

**POD BORER RESISTANCE IN *LABLAB NIGER* (L.)
CULTIVARS WITH SPECIAL REFERENCE TO THE POD BORER,
ADISURA ATKINSONI MOORE (LEPIDOPTERA : NOCTUIDAE)**

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BANGALORE
1977**

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**POD BORER RESISTANCE IN LABLAB NIGER (L.) CULTIVARS
WITH SPECIAL REFERENCE TO THE POD BORER, ADISURA
ATKINSONI MOORE (LEPIDOPTERA : NOCTUIDAE)**

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**Thesis submitted to
the University of Agricultural Sciences,
Bangalore, in partial fulfilment of the
requirements for the award of the
Degree of**

**MASTER OF SCIENCE
in
AGRICULTURAL ENTOMOLOGY**

Bangalore

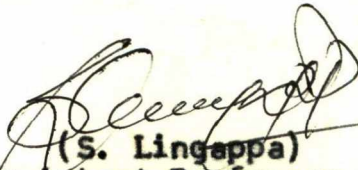
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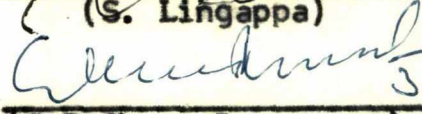
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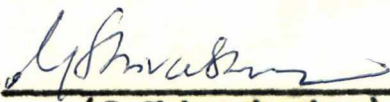
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ACKNOWLEDGEMENT

I express my deep sense of gratitude to Mr.S.Lingappa, Assistant Professor of Agricultural Entomology, University of Agricultural Sciences, Hebbal, Bangalore and the Chairman of my advisory committee for his valuable guidance, helpful criticisms and inspiring encouragement offered during the period of investigation.

I am grateful to Dr.G.P.ChannaBasavanna, Professor of Agricultural Entomology and Head of the Department, University of Agricultural Sciences, Hebbal, Bangalore and member of my advisory committee for helpful suggestions in carrying out this research work and a critical review of the manuscript.

I owe a debt of gratitude to Dr. G.Shivashankar, Professor of Agricultural Botany, U.A.S., Hebbal, and to Dr. S.SundaraRaj, Head of the Department of Statistics, U.A.S., G.K.V.K., Bangalore for their helpful suggestions as advisory committee members.

I wish to express my sincere thanks to Dr.Shyamsundar Joshi, Asst. Professor, Department of Botany, G.K.V.K., Bangalore for the help rendered in anatomical studies of the Lablab niger Cultivars.

I also wish to acknowledge my sincere thanks to all the Post-graduate students and staff members of the Division of

Entomology, U.A.S., Hebbal, Bangalore who have helped in
successfully completing the project work.

The work was supported by an I.C.A.R. Fellowship.

December, 1977
Bangalore.

(A.K. Chakravathy)

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INTRODUCTION

CHAPTER-I

INTRODUCTION

The concern of man over serious environmental problems posed by insecticides and development of insecticide resistance by pest species has made entomologists to concentrate research in the control of insects without using insecticides. One such alternative, prominently mentioned in recent years is the use of resistant varieties which may offer an ideal means of insect control.

The use of resistant varieties has been exploited as an effective method of pest control by itself and also can be integrated with other methods in pest management practices. Thus, this approach in the control of pests, especially in low income group crops and against specific pests can be highly effective. Because of this situation with respect to Lablab niger Medikus, the use of resistant varieties may offer a cumulative and persistent control of its pod borers.

Lablab niger L. is an important pulse-cum-vegetable crop in Karnataka State, cultivated for fresh raw pods mostly, seeds and fodder. The total area in Karnataka under this crop is 50,336 hectares with an annual production of over 11,837 tonnes (Anonymous, 1975).

The crop is infested with a number of insect pests, of which pod borers are considered as major pests. The damage due to pod borers was noted upto 80 per cent (Katagihallimath and

Siddappaji, 1962). Of the eight species of pod borers reported damaging the crop, Adisura atkinsoni Moore ranks first in the order of importance, inflicting heavy damage to the field beans. It was noted to be economically important insect pest of L. niger in Karnataka (Govindan, 1974). Since it is a low income crop, the chemical methods of controlling pod borers are not only expensive and ineffective but also induce toxic hazards as the green pods are used as vegetable. Though a few effective parasites have been reported on this pest, the field population of these parasites is small and not enough to keep the pest in check. Further, the control of the pod borer by these parasites is cyclic and dependent on the presence of large number of the host species before they become effective. The use of resistant varieties against the pod borers may be considered as one of the satisfactory and safe methods in combating this pest. The use of resistant varieties is expected to help keep the population of pod borers below economic injury level with minimum expenditure, once the resistant varieties are identified.

In view of the great need for the resistant varieties to the pod borers and the lacunae in this branch of applied entomology, work on the exploitation of host plant resistance to the pod borer in field bean was undertaken with the following objectives:

1. To screen the field bean germplasm against the pod borers attack (larval boring and ovipositional preference) under field conditions.

2. To confirm the reaction of promising lines to both larval feeding and ovipositional non-preference to A. atkinsoni, a predominant borer species, in the laboratory, under artificial infestation.
3. To assess the yield loss due to pod borer damage and to identify tolerant lines.
4. To study the mechanism of resistance.
5. To study the morphological and anatomical characters, if any, conditioning resistance and susceptibility.

REVIEW OF LITERATURE

CHAPTER-II

REVIEW OF LITERATURE

The oldest published record of host-plant resistance to insect damage is by J.N. Havens in 1792, in which he recognised the 'Underhill' wheat variety as showing resistance to the Hessian fly, Mayetiola destructor Say (Painter, 1941). Other early advocates of plant resistance were Chapman 1788, Lindley 1831, and Fitch 1869 (Snelling, 1941). However, it was due to the sustained efforts of Painter from 1941 to 1968 that made possible the development of this branch as one of the important fields of economic entomology. It was not before 1950, the use of resistant varieties was thought of as one of the non-hazardous, practical method of insect pest control. Painter (1951) discussed at great length the various aspects of plant resistance to insects in general and in relation to certain crops in particular, in his book. However, there have been numerous reviews on the subject, after his last review in 1968.

Painter (1941) stated that an important part of any insect control project should be the search for resistant varieties. Packard and Martin (1952) emphasized that after a resistant variety has been developed and tested, there will be little expense or effort required of the individual grower. The use of resistant varieties is an ideal method of protecting crops from insect damage (Beck, 1965). It was even stated that the use of resistant varieties might be the panacea of

insect control if a high level of resistance were available (Young, 1969). The importance of host plant resistance in pest control has been amply emphasized by a number of workers in recent years.

There have been some spectacular success in which the resistance alone is a highly effective means of insect control. Among these are the historic phylloxera, (Phylloxera vitifoliae Fitch), resistant grapes (Howard, 1930), Hessian fly resistant wheat (Painter, 1951), European corn borer resistant corn (Guthrie, 1974), boll weevil resistant cotton (Maxwell et al., 1972), stem borer resistant rice (Pathak, 1970) and greenbug resistant barley (Gardenhire and Chada, 1961; Gardenhire, 1965).

Concept of resistance:

Mumford (1931) was one of the first to define and discuss important characteristics of resistance, his division of the phenomenon into epiphyllaxis (due to externally occurring factors) and endophyllaxis (due to internal biochemical factors) has not been widely accepted. Later, Painter (1951) modified the concept of resistance of plants to insect attack and defined it as "the relative amount of heritable qualities possessed by the plant which influence the ultimate degree of damage done by the insect. In practical agriculture it represents the ability of a certain variety to produce a larger crop of good quality than do ordinary varieties at the same level

of insect population". A number of definitions of resistance have been given after Painter (1951). Beck (1965) redefined resistance to exclude tolerance from consideration because it implies a biological relationship substantially different from the other two mechanisms.

Painter (1941) divided resistance into the categories of preference, tolerance and antibiosis. Preference is described as plant qualities which influence the insect to prefer one plant over another and may be shown in respect to oviposition, food or shelter. Tolerance is defined as the ability of plant to withstand insect attack. A tolerant plant may repair, recover from damage or it may simply withstand the attack. Plant qualities which cause an adverse effect on the biology of an insect constitute antibiosis. A plant with antibiotic qualities may cause a continuing and cumulative decrease in the insect population because of the adverse effects the plant has on the insect life history. The effects on the insect take the form of reduced fecundity, decreased size, abnormal length of life and increased mortality (Painter, 1968).

Resistance in a host plant may be due to any one of the above components, as for example, hairiness in legumes to leafhoppers (Hollowell et al., 1972) and in cotton to Pink bollworm, Pectinophora gossypiella Saunders (Wilson and Wilson, 1977), morphological characters in sugarcane to stem borers (Agarwal, 1969) and in cotton to corn earworm, Heliothis armigera Hub, (Isely, 1935) etc. Resistance may also result from combination

of different components, as in alfalfa to white grub, Melolontha vulgaris Fabr. (Horber, 1965), and in wheats to Hessian fly, M. destructor (Painter, 1941).

Response to colour and intensity of light, to contact with surfaces of the plant, and to chemical constituents of the plant are the chief means by which insects find their plant host (Painter, 1968). Weiss et al. (1944) found that the yellow and red parts of the light spectrum caused the least response in insects. Isely (1928) reported red-leafed cotton varieties to be more resistant to the boll weevil, Anthonomus grandis Boh., than some of the green-leafed varieties. On the other hand Harrison and Brubaker (1943) reported that in each of three years the infestations of both worm, Pieris rapae L. were higher on the red and purple-leaf varieties of cabbage, Brassica oleracea L. as a group than on the green varieties.

I. Test plant diversity:

The plant, Lablab niger is, considered to be Asian in origin. Two types of L. niger have been distinguished based on the manner of attachment of seed in the pod as garden type, L. niger var. typicus Prain and field type as L. niger var. lignosus Prain. Each of them includes a large number of cultivated races (Piper and Morse, 1915; Anonymous, 1952).

(i) Lablab niger var. typicus Prain:

Various common names referred to this type are: Lablab bean, Bonavist bean, Hyacinth bean and Indian butter bean

(Anonymous, 1952). A perennial twining herb, cultivated mostly as an annual, distributed throughout the tropical and temperate regions of Asia, Africa and America. It is grown in India as a garden crop and never as a field crop. Lablab bean is popular as a vegetable all over the country. The pods, in most cultivars, retain their tenderness until they attain full size (Anonymous, 1952).

The chemical constituents of pods as reported by Biswas and Dàs (1938) and Ayyangar and Nambiar (1941) are as follows:

Moisture	-	82.4 per cent	Protein	-	4.5 per cent
Fat	-	0.1 per cent	Mineral matter	-	1.0 per cent
Fibre	-	2.0 per cent	Carbohydrates	-	10.0 per cent
Calcium	-	0.05 per cent	Phosphorus	-	0.06 per cent
Iron	-	1.67 mgm.	Nicotinic acid	-	0.8 mgm/100gm.
Vit. C	-	0.77 to 1.12 mgm/100 gm.			

(ii) Lablab niger var. lignosus Prain:

Australian Pea and field bean are the common names referred to this type (Anonymous, 1952).

A semi-erect, bushy perennial herb, cultivated as an annual. It shows little or no tendency to climb. It occurs throughout India up to 7,000 feet and found wild in some areas. It includes a large number of cultivated types, and is hardy and drought resistant. It is chiefly grown in South India and its cultivation is not common in North India. It is almost invariably cultivated as a mixed crop along with 'ragi'

(Eleusine coracana Gaertn.) in Karnataka; with castor (Ricinus communis Linn.) or Bajra (Pennisetum typhoides Stapf. & Hub.) or Jowar (Sorghum bicolor Pers.) in Bombay. Unlike the Lablab bean, Field bean is valued more for the seeds than for the pods (Ambekar, 1927; Aiyer, 1949).

Analysis of seed (dry) gave the following values:

Moisture	- 9.6 per cent	Protein	- 24.9 per cent
Fat	- 0.8 per cent	Mineral matter	- 3.2 per cent
Iron	- 2.0 mg.	Nicotinic acid	- 1.8 mg/100gm

The chief protein of the bean is a globulin, dolichosin. The seed is a rich source of catechol oxidase (Niyogi, 1932; Swaminathan, 1938; and Venkatiswaran and Sreenivasaya, 1940). The plant emits a characteristic odour whose chemical nature has not been reported (Ambekar, 1927; Aiyer, 1949).

II. Pod borers of Lablab niger:

Eight species of borers have been reported damaging the pods of L. niger. Krishnamurti (1936) reported Heliothis armigera Hub. causing severe damage to the pods of L. niger during December - January. The Pyralid moth, Maruca testulalis Geyer and Plume moth, Sphenarches caffer Zeller were recorded as minor pests of L. niger (Krishnamurti and Appanna, 1948).

Govindan (1974) stated that the former species occurred during the main season of the crop. He also reported four other borer species of L. niger. The larvae of Cosmolyce boeticus Linn. bored into the flowers, buds and tender pods throughout the

year; Marasmarcha liophanes Meyrick occurred in small numbers during December - January; the larvae of Etiella zinckenella Treitschke bored into the matured pods and were abundant in February - May; and Melanagromyza obtusa Malloch occurred in January - February causing negligible damage (Govindan, 1974). A perusal of literature on the various pod borers of L. niger indicate that A. atkinsoni is the predominant species prevailing in Karnataka during the main season. Review on this species is presented below.

(ii) Test insect diversity:

Adisura atkinsoni is known to occur in Sikkim, Assam hills and throughout peninsular India and Ceylon (Hampson, 1892). The pest was first noticed in the plains of India in the year 1909 (Lefroy, 1909). Two other related species occurring in India as reported by Hampson (1892) are A. lacaniodes Moore and A. pallida Moore. The host plants of A. atkinsoni include Blumea sp. (Mujtaba, 1918); Cajanus cajan Linn. (Isaac, 1946); Hibiscus mutabilis Linn. (Gardner, 1946); Cicer arietinum L. (Govindan, 1974); Lens culinaris Medic (Bhatia, 1962). A. atkinsoni larvae has been reported to be boring into the pods of L. niger in Karnataka (Krishnamurti and Appanna, 1948).

III. (i) Reaction of L. niger varieties to the Pod borers:

Information available on the resistance offered by L. niger varieties to the pod borers is very meagre. According to Ayyangar and Nambiar (1941), high degree of resistance to

pod borers was found in field type (L. niger var. lignosus). They also inferred that the extracted oil from this type acted as natural repellent to pod borers; thus this mechanism was accounted for the resistance. Raghupathy, et al. (1970) screened 17 varieties of garden type, (L. niger var. typicus) against various pod borers at Coimbatore. The evaluation of these varieties to the pod borer attack was based on the per cent pods bored. They did not find any correlation between the incidence and colour of the flower or seed coat. However, the borer incidence and yield loss was positively correlated with plant age at flowering. Among the seven varieties screened against pod borers, Govindan (1974) reported that U.S. 12 was susceptible with 70.5 per cent pods damaged and CO.8 as moderately resistant with 24 per cent damaged pods. There was significant difference in the per cent damage caused to these varieties.

Except for the above references, practically no work has been done on the resistance to A. atkinsoni in L. niger. However, efforts have been made to exploit certain strains of L. niger as trap crop to reduce the damage to the cotton bolls and corn ears by Heliothis zea Boddie in cotton and corn respectively. In tests conducted by Bedford (1936) and Mickinstry and Prentice (1937), some strains of L. niger attracted H. armigera more than cotton. Pomeroy (1925) attributed the occurrence of H. obsoleta Fab. on cotton due to the proximity of L. niger, on which it was abundant. These observations of species preference by H. obsoleta was later confirmed by

Cowland (1935). The Hyacinth Bean, L. niger var. lignosus was preferred over corn by H. zea and Heliothis virescens Fabr., (Gross et al., 1975). It was observed that certain strains of L. niger that emit strong scent attracted the adults of H. armigera for egg laying (Anonymous, 1938).

In view of the inadequate literature on the host plant resistance to pod borers in L. niger, work on pod borer resistance in other pulse crops has also been reviewed briefly.

(ii) Plant resistance in pulses to pod borers:

Cultivars FC. 31921, PL. 171451, PL. 208784, PL. 227687, PL. 229358 and commercial varieties "Lee" and "Hardee" of Soybean Glycine max Merr. were screened for ovipositional preference and larval boring by the bollworm, H. zea. PL. 171451 was least preferred for egg laying as against most preferred PL. 227687 cultivar. Though latter variety had highest number of eggs, it sustained least pod damage suggesting that the variety had antibiosis to larvae (Clark, et al., 1970). Mutsu-moto (1962) studied varietal differences in Soybean to noctuid borer, Leguminivora glycinivorella Matsumura and found that more number of eggs were laid on pubescent varieties than on the glabrous ones. There was distinct positive correlation between the number of eggs and the total length of pods at the time of the oviposition in the pubescent varieties excepting nearly matured ones. Thus the length of pods was said to be an index of the area for egg deposition. Uchida and Okada (1937) correlated the oviposition of the same species with the hairiness

of pods. Similar results were also obtained by Nishijima (1960) from Japan and Hsu et al. (1965) from China.

Studies on the preference for oviposition site by the plume moth, M. liophanes on Cajanus cajan showed that the pods were most preferred followed by leaves, flower buds and paper in order of preference (Chari and Patel, 1967). Recently Veda, et al. (1975) evaluated 164 lines of C. cajan for their susceptibility to the pod fly, M. obtusa, plume moth, M. liophanes and gram pod borer, H. armigera under field conditions in 1970-71. Based on pod and grain infestation, P-54 (6) was identified as least susceptible to pod fly (1 to 7% of damaged seeds). A positive correlation between pod width and per cent infestation of M. obtusa was noticed. However, no such relationship could be established between pod fly infestation and maturity.

James and Canerday (1968) reported that the preference differences to adults of Calcodermus aeneus Boheman was noticed in 51 cultivars, breeding lines and plant introductions of Vigna sp. They reported that a positive relationship existed between the per cent damaged pods and number of punctures per pod. Considering all criteria, cultivars were reported to be more susceptible than most breeding lines and plant introductions. According to Cuthbert and Davis (1972) preference of adult, C. aeneus for pods of southern pea (V. unguiculata) and their successes in penetrating the pods accounted for most of the differences between resistant and susceptible lines of cowpea. They inferred that the preference appeared to result

from differences in amounts of a feeding stimulant present in pods. Successful penetration of the pods was correlated negatively with pod wall thickness. Antibiosis was not an important resistance factor. Anonymous (1973) screened 100 cowpea accessions for resistance to the major pod borer, Cydia ptychora Meyrick under green house conditions. The per cent pods and seeds damaged was used as parameter of evaluation of these lines. A pod was considered as damaged if a single seed is eaten by the larvae. All wild types showed some degree of resistance except an introgression line, TVU-2994. Selections from related species viz. V. vexillata and V. lancifolia showed resistance. The nature of resistance in the promising lines was attributed to antibiosis due to the heavy mortality of I and II instar larvae.

Chalfant and Gaines (1973) obtained significant positive correlations between per cent concentration of total carbohydrates and nitrogen in the hull and feeding punctures of C. aeneus in the hull of pea, Pisum sativum L. It was thought that the varietal differences in nutrient concentrations may have reflected differences in concentrations of a feeding arrestant or stimulant.

III. YIELD-LOSS STUDIES:

No work on the crop loss estimation in L. niger due to pod borer damage has been reported, except for a solitary reference of Raghupathy et al. (1970). They found that the actual

loss in seed yields due to pod borers (H. zea, E. atomosa, M. testulalis and A. atkinsoni) ranged from 3.2 to 23.5 per cent. The incidence ranged from 6.7 to 26.8 per cent. The incidence and yield losses were positively correlated with plant age at flowering. Thus the yield loss was markedly less in early maturing varieties than in mid and late maturing ones. The information on the yield loss in various pulse crops due to pod borers is also reviewed.

By counting the number of pods and grains affected from various samples of redgram pods, Ahmed (1938) calculated the per cent grains damaged by tur-podfly, M. obtusa. Following the same technique, Gangrade (1963 & 1964) estimated yield loss in redgram varieties due to the same fly. The extent of damage to grains varied from 13.1 to 86.8 per cent in 1959-61 and from 0.8 to 3.3 per cent in 1962-63. Bindra and Jakhmola (1967) and Rawat and Jakhmola (1967) estimated the yield loss in red gram due to pod borers following a different technique, which has been described in the next chapter. Average loss in yield to grains varied from 2.4 to 43.5 per cent and from 5.5 per cent to 34.9 per cent respectively. Reddy (1973) estimated losses in 28 and 15 redgram varieties in 1971 and 1972 respectively due to the gram caterpillar, H. armigera. The loss varied from 4.63 to 31.57 per cent in 1971 and from 20.18 to 42.59 per cent in 1972. He estimated losses adopting cage studies, mechanical protection method and the quantum of food consumed by individual caterpillar. Among the techniques adopted by him, cage method was found to be the best as it could yield accurate estimate and could overcome all the flaws confronted by other two methods of yield loss estimation.

MATERIALS AND METHODS

CHAPTER-III

MATERIALS AND METHODS

I. Field screening:

Diversified types of L. niger var. lignosus and L. niger var. typicus, obtained from the plant introduction department, I.A.R.I., New Delhi were screened for their reaction to pod borers in field under natural borer population from 1975-1977. The screening programme was undertaken with the co-operation of Agricultural Botany Department, U.A.S., who maintain the germplasm at the Agricultural College Farm, Hebbal, Bangalore.

During January-February 1975, a preliminary screening study was made using 62 cultivars sown by the Agricultural Botany Department, in single replication with single plant representing a cultivar. As all the 62 cultivars were pendal type (L. niger var. typicus), they were planted at a distance of 5 meters and trailed on to a pendal, consisting of series of stone pillars interconnected with iron wires. The crop was raised following all the recommended agronomical practices.

Ten inflorescences having buds, flowers and pods were selected from each cultivar and were labelled. Fortnightly observations were taken commencing from first week of January, 1975. In view of the variation in maturity of the cultivars totally three observations were taken to synchronise one of these with blooming.

The incidence of the pod borers was recorded by counting the number of eggs laid on pods, flowers and buds; and number of pods, flowers and buds bored on ten inflorescences.

During 1975-1976, an intensive screening was made on 76 cultivars which included 49 from 1975 screening and 27 new cultivars. The same procedure as mentioned above, was followed in the screening of these cultivars. However, first observation was advanced by three weeks as the pest activity was high during December and many early maturing cultivars had come to blooming.

The promising lines from 1976 screening were retested for their reaction during 1976-1977 along with 20 fresh entries. Totally, 83 cultivars of both field and garden types were planted each over an area of 20 x 30 meters, replicated twice. A local cultivar which was most susceptible to pod borer damage was sown all round the experimental plot to help build the natural population of pod borers. Three monthly observations were taken commencing from October 15, 1976. The advancing in the observation period was due to the fact that certain early maturing cultivars had bloomed during early October. However, the peak population of pod borers was noticed during November - December which coincided with the latter two observations. Information on geographical origin for some cultivars was collected. Observations recorded on these cultivars were similar to those mentioned earlier. The criterion used in the identification of resistant lines was based on the consistency of

cultivars to larval damage to pods. Cultivars with 0-20 per cent pods bored in all the three field trials were regarded as resistant; 21-60 per cent as susceptible, and above 60 per cent as highly susceptible.

A cultivar was regarded as 'non-preferred' for oviposition, if it received less than ten eggs per ten inflorescences in all the three trials. Cultivars were regarded as 'preferred' if they received eggs from 11 to 60 and as highly preferred with more than sixty eggs. However, observations on the morphological characters of the plant were recorded to correlate plant characters with resistance or susceptibility. Each plant character was suitably divided into classes to accommodate all cultivars under each character. Further the plant characters were arbitrarily quantified for the purpose of statistical analysis as shown in Table-I.

TABLE-I

Plant morphological characters recorded with classification of each morphological character

Plant character	Classes under each character with quantified value in parenthesis
1. Leaf colour	Light green (1), Green (2), Dark green (3).
2. Days taken to flower	60 (1), 61-80 (2), 81-100 (3), 101-120 (4), 121-140 (5) and 141 and above (6).
3. Flower colour	Light pink (1), Pink (2), White (3).
4. Plant type	Erect (1), Spreading (2), Semi-spreading (3), and Highly spreading (4).

Plant character	Classes under each character with quantified value in parenthesis
5. Inflorescence type	Receme arising from leaves at lower nodes and flowers borne on the floral axis (1), axillary, flowering branch arises in the axil of each trifoliate leaf (2), axillary, floral axis is condensed and 2 to 3 flowers in each node (3), inflorescence is branching with primary, secondary & tertiary branches and each tertiary branch bears flowers (4).
6. Inflorescence length	Less than 5 cms (1), 5-20 cms (2), 21-35 cms (3), 36-50 cms (4) and more than 50 cms (5).
7. Pod colour	Green (1), Dark green (2), White (3), Red (4), Dark red (5).
8. Pod form	Flat (1) and inflated (2).
9. Pod shape	Sickle (1) and straight (2).
10. Pod texture	Soft (1), slightly hard (2) and Hard (3).
11. Fragrance	Present (1) and Absent (2).

II. Mechanism of resistance:

Based on larval boring, two resistant, four susceptible and two highly susceptible cultivars were selected to study the mechanism of resistance in the laboratory. Adisura atkinsoni, the dominant borer species in the field was used as a test insect in the study.

(i) Stock culture:

The stock culture of A. atkinsoni was maintained by collecting naturally infested field bean pods. The culture was maintained in wire mesh cages with about one inch layer of soil at the bottom. Cast skins, f^aecal matter and remnants of food were removed periodically from the cages and thus strict sanitation was maintained.

The fully grown larvae pupated in soil. The pupae, after sexing, were transferred to the oviposition cages (25 x 25 x 25 cms). The moths were provided with 10 per cent sugar solution and fresh inflorescence was provided for egg laying.

(ii) Non-preference for oviposition:

Eight selected cultivars representing resistant and susceptible groups were tested for their reaction to the ovipositional preference. The fresh inflorescences, contained in flasks, with their stalk dipped in water were placed in cage. Eight pairs of moths, after preoviposition period of two days were released into the oviposition cage containing the inflorescences of different cultivars. The experiment was repeated thrice. Observations on number of eggs laid on inflorescences were recorded upto three days when most of the moths were dead.

In the field study it was consistently noticed that the cultivars which had least number of eggs had no fragrance. Thus, the experiment was conducted in the laboratory to determine the role of fragrance in attracting the moths for oviposition.

To determine the role of fragrance (oily secretio local cultivar which emits strong fragrance was select the study. Sixteen inflorescences were divided into tw of eight each. In one set the fragrance was removed b ted washing with water and wiping with cotton wad till aroma could be detected, while the other set was undis All the inflorescences were kept in oviposition cage an pairs of moths after completing the pre-oviposition pe released into the cage. The experiment was replicated Number of eggs laid were recorded upto three days.

(iii) Non-preference for larval feeding:

Response of first instar larvae to tender pods wa studied in the eight cultivars as used in the oviposit studies. Two tender pods of each cultivar were placed and radially arranged along the periphery of a plastic of nine inches diameter. There were four replications first instar larvae of A. atkinsoni were released at t of the box and it was closed to prevent the escape of Number of larvae found inside the pods of each cultiva 24 hours of release, served as an index of preference boring.

(iv) Antibiosis:

To study the effect of host-plant on the biology A. atkinsoni, the insect was reared on the same eight cultivars in the laboratory. The tender pods of test were placed in petridishes of 10.16 cms diameter and w

infested with fully developed eggs. Fresh tender pods were provided every alternate day. The developed larvae were provided with mature pods. The mature larvae, were transferred to specimen tubes of 4 x 1 inch with about one inch soil at the bottom for pupation.

Detailed record on the hatchability of eggs, larval mortality and duration, larval and pupal weights, and sex ratio, were made.

(v) Histological studies:

Anatomical details of pod wall of four selected cultivars representing resistant, susceptible and highly susceptible ones were studied in the laboratory to establish correlations with susceptibility or resistance, if any. Transverse sections of approximately 50-75 μ thickness were taken. The sections of mature pods were stained in Safranin for 30 minutes, destained in acid water to remove excess of stain and temporary mounts were prepared.

Diagrams were made by projecting the slide mounts using micro-slide projector. Ten sections of pods of each cultivar were examined to get average thickness of pod wall in millimeters, average number of epidermal hairs per millimeter, average number of parenchymatous and other layers and relative amount of chloroplasts. Relative amount of starch was estimated after treating the sections with a drop of Iodine potassium iodide. Pigments, if any, were also noted.

Ten pods each of same four cultivars were used to obtain average surface area of pods in square centimeters and average pod width and length in centimeters.

(VI) YIELD-LOSS ESTIMATION:

Preliminary yield loss studies were made on 69 cultivars during February 1977 only to identify the tolerant lines, if any. Thirty mature pods from each cultivar were randomly selected for the study. The average number of seeds per pod, which is a characteristic of cultivar was recorded to calculate the potential seed yield, presuming that all seeds in a pod develop normally. Yield-loss assessment was made by following the method suggested by Bindra and Jakhmola (1967). The pods were split open to record the number of healthy seeds and number of partly damaged seeds. Potential seed weight of 30 pods for each cultivar was calculated from the number and weight of seeds unaffected by pod borers. The partly damaged seeds were treated as fully damaged as they would lose market value. The weight of healthy seeds was deducted from the potential seed weight. The difference in weight was accounted for the loss caused by the pod borers. The yield loss was converted to per cent for easy comparisons. The yield loss was compared with pod borer incidence in all the cultivars so as to identify the tolerant cultivars which had heavy infestation of borer, yet the yield loss was not appreciable.

The data obtained from all laboratory experiments except on the effect of fragrance on ovipositional response, have been subjected to 'Analysis of variance' test (Snedecor and Cochran, 1967), after the values were suitably transformed, wherever necessary. To correlate morphological characters with resistance or susceptibility, the data was subjected to 'Step-wise Regression', (Leabo, 1976).

RESULTS

CHAPTER-IV

RESULTS

I. Field Screening:

During the current investigation, eight species of pod borers were encountered in the field damaging the flowers, buds and pods of the field bean. The species noted were: Adisura atkinsoni Moore, Maruca testulalis Geyer, Heliothis armigera Hub., Sphenarches caffer Zeller, Casmolyce boeticus Linn., Marasmarcha liaphanes Meyrick, Etiella zinckenella Treitschke and Melanagromyza obtusa Malloch. However, the occurrence of these borers varied with the period of blooming.

(i) Resistance to larval boring:

A total of 113 Lablab niger cultivars were screened for their resistance to pod borers under field conditions and under natural infestation from 1975 to 1976-1977. These cultivars in three field trials showed a greater variation in their reaction to pod borer damage, from almost immunity to cent per cent susceptibility. The data on larval boring may not lend itself for simple statistical analysis, the obvious reasons being the great variation in the maturity of cultivars, observation timings and the number of pods, flowers and buds in each inflorescence. Further, in general it was observed that pods were most preferred by larvae for feeding over flowers and buds. Thus, the relative proportion of the buds, flowers and pods in the inflorescence at the time of observation, accounted for the variation in the

per cent infestation in each of them. It was almost consistently observed that a cultivar with higher number of pods bored had smaller number of flowers and/or buds bored. Though, the observation on the buds and flowers bored was taken in all the three field trials the data could not be used to assess the reaction of cultivars to borers as the infestation level on these parts was greatly influenced by the number of pods present. Thus, the average per cent pods bored was used to assess the varietal reaction. The differences in reactions of the entries to pods, buds and flowers infestation over three years are presented in Appendix-II.

The cultivars classed as resistant in the current investigations had nearly 4-8 times lesser borer infestations in all the three years' screening trials than on highly susceptible entries. However, no entry showed immunity to borer attack consistently. In general, field types (Lablab niger var. lignosus) were infested more than pendal types (Lablab niger var. typicus). The information on the influence of geographical origin (Appendix-I) of cultivars on the larval boring revealed that the geographic origin of cultivars did not have any impact on the resistance to larval boring. Further, both indigenous and exotic collections exhibited almost equal susceptibility to pod borer attack in general (Appendix-I & II).

The performance of entries to borer attack in three field trials is presented in the following paragraphs.

Field screening - 1975

Sixty two cultivars raised by the Agricultural Botany department of the University of Agricultural Sciences, Bangalore were screened for their resistance to the borer during the first year. The observations on the borer infestation on buds, flowers and pods were taken during January-February 1975, when most of the cultivars had pods only with few or no buds and flowers on the inflorescence.

During the year, the pod borer infestation among the 62 cultivars observed ranged from 8.6 to 100 per cent (Appendix-II). A perusal of TABLE II reveals that eight cultivars showed some resistance, 43 cultivars proved to be susceptible with more than 60 per cent pods bored. However, nine cultivars could not be assessed for their reaction to the borer damage as there were no pods on the inflorescence in all the three observations.

Among the eight resistant cultivars PLS-88 and PLS-24 had less than 10 per cent damage; while IC-9671, PLS-46 and EC-18320-B had 12.2, 14.2 and 15 per cent infestation respectively. The borer infestation in the remaining three cultivars viz. PLS-70-1, PLS-11-1 and EC-18544 was 19.3, 20.0 and 20.0 per cent respectively. The per cent infestation in the susceptible cultivars ranged from 22.0 to 57.6. Pusa bunch and PLS-9, highly susceptible cultivars, suffered heavily due to the borer attack with 65.5 and 60.2 per cent infestation.

Table-II: Classification of cultivars as resistant, susceptible and highly susceptible based on per cent pods bored.

Class	Percent pods bored	Number of cultivars		
		1975	1975-1976	1976-1977
Resistant	0-20	8	16	14
Susceptible	21-60	43	59	60
Highly susceptible	More than 60	2	1	7
	No pods	9	0	2
Total		62	76	83

Table-III: Classification of cultivars as non-preferred, preferred and highly preferred based on number of eggs laid.

Class	Number of eggs laid/ten inflorescences	Number of cultivars		
		1975	1975-1976	1976-1977
Non-preferred	0-10	19	52	57
Preferred	10-60	39	21	23
Highly preferred	More than 60	4	3	3
Total		62	76	83

Field trial - 1975-1976

Observation on the borer infestation on 76 cultivars was made during December 1975 and January, 1976. The incidence of the pod borers among the cultivars tested ranged from 0.0 to 68.66 per cent which was comparatively lower than during 1975 though majority (49) of the cultivars tested in 1975 were included in this trial also. The low level of infestation on the pods during the current year may be due to two reasons, viz. the variation in the observation timing and more important was due to the presence of buds and flowers on the inflorescence along with pods. As all these parts serve as food for the larvae, there ought to be less damage on the pods when the flowers and buds were present in 1976 unlike in 1975 when the inflorescence contained more pods than flowers and buds at the time of observation.

Probably due to the low pod borer incidence in the current year screening trial, quite a few cultivars came out as resistant. However, the general trend in the distribution of number of cultivars among resistant, susceptible and highly susceptible class was more or less same as in 1975 (Table-II). Sixteen out of 76 cultivars showed resistance to borer attack, 59 were susceptible and one was regarded as highly susceptible (Table-II). Of the 16 cultivars, PLS-16-1, IC-7523 and PLS-67, had less than five per cent infestation; PLS-46-1 and IC-11025 had between 5 and 10 per cent; U.S.-8, PLS-88, and PLS-70-2 had between 10 and 15 per cent damage. The per cent infestation in

the remaining eight resistant cultivars viz. PLS-24, PLS-70-1, PLS-98, PLS-99, PLS-102, EC-18176-A, JDL-10 and JDL-42 was between 16 and 20. Though 16 cultivars were recorded as resistant, all but two (PLS-24 and PLS-16-1) showed their susceptibility to the borer attack in either of the trials. IC-11657 was highly susceptible with 68.66 per cent pods bored. Among the 59 susceptible cultivars, PLS-79 had least (20.14) and IC-661 had maximum (53.33) per cent pods bored.

Field trial - 1976-1977

Observation on the borer infestation on 83 cultivars were made during October to December 1976. The incidence of the pod borers among the cultivars tested ranged from 7.65 to 81.47 per cent, which was intermediate in incidence to that seen during 1975 and 1976. Four cultivars namely PLS-57, PLS-62, PLS-62-1 and PLS-62-2 failed to germinate and thus they could not be tested. Fourteen of the 83 cultivars showed some resistance to borer attack, 60 were susceptible and seven were highly susceptible. However, two cultivars namely, PLS-106 and EC-7467-13 could not be assessed for their reaction to the borer damage as there were no pods during all the three observation periods. Among the 14 resistant cultivars, PLS-16-1 recorded least (7.65) per cent pod infestation. PLS-2 recorded 8.33 per cent pods bored in the current screening trials. However, it had recorded 40.66 per cent pods bored in 1976 screening trial, suggesting that the cultivar had escaped from borer attack

showing pseudo-resistance in 1976-1977. The infestation level ranged from 10.60 to 18.75 per cent among the remaining resistant cultivars (PLS-24, PLS-54, PLS-69, PLS-94, EC-28826, IC-6120-2, JDL-107, JDL-109, PLS-99, JDL-85 and L-133). Among the large number of susceptible cultivars, PLS-67 had least (21.05) and PLS-93 had maximum (58.33) pod damage. Seven cultivars, viz. EC-36365, EC-36417, IC-661-1, Local, IC-10079, H-3 and MS-9573 were highly susceptible with per cent pods bored ranging from 61.16 in IC-10079 to 81.47 in Local.

A comparison of performance of cultivars in current trials with those in 1975 trial indicated that more number of cultivars had flowers and buds at the time of observation period. However, their number was less than those recorded in 1976, despite repetition of a large number of cultivars in both the years.

A comparison of field data on larval boring from three trials indicated that peak infestation of borers was recorded during 1975. Since the general level of infestation was high as compared to that during the later two trials, the percentage of the susceptible cultivar (Table-II) was 81.13 as against 77.63 in 1976 and 74.07 in 1977. Absence of buds and flowers on the inflorescence and high incidence of borers at the time of observations were considered as the possible reasons for the increased percentage of pods bored in 1975 as compared to the later years.

A comparative analysis of data on larval boring over three years revealed that eight, 16 and 14 cultivars were found to be resistant in 1975, 1975-1976 and 1976-1977 respectively. However, a large number of cultivars did not prove their consistency in resisting the borer attack in all the trials. PLS-24 was considered as the most promising cultivar to the borer attack with less than 20 per cent pods bored in all the three years tested. PLS-16-1 also proved to have high degree of resistance as the cultivar had least percentage of pods bored in both (1975-1976 and 1976-1977) the years tested. Cultivars, JDL-107, IC-6120-2 and JDL-85 and EC-18544-A though indicated as resistant in 1976-1977, their reaction to borer attack needs to be confirmed as they were tested only once. Except for the cultivars mentioned so far the remaining cultivars which reacted as resistant in one trial were proved to be susceptible in other trials, suggesting escape (lack of infestation on a susceptible host) or pseudo-resistance (resistance of potentially susceptible hosts due to some transitory characters) in these cultivars. While there were cultivars (e.g. PLS-24 and PLS-16-1) which maintained very low level of infestation in all the trials indicating true response to insect attack, although climatic and edaphic factors do play a role in changing insect plant relationships. From the foregoing analysis, only PLS-24 and PLS-16-1 were considered as true resistant cultivars to pod borers.

Ten cultivars proved to be highly susceptible in all three trials and 16 showed pseudo-resistance. While the adjacent

cultivars were heavily attacked, the resistant ones were almost free from borer damage. These results demonstrated that the differences in the pod borer susceptibility of the cultivars tested were due to differences in their susceptibility as hosts to larvae and not merely escaping from the infestation. The causes for the low level of borer infestation in the promising lines were studied both under field conditions and in the laboratory, and the results of the same are presented in the following pages.

(ii) Non-preference to ovipositional response:

The screening of 113 Lablab niger cultivars in three field trials (1975- 1976-1977) showed a greater variation in the preference for egg laying by the borer species. The number of eggs laid among the cultivars tested varied from zero to hundred. The data on ovipositional response were not analysed statistically because of the same reasons as with larval boring data. The number of eggs laid on buds, flowers and pods in each observation and the total number of eggs laid in each year, are presented in Appendix-III. It was noticed that tender pods were most preferred by moths for oviposition over buds and flowers. The ovipositional response of pod borers was, therefore, influenced by the relative proportion of buds, flowers and pods in the inflorescence at the time of observation.

Field screening 1975:

The number of eggs laid on 62 cultivars varied from 0 to 100 (Appendix-III). A perusal of Table-III indicates that 19

cultivars were non-preferred, 39 were preferred and four were highly preferred for oviposition. Among the non-preferred cultivars, PLS-62-1 was free from eggs while the number of eggs laid on the remaining cultivars ranged from one to ten per ten inflorescences, maximum number of eggs being received by PLS-11. The number of eggs on 39 preferred cultivars varied from 12 (PLS-99 and 236) to 60 (IC-10483-1) per ten inflorescences. IC-9671, IC-5665, V.M.V. College and IC-11025 were the four highly preferred cultivars with 67, 78, 90 and 100 eggs respectively.

Field screening 1975-1976:

The range of eggs laid on the cultivars tested during 1975-1976 was not as wide as in 1975. Maximum number of eggs laid was 74 with minimum being zero. The current year's data on the ovipositional response of cultivars revealed that 52 cultivars were grouped as non-preferred, 21 as preferred and three were highly preferred for oviposition. Though, most of the cultivars tested in 1975 were included in current year screening programme, 52 cultivars came out as non-preferred, which is comparatively higher than those in 1975. The discrepancy in the maturity of the cultivars leading to the variation in the number of tender pods present at the time of observations coupled with the generally low borer incidence may be attributed as contributory factors for the variation in the number of non-preferred cultivars for egg laying in 1975 and 1975-1976.

Of the 52 non-preferred cultivars, 23 had no eggs, four cultivars namely Peotomal Local, PLS-94, PLS-55 and PLS-62-1 recorded only a single egg per ten inflorescences. While the rest of the non-preferred cultivars received eggs from two to ten per ten inflorescences. The number of eggs laid on ten inflorescences of preferred cultivars varied from 12 (PLS-16 and PLS-98) to 55 (JDL-4). Hebbal-2, Local-82 and IC-10202 were highly preferred with 61, 65 and 74 eggs ten per ten inflorescences respectively.

Field screening 1976-1977:

During October to December, 1976 the number of eggs laid on 83 cultivars varied from 0 to 81 per ten inflorescences. The pattern of distribution of cultivars into non-preferred, preferred and highly preferred classes clearly showed that a large number of cultivars came out as non-preferred for oviposition as in the previous season. Once again the large number of cultivars classed as non-preferred may be due to the reasons explained earlier, though 54 cultivars tested in 1975-1976 were also tested in 1976-1977. Among the 57 non-preferred cultivars, 27 received no eggs, while the number of eggs laid on remaining cultivars varied from one (IC-23848-A and JDL-109) to ten (IC-7523) eggs. There were 23 cultivars classed as preferred with eggs varying from 11 (IC-1846 and IC-3266-1) to 59 (EC-18176-A). Hebbal-3, Local and EC-28826 were highly preferred with 69, 73 and 81 eggs respectively.

A critical analysis of field data on ovipositional preference over three years revealed that 19, 52 and 57 cultivars were not preferred for oviposition respectively, during 1975, 1975-1976 and 1976-1977. Of these, PLS-11, PLS-24, PLS-46-1, PLS-70-1, EC-18129, EC-36414, IC-661 and IC-10191 and exhibited non-preference for egg laying consistently in all three trials. Thus they were regarded as non-preferred for egg laying. Of the 25 cultivars that showed non-preference for egg laying, 16 were tested once and nine were tested twice. Thus, their non-preference for oviposition needs to be confirmed before considering them as truly resistant cultivars to oviposition.

Totally 45 cultivars showed escape or pseudo-resistance to oviposition. Ten cultivars were highly preferred for oviposition in one or the other trial.

Among three trials maximum number of eggs were laid in 1975 followed by 1975-1976 and 1976-1977 as the average number of eggs laid were 4.39, 2.33 and 1.10 per inflorescence respectively. Consequent of this variation the per cent highly preferred cultivars in 1975 was 6.45 as against 3.94 and 3.61 in 1975-1976 and 1976-1977 respectively. However, the percentage of non-preferred cultivars for egg laying showed the opposite trend with 30.64 per cent cultivars in 1975, 60.84 in 1975-1976 and 68.67 per cent cultivars in 1976-1977. These observations clearly indicated that the peak infestation occurred in 1975. The possible reasons for high level of infestation during the above year has been explained earlier.

It was interesting to note that two cultivars, PLS-24 and PLS-16-1 which were resistant to larval boring were also non-preferred for ovipositional response.

(iii) Morphological characters in relation to susceptibility or resistance:

Variation in infestation due to pod borers among the cultivars tested necessitated the study of the difference in the morphological characters associated with the susceptibility or resistance. Detailed studies on the correlation of morphological characters with larval boring and ovipositional response were made on eight selected cultivars representing resistant, susceptible and highly susceptible groups. The data on 11 morphological characters with quantified value for each morphological character and the reaction of selected cultivars to borer attack are presented in Table-IV. Stepwise regression analysis of the data revealed non-significant results, suggesting that none of the morphological characters studied was correlated with larval boring and ovipositional response. However, among the character studied only the foliage color with average number of eggs laid and days to flower, pod color, pod texture and fragrance with larval infestation entered regression. Nevertheless, these characters did not significantly contribute in improving regression equation. However, under field conditions it was observed that resistance (as in PLS-24 and PLS-16-1) was always associated with red colored pods, pink colored flowers and buds. Contrary to this, the susceptibility was observed in cultivars with green colored pods and white colored buds and flowers.

Table-IV: Correlation of morphological characters of selected Lablab niger cultivars with ovipositional responses and larval boring.

Sl. No.	Cultivars	Per cent pods bored (X_1)	AV.No. of eggs laid (X_2)	Foliage color**	Days to flower*	Flower color	Plant type	Inflorescence type	Inflorescence length	Pod color*	Pod shape	Pod texture*	Fragrance*	Pod form
1.	PLS-24	16.66	0.00	3	3	2	2	2	3	5	2	2	2	1
2.	PLS-16-1	7.65	0.00	3	3	2	2	2	3	5	2	2	2	1
3.	EC-28826	18.50	8.10	2	2	1	2	2	3	1	2	3	1	1
4.	EC-33015	55.56	3.00	3	3	1	2	2	3	1	2	3	2	1
5.	EC-36417	69.10	1.60	2	3	3	4	2	3	1	2	3	1	1
6.	IC-10800	35.71	0.30	2	2	3	2	2	3	1	2	3	2	1
7.	PLS-93	58.33	4.60	2	2	2	2	2	3	4	2	1	2	1
8.	Local	81.47	7.30	2	2	3	2	2	3	1	2	3	1	1

Cal. F at 5% = N.S.

* Morphological characters entered regression with (X_1)

** Morphological characters entered regression with (X_2)

PLS-93 was grouped under the preferred class in view of moderate number of eggs laid though the cultivars possessed light red colored pods, pink flowers and buds. This may be due to the fact that the tender pods of this cultivar are green colored and later they turn light red. These observations confirmed that the red color imparted resistance in the cultivars. Despite strong association of color of the inflorescence, as observed in the field, failure of this character and others exhibiting definite relationship with resistance or susceptibility might be accounted for the small sample size and arbitrary quantification of qualitative characters.

Investigation on the length, breadth and epidermal hairs of the mature pods was made on four selected cultivars. The pods of resistant cultivars measured 10.75 cms. in length and 2.15 cms. in breadth. Though the pods of susceptible and highly susceptible cultivars were of smaller size, with 5.75 and 5.85 cms. in length and 1.80 and 1.85 cms. in breadth respectively, size variation among them was very little to account for the variation in larval boring and ovipositional response. From these results it was inferred that surface area of the pod did not have any relationship with degree of susceptibility or resistance.

The observations on the hairiness of pods clearly indicated that the number of eggs laid were proportional to the length and number of epidermal hairs. Non-preferred cultivars, namely, PLS-24 and PLS-16-1 had the least number (3 per mm) and much

shorter epidermal hairs as against maximum (15 per mm) and longer hairs in local, a preferred cultivar for oviposition. PLS-93 was intermediate both in the number of egg laid (Table-IV), and length and number of hairs (7 per mm) (Fig.5). These studies indicated that cultivars with glabrous pods were found unsuitable for egg laying while those with hairy pods were most preferred.

II. Factors inducing borer resistance:

Field screening of Lablab niger cultivars from 1975 to 1976-1977 indicated distinct and consistent differences in susceptibility to larval boring and ovipositional non-preference. Laboratory experiments were conducted to study the causes for the differences in larval boring and egg laying on resistant and susceptible cultivars. The role of major components of resistance, viz. non-preference, antibiosis and tolerance in offering resistance to pod borer, Adisura atkinsoni, the dominant borer species, is presented in the following pages.

Preliminary studies were made to analyze the various causes for the differences in infestation on a few selected cultivars. Based on the reaction to larval boring, eight cultivars were chosen for investigating the causes of resistance to borer damage. PLS-24 which showed resistance to borer attack consistently over three years and PLS-16-1 which had the least damage to pods in both the years tested, represented the resistant group. Out of the larger number of cultivars falling into susceptible group, only four cultivars, viz. EC-28826, EC-33015,

IC-10800 and PLS-93 were selected along with EC-36417 and Local, being the highly susceptible cultivars to pod borer damage.

(1) Non-preference for larval feeding:

Studies conducted in the laboratory to determine the consistency of preference of non-preference of first instar larvae to tender pods of eight selected cultivars revealed that resistant cultivars were least preferred as against highly preferred Local (Table-V).

Observations on the preference among the selected cultivars revealed that the larvae moved randomly in all directions soon after release. The larvae on reaching a pod started boring in; however, they came out of the pod after 20-30 minutes and moved to the next pod randomly. The migratory habit of the larvae continued until they selected a suitable host. From the behaviour exhibited by the larvae in search of food, it was inferred that detection of the host by the insect is mostly by the gustatory response and olfactory response played a minor role.

The data on the number of first instar larvae observed 24 hours after release among the cultivars tested are presented in the Table-V. These observations revealed that there was no clear indication of preference being exhibited by the larvae among the resistant, susceptible and highly susceptible groups though statistically significant differences were obtained.

Table-V: Preference exhibited by I instar larvae of Adisura atkinsoni to the tender pods of selected L. niger cultivars.

Sl. No.	Cultivars	Total No. of larvae present inside the pods	Average No. of larvae present inside the pod
1.	PLS-24	6	0.75
2.	PLS-16-1	4	0.50
3.	EC-28826	6	0.75
4.	EC-33015	14	1.75
5.	IC-10800	32	4.00
6.	PLS-93	80	10.00
7.	EC-36417	32	4.00
8.	Local	58	7.25
	C.D.	1.64*	
		2.19**	

* Significant at 5%

** Significant at 1%

Average number of larvae observed in resistant cultivars and EC-28826, a susceptible cultivar, were on par with one another; IC-10800, a susceptible cultivar was on par with EC-36417, the highly susceptible cultivar. Contrary to this, PLS-93, a susceptible cultivar recorded largest and significantly higher number of larvae than those on highly susceptible ones. These controversial results indicated that preference of a cultivar over other is merely random and the preference exhibited by the larvae did not seem to play an important role in imparting resistance or susceptibility.

(ii) Non-preference for oviposition:

Under field conditions, some susceptible cultivars namely Local, EC-28826 recorded more number of eggs as compared to resistant ones, viz. PLS-24 and PLS-16-1 (Table-VI), which had no eggs or had small number of eggs on them. These observations suggested that there appeared to be great differences in the preference for oviposition by adult moths among cultivars. The investigation was undertaken to find whether preference or non-preference accounted for part of the susceptibility or resistance in the cultivars tested. To confirm these observations and to find out the cause for preference for egg laying, the inflorescence of eight selected cultivars were exposed to oviposition by the A. atkinsoni moths in the laboratory.

The results indicated that the number of eggs laid on the resistant cultivars was significantly less than those on

Table-VI: Ovipositional response of Ac. atkinsoni to inflorescences of selected Lablab niger cultivars.

Sl. No.	Cultivars	Total number of eggs laid	Mean No. of eggs laid
1.	PLS-24	5	1.66
2.	PLS-161-1	6	2.00
3.	IC-10800	142	47.33
4.	EC-28826	301	100.33
5.	EC-33015	104	34.66
6.	PLS-93	180	60.00
7.	EC-36417	258	86.00
8.	Local	314	104.66
	C.D.		19.17*
			26.55**

*Significant at 5%

**Significant at 1%

Table-VIa: Effect of fragrance (oily secretion) on the ovipositional response of Adisura atkinsoni

Cultivar	Number of eggs laid			Mean	Mean
	RI	RII	RIII		
Local (Fragrance removed)	51	39	67	52.33	
Local	93	109	140	114.00	

susceptible cultivars (Table-VI). Resistant cultivars, PLS-24 and PLS-16-1 received five and six eggs per 24 inflorescences respectively as against 314 per 24 inflorescences in the highly susceptible Local cultivar. Other cultivars were intermediate in their preference for oviposition. EC-28826, was the most preferred among susceptible group for egg laying. Further, the number of eggs laid on this cultivar was significantly more than on EC-36417, one of the highly susceptible cultivars, suggesting that the former was highly preferred for egg laying, though it was grouped under susceptible class based on the larval boring. The above results were in conformity with the data on ovipositional preference under field conditions (Appendix-III).

In the laboratory experiment it was noticed that the eggs were laid on buds, flowers, pods, calyx, leaf petiole, leaf lamina and stalk of the inflorescence of highly susceptible cultivars, while on pods only on resistant cultivars, though eggs were laid on buds, flowers and pods of these and other cultivars in field in general and never on other parts. These observations indicated that all parts of highly susceptible cultivars served as suitable ovipositional sites in the absence of sufficient number of tender pods and thus account for higher number of eggs on them. An examination of the various parts of inflorescence of resistant and highly susceptible cultivars revealed an interesting association of fragrance (aromatic substance) and oviposition. The fragrant substance was found on all parts of Local and EC-36417, highly susceptible cultivars, in

detectable quantity by smell. Despite appreciable number of eggs recorded on susceptible and few on resistant cultivars, they were devoid of the fragrant substance. These results indicated that fragrant substance alone did not influence the egg laying but may be associated with other *plant* characters.

An experiment conducted to study the association of fragrant substance with ovipositional preference revealed that untreated local received twice as many eggs as treated local (Table-VIa). The data indicated that cultivars with fragrant substance were more preferred for egg laying and vice-versa. However, the egg laying preference was also found to be positively correlated with number of hairs on the pods (Figs.2 to 4). In the current experiment, in the process of removing fragrant substance following the procedure explained earlier, it was quite likely that the epidermal hairs were destroyed. Thus reduced number of eggs in the treated Local was due to reduced fragrant substance and or reduction in the number of epidermal hairs.

From these studies, it may be said that the increased number of eggs on the cultivar, EC-28826 (susceptible) more than on EC-36417 (highly susceptible cultivar) might be due to the presence of more epidermal hairs in the absence of fragrance.

The preference for egg laying among the cultivars tested may be due to the difference in the morphological and or chemical character of the pods.

III. Antibiosis:

(i) Effect of host plant on the hatchability of eggs:

Investigations were made in laboratory to study the effect of selected resistant and susceptible cultivars on life-cycle of A. atkinsoni. The results of the investigations are presented in Table-VII. Experiment on per cent hatchability of eggs showed that though resistant cultivars recorded least per cent hatchability of eggs, there were no significant differences among the cultivars tested, indicating that the substrate did not adversely affect the hatchability of eggs. It varied from 48.18 in PLS-16-1 to 78 per cent in local. In general, the reduced per cent hatchability of eggs in the experiment as compared to near 100 per cent hatchability in the undisturbed situation may also be due to damage caused while transferring them on to the pods of selected cultivars.

(ii) Larval mortality:

The host plant may express antibiosis to insects as the latter feeds on resistant lines and the effects will be generally pronounced during later stages of their development. A study was undertaken to investigate the effect of selected cultivars on the larval survival which may be accounted for the differences in the susceptibility or resistance in them. Though increased larval mortality was recorded on resistant cultivars it did not differ significantly from susceptible and highly susceptible cultivars (Table-VII). Highest larval mortality

Table-VII: Hatchability of eggs, larval mortality, larval period, weight of last instar larvae, weight of pupae and sex-ratio of Adisura atkinsoni reared on selected Lablab niger cultivars.

Sl. No.	Cultivars	Mean per cent hatch	Mean per cent larval mortality	Mean larval weight in gms	Mean pupal weight in gm	Mean larval duration in days	Sex-ratio
1.	PLS-24	61.62	60.41	2.09	1.64	28.50	4:9
2.	PLS-16-1	48.18	58.30	2.09	1.63	29.00	4:9
3.	PLS-93	61.00	33.33	4.87	2.39	24.47	4:6
4.	IC-10800	74.56	20.82	13.64	12.83	22.75	4:5
5.	EC-28826	73.00	18.66	14.65	13.54	24.30	4:5
6.	EC-33015	67.12	29.00	19.95	14.58	25.00	4:5
7.	EC-36417	63.43	43.75	20.95	19.52	24.00	4:5
8.	Local	78.00	18.75	20.66	17.22	20.75	4:5
	C.D.	N.S	N.S	N.S	N.S	N.S	N.S

was found in PLS-24 and PLS-16-1 with 60.44 and 58.30 per cent and least per cent mortality (18.75 per cent) was recorded in the local variety. The data on larval mortality suggested that resistant cultivars greatly reduced the larval survival due to some antibiotic factor in them. Probably lack of this factor in other cultivars may be the reason for high larval survival accounting for the susceptibility in them.

(iii) Larval weight:

Weight of last instar larvae was used as growth index to assess the suitability of the selected cultivars. The differences in the larval weight were evident among resistant and susceptible cultivars (Table-VII). The larvae reared on resistant cultivars weighted ten times less than those on highly susceptible cultivars. Though the larval weight did not differ significantly among the cultivars tested, it was noticed that the larval weight was least (2.09 gms) on PLS-24 and PLS-16-1, resistant cultivars. Striking increase in the weight was noticed in the susceptible cultivars with the exception of PLS-93. However, this trend did not prevail between susceptible and highly susceptible ones. Though the larvae reared on susceptible cultivars ranged in between resistant and highly susceptible; however, great variation in the larval weight within each group was recorded.

It was also seen that the larvae reared on resistant cultivars not only weighed less but also were small, inactive,

and paler in color in contrast to active, larger and bright colored larvae reared on highly susceptible cultivars.

(iv) Pupal Weight:

Differences in pupal weight were also of the same magnitude as those of larval weights. Resistant cultivars recorded minimum pupal weight while those of highly susceptible cultivars recorded maximum with susceptible being intermediate. Yet, the pupal weight did not differ significantly. Pupae reared on resistant cultivars were slightly malformed with eyes protruding out and paler in color as against normal and brighter coloured pupae from highly susceptible ones.

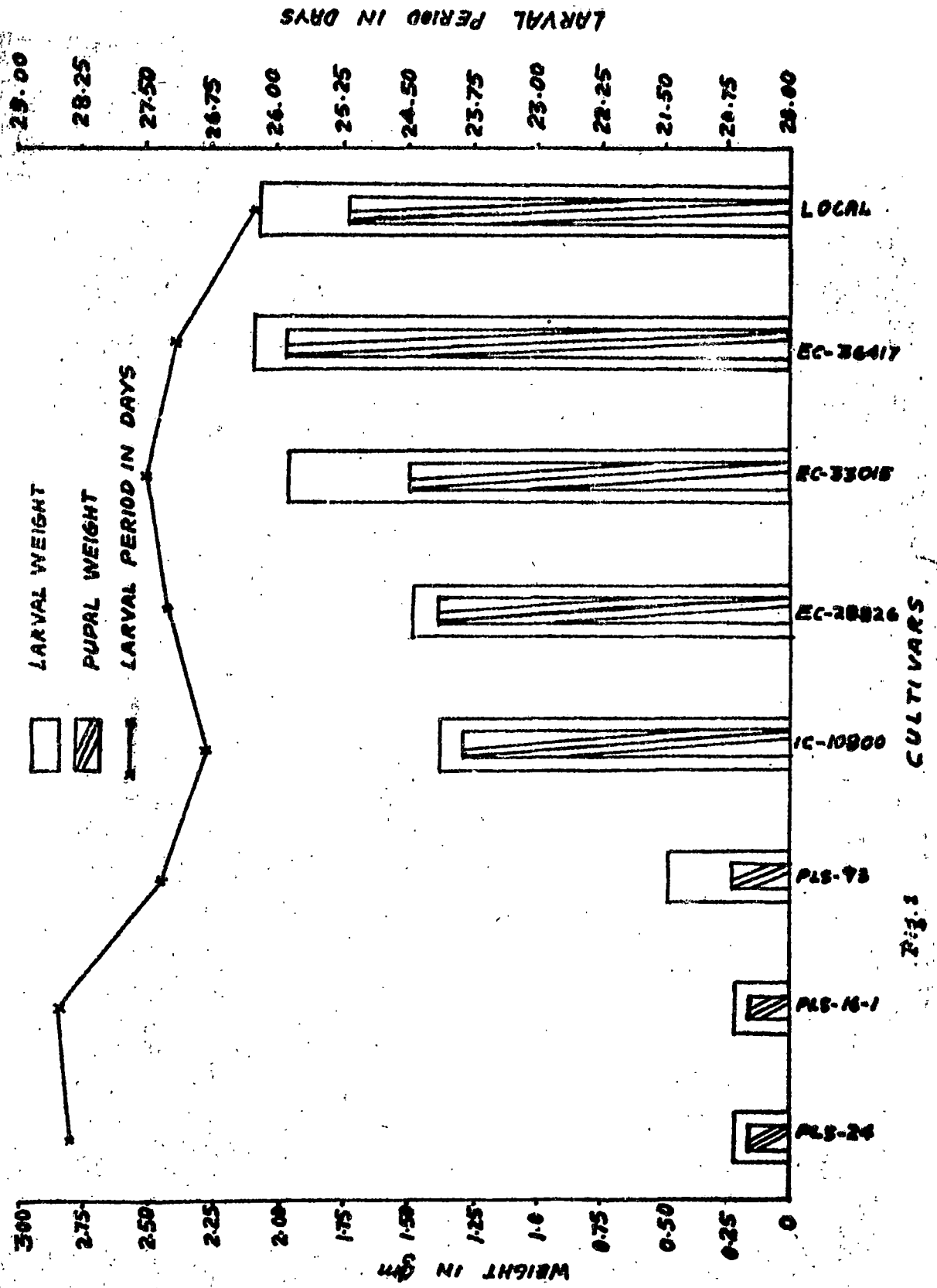
V. Larval duration:

The rate of larval growth did not differ significantly among cultivars tested (Table-VII). The larvae completed their development in shortest period in highly susceptible cultivars as against resistant and susceptible cultivars (Fig.1). On an average the larvae reared on PLS-24 and PLS-16-1 pupated in 28.50 and 29.0 days respectively. While in highly susceptible cultivars Local and EC-3641 larval duration was reduced to 20.75 and 24.00 days respectively. Further there was not much difference in larval duration among susceptible and highly susceptible groups.

(v) Sex ratio:

It was interesting to note that the sex ratio was altered

Fig.1: Larval weight, pupal weight and larval period of Adisura atkinsoni reared on selected resistant and susceptible Lablab niger cultivars.



greatly when reared on resistant cultivars (Table-VII). The males prepondered over females in PLS-16-1 and PLS-24 (9:4) as against 5:4 in highly susceptible cultivars. Male to female ratio was more or less same in susceptible and highly susceptible cultivars. It implied from these results that resistant cultivars induced production of more males than females. However, to draw a firm conclusion a larger number of pupae has to be examined.

Effect of resistant and susceptible cultivars on the pupal period, fecundity, incubation period, egg hatchability and adult longevity could not be studied as the pupae entered diapause towards the end of the season.

The results on the effects of host plants evidently demonstrated that the resistant cultivars constituted poor larval food inducing high larval mortality, lower larval and pupal weight prolonged larval duration and production of higher proportion of males to females. Despite completion of life-cycle by A. atkinsoni on resistant cultivars, the growth and development was adversely affected. The resistant cultivars consistently showed the same trend in all the components of antibiosis studied in contrast to highly susceptible ones. Thus, it is inferred that the antibiosis was greatly responsible for imparting resistance in addition to the role played by other components namely non-preference for egg laying and larval boring and tolerance.

IV. Anatomical characters in relation to resistance or susceptibility:

The present investigation was undertaken to study the association of anatomical characters of pod wall with larval boring. Cross-sections of about ten-day old pods revealed striking differences in the anatomical characters of resistant and highly susceptible cultivars. The diagram showing the anatomy of pod wall of three cultivars is presented in figures 2 to 4.

Anatomy of pod-wall of Local (highly susceptible) cultivar (Fig. 2) revealed long, multicellular epidermal hairs. The deposition of secondary wall is more at the base of the epidermal hairs than at the tip. There is a single layer of rectangular epidermal cells. Following these are 4-5 layers of angular collenchyma. Internal to these layers are layers of isodiametric, parenchymatous cells. First three to four layers of parenchyma are compressed and cells are of small size. Rest of the parenchyma contain larger cells. Following the parenchyma are three to four layers of laterally compressed parenchymatous cells. Internal to these tissues are five layers of hyaline, thin walled isodiametric cells followed by single layer of inner epidermis and cuticle. This cross section showed a large number of air spaces when compared with other cultivars studied.

Anatomy of pod wall of PLS-93 cultivar (Fig.3) revealed a layer of epidermis with epidermal hairs shorter than that of

Fig.2: Anatomy of pod-wall of Local cultivar.

1. Epidermal hair
2. Epidermis
3. Collenchyma
4. Parenchyma
5. Layers of haline cell
6. Inner epidermis
7. Cuticle
8. Vascular bundle
9. Nucleus
10. Cytoplasm
11. Chloroplast
12. Starch grain

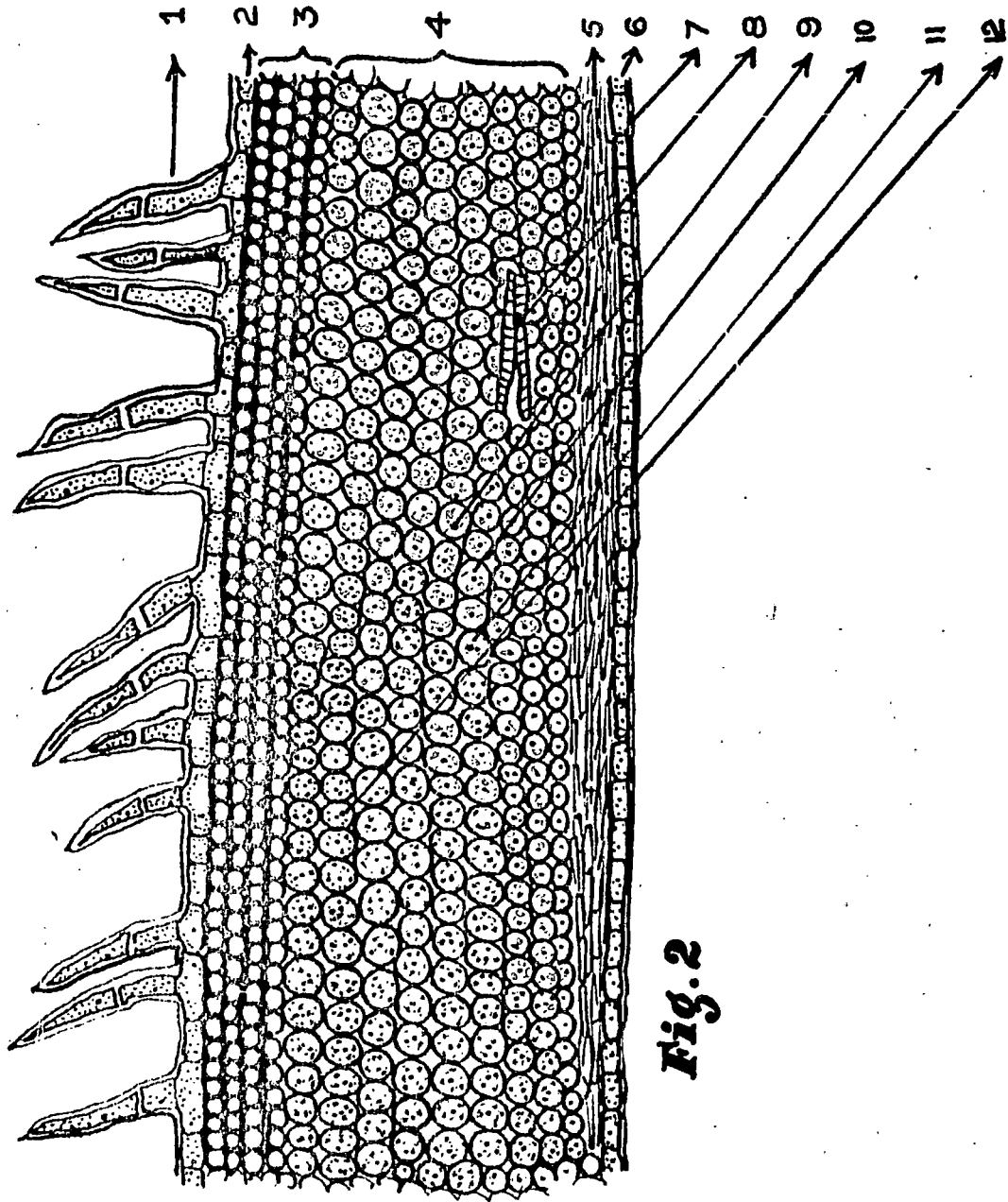


Fig. 2

0.1mm.

Fig.3: Anatomy of pod-wall of PLS-93 cultivar

- 1. Epidermal hair**
- 2. Epidermis**
- 3. Collenchyma**
- 4. Parenchyma**
- 5. Layers of hyaline cell**
- 6. Inner epidermis**
- 7. Cuticle**
- 8. Vascular bundle**
- 9. Nucleus**
- 10. Cytoplasm**
- 11. Starch grain**
- 12. Anthocyanin pigment**
- 13. Chloroplast**

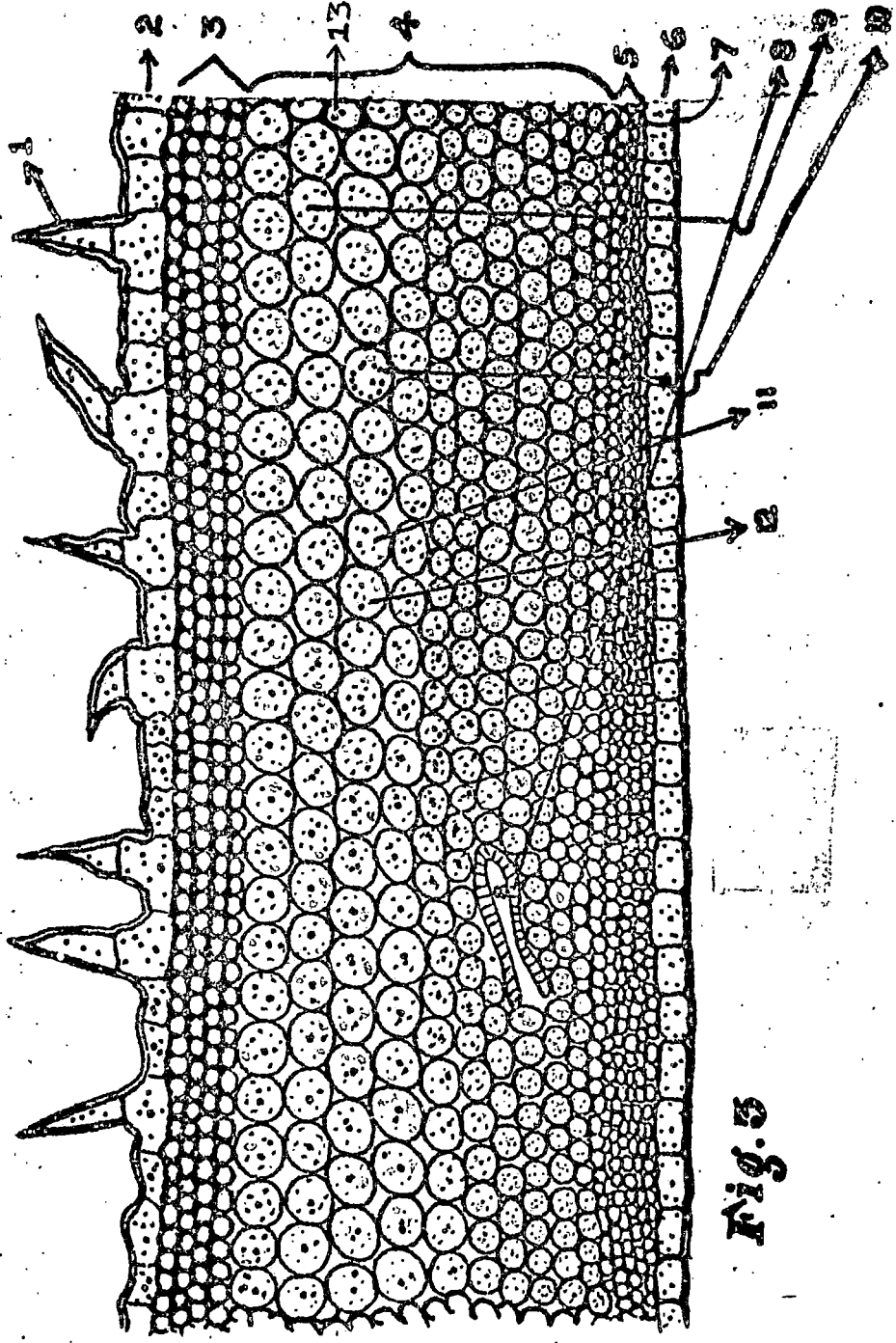


Fig. 5

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Local. Following epidermis are three to four layers of collenchyma. Rest of the layers are same as in local cultivar except that there are fewer number of air-spaces and prior to inner epidermis, are six layers of narrow, isodiametric cells.

Anatomy of pod wall of cultivars PLS-24 and PLS-16-1 (Fig.4) resistant revealed almost identical anatomical details. The anatomical structure is same as in Local cultivar except that epidermal hairs are still shorter. Parenchymatous layer contain fewer number of large air-spaces. Next to parenchyma are two layers of closely packed, rectangular hyaline cells and three to four layers of highly compressed, narrow, haline cells.

Some of the striking differences in the anatomical structure among the four cultivars studied are presented in Table-XIII.

Though the resistant cultivars, PLS-24 and PLS-16-1 possessed thickest pod walls, followed by PLS-93 and local, susceptible and highly susceptible respectively (Fig. 5), it did not form any strong barrier to the larval entry into the pods. Laboratory studies to evaluate the cultivars for their preference for larval boring indicated that the first instar larvae bored into the pods of resistant cultivars as easily as in susceptible ones, while searching a suitable host. However, as mentioned earlier, after boring, the suitability of the seed as food decided the ultimate preference for a cultivar (Table-V).

Presence of starch grains in PLS-24 was yet another feature which appeared to be associated with resistance. The susceptible

Fig.4: Anatomy of pod-wall of PLS-24 cultivar.

1. Epidermal hair
2. Epidermis
3. Collenchyma
4. Parenchyma
5. Layers of hyaline cell
6. Inner epidermis
7. Cuticle
8. Anthocyanin pigment
9. Vascular bundle
10. Nucleus
11. Starch grain
12. Cytoplasm

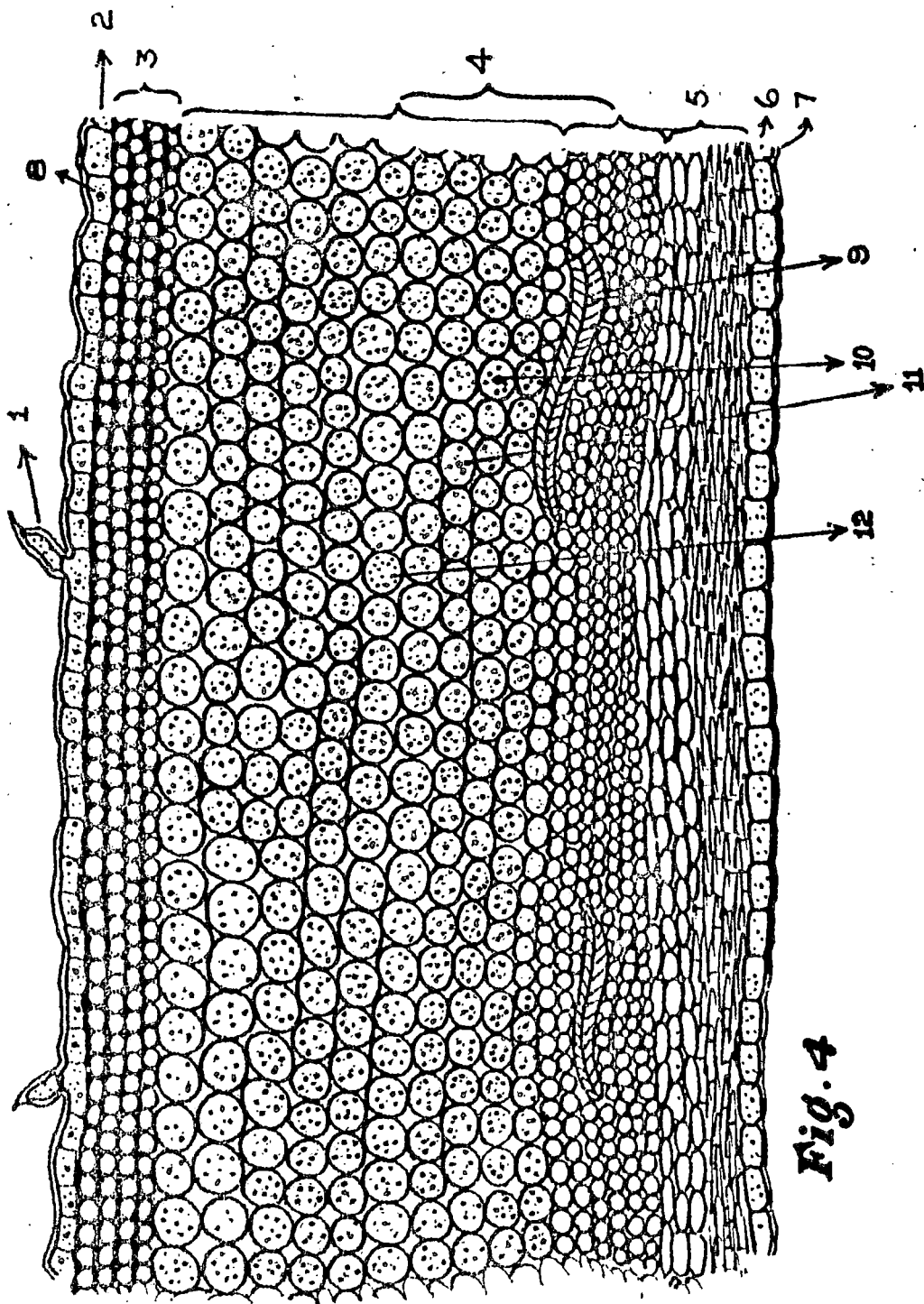


Fig. 4

0.1 mm.

**Fig. 5: Pod wall thickness and hairiness of pod
in three selected Lablab niger cultivars.**

▨ = hairs/mm.

□ = Pod wall thickness in mm.

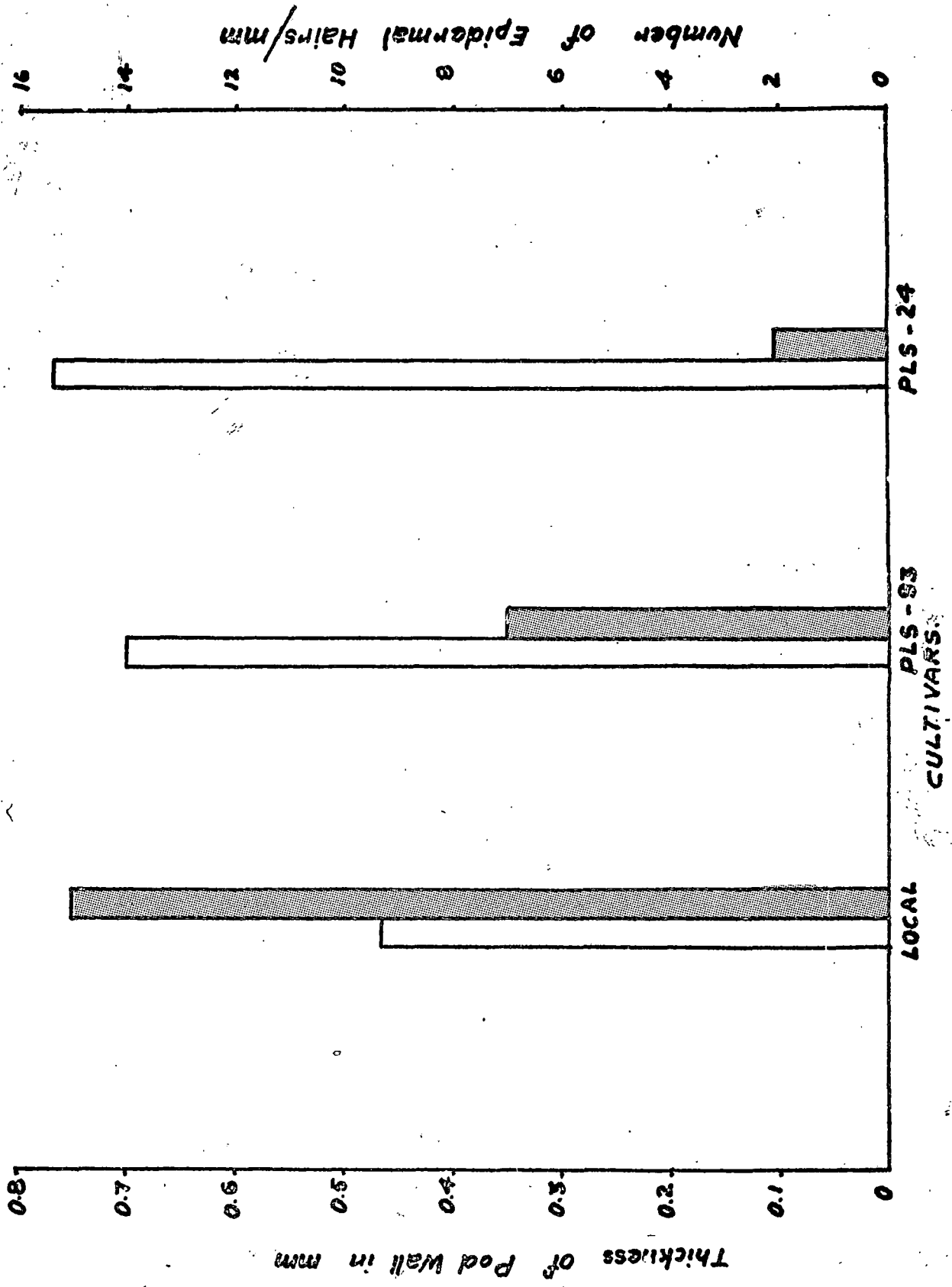


Fig. 5

Table-VIII: Histological study of pod wall of selected L. niger cultivars.

Characters	Cultivars		
	Local	PLS-93	PLS-24 & PLS-16-1
1. Number of parenchymatous layers	9-10	9-10	16-20
2. Anthocyanin pigments	Absent	Absent or present in negligible amounts	Present in comparatively large amounts
3. Starch grains	Absent or present in negligible amounts	Absent or present in negligible amounts	Present in comparatively large amounts
4. Chloroplasts	Large numbers	Fewer numbers	Absent
5. Nature of hyaline cells	Isodiametric cells	Isodiametric cells	Rectangular cells, highly compressed.
6. Average thickness of pod-wall in mm.	0.445	0.707	0.760

cultivars were devoid of starch. However both susceptible and highly susceptible cultivar did not possess the grains, suggesting that this character may not be associated with resistance at all.

Relative number of chloroplast also seemed to contribute to the resistance or susceptibility. Local and resistant cultivars were at the extremes with maximum and minimum number of chloroplasts, while PLS-93 was in between. However, association of anthocyanin pigments with resistance was in the reverse order. It was mentioned earlier that cultivars with red coloured pods were resistant. Since, the anthocyanin pigments impart red color, it was obvious that the presence of anthocyanin was associated with resistance. The results also revealed that the degree of resistance was almost related to the amount of anthocyanin pigments (Table-VIII).

Excepting for the characters mentioned above, others did not seem have direct bearing on the resistance or susceptibility.

In the current study, though quite a few of anatomical characters were observed to be associated with resistance or susceptibility to pod borers, a large number of cultivars representing resistant, susceptible and highly susceptible groups are to be studied in detail to firmly establish the role of anatomical features conditioning resistance or susceptibility critically.

V. YIELD-LOSS STUDIES:

The larvae of pod borers bore into the pods to feed essentially on the seeds. Thus, the per cent pods bored do not give true indication of the amount of seed yield lost due to borer damage. The cultivars which sustain heavy damage, based on the pods bored, may still yield appreciable amount. Conversely, low level of infestation in certain cultivars may affect yield considerably. Studies on yield loss estimation on seed weight basis were made in relation to percentage pod infestation to assess the actual yield lost and to identify tolerant cultivars. These studies were undertaken in 69 cultivars during 1977. The results are presented in Table-IX.

The per cent loss in seed yield by weight varied from 6.11 in PLS-16-1 to 93.33 in PLS-70-1. In general, the per cent loss in seed yield was more than the per cent pods bored except in few cultivars. The data indicated that a large number of cultivars (56) suffered an yield loss over 50 per cent, with infestation level varying from 8.33 to 81.44 per cent.

Considering the per cent damage caused to the pods and consequent loss in seed yield the loss in seed yield was considerably less in PLS-93 (16.67%) sustaining 58.33 per cent damage to pods. IC-661-1 and MS-9579 ranked next with an yield loss of 34.17 per cent and 27.78 per cent at 69.10 and 42.50 per cent infestation. From these results, it was inferred that PLS-93 exhibited remarkable degree of tolerance while IC-661-1 and

Table-IX: Loss in yield caused by pod borers to cultivars of Lablab niger

Cultivars	No. of seeds per pod (varietal character)	2	3	4	5	6	7	8	9	10	11
		Poten- tial No. of seeds	Total No. of healthy seeds	Total No. of damaged seeds	Weight of healthy seeds (in gm)	AV. Wt. of a healthy seed (in gm)	Poten- tial weight of seeds	Per cent loss by weight (in gm)	Av. % borer bored	Av. No. of eggs laid	
PLS-2	4	120	32	88	13.44	0.42	50.40	73.33	8.33	0	
PLS-5-1	5	150	26	124	6.76	0.26	39.00	82.67	36.67	0	
PLS-11-1	5	150	36	114	12.60	0.35	52.50	76.00	43.48	0.3	
PLS-11	5	150	52	89	46.80	0.90	135.00	65.93	42.22	0	
PLS-12	4	120	26	94	1.04	0.04	4.80	78.33	50.00	0	
PLS-16-1	6	180	169	11	3.38	0.02	3.60	6.11	7.60	0	
PLS-22	5	150	29	121	6.67	0.23	34.50	80.67	40.28	0.8	
PLS-24	5	150	134	16	77.72	0.58	87.00	11.82	16.66	0	
PLS-25	5	150	73	137	13.71	0.27	40.50	51.36	42.35	0	
PLS-23-1	4	120	42	78	10.08	0.24	28.80	65.00	27.14	0.8	
PLS-54	5	150	73	77	26.78	0.34	51.00	51.33	18.75	0	
PLS-55	5	150	73	67	22.63	0.31	46.50	51.33	26.00	0.8	
PLS-67	5	150	34	106	14.96	0.34	51.00	70.67	22.05	0.2	
PLS-70-1	5	150	10	140	2.40	0.24	36.00	93.83	28.00	2.1	

	1	2	3	4	5	6	7	8	9	10	11
PLS-79	6	180	37	143	18.87	0.51	91.80	79.52	50.00	1.7	
PLS-84	4	120	16	104	5.76	0.36	43.20	86.81	22.22	0	
EC-18130	4	120	12	108	3.24	0.27	32.40	90.00	35.26	0.3	
PLS-88	5	150	47	103	7.36	0.16	24.00	73.50	30.30	9.4	
IC-661	5	150	59	91	14.75	0.25	37.50	60.80	29.45	0	
PLS-94	5	150	53	97	12.19	0.23	34.50	62.61	10.82	4.3	
PLS-97	4	120	37	83	18.50	0.50	60.00	69.17	35.71	0	
PLS-98	5	150	41	109	16.81	0.41	61.50	72.68	28.80	1.90	
PLS-99	4	120	25	95	3.75	0.15	18.00	79.17	15.23	0.1	
PLS-106	5	150	41	109	14.76	0.36	54.00	72.67	17.60	0.5	
EC-10253-1	5	150	27	126	6.00	0.25	37.50	84.00	39.00	0	
EC-18676-A	4	120	61	59	10.37	0.17	20.40	50.00	34.26	0	
EC-18320-B	6	180	39	141	12.48	0.32	57.60	78.33	42.48	0	
EC-22899	4	120	68	32	25.16	0.37	44.40	43.33	47.80	3.4	
EC-28826	4	120	37	83	6.29	0.17	20.40	69.17	18.50	5.9	
EC-28823	4	120	40	80	20.00	0.50	60.00	66.67	26.67	3.4	
EC-33015	4	120	43	107	12.30	0.30	36.00	65.83	55.56	1.6	

1	2	3	4	5	6	7	8	9	10	11
EC-36365	4	120	35	85	8.05	0.23	27.60	71.01	70.37	0.0
EC-36413	4	120	31	89	7.75	0.25	30.00	74.33	46.66	8.1
EC-36414	5	150	34	116	8.84	0.26	39.00	77.33	23.00	0.0
EC-36417	4	120	54	66	19.44	0.36	43.20	55.00	69.10	3.0
IC-661-1	4	120	79	41	25.28	0.32	38.40	34.17	69.10	5.1
IC-3266-1	4	120	51	69	19.38	0.38	45.60	57.50	36.00	0.5
IC-5665	5	150	72	78	46.80	0.65	97.50	52.00	26.24	0.5
IC-9671	4	120	24	96	8.16	0.34	40.80	80.00	38.33	1.1
IC-10079	4	120	34	86	5.44	0.16	19.20	71.67	61.15	0.0
IC-10079-4	5	150	33	117	2.31	0.07	10.50	78.00	34.28	0.7
IC-10202	4	120	55	65	12.65	0.23	27.60	54.17	14.29	1.5
IC-11025	4	120	21	99	5.27	0.27	32.40	82.50	42.86	0.0
IC-11313	4	120	35	85	10.50	0.30	36.00	70.83	33.33	0.0
IC-11658	4	120	57	63	13.68	0.24	28.80	52.50	24.93	2.5
MS-9573	4	120	63	57	9.45	0.15	18.00	47.50	65.21	1.4
V.M.V.College	4	120	79	41	22.12	0.28	33.60	34.23	25.66	0.0
PLS-93	4	120	96	24	24.00	0.25	28.80	16.67	58.33	3.6

1	2	3	4	5	6	7	8	9	10	11
MS-9579	3	90	65	25	16.90	0.26	23.40	27.78	42.52	0.6
PLS-124	4	120	46	74	11.96	0.26	31.20	61.67	40.38	0.8
263	6	180	67	113	15.41	0.23	41.40	62.80	49.00	0.0
L-133	5	150	47	103	11.28	0.24	36.00	68.67	18.64	0.4
U.S.8	4	120	48	72	10.56	0.22	26.40	60.00	36.32	0.2
JDL-5	4	120	49	71	7.35	0.15	18.00	59.17	54.55	0.5
JDL-10	5	150	100	50	14.00	0.14	21.00	33.33	41.67	1.7
JDL-6	4	120	52	68	17.16	0.33	39.60	57.54	24.40	2.3
JDL-11	4	120	64	56	8.98	0.14	16.80	46.67	52.94	0.0
JDL-34	4	120	76	44	16.72	0.22	26.40	36.67	37.15	0.0
JDL-42	4	120	46	74	7.82	0.17	20.40	61.67	31.25	0.0
JDL-85	6	180	99	81	47.00	0.50	90.00	47.78	15.66	0.4
JDL-107	5	150	103	47	36.05	0.35	52.50	31.43	14.20	1.7
JDL-53	4	120	64	56	23.04	0.36	43.20	46.67	23.08	0.4
JDL-109	4	120	40	80	12.40	0.31	37.20	66.67	16.40	0.1
JDL-120	4	120	44	76	9.24	0.21	25.20	63.33	38.35	0.6

1	2	3	4	5	6	7	8	9	10	11
H-1	4	120	22	98	5.72	0.26	31.20	81.67	56.00	1.1
H-2	4	120	12	108	2.64	0.22	26.40	90.00	31.07	6.5
Local	4	120	48	72	12.48	0.26	31.20	60.00	81.47	7.3
188	5	150	41	109	9.43	0.23	34.50	72.67	41.00	0.2
154	5	150	63	87	13.86	0.22	33.00	58.00	34.66	1.1

MS-9579 were moderately tolerant. The per cent yield loss in EC-27889, JDL-11, JDL-53, MS-9573 and JDL-85 was 43.33, 46.67, 47.50 and 47.78 respectively, which is fairly high from the economic point of view. Thus, these cultivars could not be considered as promising tolerant lines. The least per cent yield loss in PLS-16-1 and PLS-24 was obviously due to the very low level of infestation of pod borers, as these cultivars reacted as resistant to larval boring. In the remaining four cultivars, JDL-10, JDL-34, JDL-107 and VMV college, the per cent yield loss was moderate at corresponding pod borer infestation. PLS-2 and PLS-67 suffered heavily with an yield loss of 73.33 and 70.67 per cent despite very low pod borer infestation (8.44 and 21.05 per cent). From these results, it was inferred that PLS-93 was tolerant, IC-661-1 and MS-9579 as moderately tolerant.

However, ability of these cultivars to tolerate the borer damage while producing substantial yield needs to be confirmed as the results on the yield loss in various cultivars tested, is based on one season.

In general, Lablab niger var. typicus is grown as vegetable crop, in which slightest damage caused to the pods would result in greater loss as the market value is reduced considerably, if the crop is raised for vegetable purpose. Similarly, any damage caused to the seed would also result in total loss as the seeds would be rendered unsuitable for sowing.

The above estimation of seed yield loss did not take into account the loss caused by way of boring into the buds and flowers. Though in most of the cases bored buds and flowers did not develop into pods. Further, in the current investigation on loss in seed yield noted has been accounted solely due ^{to} pod borer damage.

DISCUSSION

CHAPTER-V

DISCUSSION

I. Field screening:

The differences in the infestation among various cultivars of Lablab niger to pod borers have not been exploited in the management of pod borers. Except for Reghupathy et al. (1970) and Govindan (1974), virtually no attempt has been made in studying the host plant reaction to the pod borers. However, even these workers, mostly concentrated their efforts on the assessment of yield loss due to the pod borers in the cultivars tested. The investigation carried out during three year period has brought to light many of interesting findings which are discussed below.

(i) Resistance to larval boring:

Screening the germplasm for resistance to any pest is the most crucial phase in the host-plant resistance studies. Painter (1966) generalised that the "probability of locating inherited factors for resistance is largely proportionate to the number of cultivars examined, but generally resistance has been discovered wherever adequate search has been made". In order to study the interactions involved in host-plant relationship and the properties of the pest and the host, it is generally suggested to test the cultivars with maximum genetic variations and range of maturity. In the current study about

113 cultivars, including exotic and indigenous collections, comprising about 50 per cent of the L. niger germplasm was tested for resistance to pod borers.

Reghupathy et al. (1970), while assessing the yield loss due to pod borer attack in 17 L. niger cultivars, employed per cent pods bored as a criterion in identifying certain pseudo-resistant cultivars. Later, Govindan (1974) also studied the reaction of seven cultivars to the pod borers attack comparing per cent pods bored at the time of harvest. Similarly Veda et al. (1975) screened the cowpea lines to borer resistance using the per cent pods and seeds bored as a parameter of evaluation. However, Anonymous (1973) while evaluating cowpea accessions to borer resistance considered a pod as damaged, even if a single seed in it was eaten by the borer larvae. In all these studies, observation on the per cent pods bored was made once at the time of harvest.

In the current studies, though per cent pods bored was used as the parameter for evaluation, a total of three observations were taken at different periods of crop maturity to account for variation in the maturity of cultivars and fluctuations in the borer incidence during the cropping season. Variations in the occurrence of borer species during the cropping season have been reported. H. armigera, M. liaphanes, E. zinckenella and M. obtusa have been reported to occur chiefly during December - January (Krishnamurti, 1936; Govindan, 1974), while the occurrence of C. boeticus all round the year has been observed by Govindan (1974). Krishnamurti and Appanna (1948) reported the

occurrence of M. testulalis, S. caffer and A. atkinsoni during the main season of the crop. In view of the great variation in appearance of the borer species during the cropping season, observations at different intervals permitted a better evaluation of the cultivars to the various pod borers. Further, increased number of observations was also found to be necessary to assess the reaction of cultivars at varying levels of pest incidence.

Identification of resistant cultivars was based on the consistency of performance of cultivars to borer attack over three seasons. It was rather necessary to exercise this care to eliminate the pseudo-resistant lines as the screening was undertaken in field where the high incidence of pest is not met with every year.

None of the early workers who studied the varietal reaction to pod borers in L. niger as well as in other pulses have indicated the scale of evaluation. However, in the present screening programme, the cultivars were grouped as resistant with less than 20 per cent pods bored, susceptible with 21 - 60 per cent pods damaged and highly susceptible with ^{more than} 60 per cent pod damage.

Govindan (1974) though did not indicate scale of assessment, considered a cultivar as 'moderately resistant' with 24.00 per cent pods bored, while others as susceptible with more than 24 per cent pods damaged.

Of the 113 cultivars, screened for the resistance to larval boring, 38 were tested in all the three trials. The incidence of the pod borers as measured by the proportion of cultivars showing susceptibility was high in 1975 followed by 1975-1976. Very low level of infestation was recorded in 1977 (Appendix-II & III). A great variation in the infestation among these cultivars could be due to variation in infestation level. Further, the reaction of the cultivars to the borer attack was also influenced by the stage of the crop. Cultivars with full complement of tender pods, during the peak activity of borers, generally suffered more from borer infestations. Thus the differential infestations resulted partly due to differences in the flowering period of the cultivars. These observations supported the findings of Reghupathy et al. (1970) who observed that differences in flowering dates contributed to the differences in pod damage. Further, these workers found that early maturing cultivars showed pseudo-resistance to the pod borers. Thus, the variation in incidence of pod borers and maturity of the cultivars influenced greatly the expression of resistance to the borers. In view of this, increased number of observations was found to be a meaningful technique of assessing the varietal reaction.

(ii) Non-preference to oviposition:

None of the earlier workers has screened L. niger cultivars for resistance to ovipositional response. Out of 113 cultivars,

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33 showed non-preference. Eight cultivars showed non-preference for egg-laying consistently for three years, while nine for two years and 16 for a year only. Thus their reaction of non-preference to oviposition needs to be confirmed before considering them as truly resistant cultivars to oviposition in view of the preference of pods against flowers and buds and differential maturity periods of the cultivars tested. Six cultivars proved 'highly preferred' for oviposition.

Two cultivars, PLS-24 and PLS-16-1 were considered resistant as they maintained low borer infestation consistently (less than 20 per cent). Reghupathy et al. (1970) recorded seven cultivars (D.L. 3196, PLS-231, D.L. 2224, D.L. 2542, D.L. 3197, PLS. 122 and D.L. 1458) that had less than 20 per cent pods bored, with the per cent pods bored ranging from 6.73 (D.L. 3196) to 18.21 (D.L. 1458). In a preliminary screening trial, Govindan (1974) regarded CO.8, which suffered least damage (24 per cent pods bored) as 'moderately resistant'. However, they did not ascertain the true reaction of the cultivars under high infestation level. The former workers assessed yield losses due to pod borers under low level (6.73 to 26.80) of infestation. Further, in both the studies, the observation was taken only once in a season, at the time of harvest. In view of the various factors influencing the expression of resistance as discussed earlier, it is necessary to confirm their reaction before considering them as resistant. Thus, Reghupathy et al. (1970) inferred that the above cultivars might have showed pseudo-resistance. It is evident from the current investigation

also that a large number of cultivars showed pseudo-resistance.

Fortyfive cultivars showed pseudo-resistance to larval boring while 16 to ovipositional response. The obvious reasons for the large number of pseudo-resistant cultivars may be due to foresaid reasons. The causes for pseudo-resistance as apportioned by Painter (1951) were: (a) Host evasion (the host may pass through the susceptible stage at a time when pest numbers are reduced), (b) Induced resistance (temporarily increased resistance resulting from some condition of plant or environment) and (c) Escape. In the present study, a large number of cultivars which exhibited pseudo-resistance may be mostly due to host evasion, though the role of other causes can not be ruled out. Even under high infestation some cultivars (e.g. PLS-88 and PLS-102) showed pseudo-resistance. These observations were in agreement with Painter (1951) who was of the view that even under heavy infestations susceptible plants occasionally escape and studies of their progenies will establish their true relationship.

Differential reaction to larval boring and to egg laying has been observed in number of cases. Clark et al. (1970) reported that PL. 227687 was most preferred for oviposition by H. zea, but it sustained least pod damage. Similar differences in resistance to larval boring and to egg laying were also observed in L. niger cultivars. Cultivars, E.C. 28826 and EC-18176-A were more preferred to oviposition than to larval boring. Conversely IC-661 and PLS-70-1 which were susceptible to larval

boring showed high degree of resistance to egg laying. These observations suggested that the factors conditioning resistance to larval boring and ovipositional preference in these cultivars were different and independent. However, there were cultivars which exhibited susceptibility (Local and H-2) and resistance (PLS-24 and PLS-16-1) to both larval boring and egg laying. In such cultivars, both the factors conditioning resistance were absent or present.

Painter (1951) remarked that the adult generally deposits egg on plant part/parts on which the emerging young feed. Further, he stated that the set of stimuli attracting the adult for oviposition and feeding may be different as the adult moth feeds on nectar and other plant juices, quite different from the food of the larvae. In redgram, the plume moth, M. liophanes preferred pods, followed by leaves, flower buds and paper in order of preference (Chari and Patel, 1967). In L. niger cultivars, the preference of pods over flowers and buds by pod borers mentioned earlier has been as recorded by Govindan (1974), was also observed in the present study.

Generally, it is felt that exotic collections or plant introductions are more resistant to the pest species concerned than indigenous collections. James and Ganerday (1968) showed cultivars of Vigna species to be more susceptible than plant introductions. On the contrary, a comparison of geographical origin with infestation of cultivars tested revealed that origin of a L. niger cultivar had no impact on the resistance or susceptibility. For instance, cultivars collected from Bihar, were

both resistant (e.g. PLS-24) and susceptible (e.g. PLS-54 and PLS-55). Both indigenous and exotic collections exhibited equal susceptibility. However, Krishnamurti and Appanna (1948) stated that the life-cycle of the dominant pod-borer, A. atkinsoni coincides with that of the Local, a highly susceptible cultivar. The observations made in the present study revealed that among indigenous collections, there were cultivars equally susceptible as the Local and the pest appeared long before the appearance of the first flush of flower spikes of Local cultivar.

All wild types of cowpea showed some degree of resistance to the pod borer, C. ptychora (Anonymous, 1973). In case of L. niger, in general, garden types were less infested than field types and Anonymous (1952) recorded A. atkinsoni on field types but not on garden types. Ayyangar and Nambiar (1941) considered field types to be resistant because the extracted oil from this type acted as natural repellent to the pod borers. However, they failed to give the details of their investigation.

The field types emit a characteristic aroma, has been recorded as early as 1927 by Ambekar and by Aiyer in 1949. The results of screening of L. niger cultivars to pod borers revealed that cultivars namely, Local, EC-36417 and others were found to be highly susceptible to larval boring and oviposition. This secondary plant substance might have been seized upon by pod borers, particularly A. atkinsoni for ovipositing and feeding on the emitting L. niger cultivars. The role of secondary plant substance in attracting or repelling insect pests has been reviewed by Levin (1976) and a number of other workers.

The fact that L. niger cultivars emitting aroma attract certain insect pests of other crops and can be exploited as a trap crop has been well documented (Pomeroy, 1925; Cowland, 1935; Bedford, 1936; Mickinstry and Prentice, 1937 and Anohymous, 1938). Gross et al. (1975) recommended the utilization of this crop for biological and econogical studies of H. zea and H. viresens because these were easily available on L. niger cultivars over a long period. From the current study also, it may be inferred that certain cultivars possess great potentiality in serving as a trap crop for a number of pod borer species.

This secondary plant substance may act as a kairomonal stimulant for ovipositing and feeding. Probably due to this reason, A. atkinsoni must have favoured to establish better on cultivars with fragrant substance than on those that were devoid of the same. Preliminary studies on the role of this secondary plant substance conditioning resistance, as conducted in the laboratory have been discussed under "Factors inducing resistance".

(iii) Morphological characters in relation to susceptibility or resistance:

In the field, some morphological characters were observed to be associated with susceptibility to the pod borers attack in L. niger cultivars tested. However, step-wise Regression test negated the existence of such an association, presumably for reasons explained before. The possible role of some distinct morphological characters associated with resistance or susceptibility are discussed below:

(a) Pod color:

The red color on the inflorescence was observed to be consistently associated with resistance and green and white with susceptibility. Among the cultivars screened for the borer resistance in L. niger, only PLS-24 and PLS-16-1, resistant cultivars possessed red colored inflorescence. These observations contradicted the view of Reghupathy et al. (1970) who concluded that flower color did not have any significance with infestation of the pod borers. The response of the adult to the color may be due to that the insects concerned simply do not "see" the red plant parts, as viewed by Painter (1968). He attributed that red color contributed to the part of resistance mechanism. Infact, Weiss et al. (1944) found that red parts of the light spectrum caused the least response in insects. Isely (1928) reported that ^{red} leafed cotton varieties to be more resistant than some of the green-leafed varieties. However, the observations of Harrison and Brubaker (1943) disagreed with the above findings. They observed that red and purple leaf varieties of cabbage to be more infested by both the cabbage looper, I. ni and the cabbage worm, P. rapae than green varieties.

In PLS-93, observations showed that majority of eggs were laid on green and tender pods and few when the same pods turned pink. However, reduced egg laying may also be due to the old age of pods as the color transformation is accompanied with the age of pod. Susceptibility of this cultivar to the larval boring despite possessing red color in the later stage might be due to

green color of the tender pods. In order to clearly establish the role of color, detailed work has to be done on red coloured cultivars in response to ovipositional preference and larval boring under laboratory conditions.

(b) Hairiness of pod:

Painter (1968) held that complex genetic bases, length and density and also the groupings and the angles which the hair make with the substrate result in differences in the expression of resistance.

Relatively more number of eggs were laid on cultivars with dense and long hairs, than on cultivars with short and fewer hairs. This was true with respect to four cultivars, tested (Table-VIII). These observations were in agreement with the results of Uchida and Okada (1937), Nishijima (1960), Matsumoto (1962) and Hsu et al. (1965) who observed that more number of eggs were laid in pubescent varieties than on the glabrous ones, by the noctuid borers in soyabean. Matsumoto (1962) concluded that ovipositional response of the noctuid pod borer, L. gycinivorella was not influenced by the length of hairs in soyabean. Wilson and Wilson (1977) reported that level of hair density in cotton strains are not great enough alone to impart resistance. In the light of these findings it is not quite certain that the pubescence alone could impart resistance to pod borer in L. niger.

(c) Pod surface area:

In soyabean, the total length of pods served as an index of the area for egg deposition by the pod borer, M. glycinivorella (Matsumoto, 1962) and in redgram, pod width served as an index of per cent infestation of M. obtusa (Veda et al., 1970). In four selected L. niger cultivars, surface area of pods had no bearing on the infestation at egg stage.

Of the 11 morphological characters studied, the above mentioned and probably days to flower and fragrance influenced the preference or non-preference for egg laying. Other morphological characters seem to have little or no role in determining resistance or susceptibility. However, these observations need to be confirmed.

From foregoing discussion, it is evident that a number of morphological characters were associated with resistance or susceptibility. Thus, the cumulative effect of all these characters together may account for the resistance to pod borers attack fully or partly. Similar observations have been made in sugarcane to stem borers (Agarwal, 1969) and in cotton to pink bollworm (Wilson and Wilson, 1977). However, interestingly enough Wilson and Wilson (1977) concluded that combination of morphological characters may not be sufficient to reduce infestation below economic injury level in cotton to pink bollworm, Pectinophora gossypiella Saunders.

II. Factors inducing borer resistance:

Resistance in a host-plant may result from one or a combination of the three components of resistance, viz. non-preference, tolerance and antibiosis. Preliminary work done in the laboratory, on the causes of the resistance to the pod borer, A. atkinsoni in L. niger cultivars has been discussed briefly in the following paragraphs.

(i) Non-preference for larval boring:

Number of factors have been found to influence host selection by the I instar larvae. Of these, chemical stimuli from the host plants were said to aid the larvae in detection of host plant. Host selection in first instar larvae has been reported for Papilio ajax (L.) (Dethier, 1941); Chilo suppressalis (Watanable, 1958 and Pathak, 1967) and for other insects. The first two workers used a small amount of test chemical whereas Pathak (1967) used rice stem pieces in tubes to note the reaction of first instar larvae to rice varieties. Cuthbert and Davis (1972) have inferred that the preference for pods of southern pea by the C. aeneus appeared to result from differences in amounts of a feeding stimulant present in pods. However, the newly hatched larvae of A. atkinsoni did not exhibit definite preference to any cultivar of L. niger tested. The larvae do not seem to play major role in selecting a preferred cultivar.

Painter (1968) stated that lower populations on resistant varieties may result either from non-preference and a food value

equal to susceptible varieties, or equal preference and a difference in food value. In L. niger cultivars tested, in the absence of preference exhibited by the larvae, the differences in the nutritive value may account for differences in the reaction of cultivars to larval boring.

Number of larvae recovered in the pods of cultivars was used as parameter of assessing preference or non-preference in the laboratory. Apparently pod wall of resistant cultivars did not seem to have any impact on the larval entry into the pod as the larvae bored into the pods and thus there was no difference in the number of larvae found in resistant and susceptible cultivars. However, lack of information on the number of holes made on wall and the extent of seed material consumed after entering into the pod, the true response of cultivars could not be studied.

EC-28826, a susceptible cultivar to larval boring received three times as many eggs as in EC-33015, other susceptible cultivar to larval boring. Number of larvae recovered in the former cultivar were half the number of those recovered in the later (Table-V & VI). These observations suggested that EC-28826 was susceptible to larval boring primarily because it was highly preferred for oviposition while susceptibility in EC-33015 may be accounted for its suitability as larval host.

(ii) Non-preference for oviposition:

According to Painter (1968), resistance occurs through

non-preference in two ways, viz. (1) a resistant variety may lack one or more, or a measurable amount of the qualities which provide the attractive stimuli present in a susceptible variety or (2) a resistant variety may possess repellent qualities which take the place of, or successfully compete with or mask the attractant stimuli. The present work in L. niger cultivars showed non-preference to be linked with lack of characters for providing attractive stimuli.

Ovipositional response has been reported to be influenced by Color (Ilse, 1937; Shorey, 1964); moisture (Leeuwen, 1947; Shorey, 1964); surface texture (Painter, 1951; Beck, 1965) and chemical constituents of plants (Gupta and Thorsteinson, 1960; Yamamoto and Fraenkel, 1960). Mehta and Saxena (1970), reported that ovipositional response of E. fabia is governed by both physical and chemical characters of cotton plants. A few of these characters, viz. hairiness and color of the pod, presence of fragrant substance were also found to influence the ovipositional response of A. atkinsoni in L. niger cultivars.

Under caged conditions, the green foliage that was present on the peduncle of resistant cultivars might have been a factor for attracting the moths for oviposition, but eggs were not laid because of unfavourable pod texture, probably. However few (five to six) eggs were laid because the moths find red parts of plants partly by chance, as stated by Painter (1968).

All parts of the highly susceptible cultivars served as suitable ovipositional sites, whereas, in the resistant cultivars

eggs were laid only on pods. Preliminary experiments showed that moths preferred other parts of inflorescence of highly susceptible cultivars over pods of resistant cultivars.

In the laboratory, selected cultivars as promising against larval boring were tested for their preference to oviposition. Resistant and highly susceptible cultivars to larval boring exhibited similar performance to egg laying. However, among the susceptible cultivars few were as highly preferred as highly susceptible cultivars for egg laying. From these results it may be said that resistance to larval boring and non-preference for egg laying are influenced by independent factors. In the laboratory tests, it was confirmed that red colored pods were not preferred for oviposition. However, the field screening data showed that a number of green coloured cultivars, were also not preferred for egg laying, (Table-VI and Appendix-III). Thus the colour of the pod did not appear to be the only factor altering ovipositional behaviour of the moths.

Experiment conducted to establish the role of fragrance substance in inducing preference for egg laying or otherwise suggested that though the number of eggs were reduced by half when the fragrance was removed to the extent possible, it did not seem to influence the ovipositional pattern independently. The reduced number of eggs on the pods devoid of the fragrance was also attributed to the disruption of the epidermal hairs in the process of removing the fragrance as the hairiness is found to be positively associated with preference. Supplementary

evidence to this fact that fragrance alone did not influence oviposition was also obtained in the laboratory ovipositional preference study, where the non-fragrant cultivar, viz. EC-28826 was highly preferred for egg laying. Thus from the foregoing discussion it may be inferred that combined effect of pod color, fragrance, and hairiness influenced the preference or non-preference for egg-laying.

III. Antibiosis:

(i) Per cent hatchability of eggs:

Studies on the effect of host plants on the hatchability of eggs demonstrated that though the resistant plants reduced the hatchability of eggs, it was not significantly different from that on susceptible cultivars. These observations suggested that the cultivars did not possess any specific factor that affect the viability of eggs. Further, the reduced percentage of hatching in all cultivars, except the local, highly susceptible cultivar to larval boring and egg-laying, may be attributed to the disturbance caused to eggs during transfer of the same from other cultivars. It was also not certain whether moths laid more eggs on the cultivar that supported high per cent hatchability of eggs.

Weaver and Reddy (1977) reported that in cotton, the hatchability of eggs of Boll weevil, A. grandis was reduced by the cumulative effect of three characters, viz. fregobract, cytoplasmic male-sterility and red stem.

(ii) Larval mortality:

Perhaps the most common and most easily observable characteristic of antibiosis is death of I and II instar larvae (Painter, 1968). Few, among the several examples of such a kind has been reported by Swailes (1960) in cabbage to cabbage maggot, Hylemya brassicae Bouche; Sogawa and Pathak (1970) in rice to brown plant hopper, Nilaparvata lugans Stal., and in wheat to cereal leaf beetle, Oulema melanopa L. (Schillinger and Gallun, 1968). Sogawa and Pathak (1970) reported that brown plant hopper, N. lugans when caged on 'Mudgo' variety had high mortality of larvae, slow growth rate, small body size and low fecundity. Death of I and II instar larvae of the pod borer, C. ptchora when fed on pods of resistant cultivar of cowpea was observed (Anonymous, 1973). In contrast to these reports, the death of last instar larvae of A. atkinsoni when fed on resistant cultivars of L. niger was observed in the current study. A similar evidence to this effect has been provided by Isely (1935) for the corn earworm larvae reared on various host plants.

PLS-93 recorded moderate number of eggs and maximum number of I instar larvae in the laboratory experiments (Table-V and VI). However, high degree of mortality of older larvae, was attributed to the changes occurred in the pods as they grew old. The pods of this cultivar were green when young and turned red later due to the synthesis of anthocyanin pigments. Association of red color (anthocyanin pigment) with resistance has already been discussed. Further, changes in the chemical composition and lignification of pods might have also made it impossible for the

established larvae to survive. Results obtained by Clark et al. (1970) in soybean, where PL-227687 a cultivar most preferred for oviposition by H. zea sustained least pod damage, showing antibiosis to larvae, is supporting evidence to the results discussed above.

(iii) Larval and Pupal weights:

Overwhelming reports were published on the effect of resistant plants on the larval and pupal weights. The differences in weights were pronounced in the later instars of larvae and in pupal period. The reduced size and consequent reduction in the weight of larvae and pupae reflected the amount of food being consumed by the larvae. Thus it is likely that the fecundity of moths of A. atkinsoni reared on resistant cultivars may be reduced in proportion to the size of moth. These results were in agreement with Pathak (1967) who found that larval and pupal weight of C. suppressalis Walker, was reduced ten times when reared on resistant cultivars of rice. Shaver et al. (1971) reported decreased larval weights of H. virescens and H. zea when fed on diets with high gossypol content compared to diets with low gossypol content. On the other hand above terpene stimulated feeding in boll weevil, A. grandis (Hedin et al., 1968). The larval and pupal weight of corn earworm got drastically reduced when fed on resistant inbred corn lines (Chambliss and Wann, 1971).

It was not possible to record the fecundity of moths reared

on selected cultivars as the pupae entered diapause towards the end of season. However, Painter (1968) stated that "Differential in size is often reflected in a lower fecundity of the female which have been reared on resistant hosts".

(iv) Larval duration:

Prolonged larval period of A. atkinsoni when reared on resistant cultivars was also yet another component of antibiosis noticed in L. niger. Several examples of similar situation have been provided by Dahms (1948) in chinch bugs, B. leucopterus when fed on resistant sorghum cultivars; Chambliss and Wann (1971) in H. zea fed on inbred corn lines; and Lukefahr and Martin (1966) in Heliothis spp. fed on resistant sorghum cultivars and Maxwell et al. (1966) in cotton boll weevil.

(v) Sex ratio:

Preponderance of male over female when fed on resistant cultivars, suggested the association of some compound in resistant cultivars that altered the sex ratio. The ratio of female to male in Chilo zonellus (Swin.) did not show any strict relationship with the relative susceptibility in selected germplasms of maize (Sharma and Chatterji, 1971).

Though A. atkinsoni completed life-cycle on resistant cultivars, the biology of the pest was drastically affected, thus indicating the presence of antibiosis. The mortality of larvae, reduced larval and pupal weight, sex ratio were markedly affected by the resistant cultivars. The increased mortality

of fully grown larvae may be due to the accumulated affect of lack of a specific chemical. However, the unsuitability of the resistant cultivars as food plants for larvae reflected on the weight of larvae and pupae by reducing the feeding capacity. The suitability of host-plant for feeding may be affected by deficiency in nutrients or presence of feeding deterrents. The evidence of specific chemicals inducing inhibitory effect on the insect pest have been provided in a number of cases. Isoboldine showed feeding inhibitory activity against tobacco cutworms (Wada and Munataka, 1968); clerodendrin-A and Clerodendrin-B inhibit feeding of larvae of European corn borer, O. nubilalis at 5000 ppm, and the oriental tussock moth, Euproctis subflava at 1000 ppm (Kato, et al., 1972); L-tomatine interfered with growth and development of Manduca sexta (Schoonhoven, 1972) and number of other interesting reports of the presence of antifeedants in plants have been reviewed by Munataka (1977). The marked influence of host plants on the sex-ratio of A. atkinsoni may be due to presence of chemical factors in resistant cultivars of L. niger.

These results demonstrated that the resistant cultivars appeared to be deficient in a specific chemical or a group of chemicals and or nutrients rather than possessing the toxic chemicals that take heavy toll of larvae even in early stages. The observations of Painter (1968) who postulated that differences in quantities of food available either in total amount or in respect to certain kinds may be associated with antibiotic effects, are in support of the above supposition.

In the absence of adequate data on the chemical composition of seed or green pod of the resistant or susceptible cultivar it was rather erroneous to infer on the factors inducing antibiosis. However, based on the available data on the chemical composition of field type (L. niger var. lignosus) and garden type (L. niger var. typicus) as reported by Anonymous (1951), Biswas and Das (1938), Ambekar (1927) and Aiyer (1949), a comparison of their nutritive value in relation to susceptibility or resistance was made. The green pods of garden type to which PLS-24 and PLS-16-1 resistant cultivars belong had low amounts of protein, iron, nicotinic acid, fat and mineral matter than the seeds of field type which include most of the susceptible cultivars. Further, dolichosin, a chief protein in the field type, was absent in the garden type (Niyogi, 1932; Swaminathan, 1938 and Venkatiswaran and Sreenivasaya, 1940). It may be said that these differences might have accounted for differential performance of L. niger cultivars in the present study. However the authors have failed to mention about the details of cultivars used in studying the chemical composition of garden and field types of L. niger. There are numerous examples in the literature of known chemicals that directly affect the antibiosis component of resistance. Well known works include the identification of the benzoxazolinone compounds with European corn borer, Ostrinia nubilalis (Hub.) in maize, Zea mays (Smisson et al., 1957); gossypol with Heliothis zea (Boddie) and H. virescens (Fab.) in cotton, Gossypium hirsutum L., (Lukfahr and Martin, 1966); and saponins and protease

inhibitors affecting several insects in legumes and stored legume seeds, (Applebaum et al., 1969). Maxwell (1972) has reviewed the relationship of nutritional factors to resistance, particularly as it relate to antibiosis, preference and overall pest management. In the present investigation it was noticed that not all the garden types possessing low amounts of nutrients and lack of dolichosin offered resistance. Hence, it may be inferred that some other chemical factors appeared to impart resistance. Thus a better explanation of chemical bases of resistance awaits detailed analysis of chemical composition of resistant and susceptible cultivars.

IV. Anatomical characters and pod borer susceptibility:

Though thick-walled pods were less infested than thin-walled pods, pod-wall thickness did not seem to be a deciding factor in causing differential injury, as the I instar larvae easily bored into the tender pods of resistant (thick walled) and susceptible (thin walled) cultivars. These results suggested that there was no physical barrier for larval boring through pod wall. However, in contrast, Cuthbert and Davis (1972) obtained negative correlations of pod wall thickness of southern peas with the successful penetration of C. aeneus. The relative amount of chloroplasts, anthocyanin pigments and starch grains in the pod wall influenced the degree of susceptibility or resistance. The association of plant pigments with resistance have been reported by quite a few workers. Lukefahr and Martin (1966) suggested the increase in pigments in cotton

as part of the mechanism of resistance. Contrary to this, Miller et al. (1958 and 1960) and Lanning (1966) found no relation between plant pigments and resistance. Harrison and Brubaker (1943) showed that red and purple-leaf varieties were more susceptible to I. ni and P. rapae than green varieties, in cabbage.

In Lablab niger, the role of plant pigments influencing the degree of resistance or susceptibility agreed with neither of the reports. Among the four varieties studied for anatomical characters, it was revealed that positive relationship existed with amount of chloroplast and susceptibility. While the trend was reversed with presence of amount of starch grains. Presence of anthocyanin pigment in the pod wall rendered the cultivar resistant. These results obviously suggested that the effects of chloroplast and anthocyanin pigments were antagonistic in inducing a cultivar susceptible or resistant.

V. YIELD LOSS STUDIES:

The seed yield loss was estimated following the method of Bindra and Jakhmola, (1967). This method, though giving practical approach to the problem, has it's own shortcomings. According to Reddy (1973) 'cage method' was best for assessing yield loss due to pod borers in Pigeon pea, as it could avoid all the flaws confronted in other methods.

The seed yield loss ranging from 3.2 to 23.5 per cent at infestation level ranging from 6.7 to 26.8 per cent at Coimbatore

was reported by Reghupathy et al. (1970). In the present study, the former varied from 6.11 to 93.33 at 8.33 to 81.47 per cent infestation. It may be noted that per cent seed yield loss was more at corresponding infestation level at Coimbatore than at Bangalore. The differences in maturity period of cultivars, number of cultivars studied, sample size, activity of pod borers etc. were thought to be few, among the several factors that accounted for the difference in the results obtained at Bangalore and Coimbatore.

Tolerance is a basis of resistance in which the plant shows an ability to grow and reproduce itself or to repair injury to a marked degree inspite of supporting a population approximately equal to that damaging a susceptible host (Painter, 1968). Beck (1965) redefined tolerance and separated it from other mechanisms, because it involved a different kind of relationship (physiological) with insect, than other mechanisms of resistance. Few among the several examples of tolerant strains reported are, Hessian fly tolerant wheat (Painter, 1968) and sorghum hybrids tolerant to shoot-fly Atherigona varia var. soccata (Blum, 1967).

Based on the yield loss caused by the pod borers at corresponding infestation level in cultivars tested, it was revealed that certain cultivars have remarkable ability to yield more despite sustaining heavy damage by the pest. PLS-93 was identified as tolerant; IC-661-1, MS-9579, as moderately tolerant (Table-IX), in view of the least amount of yield loss inflicted ^{at} fairly high level of infestation. However, the

results of Reghupathy et al. (1970) contradicted the performance of PLS-93 in the present study. They reported an yield loss of 19.97 per cent at 23.44 as against 16.67 at 58.33 in the current study.

The correlation studies between the yield loss and per cent infestation were not made in the present investigation. However, as seen from Table IX, there seemed to be no positive correlation between the yield loss and per cent pods bored. The yield loss of 73.33, 79.17, in cultivars PLS-2 and PLS-99 with 8.33 and 15.23 per cent pods bored respectively and 16.67 and 34.17 in PLS-93 and IC-661-1 sustaining 58.33 and 69.10 per cent damage respectively were two examples to demonstrate absence of any positive correlation between yield loss and per cent infestation. Conclusions of Reghupathy et al. (1970) are based on studies carried out in small number of cultivars viz. 17 as against 69 in the present study. Further the said contrary results may also be due to the variation in sample size, pest population and other factors. Thus, the correlation studies needs to be confirmed in large number of cultivars at varying levels of infestation. Degree of tolerance exhibited by one cultivar in comparison with others as reported by Painter (1968) is said to be strongly influenced by the age or size of the plant and insect population. Painter (1968) is of the opinion that tolerance response is perhaps more subjected to variation as a result of environmental conditions than are preference and antixenosis. The tolerance component of resistance

is principally concerned with the reaction of the plant to insect and the plants ability to recover and repair injury (Painter, 1968). He further stated that this component is apparently subjected to environmental influence and its basis has not been studied extensively.

Painter (1968) suggested that the insects with chewing mouth-parts, as a rule, destroy the plant part attack so completely that the only type of tolerance that can be developed is that concerned with regrowth. If this is so, then in L. niger tolerance to pod borer does not seem to be an important component of resistance as the pod borers attack fruits, economically important or valuable parts, thus leaving no scope for the replacement or regrowth as the fruits are borne at the end of the plant growth. However, certain cultivars possess ability to flower continuously as in the case of PLS-93, tolerance may form valuable component of resistance.

SUMMARY

CHAPTER-VI

S U M M A R Y

I. Field screening:

One hundred and thirteen cultivars of Lablab niger were screened for pod borer resistance in three field trials. The field population of pod borers in all three years was high enough to assess the differences amongst the cultivars tested. The cultivars were evaluated for their reaction to larval boring based on the per cent pods bored. The cultivars were grouped as 'Resistant', 'Susceptible' and 'Highly susceptible' based on the consistency of their reaction of three years with 0-20, 21-60, and above 60 per cent pods bored by different borer species, respectively.

(i) Field screening for larval boring:

Two cultivars, namely PLS-24 and PLS-16-1 reacted as resistant. A large number of cultivars were grouped as susceptible and highly susceptible. A number of cultivars exhibited pseudo-resistance despite high borer population under field conditions.

(ii) Field screening for ovipositional response:

Of 113 cultivars, nine cultivars exhibited non-preference for egg-laying consistently in all three trials. Once again a number of cultivars showed pseudo-resistance to ovipositional response also.

A few cultivars exhibited differential reaction to larval boring and egg laying, suggesting that the factors conditioning resistance to oviposition and larval boring were different and independent.

II. Morphological and anatomical characters in relation to susceptibility or resistance:

Pod color, pod hairiness and fragrance seemed to be closely associated with resistance or susceptibility. However, the presence or absence of any one of these characters alone did not seem to impart resistance or susceptibility partly or fully. Cumulative effect of the above said characters together may impart resistance to pod borers attack.

Among the four cultivars studied for anatomical details, it was revealed that positive relationship existed with amount of chloroplast and susceptibility, while the trend was reversed with respect to starch grains. Presence of anthocyanin pigment in the pod wall rendered the cultivar resistant. Pod wall thickness did not form a physical barrier to larval entry.

III. Factors inducing borer resistance:

(i) Preference or non-preference:

Non-preference to oviposition, seemed to be an important factor in imparting resistance to borer damage in L. niger cultivars. Non-preference to larval boring was not found to be an effective component of resistance in the cultivars tested.

(ii) Antibiosis:

PLS-24 and PLS-16-1 contained significant degrees of antibiosis, as demonstrated by reduced larval survival, reduced larval and pupal weights, prolonged larval duration and altered sex-ratio. The reduced larval and pupal weights would obviously result in decreased fecundity of the moths. Mortality of larvae during the later stages of development formed an important component of antibiosis.

IV. Yield-loss studies:

Cultivars sustained varying levels of seed yield loss at corresponding infestation levels. A few cultivars suffered negligible amount of seed yield loss inspite of heavy borer incidence. Such cultivars were identified as tolerant. PLS-93 exhibited high degree of tolerance, while MS-9579 and IC-661-1 were moderately tolerant.

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*Originals not seen.

APPENDICES

APPENDIX-I

Lablab niger cultivars screened for the pod borer resistance with their geographical origin

Sl. No.	Cultivar	Collected from*	Sl. No.	Cultivar	Collected from*
1	2	3	4	5	6
1.	PLS-2	Akola (M.)	23.	PLS-62-2	NK
2.	PLS-3-1	NK	24.	PLS-67	Veteria (?)
3.	PLS-5	Mushin (M.)	25.	PLS-69	Veteria (?)
4.	PLS-5-1	NK	26.	PLS-70-1	NK
5.	PLS-9	Niphad (M.)	27.	PLS-70-2	NK
6.	PLS-11-1	NK	28.	PLS-79	Ratangarh (?)
7.	PLS-11	Parbhani (M.)	29.	PLS-84	Monga (N)
8.	PLS-12	Poona (M.)	30.	PLS-86	Shillong (Megh.)
9.	PLS-15	Sabour (M.P.)	31.	PLS-88	Lanakotla (H.P.)
10.	PLS-16	Sabour (M.P.)	32.	PLS-92	NK
11.	PLS-16-1	NK	33.	PLS-94	Kutubuddinpur (H.P.)
12.	PLS-22	Alwar (R.)	34.	PLS-97	Coimbatore (T.N.)
13.	PLS-24	Bijpuri (B.)	35.	PLS-98	Coimbatore (T.N.)
14.	PLS-25	Kanpur (U.P.)	36.	PLS-99	Coimbatore (T.N.)
15.	PLS-29-1	NK	37.	PLS-102	Sambalpur (O.)
16.	PLS-46	Chirgani (?)	38.	PLS-106	Dindigul (T.N.)
17.	PLS-46-1	NK	39.	EC-7467-13	Australia
18.	PLS-54	Bahadurpur (B.)	40.	EC-10953-1	NK
19.	PLS-55	Lalgunj (B.)	41.	EC-18129	Nepal
20.	PLS-57	Tori (U.P.)	42.	EC-18130	Nepal
21.	PLS-62	Jampur (Pak.)	43.	EC-18176-A	Nepal
22.	PLS-62-1	NK	44.	EC-18320-B	Nepal

1	2	3	4	5	6
45.	EC-18544-A	NK	71.	IC-10800	NK
46.	EC-24653	Senegal	72.	IC-11025	NK
47.	EC-27889	Ghana	73.	IC-11313	NK
48.	EC-28826	Australia	74.	IC-11657	NK
49.	EC-28823	Australia	75.	Pusa bunch	Pusa (B.).
50.	EC-33015	U.S.S.R.	76.	Peotomal local	NK
51.	EC-36365	Australia	77.	V.M.V.College	NK
52.	EC-36413	Australia	78.	PLS-93	Bahraich (U.P.)
53.	EC-36414	Australia	79.	MS-9573	NK
54.	EC-36417	Australia	80.	MS-9579	NK
55.	IC-661	Karjat (M.)	81.	PLS-223	NK
56.	IC-661-1	NK	82.	PLS-124	NK
57.	IC-1846	AZadpur (D.)	83.	236	NK
58.	IC-23848-A	NK	84.	US-8	U.S.A.
59.	IC-3266-1	Bikaner (R.)	85.	Ginnu	NK
60.	IC-5665	Sangar (O.)	86.	263	NK
61.	IC-6120-2	Saklespur (K.)	87.	JDL-4	Jabalpur (M.P.)
62.	IC-7523	NK	88.	JDL-5	-do-
63.	IC-7523-1	NK	89.	JDL-6	-do-
64.	IC-9671	Sikkim	90.	JDL-31	-do-
65.	IC-10079	NK	91.	JDL-10	-do-
66.	IC-10079-A	NK	92.	JDL-34	-do-
67.	IC-10191	Latipura (R.)	93.	JDL-11	-do-
68.	IC-10193	NK	94.	JDL-42	-do-
69.	IC-10202	NK	95.	JDL-59	-do-
70.	IC-104831	NK	96.	JDL-88	-do-

1	2	3
97.	JDL-111	Jabalpur (M.P.)
98.	JDL-94	-do-
99.	JDL-107	-do-
100.	JDL-85	-do-
101.	JDL-53	-do-
102.	JDL-109	-do-
103.	JDL-120	-do-
104.	Local	Bangalore (K.)
105.	L-9	-do-
106.	L-83	-do-
107.	L-113	-do-
108.	L-119	-do-
109.	Annekieve	NK
110.	H-1	Hebbal (K.)
111.	H-2	-do-
112.	L-82	-do-
113.	H-3	-do-

*(B.) = Bihar, (D) = Delhi, (H.P.) = Himachal Pradesh
(K.) = Karnataka, (Megh.) = Meghalaya, (M.P.) = Madhya
Pradesh, (M.) = Maharashtra, (N.) = Nagaland, (O.) =
Orissa, (Pak.) = Pakisthan, (R.) = Rajasthan, (T.N.) =
Tamil Nadu, (NK) Not known, (U.P.) = Uttar Pradesh.

Appendix-II: Average pod borers damage to buds, flowers and pods of 113 Lablab niger cultivars in 1975, 1975-1976 and 1976-1977.

Sl. No.	Cultivar	1975			1975-1976			1976-1977		
		Av. % buds bored	Av. % flow-ers bored	Av. % pods bored	Av. % buds bored	Av. % flow-ers bored	Av. % pods bored	Av. % buds bored	Av. % flow-ers bored	Av. % pods bored
1	2	3	4	5	6	7	8	9	10	11
1.	PLS-2	-----NT-----	-----NT-----	-----	-	7.14	40.66	8.3	-	8.33
2.	PLS-3-1	-	-	32.3	-----NT-----	-----NT-----	-----	-----	-----NT-----	-----
3.	PLS-5-1	48	-	No pods	-----NT-----	-----NT-----	-----	27.41	18.18	36.67
4.	PLS-9	55	-	60.2	10.00	16.67	20.50	-----	-----NT-----	-----
5.	PLS-11-1	81	-	20.0	-	9.09	23.00	8.40	6.25	43.48
6.	PLS-11	56	-	27.0	-----	-----NT-----	-----	10.00	-	42.22
7.	PLS-12	-	-	42.0	-----	-----NT-----	-----	-	-	50.00
8.	PLS-15	36	50	52.0	-----	-----NT-----	-----	-----	-----NT-----	-----
9.	PLS-16	-----	-----NT-----	-----	11.50	10.50	23.35	-	-	34.55
10.	PLS-16-1	-----	-----NT-----	-----	14.50	13.64	4.50	9.09	10.00	7.65
11.	PLS-22	-	-	39.0	10.00	-	25.00	16.67	27.78	40.28
12.	PLS-24	-	-	8.16	15.00	8.33	18.11	-	-	16.66
13.	PLS-25	-----	-----NT-----	-----	-----	-----NT-----	-----	7.14	-	42.35
14.	PLS-29-1	-----	-----NT-----	-----	-----	-----NT-----	-----	30.77	-	27.14

1	2	3	4	5	6	7	8	9	10	11
15. PLS-46		27	-	14.28	25.00	7.14	31.00		-----NT-----	
16. PLS-46-1		-	-	28.57	0.0	0	8.40	-	-	54.55
17. PLS-54		-	-	51.33	4.16	0	28.65	20.00	25.00	18.75
18. PLS-55		-----NT-----		-----	2.35	2.15	29.16	-	-	26.00
19. PLS-57		56	-	-	12.50	0	32.00		-----NT-----	
20. PLS-62		22.30	-	22.00	0	0	35.66		-----NT-----	
21. PLS-62-1		6	-	23.00	0	0	27.94		-----NT-----	
22. PLS-62-2		-	-	27.00	2.7	1.7	26.33		-----NT-----	
23. PLS-67		-	-	50.00	-	1.5	2.68	33.33	12.50	21.05
24. PLS-69		52	57	26.50	-	27.27	26.33	-	-	18.75
25. PLS-70-1		-	-	19.23	8.35	24.20	18.34	14.28	-	28.99
26. PLS-70-2		40.74	-	34.23	0	0	14.65		-----NT-----	
27. PLS-79		-----NT-----		-----	6.25	5.10	20.14	28.57	9.50	50.00
28. PLS-4		-----NT-----		-----	7.50	0.0	21.56	20.00	60.00	22.22
29. PLS-86		-	-	54	0	0.0	39.00		-----NT-----	
30. PLS-88		25	16.66	7.65	0	7.80	11.73	45.00	54	30
31. PLS-93		50	33.33	38	51.50	24.00	48.00	7.35	25.00	58.33

	1	2	3	4	5	6	7	8	9	10	11
32. PLS-94	65	-	-	No pods	0	10.00	25.00	20.00	64.29	10.81	
33. PLS-97	-	-	57	36	6	10.00	36	-	-	35.71	
34. PLS-98	56.33	21.42	-	5.70	10.50	19.75	6.67	-	-	28.80	
35. PLS-99	95	-	56	0	6.25	19.33	2.94	21.43	15.23		
36. PLS-102	26	-	24.62	0	6.25	17.50	23.08	5.28	22.666		
37. PLS-106	36.36	72.72	29.33	10	33.30	30.65	9.09	37.50	No pods		
38. EC-7467-13	19	80	53	4.35	7.50	26.67	20.96	-	No pods		
39. EC-10953-1	-	-	-	-	-	-	-	25.12	40.10	39.00	
40. EC-18129	11.11	-	45	0	-	48.80	-	-	-	24.60	
41. EC-18130	-	-	-	-	-	-	-	12.00	73.33	35.26	
42. EC-18176-A	-	-	-	0	-	18.93	-	-	-	34.26	
43. EC-18320-B	29.50	-	15.50	5.7	0	27.33	0.0	38.46	42.48		
44. EC-18544-A	-	-	2.0	-	-	-	-	-	-	-	
45. EC-24653	-	-	-	43	9.09	31.50	-	-	-	-	
46. EC-27889	-	-	-	-	-	38.18	26.49	28.50	47.80		
47. EC-28826	-	-	54	-	-	39.00	54.54	20.45	18.50		
48. EC-36365	-	-	-	-	-	-	2.38	37.50	70.37		

1	2	3	4	5	6	7	8	9	10	11
49.	EC-36413	-	-	36	1.23	8.77	35.00	47.73	20.00	46.66
50.	EC-36414	56.30	-	46.50	-	-	40.10	10.00	-	23.00
51.	EC-36417	-	-	25.41	12.50	-	51.00	11.54	20.00	69.10
52.	IC-661	-	-	56.60	-	-	53.33	-	66.73	29.45
53.	IC-661-1	-	-	52.30	-	-	32.15	25.81	43.75	69.00
54.	IC-1846	0	-	45.25	51.00	0.00	23.00	58.94	58.67	28.57
55.	IC-23848-A	-	-	41.00	-	NT	-	-	-	46.00
56.	IC-3266-1	-	0	37.00	-	-	24.05	30.00	-	36.00
57.	IC-5665	37.50	-	No pods	3.03	7.40	27.46	15.50	19.05	26.24
58.	IC-6120-2	-	NT	-	-	NT	-	-	-	10.60
59.	IC-7523	32	-	No pods	25.00	1.00	0.00	-	-	36.66
60.	IC-9671	32.50	-	12.26	-	0.0	45.67	16.67	14.29	38.33
61.	IC-10079-A	-	NT	-	-	NT	-	21.00	27.27	34.28
62.	IC-10191	-	-	41.00	17.41	3.33	25.25	36.36	16.69	29.17
63.	IC-10193	-	NT	-	-	NT	-	37.00	28.57	40.63
64.	IC-10202	22	66	No pods	25.90	45.50	32.36	0	60.00	14.29
65.	IC-10483-1	58	-	No pods	-	NT	-	-	NT	-

	1	2	3	4	5	6	7	8	9	10	11
66. IC-10800				-----NT-----		50.00	-	22.14	7.50	-	35.71
67. IC-11025			41	-	2.5	2.70	8.33	8.56	-	-	42.86
68. IC-11313			80	-	100	21.42	22.22	37.33	-	-	33.33
69. IC-11657			-	-	45	6.48	17.55	68.66	-----NT-----		
70. IC-11658				-----NT-----		3.57	0	25.66	13.85	-	24.93
71. Pusa bunch			52.80	-	65.50	-----NT-----			-----NT-----		
72. Peotomal local			52	-	22	1.75	16.50	25.00	-----NT-----		
73. V.M.V.College			9.50	-	No pods	0	0	34.37	14.28	23.26	25.66
74. MS-9573			36.36	-	40	0	-	42.15	13.28	71.43	65.21
75. MS-9579				-----NT-----		0	27.27	23.67	-	-	42.52
76. PLS-223			6.25	-	43.37	-----NT-----			-	-	42.86
77. 236			37.50	-	38.14	-----NT-----			-----NT-----		
78. U.S.8			-	-	26.78	0	11.11	13.85	0	7.14	36.32
79. Ginnu			84.62	-	50.00	-----NT-----			-----NT-----		
80. 263				-----NT-----		-----NT-----			58.77	-	49.00
81. JDL-4				-----NT-----		14.71	18.62	26.30	-----NT-----		
82. JDL-10				-----NT-----		6.82	15.90	16.50	5.56	-	41.67
83. JDL-31				-----NT-----		1.10	2.57	40.20	-----NT-----		

	1	2	3	4	5	6	7	8	9	10	11
84. JDL-42				-----NT-----		3.41	16.50	19.28	-	-	31.25
85. JDL-59				-----NT-----		0	11.11	28.82	-----NT-----		
86. JDL-88				-----NT-----		24	34.66	42.90	-----NT-----		
87. JDL-111				-----NT-----		0	7.32	24.30	-----NT-----		
88. JDL-94				-----NT-----		3.50	24.18	50.46	-----NT-----		
89. JDL-5				-----NT-----		-----NT-----	-----NT-----	-----NT-----	13.64	30.00	54.55
90. JDL-6				-----NT-----		-----NT-----	-----NT-----	-----NT-----	25.63	-	24.40
91. JDL-11				-----NT-----		-----NT-----	-----NT-----	-----NT-----	20.00	-	50.94
92. JDL-34				-----NT-----		-----NT-----	-----NT-----	-----NT-----	0	-	37.15
93. JDL-107				-----NT-----		-----NT-----	-----NT-----	-----NT-----	-	-	14.20
94. JDL-85				-----NT-----		-----NT-----	-----NT-----	-----NT-----	37.50	-	15.66
95. JDL-53				-----NT-----		-----NT-----	-----NT-----	-----NT-----	0	-	23.08
96. JDL-109				-----NT-----		-----NT-----	-----NT-----	-----NT-----	11.11	-	16.40
97. JDL-120				-----NT-----		-----NT-----	-----NT-----	-----NT-----	3.50	-	38.35
98. Local				-----NT-----		-----NT-----	-----NT-----	-----NT-----	80.00	-	81.47
99. L-82				-----NT-----		0	3.12	24.85	-----NT-----	-----NT-----	
100. L-9				-----NT-----		2.50	45.17	40.26	-----NT-----	-----NT-----	

	1	2	3	4	5	6	7	8	9	10	11
101. L-83				-----NT-----		6.75	24.40	33.27		-----NT-----	
102. L-133				-----NT-----		11.36	36.36	50.43	20.00	-	18.64
103. L-119				-----NT-----		4.16	34.22	52.15	20.64	-	-
104. H-1				-----NT-----		-----NT-----	-----NT-----	-----NT-----	-	-	56.00
105. H-2				-----NT-----		21.00	44.05	37.14	31.05	42.16	31.07
106. EC-28823			28.57	-	28.33	0	0	34.13	12.48	20.00	26.67
107. EC-33015			15.38	42.85	53.33	-	-	37.15	18.46	20.05	55.56
108. Annekieve			63.64	-	33.33	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----
109. PLS-5			-----NT-----	-----NT-----	-----NT-----	15.56	28.43	28.84	-----NT-----	-----NT-----	-----NT-----
110. PLS-103			-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	37.12	10.08	36.20
111. IC-10079			-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	0	-	61.16
112. PLS-124			-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	29.09	-	40.38
113. H-3			-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	12.17	43.02	64.17

- Part not present at the time of observation

NT Not tested

Appendix-III: Ovipositional response of pod borers to 113 Lablab niger cultivars in 1975, 1975-1976 and 1976-1977 field tests.

Sl. No.	Cultivar	Average number of eggs laid per inflorescence										Total	1976-1977		
		1975					1975-1976						1976-1977		
		8-1-75	22-1-75	22-2-75	16-12-75	30-12-75	25-1-76	18-10-76	9-11-76	20-12-76	20-12-76	20-12-76	20-12-76	20-12-76	20-12-76
1.	PLS-2	-----NT-----			0.6	0.8	0.4	1.8	-	-	-	0	0	0	
2.	PLS-3-1	0.8	0	0	0.8	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	0	0	
3.	PLS-5-1	1.7	0.1	0	1.8	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	0	0	
4.	PLS-9	1.3	0.8	0.6	2.8	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	
5.	PLS-11-1	1.1	1.2	0	2.3	0	0	0	0.3	0	0	0	0	0.3	
6.	PLS-11	1.0	0	0	1.0	0	0	0	-	-	-	0	0	0	
7.	PLS-12	0.8	0.3	0.4	1.5	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	0	0	
8.	PLS-15	0.9	1.3	0	2.2	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	
9.	PLS-16	-----NT-----	-----NT-----	-----NT-----	-----NT-----	0	0.9	0.3	1.2	-	-	-	0.2	0.2	
10.	PLS-16-1	-----NT-----	-----NT-----	-----NT-----	-----NT-----	0	0.2	0	0.2	-	-	-	0	0	
11.	PLS-22	1.7	1.2	0	2.9	0	0.2	0	0.2	-	-	0.8	0	0.8	
12.	PLS-24	0	0.1	0	0.1	0.2	0	0	0.2	-	-	0	0	0	
13.	PLS-25	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	0	0	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
14. PLS-29-1				-----NT-----			-----NT-----						0.8	0.8
15. PLS-46			1.2	0.4	0	1.6	0	0	0	0.0		-----NT-----		
16. PLS-46-1			0.3	0.3	0	0.6	0	0	0	0.0			0	0
17. PLS-54			0.7	0.0	2.7	3.4	0.5	0.4	0.1	1.0			0.8	0.8
18. PLS-55			-----NT-----	-----NT-----			0.1	0	0	0.1			0	0
19. PLS-57			-----NT-----	-----NT-----			0	0	0	0.0		-----NT-----		
20. PLS-62			0.2	0.3	0	0.5	0	0	0	0.0			0	0
21. PLS-62-1			0	0	0	0	0.1	0	0	0.1			0	0
22. PLS-62-2			0.7	0.2	0.7	1.6	0.5	0	0	0.5			0	0
23. PLS-67			1.0	0.2	0.1	1.3	0	0	0	0			0	0
24. PLS-69			1.4	1.0	0.7	3.1	0	0	0	0			2.1	2.1
25. PLS-70-1			0.3	0	0	0.3	0.4	0.2	0	0.6			0	0
26. PLS-70-2			1.2	0.3	0.3	1.8	0	0	0	0	0	0.5	0.2	0.7
27. PLS-79			-----NT-----	-----NT-----			0.7	0	0	4.7			0	0
28. PLS-84			-----NT-----	-----NT-----			2.1	2.1	0	4.2			0.3	0.3
29. PLS-86			0	0.1	0	0.1	0.3	0	0	0.3		-----NT-----		
30. PLS-88			0.5	1.8	0	2.3	0.4	0.2	0	0.6			0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
31.	PLS-93	1.1	0.9	0.5	2.5	0.8	0	0.1	0.1	0.9	4.0	0.3	0.3	4.6
32.	PLS-94	1.6	1.1	0.1	2.8	0	0.1	0	0	0.1	-	0	0	0
33.	PLS-97	1.1	1.1	0.8	3.0	0	0	0	0	0	-	1.9	0.1	2.0
34.	PLS-98	1.1	2.8	1.6	5.5	0.5	0.7	0	0	1.2	0	0.1	0	0.1
35.	PLS-99	0.6	0.6	0	1.2	0	0	0	0	0	0	0.9	0	0.9
36.	PLS-102	1.5	0.9	0.1	2.5	0	0	0	0	0	0	0.5	0	0.5
37.	PLS-106	2.2	1.0	0.5	3.7	0	0	0	0	0	0	0.4	0	0.4
38.	EC-7467-13	3.6	1.3	0.1	5.0	1.4	1.5	0.3	0.3	3.2	-	-	0	0
39.	EC-10953-1	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	0.7	4.7	5.4
40.	EC-18129	0.4	0	0.5	0.9	0	0	0	0	0	-	0	0	0
41.	EC-18130	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	0	0.2	1.6	1.8
42.	EC-18176-A	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-	0.1	5.8	5.9
43.	EC-18320-B	1.2	0.4	0	1.6	0	0	0	0	0	1.5	0	1.9	3.4
44.	EC-18544-A	0	0.3	0.1	0.4	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----
45.	EC-24653	-----NT-----	-----NT-----	-----NT-----	-----NT-----	1.4	0	0	0	1.4	-----NT-----	-----NT-----	-----NT-----	-----NT-----
46.	EC-27889	-----NT-----	-----NT-----	-----NT-----	-----NT-----	0	0	0	0	0	-	0.3	1.3	1.6

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
47.	EC-28826	1.2	0.6	0.4	2.4	0	0	0	0	0	-	-	8.1	8.1
48.	EC-36365	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-	-	5.1	5.1
49.	EC-36413	0.8	0	0	0.8	0.2	3.1	0	0	3.3	-	0.3	0.2	0.5
50.	EC-36414	0.2	0.2	0	0.4	0	0.1	0.2	0.2	0.3	0.5	-	-	0.5
51.	EC-36417	0.4	0	0	0.4	0.8	0	0	0	0.8	-	0.9	0.6	1.5
52.	IC-661	0.6	0	0	0.6	0	0	0	0	0	-	0	0	0
53.	IC-661-1	2.8	0	0	2.8	0	0	0	0	0	-	-	0	0
54.	IC-1846	2.5	0.8	0	3.3	0.4	0.1	0	0	0.5	-	0.2	0.9	1.1
55.	IC-23848-A	0.0	0.1	0	0.1	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-	0	0.1	0.1
56.	IC-3266-1	0.3	0	0	0.3	0	0	0	0	0	-	0	1.1	1.1
57.	IC-5665	3.7	3.1	1.0	7.8	0.4	0	0	0	0.4	-	0	0	0
58.	IC-6120-2	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-	0.4	0.3	0.7
59.	IC-7523	1.4	2.1	0.3	3.8	0.8	0.2	0	0	1.0	-	0.1	0.9	1.0
60.	IC-9671	6.0	6.7	0.0	6.7	0	0	0	0	0	-	0.3	0.7	1.0
61.	IC-10079-A	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	-----NT-----	1.7	0.8	0	2.5
62.	IC-10191	0.4	0	0	0.4	0.5	0.3	0	0	0.8	-	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
63. IC-10193					NT				NT			1.1	0.3	1.4
64. IC-10202			1.7	0.2	0	1.9	1.9	5.5	0	7.4		1.2	2.4	3.6
65. IC-10483-1			3.8	2.2	0	6.0			NT				NT	
66. IC-10800					NT		0	0	0	0		0.2	0.1	0.3
67. IC-11025			4.1	5.3	0.6	10.0	1.4	0	0	1.4			0.6	0.6
68. IC-11313			0.3	0.2	0.0	0.5	0.2	4.7	0	4.9		0.4	0.4	0.8
69. IC-11657			1.7	0.1	0	1.8	0.6	2.8	0	3.4			NT	
70. IC-11658			1.0	-	-	1.0	1.4	0	0	1.4		0	0	0
71. Pusa bunch			1.6	0.7	0	2.3	-	-	-	1.0			NT	
72. Peotomal local			1.4	3.2	0.9	5.5	0.1	0	0	0.1			NT	
73. V.M.V.College			5.6	2.6	0.8	9.0	0.4	0	0	0.4		0.4	0.4	0.8
74. MS-9573			-	-	0.3	0.3	0.6	0	0	0.6	0.2	0	0.2	0.4
75. MS-9579			-	-	-	-	1.2	0.2	0	1.4		0.2	1.5	1.7
76. PLS-223			2.4	0	0	2.4			NT				NT	
77. 236			1.2	0	0	1.2			NT				NT	
78. U.S.8			1.7	0	0	1.7	0.8	0	0	0.8	0	0.2	-	0.2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
79. Ginnu			4.8	0.2	0	5.0			-----NT-----			-----NT-----		
80. 263					-----NT-----				-----NT-----			0	0	0
81. JDL-4					-----NT-----		2.4	3.1	-	5.5		-----NT-----		
82. JDL-10					-----NT-----		0.3	0.2	-	0.5		0	0.2	0.2
83. JDL-31					-----NT-----		0.2	0.2	-	0.4		-----NT-----		
84. JDL-42					-----NT-----		0.5	1.7	-	2.2		0	0	0
85. JDL-59					-----NT-----		0.2	0	-	0.2		-----NT-----		
86. JDL-88					-----NT-----		0.5	2.3	-	2.8		-----NT-----		
87. JDL-111					-----NT-----		2.1	0.5	-	2.6		-----NT-----		
88. JDL-94					-----NT-----		0.2	3.0	-	3.2		-----NT-----		
89. JDL-5					-----NT-----				-----NT-----			0.2	0.3	0.5
90. JDL-6					-----NT-----				-----NT-----			0	2.3	2.3
91. JDL-11					-----NT-----				-----NT-----			0	0	0
92. JDL-34					-----NT-----				-----NT-----			0	0	0
93. JDL-107					-----NT-----				-----NT-----		1.2	0.5	0	1.7
94. JDL-85					-----NT-----				-----NT-----		0.2	0.2	0	0.4
95. JDL-109					-----NT-----				-----NT-----		0.0	0.4	0	0.4
96. JDL-120					-----NT-----				-----NT-----			0.6	0	0.6

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
97. Local					-----NT-----			-----NT-----			-	4.6	2.7	7.3
98. L-82					-----NT-----		1.0	5.5	-	6.5		-----NT-----		
99. L-9					-----NT-----		1.2	1.6	-	2.8		-----NT-----		
100. L-83					-----NT-----		1.4	1.8	-	3.2		-----NT-----		
101. L-133					-----NT-----		0.3	0.2	-	0.5	0.2	0.2	-	0.4
102. L-119					-----NT-----		0	0.4	-	0.4		-----NT-----		
103. H-1					-----NT-----				-----NT-----		-	1.7	0.6	2.3
104. H-2					-----NT-----		2.6	3.5	0	6.1	2.9	0.8	0.8	4.5
105. EC-28823			0.7	0.9	0.2	1.8	0	0.3	0	0.3	-	-	0	0
106. EC-33015			0.8	0.5	0	1.3	0.3	0.1	0	0.4	-	2.2	0.8	3.0
107. Annekieve			0.2	0	0	0.2	0	-	-	0		-----NT-----		
108. PLS-5					-----NT-----		0.2	1.2	0	1.4		-----NT-----		
109. PLS-103					-----NT-----				-----NT-----		3.2	0	0	3.2
110. IC-10079					-----NT-----				-----NT-----		-	-	1.5	1.5

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
111. PLS-124				-----NT-----				-----NT-----			0	0.6	0.0	0.6
112. H-3				-----NT-----				-----NT-----			0	3.8	3.1	6.9
113. JDL-53				-----NT-----				-----NT-----			0	0.4	0.0	0.4
Mean No. of eggs laid.			2.31	1.41	0.67	4.39	1.19	0.67	0.47	2.33	1.89	2.32	0.683	1.104

- Part not present at the time of observation

NT Not tested.