultivars for adult and oviposition preference and between blocks. The blocks were probably significantly different because infestation rates per plant in the first release were different from those in the second and third replications.

Another possible cause of this significant block effect was that they were tested one at a time, due to space and time limitations. Although attempts were made to maintain controlled conditions, differences in time could have exposed replications to minor changes in soil, temperature, photoperiod (sunlight hours); plus a different generation of test insects and perhaps unconscious small changes in methodology could also have affected them.

Figure 5 shows the frequency of cultivars falling into each of the adult (A), and oviposition (B) classes of preference. In the adult preference test, 5.9 percent of the cultivars were non-preferred, 10.2 percent were moderately non-preferred, 34.7 percent were intermediately preferred, 33.9 percent were preferred, and 15.2 percent were very preferred (Figure 5A). In the oviposition test 5.9, 4.2, 37.3, 41.5, and

RESULTS AND DISCUSSION

To determine the statistical significance of both adult and nym-

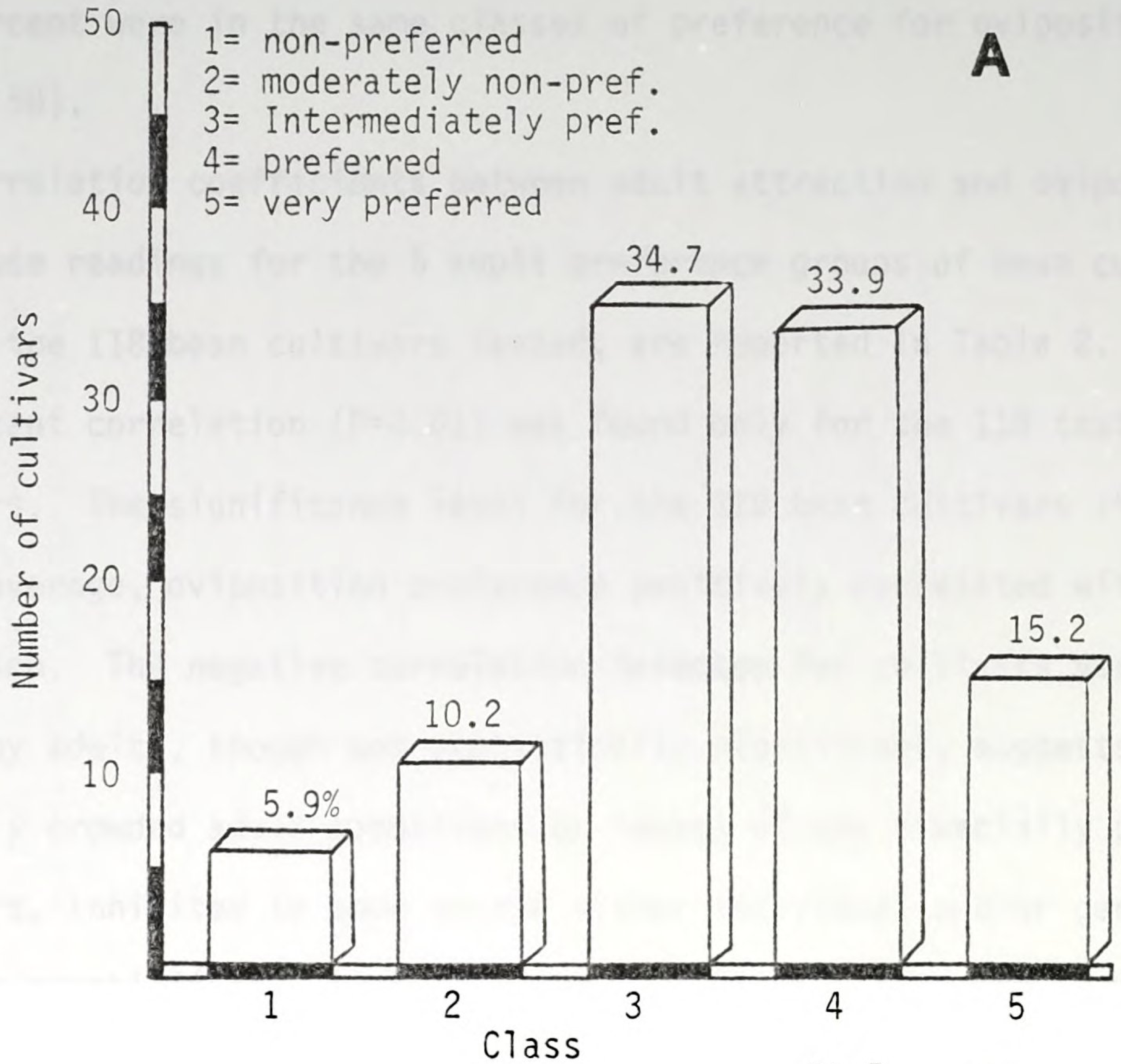
Table 1. Analysis of variance of whitefly adult preference ($\sqrt{\text{No. of adults}}$), and of oviposition preference readings (1-5) for the 118 bean cultivars evaluated.

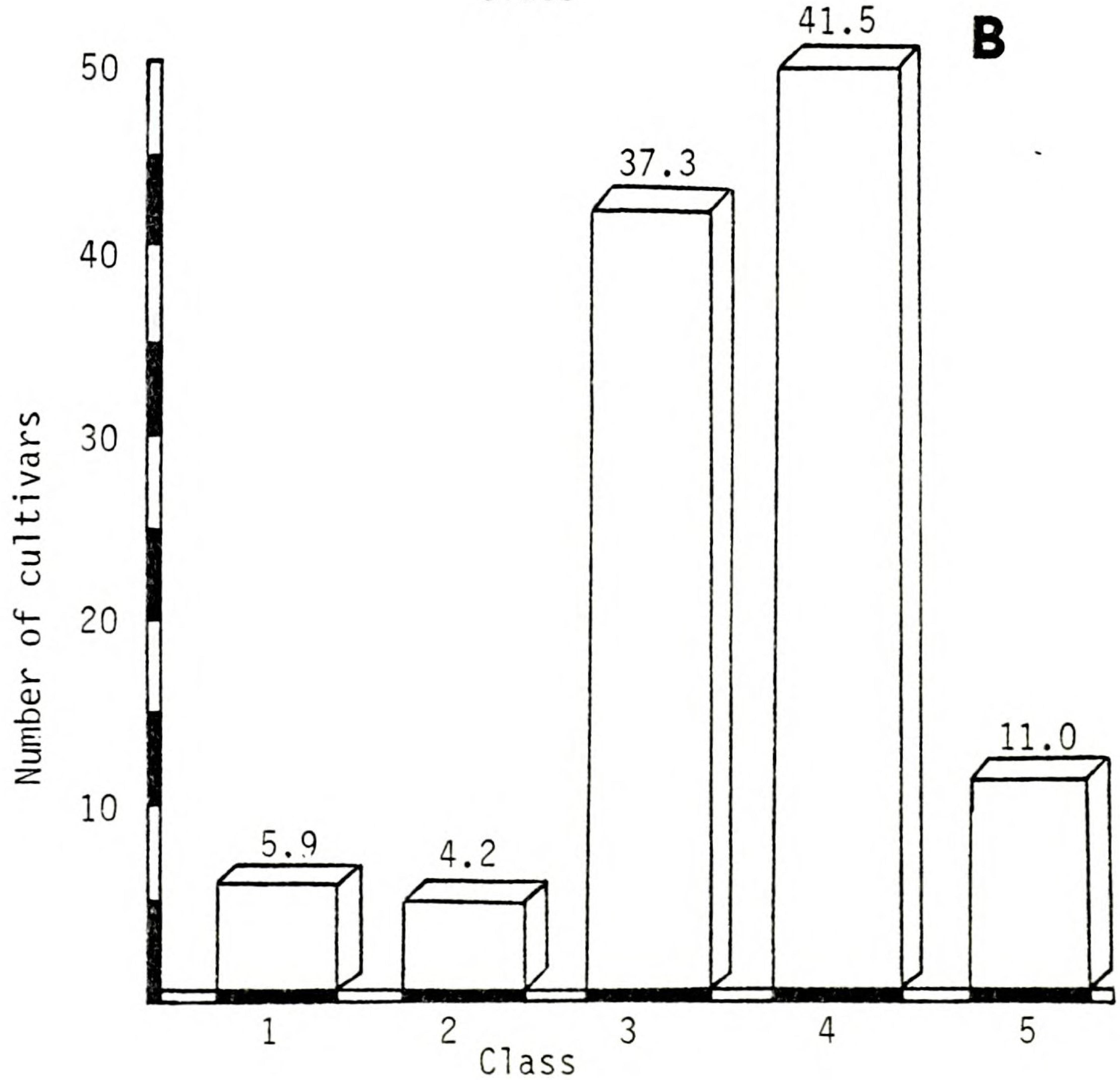
Source of	df	Adult Pref.		Ovi. Pref.	
variance		MS	F	MS	F
Blocks	2	81.77	14.91 **	78.46	13.25 **
Cultivars	117	18.98	3.46 **	2.28	3.84 **
Error	234	5.48		0.59	
Total	353				

** Significant at P=0.01

50
40
30
1= non-preferred
2= moderately non-pref.
3= intermediately pref.
4= preferred
5= very preferred
A

Figure 5. Frequency of bean cultivars in each whitefly: adult (A) and oviposition (B) preference class.


A
1= non-preferred
2= moderately non-pref.
3= Intermediately pref.
4= preferred
5= very preferred
Number of cultivars
50
40
30
20
10
5.9%
10.2
34.7
33.9
15.2
1
2
3
4
5
Class


B
Number of cultivars
50
40
30
20
10
5.9
4.2
37.3
41.5
11.0
1
2
3
4
5
Class

11.0 percent were in the same classes of preference for oviposition (Figure 5B).

Correlation coefficients between adult attraction and oviposition preference readings for the 5 adult preference groups of bean cultivars, and for the 118 bean cultivars tested, are reported in Table 2. A highly significant correlation (P=0.01) was found only for the 118 tested bean cultivars. The significance level for the 118 bean cultivars shows that, on the average, oviposition preference positively correlated with adult attraction. The negative correlation detected for cultivars very preferred by adults, though not statistically significant, suggests that extremely crowded adult conditions on leaves of the especially preferred cultivars, inhibited to some degree either individual and/or general oviposition capabilities. Such inhibition could be due to the increasing competition for space for feeding and oviposition.

Statistics describing the scale population from the first release of adults in replicates I and II are shown in Table 3. Mean rank of scales for the oviposition preference classes were found to be: from 1.0 to 14.0 scales for the non-preferred class; from 9.5 to 58.0 for the moderately non-preferred class; from 55.0 to 117.5 for the intermediately preferred class; from 109.0 to 272.5 for the preferred class; and from 153.0 to 325.5 for the very preferred class. Overlapping of ranks is possible since the real discrimination of cultivars into single categories of preference was based on mean oviposition ratings values (1 through 5) which were merely visual readings. Mean oviposition values per cultivar were 4.5, 25.0, 104.3, 170.8 and 230.0 scales, respectively, for each class of resistance, assuming equal percent of survivorship. The highest

11.0 percent were in the same classes of preference for oviposition (Figure 58).

Correlation coefficients between adult attraction and oviposition preference readings for the 6 adult preference groups of bean cultivars, and for the 128 bean cultivars tested, are reported in Table 2. A highly [illegible]

Table 2. Correlation coeficients between adult attraction and oviposition readings for the five adult-resistance groups of cultivars and for the 118 bean cultivars evaluated.

Group	Number Compared	r
Tested Bean-cultivars	118	0.6990 **
Non-preferred	7	0.1874
Moderatelly non-preferred	12	0.3145
Intermedia preferred	41	0.3597
Preferred	40	0.2445
Very-preferred	18	-0.3240

** Significant at P=0.01

Table 3. Statistics describing the whitefly scale (larval) population from the first release of adults in replicates I and II.

Resistance class	Number of Cultivars	Number of Scales		
		Rank	Mean	S.D.
Non-preferred	7	1.0-14.0	4.50	3.16
Moderately non-preferred	5	9.5-58.0	25.00	14.89
Intermediately preferred	44	55.0-177.5	104.33	33.45
Preferred	49	109.0-272.5	170.78	47.53
Very preferred	13	153.0-325.5	230.00	49.97

deviation was in the non-preferred and the moderately non-preferred classes, while the remainder of classes were fairly uniform in variability.

Mean rank values per cultivar for the different classes of resistance for adult preference (Table 4) were: from 1 to 7 adults for the non-preferred; from 13 to 43 for the moderately non-preferred; from 40 to 85 for the intermediately preferred; from 70 to 110 for the preferred; and from 100 to 203 adults for the very preferred class. Mean values were 4, 30, 57, 86, and 138 adults, respectively, for each category (Table 4).

The mean rank for each resistance class for oviposition varied from 1.00 to 1.18, from 2.00 to 2.50, from 2.53 to 3.50, from 3.53 to 4.43, and from 4.57 to 5.00, respectively, for the non-preferred, moderately non-preferred, intermediately preferred, preferred and for the very preferred class. Mean values of each class were 1.04, 2.26, 3.13, 3.86, and 4.71, respectively. In Table 4, the magnitude of the standard deviation values shows fairly uniform plant response in each class of resistance. Highest deviation was observed in the adult non-preferred class, and the lowest was found in the very preferred class for oviposition.

In the adult preference test 7, 12, 41, 40, and 18 cultivars fell in the non-preferred, moderately non-preferred, intermediately preferred, preferred, and very preferred classes, respectively. In the oviposition test, 7, 5, 44, 49, and 13 were respectively in the same resistance classes.

Selected bean cultivars showing different levels of preference to the whitefly adult are presented in Tables 5 through 9. The highest level of adult non-preference was found in genera other than Phaseolus.

Table 4. Statistics describing each observed resistance category either for adult preference or for oviposition preference.

Class of resistance	Range	Mean	S.D.
Adult Preference:			
Non-preferred	1.11-7.00	4.18	2.05
Moderately non-preferred	13.00-43.33	30.14	9.32
Intermediately preferred	40.00-85.33	56.77	11.88
Preferred	70.00-110.33	86.62	14.28
Very preferred	110.33-203.00	138.49	27.08
Oviposition preference:			
Non-preferred	1.00-1.18	1.04	0.07
Moderately non-preferred	2.00-2.50	2.26	0.20
Intermediately preferred	2.53-3.50	3.13	0.29
Preferred	3.53-4.43	3.86	0.26
Very preferred	4.57-5.00	4.71	0.13

Within the genus Phaseolus, attractiveness to the whitefly adult was also lower in species other than Ph. vulgaris.

Seven cultivars were assigned to the non-preferred class (Table 5). Both Vigna repens and V. radiata cultivars ranked highest in the non-preferred class (1.11 and 2.67 adults, respectively). However, G00127 (Ph. lunatus), G00046 and G00038 (both Ph. coccineus), H-00126 (Dolichos lablab), and G01154 (the other Ph. lunatus) were somewhat more attractive to the whitefly adult (3.17, 4.00, 5.33, 6.00, and 7.00, respectively).

The moderately non-preferred class, except for Ph. accutifolius, consisted exclusively of 11 Ph. vulgaris cultivars (Table 6). This might be expected since 92.4 percent of the entries tested were Ph. vulgaris. This reasoning would also hold true for the intermediately preferred and very preferred classes.

Three black seeded Ph. vulgaris, the wild type G00132 with 13 adults, G03645 a selection of Jamapa, and PI-309-804 both with 19 adults ranked least preferred in the moderately adult non-preferred class. This suggests that wild types of Ph. vulgaris, and among them perhaps the black types, would probably be the best sources of higher levels of whitefly adult non-preference. Perhaps black seeded types have been exposed more often to other genera of whiteflies or to other insects with similar feeding habits in the more tropical countries. However, the author has observed nearly all seeded types growing in the low lands of Mexico (in Sonora, Sinaloa, Veracruz, and Yucatan), in Guatemala, in El Salvador, in Honduras, in Nicaragua, in Costa Rica, in Panama, in Colombia (in Cali), in Venezuela (in Bolivar), in Puerto Rico, and in the Dominican Republic as well as in intermediate and high altitudes.

Within the genus *Phaseolus*, attractiveness to the whitefly adult was also

vulgaris.

Table 5. Bean cultivars categorized as non-preferred for whitefly adult attraction and their seed coat color.

Cultivar +	Mean No. of adults	Seed coat color
G00037 (Vigna repens)	1.11	Brown
G00128 (Vigna radiata)	2.67	Green
G00127 (Ph. lunatus	3.17	White
G00046 (Ph. coccineus)	4.00	Reddish Brown
G00038 (Ph. coccineus)	5.33	Reddish Brown
H00126 (Dolichos lablab)	6.00	Cream
G01154 (Ph. lunatus)	7.00	White

+ Cultivar names are sorted according to the transformed means.

Table 6. Bean cultivars categorized as moderately non-preferred for whitefly adult attraction and their seed coat color.

Cultivar +	Mean No. of adults	Seed coat color
G00132 (Ph. vulgaris, Wild)	13.00	Black
G03645 (Ph. vulgaris)	19.00	Black
PI 309-804 (Ph. vulgaris)	19.00	Black
Porrillo No.1 (Ph. vulgaris)	42.00	Black
G04485 (Ph. vulgaris)	35.67	Black
G04487 (Ph. vulgaris)	27.33	Black
G00787 (Ph. vulgaris)	29.33	Red
G03244 (Ph. vulgaris)	31.33	Black
G01222 (Ph. acutifolius)	31.67	White
G02980 (Ph. vulgaris)	32.67	Black
G03097 (Ph. vulgaris)	43.33	White
Porrillo sintetico (Ph. vulgaris)	37.33	Black

+ Cultivar names are sorted according to the transformed means.

G04487 (black), G00787 (red), and G03244 (black) were other Ph. vulgaris entries which were preferred less than Ph. accutifolius (G01222). G01222 ranked sixth in the moderately non-preferred class with 31.67 adults. Porrillo sintetico (a black seeded synthetic variety and ranked ninth), as expected showed a better performance as moderately non-preferred, than what was exhibited by Porrillo No. 1 (ranked tenth), which is a line.

Twelve Ph. vulgaris cultivars in the intermediately preferred class are listed in Table 7. Pinto-114 (striped), 15R-52 (black), and G00129 (black), had the lowest attraction values. The highest attractiveness in this class was found for the cultivar G03195 (black). Some Ph. vulgaris of the black, red, and white seeded types were mostly in the non-preferred and moderately non-preferred classes. Thus, it appears that in this species, and in this test, black and red types in ascending order of preference showed higher adult non-preference than white and striped types.

Table 8 shows 12 of the most preferred Ph. vulgaris entries assigned to the preferred class for adult attraction. One Ph. coccineus (G00039) in this category is also included in the table. A very susceptible leaf-hopper Ph. vulgaris variety, 1-59 (light brown seeded), was also one most preferred by whitefly adults, which suggests that common mechanisms of susceptibility might be involved. The four following it in ascending order of preference were G04525 (black), 703 (black), Rayada (striped), and G01225 (striped).

The presence of Ph. coccineus (G00039) in this class compared with the presence of the other two Ph. coccineus (G00046, and G00038) in the

Table 7. Eleven Ph. vulgaris categorized as the least intermediately preferred for whitefly adult attraction, compared with the most preferred cultivar in the same class, and their seed coat color.

Cultivar +	No. adults	Seed coat color
Pinto-114	40.00	Striped
15R-52	49.67	Black
G00129	41.00	Black
G04481	42.00	Black
G02983	43.33	Black
Brazil-2	46.00	Light brown
G02977	46.67	Black
Venezuela-2	45.67	Black
G03108	48.00	Black
S-116-A-N	49.33	Black
G02960	46.00	Black
G03195	85.33	Black

+ Cultivar names are sorted according to the transformed means.

Table 8. Thirteen most attractive bean cultivars in the preferred category of adult attraction and their seed coat color.

Cultivar [+]	No. of adults	Seed coat color
G00039 (*Ph. coccineus*)	90.00	Reddish brown
Red Kidney (*Ph. vulgaris*)	123.33	Red
G03178 (*Ph. vulgaris*)	132.00	Brown
G03050 (*Ph. vulgaris*)	124.67	Black
G03167 (*Ph. vulgaris*)	129.00	Black
G03242 (*Ph. vulgaris*)	127.00	Black
G03252 (*Ph. vulgaris*)	125.33	Brown
G03645 (*Ph. vulgaris*)	132.33	Black
1-59 (*Ph. vulgaris*)	136.33	Brown
G04525 (*Ph. vulgaris*)	110.33	Black
703 (*Ph. vulgaris*)	109.67	Black
Rayada (*Ph. vulgaris*)	109.33	Striped
G01225 (*Ph. vulgaris*)	110.33	Striped

+ Cultivar names are sorted according to the transformed means.

non-preferred class shows the broad genetic variability in this species for whitefly adult attraction.

The six most preferred Phaseolus vulgaris entries placed in the very preferred category of adult whitefly attraction are reported in Table 9. In descending order of preference, G00718 (striped), G03101 (black), G04494 (striped), G01054 (dark red), G01083 (striped) and G01204 (white), were in this class. The place that striped seeded types occupied in this category suggests that they are perhaps the most preferred by adults.

The Ph. vulgaris entries were also placed in the five resistance categories according to seed coat color (Table 10). Eighty percent of the brown seeded types and 58% of the striped seeded types were in the preferred and very preferred classes of adult attraction. As observed in Tables 5 through 10, as well as in the appendix, in the Ph. vulgaris species, some black, some red, and some white seeded types were less attractive to the whitefly adult. Thus, it is suggested that in this test striped and brown seeded varieties of Ph. vulgaris were apparently most preferred by the whitefly adult. This result might be due to the presence in the leaves of differential precursors of tanins, to their differential concentration and/or to the differential presence of pigments which later determine the seed coat color.

According to the visual oviposition ratings (1 through 5), taken 20 days after each infestation, seven cultivars were classified as non-preferred (Table 11).

The highest non-preference for whitefly oviposition was found in genera other than Phaseolus. This non-preference reaction was also

Table 9. Six bean cultivars (Ph. vulgaris) categorized as very preferred for adult attraction and their seed coat color.

Cultivar +	No. of adults	Seed coat color
G01204	151.33	White
G01083	156.00	Striped
G01054	157.33	Red
G04494	158.67	Striped
G03101	198.33	Black
G00718	203.33	Striped

+ Cultivar names are sorted according to the transformed means.

Table 10. Percentage of *Ph. vulgaris* in five classes of whitefly adult preference according to their seed coat color.

Resistance	seed coat color						
	Black	Red	Brown	Creamish Orange	Very dark Purple	White	Striped
	%						
Non-preferred	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mod. non-preferred	12.68	0.00	0.00	0.00	0.00	25.00	0.00
Int. preferred	35.21	42.86	20.00	0.00	100.00	62.50	41.67
Preferred	40.84	0.00	60.00	100.00	0.00	0.00	25.00
Very preferred	11.87	42.86	20.00	0.00	0.00	12.50	33.33
Number of Cultivars	71	7	10	1	1	8	12

Table 11. Bean cultivars classified as non-preferred and moderately non-preferred for oviposition and their seed coat color.

Cultivar	Mean Reading/ cultivar	Seed coat color
Non-preferred:		
G01154 (Ph. lunatus)	1.00	White
G00127 (Ph. lunatus)	1.00	White
H00126 (Dolichos lablab)	1.00	Cream
G00037 (Vigna repens)	1.00	Brown
G00128 (Vigna radiata)	1.00	Green
G00046 (Ph. coccineus)	1.13	Reddish brown
G00038 (Ph. coccineus)	1.18	Reddish brown
Moderately non-preferred:		
G00129 (Ph. vulgaris)	2.00	Black
G00132 (Ph. vulg. Wild)	2.13	Black
G01222 (Ph. accutifolius)	2.16	White
G00787 (Ph. vulgaris)	2.50	Red
G03244 (Ph. vulgaris)	2.50	Black

highest in species of Phaseolus different than Ph. vulgaris. A fairly identical non-preferred response of 1.00 was recorded for Vigna repens (G00037), V. radiata (G00128), Ph. lunatus (G01154 and G00127), the Dolichos lablab cultivar, and both Ph. coccineus (G00046 and G00038), which had oviposition ratings of 1.13 and 1.18, respectively. Ph. vulgaris cultivar was not in this resistance category.

Only four Ph. vulgaris--G00129 (black), G00132 (black), G00787 (red) and G03244 (black), and the Ph. accutifolius (G01222, white seeded and in place No. 3)--were in the moderately non-preferred class for whitefly oviposition (Table 11). Since no striped seeded or white seeded Ph. vulgaris cultivars were again in this non-preferred class for oviposition, it is suggested that black and red seeded cultivars of this species were the least preferred for oviposition than cultivars having seeds of other colors.

There were 44 Ph. vulgaris cultivars in the intermediately preferred class for oviposition. The 13 least preferred and the most preferred cultivar (G04485, black) in this class are reported in Table 12. The four least preferred cultivars in this resistance class, were: 15R-52 (black), Pinto (striped), G00773 (white), and PI-309-804 (black). Porrillo sintetico (black), G02980 (black), Porrillo No. 1 (black), and G04485 (black) were also in this category, despite the fact they were moderately non-preferred for adult attraction.

There were 49 and 13 bean cultivars, respectively, in the preferred and very preferred classes for oviposition.

Two striped seeded cultivars (G01225 and G00718), one white seeded (G00808), and two black (G03115 and G03167) showed the highest attraction for whitefly oviposition in the preferred class (Table 13).

Table 12. Thirteen *Ph. vulgaris* classified as the least intermediately preferred for whitefly oviposition, compared to the most highly preferred cultivar in the same class, and their seed coat color.

Cultivar	Mean Ovip. Reading	Seed coat color
15R-52	2.53	Black
Pinto	2.57	Striped
G00773	2.70	White
PI-309-804	2.70	Black
G03645	2.73	Black
Sanilac	2.80	White
Black turtle	2.83	Black
Porrillo sintetico	2.83	Black
G05706	2.90	Black
G02980	2.90	Black
Porrillo No.1	2.90	Black
Pompadour-2	2.93	Striped
G02977	2.97	Black
G04485	3.50	Black

Table 12. Thirteen *Ph. vulgaris* classified as the least intermedi-
ately preferred for winterly oviposition, compared to
the most highly preferred cultivars in the same class, and

Table 13. Five Ph. vulgaris cultivars classified as the most attractive in the preferred catwgory for whitefly oviposition and their respective seed coat color.

Cultivar	Mean Reading/ cultivar	Seed coat color
G01225	4.30	Striped
G00718	4.30	Striped
G00808	4.33	White
G03115	4.33	Black
G03167	4.33	Black

The most preferred cultivar for oviposition in the very preferred class was G01204 (white) which was also very preferred for adult attraction (Table 14). Following it were G02997 (black), Rayada (striped), and 1-59 (brown seeded and very susceptible to leafhopper).

Ph. coccineus (G00039), a preferred cultivar for adult attraction, was also one of the most very preferred for oviposition (Table 14), thus showing again the broad genetic variability in this species for whitefly resistance.

The Ph. vulgaris entries were also placed in the five preference classes for oviposition according to their seed coat color (Table 15). The striped and brown seeded types were the most preferred by whitefly for oviposition. Some black and some red seeded cultivars were found to be the least preferred for whitefly oviposition. Some white seeded cultivars seemed to be somewhat intermediate in their attractiveness, but brown types were more preferred than white ones (see also the appendix). Creamy orange and very dark purple seeded cultivars (one of each), were in the preferred class for oviposition, despite the fact that the very dark purple cultivar was only intermediately preferred in whitefly adult attractiveness.

Thus, based on the supporting facts previously mentioned about the apparent seed coat color relationship with whitefly adult attraction, it is suggested that the greatest attractiveness for oviposition was also found in cultivars with striped seed coats, but highest non-preference was observed in some black and red seeded cultivars.

The most preferred cultivar for oviposition in the very preferred class was 60I204 (white) which was also very preferred for adult attraction (Table 14). Following it were NCC302 (black), [illegible] (Sierra), and 1-69 (brown seeded and very susceptible to leafhopper).

Ph. coccineus (500007), a preferred cultivar for adult attraction, was also one of the most very preferred for oviposition (Table 14), thus showing again the [illegible]

Table 14. Thirteen bean cultivars classified as very preferred for whitefly oviposition and their seed coat color.

Cultivar	Mean Reading/ cultivar	Seed coat color
G01083 (*Ph. vulgaris*)	4.57	Striped
G03099 (*Ph. vulgaris*)	4.57	Black
G04494 (*Ph. vulgaris*)	4.60	Striped
G03242 (*Ph. vulgaris*)	4.63	Black
G03128 (*Ph. vulgaris*)	4.63	Brown
G03252 (*Ph. vulgaris*)	4.63	Brown
G02987 (*Ph. vulgaris*)	4.63	Black
G00039 (*Ph. coccineus*)	4.70	Brown
G03050 (*Ph. vulgaris*)	4.73	Black
1-59 (*Ph. vulgaris*)	4.77	Brown
Rayada (*Ph. vulgaris*)	4.87	Striped
G02997 (*Ph. vulgaris*)	4.90	Black
G01204 (*Ph. vulgaris*)	5.00	White

Table 15. Percentage of *Ph. vulgaris* in five classes of whitefly oviposition preference according to their seed coat color.

Class of Resistance	Seed coat color						
				Creamish	very dark		
	Black	Red	Brown	Orange	Purple	White	Striped
	%						
Non-preferred	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mod. non-preferred	4.22	14.29	0.00	0.00	0.00	12.50	0.00
Int. preferred	47.89	0.00	30.00	0.00	0.00	50.00	25.00
Preferred	40.84	57.14	60.00	100.00	100.00	25.00	50.00
Very preferred	7.04	28.57	10.00	0.00	0.00	12.50	25.00
Number of cultivars	71	7	10	1	1	8	12

GREENHOUSE WHITEFLY (T. vaporarium WESTW.) ADULT PREFERENCE FOR SEVERAL PLANT PARTS OF Phaseolus, Vigna, AND Dolichos BEAN SPECIES

Introduction

In addition to extrinsic environmental influences, insect responses to any given host depend on several intrinsic factors of the insect and also on several factors of the host. The better they fit each other, the higher the insect population on a given host is, and the more susceptible the host becomes. Changes in behavior and mechanisms of host selection are areas where insects most often have evolved to adapt to their hosts. A counter response from the host plant directly against the insect pest or its biology often evolves. Host responses leading either to repel, to kill, to tolerate, or to adversely affect the normal growth of the insect are very common.

The purpose of this research was to study plant leaf preferences of adult whiteflies when confined to species of three bean genera (Phaseolus, Vigna, and Dolichos) with varying degrees of resistance.

Materials And Methods

Whitefly adult attraction preferences to two plant leaf levels of 38 bean cultivars with varying degrees of resistance were studied in

greenhouse and laboratory conditions. There were seven non-preferred, ten moderately non-preferred, nine intermediately preferred, six preferred, and six very preferred cultivars, which were previously identified in the free-choice test of germplasm in the greenhouse.

During the winter of 1978-1979, two plants of each experimental unit were grown in the plant science greenhouse. The soil mixture used was 1 part sand:1 part peat:1 part topsoil. In order to avoid differences in color due to soil fertility differences, the soil in each pot was fertilized 2 and 30 days after germination with one gram of 12-12-12 fertilizer. Two seeds per pot were sown to guarantee one plant per pot.

The experimental part of this study was conducted in laboratory conditions from January 15 to February 5, 1979, at 25^{o}C with 11 hours of light. The two plant leaf levels studies were: (1) the first not fully expanded trifoliate leaf (shoot), (2) and the two first well expanded leaflets. Both leaf types were located at the upper part of the plant (Figure 6).

Bean stems bearing the leaves were in glass assay tubes of about 25cc filled with a plant nutrient solution (28). A foam ring in the opening of the tube was used to keep the stems in place. Transparent plastic chambers, 20 cm high with an open base and a removable top with a very fine screen cloth, were used to confine the whiteflies to both kinds of leaves. Wooden racks with holes of the proper size supported the assay tubes and the chambers. Two well expanded first leaflets and a shoot from a single plant cultivar were placed in each assay tube-chamber combination at each test time.

Three replications of each plant part were tested. Due to space and equipment limitations, one replication was tested at a time.

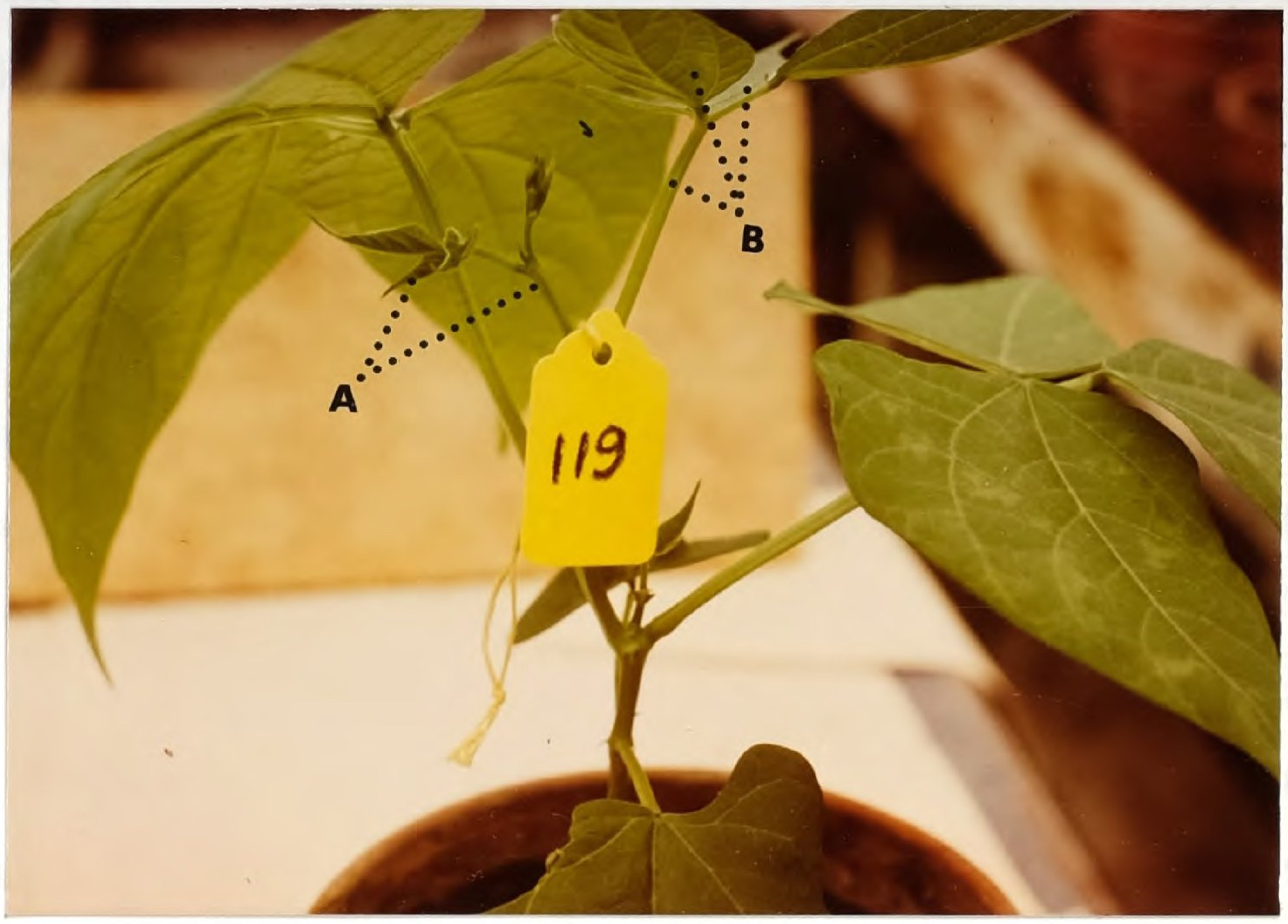


Figure 6. Bean plant showing the two leaf types studied in the leaf-part attraction experiment; (A) first not fully expanded trifoliate leaf (shoot), (B) two first well expanded leaflets.

Plant leaf samples were collected at 15, 25 and 35 days after plant emergence. A whitefly population reared for at least 9 generations on a susceptible pinto-bean cultivar was used for infesting.

For the tests, whiteflies were captured with an aspirator. Whiteflies were then placed in a refrigerator (15^{o}C) for a 2-hour starving period. For infesting purposes, insects were inactivated by exposure for 15 minutes in a 0^{o}C refrigerator. The infestation rate per chamber was 8 ± 2 whitefly adults.

Whitefly adult preference data were taken 36 hours after each infestation. The number of adults attracted by the shoot, expanded leaf blades, petiole, stem, and the number present in any part of the chamber wall were recorded at the same time.

Analysis of variance, honestly significant differences values, the multiple mean rank test (Student-Newlman-Knewls Test), some statistics helpful in describing populations, a previously designed rating scale of classes of adult preference and some graphic techniques were used to discriminate variety, to determine leaf and leaf part effects, and to present the results.

Results And Discussion

The analysis of variance for the bi-factorial arrangement (cultivars x location), showed that only location factors and the interaction of cultivars with location factors were significantly different (P=0.01) in adult attraction (Table 16). The non-significant effect found between bean cultivars is explainable since the percentage of adults

Table 16. Analysis of variance of leaf part effect on whitefly adult attraction (data=Arc-sine transformed).

Source of variance	df.	MS	F
Blocks	2	0.0060	0.111
Cultivars (A)	37	0.0048	0.089
Leaf+Leaf part + chamber (B)	4	15.3060	282.680 **
Interaction AxB	148	0.1484	2.740 **
Error	378	0.0541	
Total	569		

** Significant at P= 0.01

registered in the chamber were also included in the analysis (Table 16) in addition to the plant treatments. But, significant varietal differences at P=0.01 were found in the separate analysis of variance for cultivars as a whole (Table 17). Also, there were significant varietal differences in adult attraction in the 4 separate analysis of variance for the first well expanded leaf blades, the shoot, the petiole, the stem and the chamber (Table 17). The term chamber stands for the number of adults recorded in any place other than on the plant material.

The non-significant block effect for nearly all variables analyzed indicates that the methodology was uniform in all treatments, and that there were no differences in leaf-part response due to the different plant ages. This is expected because although the plants themselves were different ages at the different infestation times, the plant parts tested were still in the active growth phase.

The significant block effect (P=0.05 level) found only for the "cultivar leaf-blades" effect, is attributed to variations in adult attraction which was exhibited for some cultivars at different replications (Table 17). Differences in leaf size were a probable cause. A different cultivar neighbor effect could also have been involved since the chambers were fully transparent and there was a different assortment of cultivars in each replicate.

The highly significant chamber effect (Table 17) could have been attributable either to a strong attraction effect from neighboring plants, to the presence of a repellent effect of the cultivars within the chamber, or to a combined effect of both.

Figure 7 shows the number of groups of cultivars differentiated by adding the hsd-values to the lowest mean transformed value of:

Table 17. Significance of the analysis of variance (F-values) for cultivars, leaves, leaf parts and chamber effect whitefly adult attraction (data=Arcsine transformed).

Source of Variation	df	Treatments: Cultivar	Leafblade	Shoot	Petiole	Stem	Chamber
Blocks	2	1.9180	3.23 *	0.987	2.42	1.15	2.01
Cultivars	37	2.636 **	2.95 **	2.56 **	1.93 **	1.47	2.59 **
Error	74						
Total	113						

** Significant at P= 0.01
 * Significant at P= 0.05

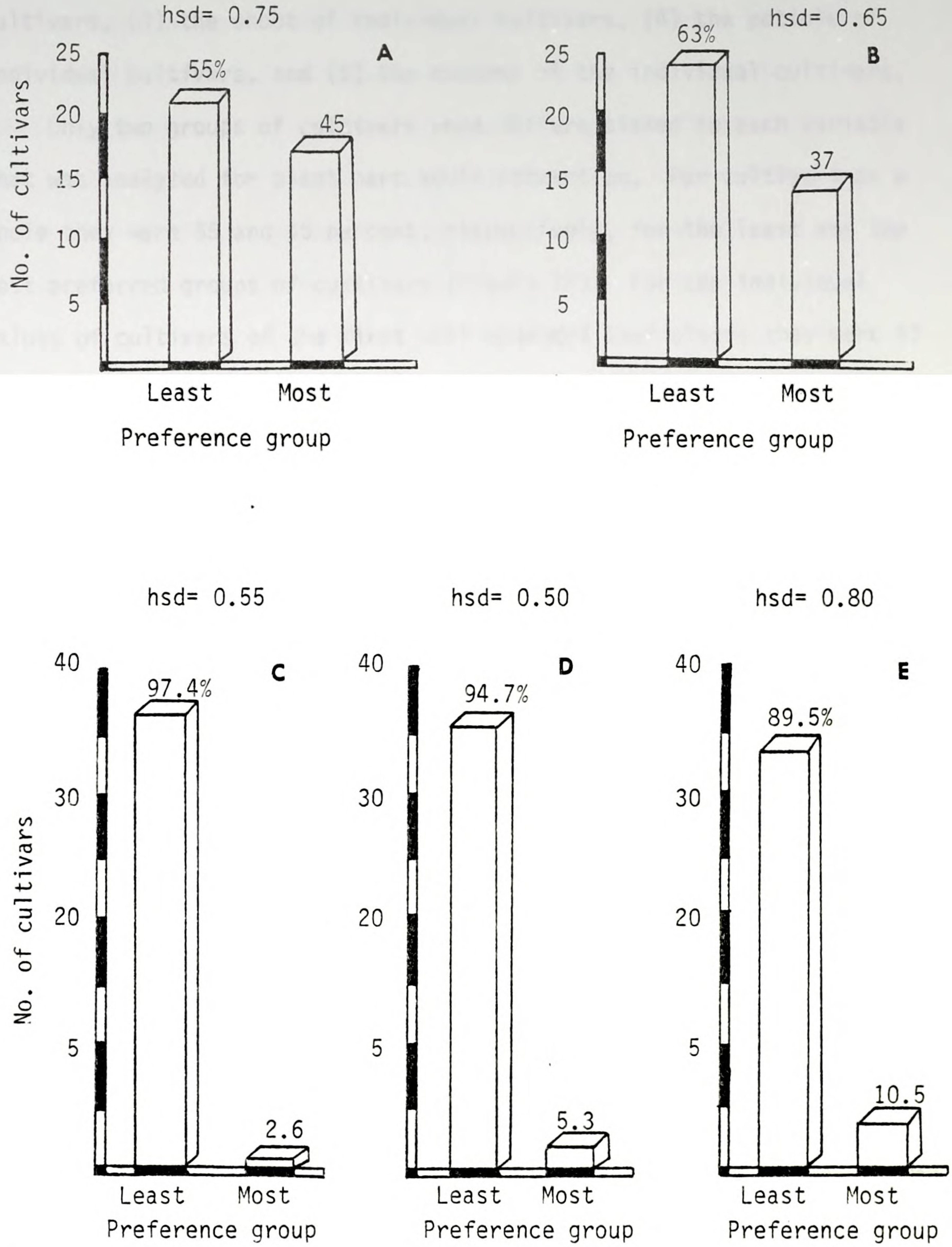


Figure 7. Frequency of bean cultivars into two hsd-groups A= groups according to mean variety effect; B= according to variety first well expanded leaf effect; C= according to variety-shoot effect; D= according to variety-petiole effect; and E= according to variety-chamber effect.

(1) cultivars, (2) the first well expanded leaflets of individual cultivars, (3) the shoot of individual cultivars, (4) the petiole of individual cultivars, and (5) the chamber of the individual cultivars.

Only two groups of cultivars were differentiated in each variable that was analyzed for plant part adult attraction. For cultivars as a whole they were 55 and 45 percent, respectively, for the least and the most preferred groups of cultivars (Figure 7A). For the individual values of cultivars of the first well expanded leaf blades they were 63 and 37 percent of cultivars, respectively, for the groups previously mentioned (Figure 7B).

In Figures 7C, 7D, and 7E about the same frequency of cultivars were in the most preferred and the least preferred groups for leaf parts and for the chamber. There were 97.4 and 2.6 percent, respectively, for the least and the most preferred groups according to shoot attractiveness to the whitefly adult. There were 94.7 and 5.3 percent of cultivars, respectively, in the same groups previously mentioned for petiole attractiveness. And there were 89.5 and 10.5 percent of the cultivars also in the same groups for the number of adults counted in the chamber.

The general reduction of groups observed in this test compared with the number detected in the free-choice germplasm evaluation experiment, is attributed to the fact that infesting pressure in confining conditions was greater, since there was no alternative for host selection. Confining conditions, however, in relation with variety mean values allowed identification of those cultivars exhibiting that non-preferred response, which is shown even under greater infesting pressure. This is an example of one of the two kinds of non-preference cited by Painter (40).

Highly statistically significant differences in adult attraction were also found between the five locations evaluated (Table 18). The chamber, shoot, petiole, and stem accounted for 64, 18, 16 and 2 percent, respectively, of the adult attraction for the first well expanded leaf blade. All treatments, except the shoot and petiole were statistically different in adult attraction. Preference for the leaf blade was outstanding (Table 19).

Significant positive correlations were found between the overall variety adult attraction values and leaf blade adult attraction values in all groups of resistance (Table 20). Stronger association (P=0.01 level) was found only for the non-preferred and the intermediately preferred classes. The positive correlation found between the variety adult attraction values and the leaf blade adult attraction values is explained, because the first well expanded leaf blades, as shown in Table 19, were the most preferred parts of the plant to the whitefly adult.

Although not always significant, negative correlation between leaf-adult attraction values registered in the leaf blades versus those found in the shoot, the petiole, and the chamber were nearly always (73% of the time) observed in all classes.

Significant negative association, at P=0.05 between attraction values for the first well-expanded leaf blade and the shoot was found only for the moderately non-preferred and the two most preferred classes (preferred + very preferred). Since the non-preferred class consisted mainly of genera other than _Phaseolus_, it is concluded that in general the _Ph. vulgaris_ group of cultivars least and most adult

Table 18. Analysis of variance of leaf-part and cage wall effect upon whitefly adult attraction (data=Arcsine transformed).

Source of variance	df	MS	F
Blocks	37	0.0036	0.081
Leaf parts + chamber wall	4	4.9039	110.002 **
Error	148	0.0446	
Total	189		

** Significant at P= 0.01

Table 19. Student-Newman-Keuls multiple range mean test of five treatments for whitefly adult attraction, relative percentage of adult attraction value (both of arcsine transformed data), and true observed leaf-part mean values (%) of adults.

Freatment	Mean (arcsine transf. values).	Relative %	True Mean value (%)
Stem	0.0166 d	1.89	0.52
Petiole	0.1394 c	15.89	4.74
Shoot	0.1570 c	17.89	5.66
Chamber	0.5629 b	64.16	29.92
Leaf blade	0.8774 a	100.00	58.79

Transformed means sharing the same letters are statisticaly indistinguishable at 0.05 level of probability.

Table 20. Correlation coefficients between adult attraction values registered for the overall variety attraction with leaf-blade attraction, and between leaf-blade with the adult attraction observed by the shoot, the petiole, and the chamber.

Group correlated	r	Group correlated	r
Non-preferred:		Intermediately preferred:	
Cultivar values vs. leaf-blade	0.99**	Cultivar value vs. leaf-blade	0.92**
Leaf-blade value vs. shoot	0.32	Cultivar leaf-blade vs. shoot	-0.55
vs. petiole	0.38	vs. petiole	0.26
vs. chamber	-0.85**	vs. chamber	-0.88**
Moderately non-preferred:		Preferred+Very preferred:	
Cultivar value vs. leaf-blade	0.74*	Cultivar value vs. leaf-blade	0.63*
Cultivar leaf-blade vs. shoot	-0.75*	Cultivar leaf-blade vs. shoot	-0.61*
vs. petiole	----	vs. petiole	-0.08
vs. chamber	-0.85**	vs. chamber	-0.62*

** Significant at P= 0.01
* Significant at P= 0.05
---= Insuficient data

preference showed the most consistent negative association in attraction values between leaf blade and shoot. Highly negative association (P=0.01) between leaf blade adult attraction and the number of whitefly adults in the chamber was found in the non-preferred, the moderately non-preferred class and the intermediately preferred classes.

Significant negative association, but only at P=0.05 level, was found for the group of the two highest preferred classes, (r= -0.62). Thus it is also concluded that in the Ph. vulgaris group, there was a tendency of cultivars in the most preferred classes to show greater adult attraction to leaves and less adult attraction on the chamber than in the cultivars in the non-preferred group. Specifically in the non-preferred class, the r-values indicated almost no correlation between leaf blade adult attraction with shoot-adult attraction.

The mean percentage values as well as the X^2 values for the mean adult attraction by each plant part and by the chamber in the five adult preference classes are graphically shown in Figure 8.

The first well expanded leaf blades exhibited the highest mean adult attraction values in all classes of resistance. The lowest mean adult attraction values were in the non-preferred class (30%), followed by the moderately non-preferred class (61%), the very preferred class (66%), the intermediately preferred class (69%), and the preferred class (71%). The non-preferred and intermediately preferred classes were the least attractive on the shoot for the whitefly adult, 1.75 and 2.76% respectively. They were followed by the moderately non-preferred, the preferred and the very preferred, with 4.88, 6.38, and 12.21% of the adults attracted, respectively.

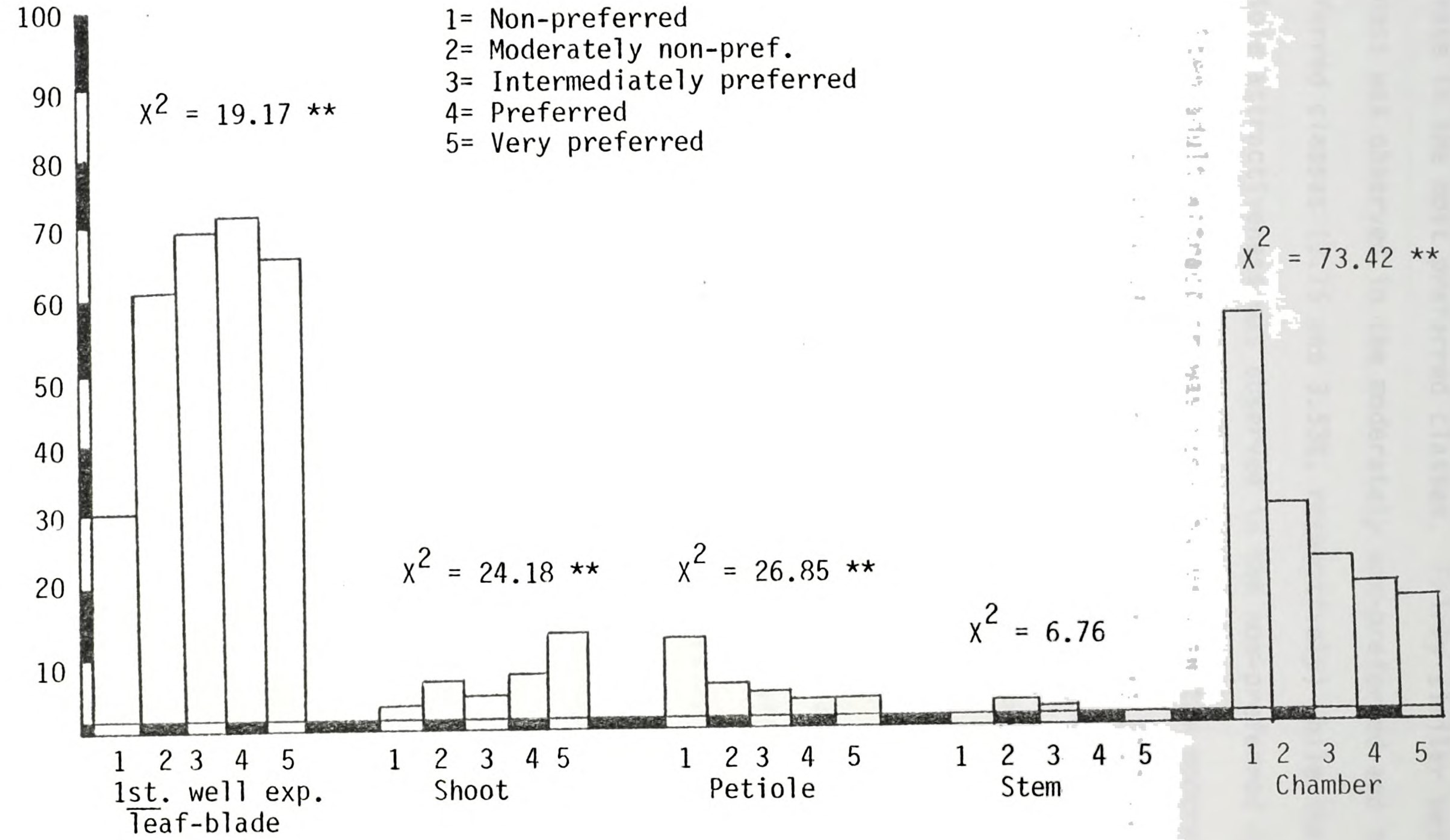


Figure 8. Mean percentage of whitefly adults on each leaf, leaf-part, and chamber, and their significance (X^2) in attraction between classes.

Lowest petiole attractiveness to the adult was observed on the average in the most preferred classes. Fairly similar petiole attractiveness was observed in the moderately non-preferred and intermediately preferred classes (3.75 and 3.53%, respectively) while the highest mean petiole attractiveness was observed in the non-preferred class (11.46%).

Stem adult attraction was recorded only in the moderately non-preferred and the intermediately preferred cultivars (1.3 and 0.41%).

The highest mean percentage of whiteflies on the chamber was in the non-preferred group (± 56%). In decreasing order were the moderately non-preferred (29%), the intermediately preferred (± 21%), and the preferred group (± 17%).

The X^2 values calculated for each leaf part and for the chamber indicated that, except by the stem, all other leaf parts in general exhibited significantly different mean adult attraction values between classes.

The percentage of bean cultivars by resistance category with some adult attraction values in the first well expanded leaf blades, the shoot, the petiole, the stem, and the chamber, as well as their X^2 values for the respective percentage of cultivars with adult attraction, are graphically presented in Figure 9.

One hundred percent of the bean cultivars had at least some whitefly adult attraction to the first well expanded leaf blade, as well as in the chamber wall.

The highest percentage of cultivars exhibiting adult attraction to shoots was in the very preferred and preferred classes, 100 and 50%, respectively. But the lowest proportion (33%) was in the intermediate

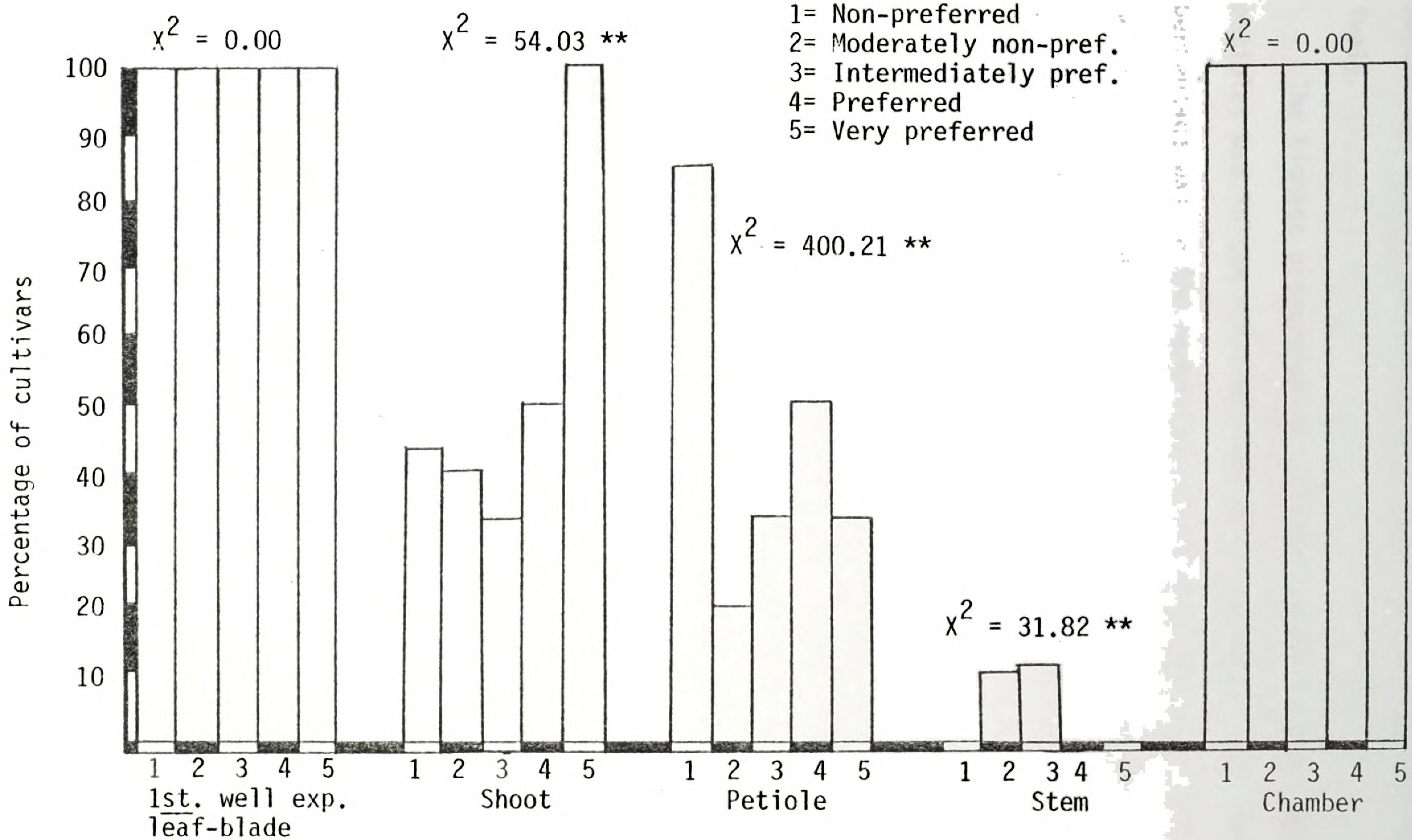


Figure 9. Percentage of bean cultivars in each resistance category with adult attraction to the leaf, leaf-part, and chamber, and their significance (X^2) in attraction between resistance classes.

class. Non-preferred and very preferred classes had a fairly similar percentage of cultivars with adult attraction of 40 and 43%, respectively.

The highest proportion of cultivars showing adult attraction to petioles was in the non-preferred class (± 86%). But, the lowest percentage was in the moderately non-preferred class (20%). Intermediately preferred and very preferred classes were fairly similar in percentages of cultivars with petiole adult attraction (31 and 33, respectively), while the proportion of cultivars in the preferred class was somewhat intermediate (50%).

Cultivars with adult attraction to the stem were recorded only in the moderately non-preferred and in the intermediately preferred classes (10 and 11%). The X^2 values calculated for each leaf and for the chamber indicated that only the shoot, the petiole, and the stem exhibited in general significantly different mean adult attraction values between the classes of resistance (Figure 9).

The mean percentage of adults in each leaf-part and in the chamber for the five groups of cultivars are reported in Tables 21 through 24.

The first well expanded leaf blade and the shoot in the non-preferred and moderately non-preferred groups, were the least attractive to the whitefly adult. Intermediately preferred groups of cultivars were less stable in their response under the greater insect pressure. Such variation in place with the observed values in the free-choice screening experiment was likely due in part to the narrowed choice for host site selection by the adult.

class. Non-preferred and very preferred classes had a fairly similar percentage of cultivars with adult attraction of 41 and 43%, respectively.

The highest proportion of cultivars showing adult attraction on petioles was in the non-preferred class (± 65%). But, the lowest percentage was in the moderately non-preferred class (20%). Intermediately preferred and very preferred classes were fairly similar in percentages of cultivars with petiole adult attraction [illegible]

In the non-preferred class (Table 21), it is shown that genera other than Phaseolus and species other than Ph. vulgaris were again least attractive to the whitefly adult. Leading the leaf blade non-preferred category was Dolichos lablab (5.5%) followed by Vigna repens (12%). In decreasing order of non-preference, but still with considerable adult non-preference, were Ph. lunatus G01154 with 24% and Ph. coccineus G00046 with 27%. Vigna radiata G00128, Ph. coccineus G00038, and Ph. lunatus G00127 were lower in adult non-preference response than in the screening experiment. Their leaf blades attracted only about one-half of the infested number of adults (42, 43, and 57%, respectively). The reduction of adult attraction in the most resistant cultivars was also probably due to the reduced opportunity of the adult for plant site selection.

In the moderately non-preferred class (Table 22), nearly all cultivars (about 70%), fairly well filled their class. In this adult attraction category, and mainly in the Ph. vulgaris group, adult attraction was associated with almost no attractiveness to the shoot and by a fairly low percentage of attraction to the first well expanded leaf blade. Exceptions in this group were PI 309-804, G03097, and G02980, whose shoot attraction values were 5.56, 8.47 and 23.81%, respectively.

A Ph. vulgaris G04485, was apparently the only cultivar in the moderately non-preferred category that was outstandingly more attractive under confining conditions. Lowest adult attraction for the leaf blade was exhibited by the Ph. vulgaris cultivar G02980 (28%), but this low attraction seemed to be associated with a fairly similar attractiveness shown by the shoot (24%). Following this cultivar in ascending

Table 21. Percentage of adults on each leaf-part and chamber wall in cultivars of the non-preferred class for adult attraction.

Cultivars +	Percentage				
	Leaf-blade	Shoot	Petiole	Stem	Chamber
G00037 (Vigna repens)	12.22	0.00	18.10	0.00	69.7
G00128 (Vigna radiata)	42.38	3.33	8.33	0.00	45.9
G00127 (Ph. lunatus)	57.04	0.00	7.04	0.00	35.9
G00046 (Ph. coccineus)	26.79	4.76	0.00	0.00	68.4
G00038 (Ph. coccineus)	43.33	4.17	4.17	0.00	44.2
H00126 (Dolichos lablab)	5.56	0.00	11.11	0.00	83.3
G01154 (Ph. lunatus)	24.54	0.00	31.49	0.00	44.0

+ Cultivars sorted according to the screening experiment categorization.

Table 22. Percentage of adults on in each leaf-part and chamber wall in cultivars of the moderately non-preferred class for adult attraction.

Cultivars +	Percentage				
	Leaf-blade	Shoot	Petiole	Stem	Chamber
G00132 (Ph. vulgaris)	79.55	0.00	4.17	0.00	16.3
G03645 (Ph. vulgaris)	78.57	0.00	0.00	0.00	21.4
PI 309-804 (Ph. vulgaris)	52.22	5.56	0.00	0.00	42.2
Porrillo No.1 (Ph. vulgaris)	75.48	0.00	0.00	13.10	14.4
G04485 (Ph. vulgaris)	90.74	0.00	0.00	0.00	9.3
G00787 (Ph. vulgaris)	40.28	0.00	0.00	0.00	59.7
G01222 (Ph. accutifolius)	40.00	10.00	33.33	0.00	16.7
G02980 (Ph. vulgaris)	28.57	23.81	0.00	0.00	47.6
G03097 (Ph. vulgaris)	56.62	8.47	0.00	0.00	34.9
Porrillo sintetico (Ph. vul.)	69.84	0.00	0.00	0.00	30.2

+ Cultivar names are sorted according to the screening experiment categorization.

order of attractiveness were: Ph. accutifolius G01222 and Ph. vulgaris entry G00787 both with 40% leaf-blade adult attraction. However, Ph. accutifolius registered 10% of adult attraction compared with the zero attraction value registered for the G00787 shoot. A good deal of non-preference to the leaf-blade was also recorded for Ph. vulgaris entry PI-309-804 and G03097 (52 and 57% of adult attraction).

Plant phenotypic differences, such as intrinsic differences in color, light refraction, number of stomata, and hardness of the leaf cuticule, as well as some chemical factors, such as differences in precursors of tanins and/or pigments later determining the seed coat color, might be conferring the observed resistance in some of the cultivars in these two groups of cultivars previously referred.

Intermediately preferred cultivars (Table 23) in general exhibited higher leaf blade adult attraction but fairly similar shoot attraction than the moderately non-preferred group.

Table 24 shows the mean percentage values of adults in each treatment by each cultivar in the preferred and very preferred classes of adult attraction.

No really distinctive differences in leaf blade adult attraction were observed between cultivars in the most preferred categories compared with those of the intermediately preferred class. But a distinctly greater single shoot attractiveness and a greater proportion of cultivars having shoot adult attractiveness was generally observed, thus suggesting that susceptibility in these groups of cultivars might be associated with the greater preference of the shoot.

This shows that whitefly non-preference in bean cultivars, and mainly in the Ph. vulgaris group, depends more on the non-preference

Table 23. Percentage of adults on each leaf-part and chamber wall in cultivars of the intermediately preferred class for adult attraction.

Cultivar [+]	Mean percentage				
	Leaf-blade	Shoot	Petiole	Stem	Chamber
15R-52 (*Ph. vulgaris*)	43.65	15.08	0.00	0.00	41.3
G04481 (*Ph. vulgaris*)	67.62	0.00	11.43	0.00	20.9
581 (F4)	80.00	0.00	0.00	0.00	20.00
Nep-2	53.33	0.00	0.00	0.00	40.00
ICA-Tui	70.90	0.00	0.00	0.00	18.80
G00133	78.20	6.06	0.00	0.00	15.70
PI-197-444	70.00	0.00	5.56	6.67	17.80
G00773	80.56	3.67	0.00	0.00	15.70
15-R-194	81.48	0.00	14.81	0.00	3.70

+ *Ph. vulgaris* cultivars names are sorted according to the screening experiment categorization.

Table 24. Percentage values of adults on each leaf-part and chamber wall in cultivars of the preferred and the very preferred class for adult attraction.

	Mean percentage				
Cultivar +	Leaf-blade	Shoot	Petiole	Stem	Chamber
Preferred:					
15R-287	57.41	0.00	3.70	0.00	29.00
Calima	67.26	18.45	4.76	0.00	9.50
G03037	80.82	0.00	0.00	0.00	19.80
G03159	67.86	9.52	4.17	0.00	18.40
G01225-N	74.60	10.32	0.00	0.00	15.10
G01225-S	80.42	0.00	0.00	0.00	19.60
Very preferred:					
G03042	68.89	5.56	0.00	0.00	18.80
G03167	48.61	25.00	4.17	0.00	22.20
1-59	77.25	9.53	0.00	0.00	3.20
G01204	49.80	9.52	8.33	0.00	32.30
G01083	70.79	18.89	0.00	0.00	10.30
G00718	82.14	4.76	0.00	0.00	13.10

+ *Ph. vulgaris* cultivars names are sorted according to the screening experiment categorization.

responses of the shoot, though in the least preferred groups of cultivars, non-preference of well expanded leaflets in the upper part of the plant is certainly more important.

Petiole attractiveness exhibited by the two, or perhaps three, most adult preferred classes might be attributable to changes in leaf turgidity and perhaps to other unknown physiological processes also changing at greater extent in the leaf blade of these particular groups of cultivars.

Since the petiole and stem, under natural conditions, have been observed by the author to be plant parts not commonly selected by the whitefly adult, and considering the fact that adult attraction by these parts was recorded mainly in the most non-preferred cultivars, it is believed that this kind of adult attraction was merely a kind of escape alternative whitefly adults used in perhaps looking for a place showing a less repellent effect, or a place better supplied with sap, or both.

The number of adults recorded on the chamber wall of the most preferred cultivars are attributed to: (1) the intrinsic and natural searching of any animal in a foreign "habitat", and (2) short flights, especially in the more susceptible cultivars (perhaps as part of the whitefly adult normal behavior). This probably predisposed some of the adults to rest on the chamber wall.

The greater number of adults on the chamber wall of the most resistant categories of cultivars might be due either to the presence of a repellent effect from the cultivar or to a strong attraction exhibited by some more preferred neighboring cultivars, or both.

Factors strongly suggesting the presence of mechanisms which were either physically or chemically repelling to a greater extent in the non-preferred and in the moderately non-preferred groups of cultivars, or at least in some of them, are the following: (1) these groups had the lowest leaf blade adult attraction values of 5.5 and 40%, respectively, (2) the petioles received significantly higher attraction (31 and 33%, respectively), (3) these groups had a higher percentage of cultivars with less than 6% of adult attraction (59 and 29% of the cultivars had zero and less than six percent attraction, respectively).

Additional support for these hypotheses is that such whitefly "repelling" responses were more distinctive in the most non-preferred cultivars. Moreover, most of the preferred cultivars, though they exhibited adult attraction toward almost every leaf part, attracted adults mainly to the leaf blade and to the shoot. These are the most often selected plant parts in the field, perhaps because they are more succulent and better supplied with sap.

Correlation coefficients between the whitefly adult attraction values in each cultivar in the screening experiment and the corresponding mean values of varieties and leaf-blades in the adult leaf preference experiment are reported in Table 25. No significant correlation was found for any single resistant class compared. However, highly significant correlation was found for both mean variety values and mean leaf-blade values when comparing the 38 cultivars in the five resistant classes studied.

The magnitude of the calculated r-values for each class suggests that the most consistent response was found in the non-preferred and

Factors strongly suggesting the presence of mechanisms which were either physically or chemically repelling to a greater extent in the non-preferred [illegible] nonpreferred groups [illegible]

or [illegible]

Table 25. Correlation coefficients between the adult attraction values observed in each cultivar in the screening experiment and corresponding mean varieties and leaf-blades in the adult leaf preference experiment.

Group correlated	r
Non-preferred:	
Screening exp. vs. adult pref. variety value	0.59
adult pref. variety-blade	0.65
Moderately non-preferred:	
Screening exp. vs. adult pref. variety value	0.19
adult pref. variety leaf-blade	0.26
Intermediately preferred:	
Screening exp. vs. adult pref. variety value	0.05
adult pref. variety leaf-blade	0.26
Preferred:	
Screening exp. vs. adult pref. variety value	0.38
adult pref. variety leaf-blade	0.30
Very preferred:	
Screening exp. vs. adult pref. variety value	0.47
adult pref. variety leaf-blade	0.82
Screening exp. vs. adult pref. experiment var. value	0.54 **
adult pref. variet leaf-blade	0.43 **

** Significant at P= 0.01

very preferred cultivars (r=0.59 and r=0.47) selected in the screening experiment. These higher values were probably beside the number of varieties compared, with the greater contribution afforded to the high significance level (P=0.01) obtained in the correlation coefficient between adult attraction values of both experiments.

Groups classified intermediate in their attractiveness in the screening test were more erratic in their responses in the chamber test. Again phenotypic considerations of the nature previously mentioned supported mainly in genotypic differences than in environmental contributions might be the main factors involved to show such responses.

very preferred cultivars (r=0.53 and r=0.47) selected in the screening experiment. These higher values were probably beside the number of varieties comparison afforded.

SUMMARY AND CONCLUSIONS

Breeding bean plants for genetic resistance to either the greenhouse whitefly (T. vaporarium West.), or to the tropical bean whitefly (B. tabaci Gen.), provides an ideal way of controlling physical damage, and can greatly reduce the frequency of bean plants with virus diseases. Thus, this research evaluated 118 bean cultivars of four species of Phaseolus, two species of Vigna, and one of Dolichos (all Leguminosae members), for shelter and oviposition in free-choice greenhouse conditions, and studied leaf part preferences exhibited by adult whiteflies confined to 38 selected cultivars of the three genera with varying degrees of resistance.

The highest level of adult-shelter and oviposition non-preference was found in genera other than Phaseolus. Within the genus Phaseolus, attractiveness to the whitefly was also lower in species different than Ph. vulgaris. The adult non-preferred class for shelter consisted of the two Vigna repens and V. radiata, the two Ph. lunatus G00127 and G01154, and two Ph. coccineus G00046 and G00038.

In the moderately non-preferred class there were eleven Ph. vulgaris cultivars and Ph. accutifolius. Three Ph. vulgaris, a wild and black seeded type G00132, G03645, and PI 309-804, both black seeded cultivars, were the least preferred in this resistance class.

G04487 black seeded, G00787 red seeded, and G03244 black seeded, in descending order of preference, were less adult preferred for shelter than the Ph. accutifolius G01222.

Probably the wild types of Ph. vulgaris and among them, the black types, are the best sources in this species to search for higher levels of whitefly adult non-preference.

One of the cultivars leading the adult shelter preferred class was a very susceptible leafhopper Ph. vulgaris cultivar, 1-59 which is a light brown seeded type. The four Ph. vulgaris following it in ascending order of preference were G04525, 703 (black), Rayada (striped), and G01225 (striped).

The presence of Ph. coccineus G00039 in this class, compared with the presence of the other two Ph. coccineus (G00046, and G00038), in the non-preferred class shows the broad genetic variability in this species for whitefly adult attraction.

The six Ph. vulgaris very preferred for adult attraction, in decreasing order of preference were: G00718 (striped seeded), G03101 (black), G04494 (striped), G01054 (dark red), G01083 (striped), and G01204 (white).

In the non-preferred class for oviposition, Vigna repens G00037 and V. radiata G00128, Ph. lunatus G01154 and G00127, and the Dolichos lablab were the least preferred. Also, in this class were both Ph. coccineus G00046 and G00038, which had oviposition readings of 1.3 and 1.8 compared with the oviposition reading of 1.0 in the previously mentioned entries.

Only four Ph. vulgaris cultivars, G00129, G00787, G03244 (black seeded types), G00787 (red seeded type), and the Ph. accutifolius, G01222 (white seeded), were in the moderately non-preferred category for whitefly oviposition.

In the preferred class for oivposition, two striped cultivars G01225 and G00718, a white seeded G00808, and two black seeded G03115 and G03167, in ascending order of preference, exhibited the highest attraction. The most preferred cultivars in the very preferred class in ascending order of attractiveness were: 1-59, brown seeded; Rayada and G02997, both black seeded; and G01204, a white seeded cultivar which was also very adult preferred for shelter.

The presence of the Ph. vulgaris cultivar, 1-59, a very susceptible leafhopper cultivar in the adult preferred class, and the presence of this cultivar in the very-preferred class for whitefly oviposition suggests that in the Ph. vulgaris group the same factors for leafhopper and whitefly susceptibility might be involved.

In the Ph. vulgaris species, striped and brown seeded varieties were the most preferred for whitefly shelter and for oviposition. Some black seeded types, followed by red ones and some white ones, were the least attractive for whitefly shelter and oviposition.

In confined conditions, only two groups of cultivars were discriminated with Tukey's hsd-values when plant parts were separately analyzed for adult attraction. It allowed identification of cultivars exhibiting non-preference even under greater infesting pressure which is an instance of Painter's two types of non-preference distinctions (40).

Adult preference for the leaf blade of the first well expanded leaflet was statistically different. Attraction values of the shoot, the petiole and the stem were 18, 16 and 2 percent, respectively, of the attraction value of the first well expanded leaf blade.

In all groups of resistance, significant association was found between the variety adult attraction values and the first well expanded leaf blade attraction values. Although not always significant, negative correlation between leaf blade adult attraction versus shoot, petiole, and chamber effect was nearly always found (70%). A highly negative association between leaf blade adult attraction and the number of whitefly adults in the chamber was found for the non-preferred, the moderately non-preferred, and the intermediately preferred. Significant negative association, but only at P=0.05 level, was found for the group of the two highest preferred classes. Therefore, in the Ph. vulgaris group there was a tendency for cultivars in the most preferred classes to show greater adult attraction to leaves and less adult attraction on the chamber than in those cultivars in the non-preferred group.

Almost no correlation between leaf blade adult attraction with shoot adult attraction was found in the non-preferred class. The lowest mean adult attraction value in the first well expanded leaf blade was in the non-preferred class (30%), followed by the moderately non-preferred class (61%), the very preferred class (66%), the intermediately preferred class (69%), and the preferred class with about 71%.

Lowest shoot adult attraction was in the non-preferred and the intermediately preferred classes (1.75 and 2.76%, respectively). This attractiveness was highest in the most preferred classes.

The lowest petiole attractiveness was observed in the most preferred classes, but highest attractiveness was observed in the non-preferred class.

Stem-adult attraction was recorded only in the moderately non-preferred and the intermediately preferred cultivars (with 1.3 and 0.41 percent, respectively).

The highest proportion of cultivars showing shoot adult attraction was recorded in the very preferred and preferred classes with 100 and 50%, respectively. The highest proportion of cultivars showing petiole adult attraction was recorded in the non-preferred class with 86%. Only 10 and 11% of the moderately non-preferred and the intermediately preferred classes, respectively, showed stem-adult attraction.

Leading the first well expanded leaf blade non-preferred category was Dolichos lablab, with 5.5 percent of the adults attracted. This was followed by Vigna repens with 12%, Ph. lunatus G01154 with 24%, Ph. coccineus G00046 with 27%, V. radiata with 42%, Ph. coccineus G00038 with 43%, and Ph. lunatus G00127 with 57%.

In the moderately non-preferred category, lowest adult attraction to the first well expanded leaf blade was Ph. vulgaris G02980 with 28%. However this low attraction was associated with a fairly similar attractiveness exhibited by the shoot (24%). Following this cultivar in ascending order of attractiveness were: Ph. accutifolius G01222 and Ph. vulgaris G00787 each having 40% leaf blade adult attraction. However, the shoot of Ph. accutifolius had 10 times greater adult attraction than G00787 (10% vs. 0%).

The lowest petiole attractiveness was observed in the most preferred classes, but highest attractiveness was observed in the non-preferred class.

Stem-adult attraction was recorded only in the moderately non-preferred and the intermediately preferred cultivars (with 1.3 and 0.47 percent, respectively).

The highest proportion of cultivars showing shoot adult attraction was recorded in the very preferred and preferred classes with 100 and

Higher cultivar-shoot attractiveness and a higher proportion of cultivars showing shoot-adult attraction was recorded in the two most preferred classes. Thus, susceptibility seemed to be associated in part with the preference shown for the shoot.

Petiole attractiveness in the two or three most preferred classes was considered to be an escape alternative that whiteflies used in searching for more succulent plant tissue. Among other unknown physiological changes, perhaps substantial changes in the leaf turgidity caused by excision of the leaves in this particular group of cultivars was the main factor involved.

The greater number of adults on the chamber wall (56% and 29%) was recorded in the non-preferred and the moderately non-preferred classes. The significant higher attraction of the petiole of these classes (31 and 33%), the higher percentage of cultivars with less than 6% of adult attraction (88% of the cultivars), and the lowest leaf blade adult attraction values (5.5 and 40%, respectively), suggests that these two groups of cultivars, or at least some of them, have mechanisms which either physically, chemically, or both, were repelling the whitefly to a greater extent.

Whitefly non-preference in all bean cultivars, but more in the Ph. vulgaris group, depended on very low attractiveness of the shoot, although non-preference for the well expanded leaflet at the upper part of the plant was shown in the least preferred cultivars to be a more desirable characteristic.

Higher cultivar-shoot attractiveness and a higher proportion of cultivars showing shoot-adult attraction was recorded in the two most preferred classes. Thus, successfulity seemed to be associated in part with the preference shown for the cereal.

Petiole attractiveness in the two or three most preferred classes was considered to be an escape alternative that weiscatlet uses in searching for more succulent plant tissue. Among other unknown

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APPENDIX

Free-choice Greenhouse Bean Adult Preference.

Table 1. Sorted transformed means (No. of adults attracted) per cultivar given by the computer in the ANOVA, (hsd= 2.3326).

Cultivar	Mean	Seed coat color
G00037 (Vigna repens)	1.1630	Brown
G00128 (Vigna radiata)	1.7743	Green
G00127 (Phaseolus lunatus)	1.8068	White
G00046 (Phaseolus coccineus)	2.1125	Redish Brown
G00038 (Ph. coccineus)	2.3863	Redish Brown
H00126 (Dolichos lablab)	2.4673	Cream
G01154 (Ph. lunatus)	2.7345	White
G00132 (Phaseolus vulgaris, Wild)	3.6675	Black
G03645 (Jamapa-sel.)(Ph. vulgaris)	4.3592	Black
PI-309.804 (Ph. vulgaris)	4.3944	Black
Porrillo No. 1 (Ph. vulgaris)	4.9063	Black
G04485 (Ph. vulgaris)	5.1513	Black
G04487 (Ph. vulgaris)	5.1817	Black
G00787 (Ph. vulgaris)	5.2066	Red
G03244 (Ph. vulgaris)	5.5386	Black
G01222 (Ph. accutifolius)	5.5637	White
G02980 (Ph. vulgaris)	5.6121	Black
G03097 (Ph. vulgaris)	5.7355	White
Porrillo Sintetico (Ph. vulgaris)	5.7597	Black
Pinto-114 (Ph. vulgaris)	5.9402	Striped
15R-52 (Ph. vulgaris)	6.0160	Black
G00129 (Ph. vulgaris)	6.2755	Black
G04481 (Ph. vulgaris)	6.3131	Black
G02983 (Ph. vulgaris)	6.4460	Black
Brazil-2 (Ph. vulgaris)	6.4681	Brown
G02977 (Ph. vulgaris)	6.5490	Black
Venezuela-2 (Ph. vulgaris)	6.5916	Black
G03108 (Ph. vulgaris)	6.2028	Black
S-116-A-N (Ph. vulgaris)	6.6701	Black
G02960 (Ph. vulgaris)	6.7083	Black
584(F4) (Ph. vulgaris) (MSU-record)	6.7144	Black
G00805 (Ph. vulgaris)	6.7483	Red
G51051 (Ph. vulgaris)	6.7505	Black
Nep-2 (Ph. vulgaris)	6.7581	White
G01205 (Ph. vulgaris)	6.7997	Striped
ICA-Tui (Ph. vulgaris)	6.8089	Black
Colorada del pais (Ph. vulgaris)	6.8564	Striped
G03164 (Ph. vulgaris)	7.0622	Black

Cont. appendix, Table 1.

Cultivar	Mean	Seed coat color
G03064 (*Ph. vulgaris*)	7.0710	Black
Puedo (*Ph. vulgaris*)	7.2279	Black
Pompadour-2 (*Ph. vulgaris*)	7.2367	Striped
G04298 (*Ph. vulgaris*)	7.4363	Red
Pinto (*Ph. vulgaris*)	7.4368	Striped
G00133 (Negro Palencia) (*Ph. vulgaris*)	7.4500	Black
G00808 (*Ph. vulgaris*)	7.5166	White
Sanilac (*Ph. vulgaris*)	7.6469	White
Charleriox (*Ph. vulgaris*)	7.6596	Red
Ex-Rico 23 (*Ph. vulgaris*)	7.6700	White
Mexico-309 (*Ph. vulgaris*)	7.6863	Black
G00773 (*Ph. vulgaris*)	7.7129	White
G03211 (*Ph. vulgaris*)	7.8650	Black
15R-194 (*Ph. vulgaris*)	7.9255	Brown
G03248 (*Ph. vulgaris*)	7.9566	Black
71-IR-101 (*Ph. vulgaris*)	7.9665	Dark Purple
G03008 (*Ph. vulgaris*)	8.0356	Black
G03059 (*Ph. vulgaris*)	8.0524	Black
G03215 (*Ph. vulgaris*)	8.0609	Black
G03027 (*Ph. vulgaris*)	8.0665	Black
G04489 (*Ph. vulgaris*)	8.1307	Black
G03195 (*Ph. vulgaris*)	8.1584	Black
1203 (*Ph. vulgaris*)	8.1651	Creamish-orange
G03213 (*Ph. vulgaris*)	8.1777	Black
ICA-Pijao (*Ph. vulgaris*)	8.1825	Black
15R-287 (*Ph. vulgaris*)	8.2389	Brown
G01224 (*Ph. vulgaris*)	8.3418	Brown
Black Turtle (*Ph. vulgaris*)	8.3675	Black
G02988 (*Ph. vulgaris*)	8.3906	Black
Calima (*Ph. vulgaris*)	8.4914	Striped
G03236 (*Ph. vulgaris*)	8.5207	Black
G03229 (*Ph. vulgaris*)	8.5246	Black
G03235 (*Ph. vulgaris*)	8.5532	Black
G03132 (*Ph. vulgaris*)	8.6012	Black
G03165 (*Ph. vulgaris*)	8.6129	Black
G00822 (*Ph. vulgaris*)	8.6332	Brown
G00130 (Negro Parramos) (*Ph. vulgaris*)	8.6639	Black
G03037 (*Ph. vulgaris*)	8.7006	Black
Porrillo-Mex. (*Ph. vulgaris*)	8.8721	Black
G03233 (*Ph. vulgaris*)	8.9342	Black
G03109 (*Ph. vulgaris*)	9.0828	Black
G03013 (*Ph. vulgaris*)	9.1481	Black
G03184 (*Ph. vulgaris*)	9.2653	Black
G02994 (*Ph. vulgaris*)	9.3295	Black
G03012 (*Ph. vulgaris*)	9.3646	Black
G03126 (*Ph. vulgaris*)	9.3699	Black
G00039 (*Ph. coccineus*)	9.5107	Redish Brown

Cont. appendix, Table 1.

Cultivar	Mean	Seed coat color
G02963 (Ph. vulgaris)	9.5135	Black
G03159 (Ph. vulgaris)	9.5563	Black
G02987 (Ph. vulgaris)	9.6307	Black
G00131 (Ph. vulgaris)	9.6689	Black
2-1029 (Ph. vulgaris)	9.7465	Black
G03024 (Ph. vulgaris)	9.7645	Black
S-630-B-C-63 (Ph. vulgaris)	9.8624	Brown
G05706 (Ph. vulgaris)	9.9177	Black
G02997 (Ph. vulgaris)	9.9206	Black
Sw.Br. (Ph. vulgaris)	9.9942	Brown
Puebla-52 (Ph. vulgaris)	10.1234	Brown
G03115 (Ph. vulgaris)	10.1805	Black
703 (Ph. vulgaris)	10.3253	Black
Rayada (Ph. vulgaris)	10.4426	Striped
G01225 (Ph. vulgaris)	10.4912	Striped
G03145 (Ph. vulgaris)	10.6645	Black
G03099 (Ph. vulgaris)	10.7254	Black
G01051 (Ph. vulgaris)	10.9868	Striped
Red Kidney (Ph. vulgaris)	11.0708	Red
G03178 (Ph. vulgaris)	11.1557	Brown
G03042 (Ph. vulgaris)	11.1699	Black
G03167 (Ph. vulgaris)	11.1878	Black
G03245 (Ph. vulgaris)	11.2102	Black
G03252 (Ph. vulgaris)	11.2122	Red
G03645 (Ph. vulgaris)	11.2885	Black
1-59 (Ph. vulgaris)	11.6318	Brown
G04525 (Ph. vulgaris)	11.7655	Black
G01204 (Ph. vulgaris)	12.2315	White
G01083 (Ph. vulgaris)	12.4303	Striped
G01054 (Ph. vulgaris)	12.5316	Red
G04494 (Ph. vulgaris)	12.5575	Striped
G03101 (Ph. vulgaris)	13.2147	Black
G00718 (Ph. vulgaris)	14.2484	Striped

Cont. appendix.

Table 2. Sorted means of readings of oviposition preference (1 through 5) per cultivar given by the computer in the ANOVA, (hsd= 0.7668).

Cultivar	Sorted means
G01154 (Ph. lunatus)	1.0000
H00126 (Dolichos lablab)	1.0000
G00037 (Vigna repens)	1.0000
G00128 (Vigna radiata)	1.0000
G00127 (Ph. lunatus)	1.0000
G00046 (Ph. coccineus)	1.1333
G00038 (Ph. coccineus)	1.1667
G00129 (Ph. vulgaris)	2.0000
G00132 (Ph. vulgaris, Wild)	2.1333
G01222 (Ph. accutifolius)	2.1667
G00787 (Ph. vulgaris)	2.5000
G03244 (Ph. vulgaris)	2.5000
15R-52 (Ph. vulgaris)	2.5333
Pinto (Ph. vulgaris)	2.5667
Porrillo-Mex. (Ph. vulgaris)	2.6333
G00773 (Ph. vulgaris)	2.7000
PI.309.804 (Ph. vulgaris)	2.7000
G03645 (Jamapa-sel.) (Ph. vulgaris)	2.7333
Sanilac (Ph. vulgaris)	2.8000
Black Turtle (Ph. vulgaris)	2.8333
Porrillo Sintetico (Ph. vulgaris)	2.8333
G05706 (Ph. vulgaris)	2.9000
G02980 (Ph. vulgaris)	2.9000
Porrillo No. 1 (Ph. vulgaris)	2.9000
Pompadour-2 (Ph. vulgaris)	2.9333
G02977 (Ph. vulgaris)	2.9667
ICA-Pijao (Ph. vulgaris)	3.0000
G00133 (Negro Palencia) (Ph. vulgaris)	3.0000
G02983 (Ph. vulgaris)	3.0000
G00130-Parramos (Ph. vulgaris)	3.0000
Sw.Br. (Ph. vulgaris)	3.1000
Puedo (Ph. vulgaris)	3.1000
G03097 (Ph. vulgaris)	3.1000
G00131-Chimaltenango (Ph. vulgaris)	3.1333
Puebla-52 (Ph. vulgaris)	3.1333
G02960 (Ph. vulgaris)	3.2000
ICA-Tui (Ph. vulgaris)	3.2333
G03132 (Ph. vulgaris)	3.2333
G03012 (Ph. vulgaris)	3.2667
Venezuela-2 (Ph. vulgaris)	3.3333
G00822 (Ph. vulgaris)	3.3333

Cont. appendix, Table 2.

Cultivar	Sorted means
Mexico-309 (Ph. vulgaris)	3.3333
G02963 (Ph. vulgaris)	3.3667
G02994 (Ph. vulgaris)	3.3667
581(F4) (Ph. vulgaris)	3.3667
Ex-Rico 23 (Ph. vulgaris)	3.3667
G04525 (Ph. vulgaris)	3.4000
703 (Ph. vulgaris)	3.4333
G03213 (Ph. vulgaris)	3.4333
G03236 (Ph. vulgaris)	3.4333
G02988 (Ph. vulgaris)	3.4667
G03064 (Ph. vulgaris)	3.5000
51051 (Ph. vulgaris)	3.5000
G03211 (Ph. vulgaris)	3.5000
Colorada del pais (Ph. vulgaris)	3.5000
G04485 (Ph. vulgaris)	3.5000
Brazil-2 (Ph. vulgaris)	3.5333
G03159 (Ph. vulgaris)	3.5333
G03101 (Ph. vulgaris)	3.5667
G00805 (Ph. vulgaris)	3.5667
G03108 (Ph. vulgaris)	3.5667
Calima (Ph. vulgaris)	3.6000
G03109 (Ph. vulgaris)	3.6333
G03229 (Ph. vulgaris)	3.6333
G03184 (Ph. vulgaris)	3.6333
G03059 (Ph. vulgaris)	3.6333
Red Kidney (Ph. vulgaris)	3.6333
G01205 (Ph. vulgaris)	3.6333
G03233 (Ph. vulgaris)	3.6333
15R-194 (Ph. vulgaris)	3.6667
G04481 (Ph. vulgaris)	3.6667
G03013 (Ph. vulgaris)	3.6667
G03164 (Ph. vulgaris)	3.7000
G01224 (Ph. vulgaris)	3.7333
71-IR-101 (Ph. vulgaris)	3.7667
G03248 (Ph. vulgaris)	3.7667
S-630-B-C-63 (Ph. vulgaris)	3.7667
G03037 (Ph. vulgaris)	3.7667
G03136 (Ph. vulgaris)	3.7667
G03024 (Ph. vulgaris)	3.7667
Pinto-114 (Ph. vulgaris)	3.8000
Charleriox (Ph. vulgaris)	3.8000
15R-287 (Ph. vulgaris)	3.8000
G01054 (Ph. vulgaris)	3.8333
S-116-A-N (Ph. vulgaris)	3.8333
G03215 (Ph. vulgaris)	3.8333
G04489 (Ph. vulgaris)	3.9000
G03195 (Ph. vulgaris)	3.9000

Cont. appendix, Table 2.

Cultivar	Sorted means
2-1029 (*Ph. vulgaris*)	4.0000
1203 (*Ph. vulgaris*)	4.0000
Nep-2 (*Ph. vulgaris*)	4.0000
G03645 (*Ph. vulgaris*)	4.0000
G03008 (*Ph. vulgaris*)	4.0333
G03235 (*Ph. vulgaris*)	4.1000
G04487 (*Ph. vulgaris*)	4.1333
G01051 (*Ph. vulgaris*)	4.2000
G03027 (*Ph. vulgaris*)	4.2333
G04298 (*Ph. vulgaris*)	4.2333
G03145 (*Ph. vulgaris*)	4.2333
G03165 (*Ph. vulgaris*)	4.2667
G01225 (*Ph. vulgaris*)	4.3000
G00718 (*Ph. vulgaris*)	4.3000
G00808 (*Ph. vulgaris*)	4.3333
G03115 (*Ph. vulgaris*)	4.3333
G03167 (*Ph. vulgaris*)	4.4333
G01083 (*Ph. vulgaris*)	4.5667
G03099 (*Ph. vulgaris*)	4.5667
G04494 (*Ph. vulgaris*)	4.6000
G03242 (*Ph. vulgaris*)	4.6333
G03178 (*Ph. vulgaris*)	4.6333
G03252 (*Ph. vulgaris*)	4.6333
G02987 (*Ph. vulgaris*)	4.6333
G00039 (*Ph. coccineus*)	4.7000
G03042 (*Ph. vulgaris*)	4.7333
1-59 (*Ph. vulgaris*)	4.7667
Rayada (*Ph. vulgaris*)	4.8667
G02997 (*Ph. vulgaris*)	4.9000
G01204 (*Ph. vulgaris*)	5.0000

Table 3. Adult preference for several plant parts (laboratory study) (Data analysed = Arcsine transformed).

3a. ANOVA for the overall adult attraction for the 38 bean cultivars.

Cont. appendix, Table 3a.

Source of variation	DF	SS	MS	F
Blocks	2	0.2739	0.1369	1.918
Cultivars	37	6.9643	0.1882	2.636 **
Error	74	5.2848	0.7142	
Total	113	12.5230		

3b. ANOVA for leaf-blade adult attraction for the 38 bean cultivars.

Source of variation	DF	SS	MS	F
Blocks	2	0.3184	0.1592	3.233 *
Cultivars	37	0.5375	0.1453	2.950 **
Error	74	0.3643	0.4924	
Total	113	0.9336		

3c. ANOVA for shoot adult attraction for the 38 bean cultivars.

Source of variation	DF	SS	MS	F
Blocks	2	6.8346	3.4173	0.987
Cultivars	37	3.2720	8.8433	2.555 **
Error	74	2.5610	3.4607	
Total	113	5.9013		

3d. ANOVA for petiole adult attraction for the 38 bean cultivars.

Source of variation	DF	SS	MS	F
Blocks	2	0.1534	0.0767	2.422
Cultivars	37	2.2605	0.0611	1.929 **
Error	74	2.3432	0.0317	
Total	113	4.7571		

3e. ANOVA for stem adult attraction for the 38 bean cultivars.

Source of variation	DF	SS	MS	F
Blocks	2	0.0250	0.0125	1.254
Cultivars	37	0.5412	0.0146	1.467
Error	74	0.7376	0.0100	
Total	113	1.3038		

3f. ANOVA for chamber adult attraction for the 38 bean cultivars.

Source of variation	DF	SS	MS	F
Blocks	2	0.3072	0.1536	2.099
Cultivars	37	0.7006	0.1893	2.588 **
Error	74	0.5415	0.0732	
Total	113	0.1273		

** Significant at P=0.01
 * Significant at P=0.05