MORPHO-PHYSIOLOGICAL BASIS OF RESISTANCE TO WHITEFLY BEMISIA TABACI GENNADIUS ON SOME COTTON CULTIVARS

By
VISHWAS KRISHNA PALIMKAR
M. Sc. (Agri.)

A DISSERTATION
SUBMITTED TO THE
MARATHWADA AGRICULTURAL UNIVERSITY
IN PARTIAL FULFILMENT OF THE
REQUIREMENT FOR THE DEGREE OF
Doctor of Philosophy
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DEPARTMENT OF ENTOMOLOGY
MARATHWADA AGRICULTURAL UNIVERSITY
PARBHANI

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1993

DEDICATED TO

MY BELOVED PARENTS

CANDIDATE'S DELCARATION

I hereby declare that dissertation or part thereof has not been submitted by me to any other University or institution for a degree or diploma.

PARBHANI

DATE : June 30th, 1993

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CERTIFICATE I

The dissertation, entitled "**Morpho-physiological basis of resistance to whitefly *Bemisia tabaci* Gennadius on some cotton cultivars**" presented herein by the candidate Shri Vishwas Krishna Palimkar, to the Marathwada Agricultural University, Parbhani, in partial fulfilment for award of the degree of Doctor of Philosophy in Agricultural Entomology, is a record of original and bonafide research work prosecuted by him under my supervision and guidance for a period of two years. The results in this dissertation have not been submitted to any other University or Institution for award of a degree or a diploma. The assistance received by the candidate during the course of investigation and also the sources of literature cited have all been duly acknowledged.

Therefore, I hereby opine and certify that this dissertation is of a high standard fit to warrant its presentation for the award of the said degree.

PARBHANI **(S.N. PURI)**

DATE: JUNE 30th, 1993 **Chairman**

CERTIFICATE II

This is to certify that this dissertation entitled "Morpho-physiological basis of resistance to whitefly *Bemisia tabaci* Gennadius on some cotton cultivars" submitted by the candidate, Shri. Vishwas Krishna Pal.ekar, to the Marathwada Agricultural Un.versity, arbhani, in partial fulfilment for the award of the degree of Doctor of Philosophy in the sub;ect of Agricultural Entomology is hereby approved for the said purpose by the External Examiner and the Student's Advisory Committee after an oral examination of the candidate.

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(V.K. Palimkar)

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INTRODUCTION

1. INTRODUCTION

Cotton, *Gossypium* spp., despite increasing stiff competition from synthetic fibres, has still retains its unique place as king of textile fibres all over the world. Among the several commercial crops grown in India, cotton has great impact on the rural economy besides providing employment to about five millions. India has a place of pride in the cotton map of the world, accounting for about 25 per cent of the area with about 7.76 million hectares and producing about 1.81 million tonnes lint. Maharashtra has 2.69 million hectares under cotton with lint production of 0.44 million tonnes(Anonymous, 1990).

The low yield level in our country is attributable to various reasons. But, of the several factors responsible for limiting the production, losses due to insect pests and diseases which reaches as much as 35 per cent, (Bindra, 1983) is considered as the most important one. As many as 160 species of pests have been reported to attack the cotton crop in India. In Maharashtra state 22 pest sepcies have been reported to infest the cotton crop (Kulkarni, 1979).

The cotton growers of the major cotton growing states of India through intensive insecticidal applications with conventional insecticides were able to control these pests to some extent, but not completely and

the yields were therefore low. With the advent of new synthetic pyrethroids the task became easier and even the most destructive bollworms inflicting heavy losses could be effectively managed. This situation suddenly changed during 1984-85 with build up of whitefly *Bemisia tabaci* Genn. which was till this period considered to be the pest of minor importance, assumed the status of a major pest in Andhra Pradesh, Tamil Nadu, Maharashtra and Karnataka so much so this becomes national problem and this pest is now recognised as an important enemy of cotton in our country.

The uniterrupted sap sucking by both nymphs and adults of whitefly located on the underside of the leaf, coupled with the ability to multiply rapidly, has resulted in yield losses in Maharashtra during 1984-85 crop season (Puri *et al.*, 1986). Moreover, the quality of Kapas, oil and protein content in seed was also drastically affected. Due to its continuous feeding, the leaves develop chlorotic appearence, turn reddish and become brittle and finally drop down from the plant. This leads to the stunting of plants, shedding of fruiting bodies and reduction in the size of bolls. The bolls are also forced to burst prematurely, affecting the quality of lint. Besides these direct damages, the sticky honeydew exuded by the insect, drops on the open bolls and the cotton gets discoloured due to mold formation affecting picking, slows down ginning and spinning operation.

The unabated population explosion of whitefly in recurrent spells, season after season has exposed the inadequacy of the existing control measures. Control of *B. tabaci* through the use of insecticides has become less effective because the insect has developed resistance to several insecticides. Therefore, the possibility of the insect further intensifying its activity in Maharashtra and spreading in adjoining states in future posed a serious threat to cotton cultivation in the country. This grave situation calls for an all out attempt to develop other strategies for its effective management. The use of resistant genotypes offers an opportunity to avoid sole reliance on the use of chemicals for management of insect pests and is most important constituent for effective integrated pest management programme.

According to van Emden (1974) plant resistance to insect pests may be identified as "any reduction in growth rate of the pest populaltion, influenced by the host plant". Since the damage to host plants is often correlated with pest population density, the resistance can also be expressed as "any reduction in damage developmental rate" i.e. the reduction in the amount of damage caused during a unit of time. Investigation were therefore initiated to study the mechanism of resistance and identify the most important source of resistance by studying different plant

characters. This may help to incorporate desirable characters in the future breeding programme to develop resistant cultivars of cotton.

The present research project was initiated with the following objectives :

1. To study behaviour of *B. tabaci* on different cultivars of cotton.
2. To study ovipositional preference/non-preference for egg laying on different cultivars of cotton under choice and no choice conditions.
3. To determine egg incubation period and development time on different cotton cultivars.
4. To examine stability of resistance on different cotton cultivars.
5. To observe impact of morphological, anatomical, physiological, nutritional and biochemical characters of plant on intensity of whitefly.
6. To study the behaviour of *B. tabaci* in relation with cotton species.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The importance of whitefly *Bemisia tabaci* (Genn.), is known since early part of this century in India. However, the work on this pest, particularly on cotton, is scanty as this pest was confined to certain pockets in India. The present investigations were therefore, undertaken to find out the most important source of resistance to whitefly. The literature reviewed pertaining to these aspects throughout the world is mentioned here under the following heads.

2.1 The problem of whitefly

Whitefly was originally described on tobacco in 1889 in Greece. It is a polyphagous pest reported on more than 506 host plants belonging to 74 botanical families and widely distributed over 98 countries of the world (Cock, 1986).

As early as in 1905, it was reported for the first time in India on cotton (Misra and Lamba, 1929) and was described as *Bemisia gossypiperda* (M & L).

Husain and Trehan (1933) had reported severe damage of whitefly to cotton crop in Punjab. They further reported that whitefly damage reduced nutrition to plants leading to shedding of fruiting parts, reduction in boll setting, reduction in boll size and stunting of plants ultimately reducing yield and quality of cotton.

Mound (1965) reported reduction in yield to the extent of 50 per cent. Further, honey-dew excreted by nymphs of whitefly subsequently colonising black sooty mold fungi affected the photosynthesis of plant (Watson *et al.*, 1982).

Whitefly also acts as a potential vector of many viral diseases and its importance has increased many fold. More than 70 diseases have been reported in cultivated and weed plants, most of them transmitted by *B. tabaci* (Muniyappa, 1983).

Borad (1991) reported that seasonal periodicity of yellow vein mosaic disease of Okra and leaf curl virus of tomato corresponded with fluctuations in the population density of their vector, *B. tabaci*. The incidence, severity and rate of spread of yellow vein mosaic of Okra and leaf curl virus were maximum in summer and rabi, respectively. An appearent infection rate of leaf curl virus of different tomato varieties, was found to be more dependent on the stage of the varieties rather than abundence of *B. tabaci*.

There was severe infestation of whitefly in cotton which resulted in heavy losses in Andhra Pradesh (Reddy *et al.*, 1986 a), Karnataka (Patil *et al.*, 1986), Maharashtra (Puri *et al.*, 1986) and Gujarat (Patel *et al.*, 1987). The losses due to whitefly in India were estimated by Rajak and Diwakar (1987) to the tune of 20 lakh bales

(worth Rs. 103 crores) in Andhra Pradesh and 1.52 lakh bales (worth Rs. 78 crores) in Karnataka during 1985-86. Whereas, during 1986-87, the losses were estimated to the tune of 40 per cent in Gujarat and 20-30 per cent in Maharashtra.

2.2 Nature of damage

Adults and nymphs of *B. tabaci* suck the cell sap from lower surface of the leaves by inserting their sharp stylet in the leaf tissues. Due to contineous feeding chloratic spots develop on the leaves which later coalesce and the leaves become reddish, brittle and finally drop from the plant prematurely. This results in shortage of nutrition to plant leading to shedding of fruiting bodies and reduction in size of both as well as stunting of plants. The bolls are also forced to burst prematurely leading to poor quality lint (Watson *et al.* 1982).

In addition to direct damage, whitefly excrets a honey-dew like sticky fluid which drops on lower leaves and favours the development of black sooty mould which interferes with photosynthesis, ultimately creating deficiency of nutrients to the plants. Further, honey-dew falls on open bolls and causes "stickiness" which affects the quality of cotton (Berlinger, 1983).

2.3 Egg incubation period and Development time from egg to adult emergence

Biology of whitefly greatly vaired due to temperature and humidity as well as nutritive value of the plants.

Husain (1931) studied the biology of *B. tabaci* on cotton and reported that duration of egg stage ranged from 4 to 5 days in May to October, while it lasted for 13 days in April. A complete life cycle was observed to require 14 to 27, 36, 72 to 107 and 30 days during April-Sept., Oct.-Nov., Nov. to Feb. and in March respectively.

Husain and Trehan (1933) studied the life history of whitefly in detail on cotton and they reported that female laid 6 to 8 eggs per day with an egg laying capacity from 28 to 43, maxmum being 119 in total life span. Incubation, nymphal and pupal periods varied from 5 to 7, 14 to 17 and 3 to 5 days, respectively. Total life cycle was completed in 22 to 35 days in October.

Bedford (1936) reported that in the laboratory the developmental periods from oviposition to adult emergence varied from 14 to 23 days in August and 25 to 41 days in December.

El-Helay *et al.* (1971) studied biology of whitefly on sweet potato in laboratory and found that egg hatched in 10.7, 10.1 and 5 days at 23°C, 28°C and 31°C

temperatures, respectively. The larval and pupal periods were 9.8 and 6.2 days at 24.5°C temperature, respectively.

Azab *et al.* (1971) also studied the life cycle of *B. tabaci* on sweet potato and reported that female laid 48 to 394 eggs with an average of 161. The egg, larval and pupal periods lasted for 3 to 29, 5 to 18 and 4 to 23 days, respectively. The total life cycle was completed in 17 to81 days. Nene (1972) observed total life cycle of 13 to 72 days on urdbean.

Butler *et al.* (1983) studied biology of *B. tabaci* on cotton in laboratory at constant temperatures. The egg stage varied from 5 days at 32.5°C to 22.5 days at 32.5°C temperatures. Whereas the total developmental time from egg to adult varied from 16.6 days at 30°C to 61.5 days at 14.9°C temperatures.

Pimple and Summanwar (1984) studied the life cycle of *B. tabaci* on tobacco under laboratory conditions during different months of the year and they reported duration of total life cycle 11 to 17 days during April to June, 17 to 25 days during July to October and 83 days during December to February. They observed 15 broods of whitefly during the year.

Coudriet *et al.* (1985) studied the total developmental time from egg to adult of *B. tabaci* on different hosts and reported that developmental time varied from 20 to27 days with an average of 21.7 ± 1.9 days on cotton.

Gerling *et al.* (1986) reported total developmental period of *B. tabaci* ranging from 14 days in summer to 85 days in winter, of which 40 to 50 per cent time was under the pupal stage. The number of eggs laid by a female were 100 during total life span.

Coikesen and Sekeroglu (1987) studied the effect of changes in temperature on the development of the cotton whitefly under laboratory in Turkey and stated that total development from egg to adult required 68 and 36 days at fluctuating temperature of 12^{o} - 20^{o}C (mean 16.8^{o}C) and 18^{o} - 24^{o}C (mean 21.3^{o}C), respectively, while it required 24.2 days at constant temperature of 25^{o}C.

Mohanty and Basu (1987) had reported total developmental period of 13 to 16 days from egg to adult stage in April-May and 33 to 47 days during November to February.

Sakalkale (1987) also studied the biology of *B. tabaci* on cotton plants and reported that the development time was 15 to 24 days with an average of 17.7 days.

Borad (1991) studied the development period of whitefly on different hosts and required comparatively shorter period when reared on brinjal, cotton, soybean, tobacco, greengram and tomato in descending order compared with other host plants.

2.4 Resistance to B. tabaci

Painter (1951) reported that resistance of plant to insect attack may be defined as the relative amount of heritable qualities possessed by the plant which influence the ultimate degree of damage done by an insect. In practical agriculture it represents the ability of a certain variety to produce the large crop of good quality than do ordinary varieties at the same level of insect population.

The sweet potato whitefly *Bemisia tabaci* (Genn). has assumed a status of serious pest on cotton and several other important vegetable crops. Conventional methods of its control are ineffective because of positioning of *B. tabaci* on underside of leaves and natural coating of waxy material on immature forms that reduces the efficacy of insecticides used. Further, rapid development of resistance to insecticides and undesirable effect on natural enemies of whitefly makes it necessary to develop alternative methods for whitefly management. The genetic resistance in crop varieties to insects is often referred as plants' first line of defence. Some morphological, physiological and biochemical traits could play an important role in imparting resistance to cotton whitefly.

2.5 Morphological Characters

2.5.1 Leaf Hairiness

The pubescence of the plant is increased by H, gene. When Sm gene is present, the stem and mature leaves have very few trichomes even though the terminal has increased pubscence. The combination of these two genes offers a possibility to reduce both trash content and thrips susceptibility (Remey, 1962).

Mound (1965) reported that *B. tabaci* posses greater flight activity on glabrous than hairy cotton cultivars. He concluded that whitefly stayed longer on hairy leaves because microclimate there was more favourable for them.

The correlation was studied between hair density of leaf and whitefly incidence on different cotton varieties / crosses. It was observed that number of whiteflies increased as the hair per 1/4 th circle of microscopic field increased. The correlation coefficient was 0.87 showing highly significant correlation betwen number of whiteflies and hair density (Butler and Muramato, 1967).

On soybean cultivars *B. tabaci* laid more eggs on young leaves than on mature leaves of the same plant although young leaves possessed greater hair density (Rossetto *et al.*, 1977).

Omran and El-Khider (1978) have reported that hairy varieties were preferred by whitefly for egg laying. It fixed the egg at the base of the hair.

In an investigation in the Sudan on the characters conferring resistance to *B. tabaci* (Genn.) in cotton, low leaf hair density and deeply lobed cotton leaves reduced the infestation. These two characters conferred 40 and 20 per cent resistance, respectively (Sippel *et al.*, 1983).

Butler and Henneberry (1984) reported that Stoneville-825 and Deltapine-41 cotton varieties with pubescent leaves had the highest population of *B. tabaci* in Arizona and California in 1982. Eight smooth leaved cotton had significantly fewer adults in two minute vaccum samples than their semi-smooth and pubescent counterparts. Smooth leaf cultivars `AET-5' had significantly fewer adults of both whitefly species viz. *Bemisia tabacci* (Genn.) and *Trialeurodes abutilonea* (Haldeman), than did pubescent leaf plants (Butler and Wilson, 1984).

The number of eggs and adult whiteflies were found significantly lower in the glabrous varieties than hairy or pubescent varieties of cotton. The adult activity and cultivar ovipositional preference of *B. tabaci* on cotton Stoneville-825, with normal hairy leaves had more adults and eggs than either the semi-smooth or smooth leaf iso-lines (Butler *et al.*, 1986).

Reddy *et al.* (1986)c observed the lower incidence of whitefly on cultivars LK-861 and LPS-141 as compared to MCU-5 and LRA-5166 in Andhra Pradesh.

Butter and Vir (1989) reported that there are high significant correlation between the whitefly nymph population and hair density, and between eggs and hair density. They further found that genotype USA 22 was almost resistant to whitefly because it had fewer leaf hairs.

Venugopal Rao *et al.* (1990) reported that incidence of *B. tabaci* was proportional to the number of stellate haris and total hair on the abaxial surface of leaves. The mean of stellate hair was 14.2 per cm^2 and of total hair was 67.1 per cm^2 in resistant genotypes LK-861, LPS-141, D-53, NHV-1, JK-97, FBRN, 2F, Aloz and JK-286 while, corresponding values in the most susceptible genotypes were 428.1 and 2439 per cm^2.

Md. Ilyas (1988) studied 22 diversified cotton genotypes and revealed that there was highly significant positive correlation between hair density and whitefly incidence.

Ajankar (1992) observed a highly significant positive correlation between hair density and whitefly incidence on cotton at Parbhani.

2.5.2 Hair length

In a study with *E. devastans* Tidke and Sane (1962) found a high correlation of resistance with thickness of leaf lamina, angle of insertion of hairs, length of hairs per unit of leaf vein, and hairs on the leaf lamina.

Muttuthamby *et al.* (1969) reported that the HP, gene is present in the local cotton varieties of Pakistan viz. Pak 51, L11 and Al 134, producing hair of sufficient lengh and density to confer resistance to jassid.

When different cotton cultures were studied for their reaction against whitefly Md. Ilyas (1988) found that there was also highly significant positive correlation between hair length and whitefly population.

Butter and Vir (1989) concluded that hair length had a negative effect on the egg count of whitefly on cotton.

In cultivars Eknath, Sarvottam and SM-150 having higher hair density but lower incidence of whitefly could be due to shorter hair length (Ajankar, 1992).

2.5.3 Leaf Area

Niles (1980) reported that modification of cotton leaf shape seemed to be an effective means to increase tolerance to the banded-winged whitefly.

Jones (1982) concluded that high level of resistance to banded whitefly may probably be due to the

decreased shade and humidity associated with the okra leaf canopy which is less favourable to this pest.

Bindra (1983) thought that Okra leaf character might play an important part in imparting resistance to *B. tabaci*.

Okra and super-okra type conferred high degree of resistance and this difference was related to the difference in microclimate which prevailed within the reduced canopy due to okra or super okra leaf shape. This indicated that the reduced canopy helped in better air movement, providing lower relative air humidity and probably higher temperatures, which as an overall effect rendered the environment less favourable for the whitefly (Sippel *et al.*, 1983).

According to Khalifa and Gameel (1983) the whitefly build up was significantly reduced in the Sudan on the okra leaf line. Plant with this characters tends to have an open plant canopy which differs from the shady, humid and warm conditions usually favoured by the whitefly.

[illegible] characters [illegible], [illegible] [illegible] okra leaf [illegible] normal leaf [illegible] ([illegible] [illegible]).

Butler and Wilson(1984) found that increased *B. tabaci* caught on sticky traps might be due to dislike for the okra leaf character, thus in moving around to locate more suitable hosts more adult whiteflies encounterd the sticky traps.

Chakravarthy *et al.* (1985) reported that the populations of *B. tabaci* were positively correlated with the number of leaves per plant.

The Okra leaf isolines of ST-8701 N and ST-8737 N had significantly fewer whiteflies than the parental breeding stocks; but the Okra leaf isolines of ST-825 N and DES-24-8N did not differ significanly (Butler and Wilson, 1986).

Ozgur and Sekeroglu (1986) found that the cultivars having large, dense leaves and a closed canopy had much higher number of immature stages of whitefly, whereas, the resistant cultivars had less, either small or okra leaf shapes, were taller and had an open canopy. This open canopy shape provided good air circulation and lacked the shady and. humid condition usually favoured by *B. tabaci*.

Sekeroglu and Ozgur (1988) reported that the cultivar infested by smaller population of the *aleurodidae* than were found on Caroline Queen, locally grown variety, had an open canopy and glabrous leaves that were either

small or shaped like okra leaves. The cultivar LA 510 was the most important resistant variety, as the population of *B. tabaci* was consistently lower on this type than those on Caroline Queen.

Md. Ilyas (1988) did not find significant correlation between leaf area of cotton plants and the whitefly incidence. Leaf area had a negative effect on the egg count of *B. tabaci* on cotton (Butter and Vir, 1989).

Flint and Parks (1990) stated that okra leaf characteristic did not have any considerable effect on the number of nymphs.

2.6. Anatomical character of leaf

B. tabaci has to penetrate it's stylet and ovipositor into the tissues for feeding and egg laying, respectively. Therefore anatomical structure of leaf has a great effect on their feeding as well as egg laying habit, that ultimately results into preference or non preference of host. It would appear that the differences in anatomical structure occuring in plants may affect the relative accessibility of the tissues, especially the vascular bundles. Thus anatomical structure of leaf could also play an important role in imparting resistance to cotton whitefly.

Nymphal whiteflies always occur on the lower surface. Hargreaves (1915) suggested two reasons for this; i.e. thinness of lower cuticle and closeness of phloem to

lower surface. With *B. tabaci* on cotton the most important is probably that its stylets can't reach the phloem from upper surface.

Pollard (1955) reported that stylets of the nymphs on the lower surface can reach the phloem except when they follow a convoluted path. The stylets ususally penetrate between the epidermal cells. Penetration through the parenchyma is predominantly intercellular, and the objective is phloem.

Dobrowski (1972) reported that the thick leaf tissues of *Polargonium peltatum* served as a mechanical obstacle to feeding by the green house whitefly (*Aleurodidal vaporarium*).

Garava *et al.*, (1982) also reported that lamina thickness was a contributing factor towards resistance to several sucking pests of cotton.

Butter and Vir (1989) suggested a morphological basis of resistance to the whitefly, *B. tabaci* (Genn.) on cotton. The population of whitefly nymphs and eggs were positively correlated with leaf thickness. Thickness of leaf was directly related with anatomical structure.

Incidence of whitefly was inversely proportional to the thickness of lamina as well as distance betwen abaxial epidermis and phloem tissue of cotton leaf. Lamina thickness and distance between abaxial

epidermis and phloem were higher in resistant group than susceptible group (Venugopal Rao *et al.*, 1990).

In a study for multiple resistance to sucking pest complex in cotton, Ansingkar *et al.* (1992) suggested that compact arrangement of cellular layers, accompanied with shorter mesophyll layer, presence of palisade layer on abaxial surface and longer distance to phloem from abaxial epidermis are the desirable characters in developing resistance. All these characters are in favourable direction in diploid asiatic cotton species while most of them except one are evidenced in resistant *hirsutum* genotypes.

Puri *et al.* (1993) studied the role of leaf morphology of cotton on incidence of whitefly (*B. tabaci*). They concluded that, the probable reason for differential reaction of *B. tabaci* towards different cultivars of cotton could be due to differences in their anatomical structures. Genotypes having shorter distance to phloem tissues could help in easy penetration of stylets as compared to cultivars with longer distance. Increased distance of phloem from abaxial epidermis resulted in significant reduction in adult population. Similarly, cotton varieties with thicker mesophyll tissue layer were preferred by whitefly adults. Wider width of mesophyll tissue might provide an easy and ample food and space for holding the egg peduncle of whitefly. Hence, most of the upland cotton varieties are susceptible to whiteflies as compared to asiatic cotton.

2.7 Physiological characters

2.7.1 pH of cell sap

Husain *et al.* (1936) observed that there was correlation between whitefly incidence and pH of cotton leaves. They reported that whitefly population had increased on the cotton having higher pH of leaves.

Magal *et al.* (1982) studied effect of pH on whitefly incidence within the range of 4 to 8 under laboratory conditions. They found that old leaves with 6.8 pH were significantly more attractive to whitefly as compared to young leaves having pH values 5.9.

Berlinger *et al.* (1983) reported that whitefly adults were able to differentiate between pH values at the level of 0.25 and showed clear preference for pH varying from 6 to 7.25. They reported that the number of resting whiteflies were highest at pH 7. There was significant reduction in the number of resting whiteflies below 6 and above 7 pH. They further observed that in commercial crop whitefly preferred old cotton leaves (120 days old) having pH 6.8 than younger cotton leaves (60 days old) having pH 5.9.

Md. Ilyas (1988) also observed highly significant positive correlation between pH of leaf and whitefly incidence. He observed higher population of whitefly in the cotton cultivars having high pH of 6.3 as compared to cotton cultivars having low pH values.

Rote (1989) however reported that the association between pH of leaf and adult population of whitefly was non significant as the correlation co-efficients were -0.166 and -0.144 during 1987-88 and 1988-89, respectively.

2.7.2 Chlorophyll

Md. Ilyas (1988) found that there was highly singificant negative correlation between chlorophyll content of leaf and whitefly incidence. As the chlorophyll content of leaf increased the whitefly population showed a decrease.

Shaw *et al.* (1989) reported that statistically no correlation could be established between the total chlorophyll content and the thrip population. The correlation co-efficient value between thrips population and percentage loss of chlorophyll was positive but was marginally lower than the statistical significance. They also reported that the thrip population had no clear correlation with the chlorophyll 'a' as well as chlorophyll 'b' but on the other hand thrip population had positive correlation with percentage reduction of chlorophyll 'a' and 'b'.

2.8 Nutritional characters

2.8.1 Nitrogen

Nitrogen content of leaf plays an important role in whitefly incidence. It increases as a result of high fertilization and /or application of insecticides.

Joyce (1958) and Joyce and Robert (1959) reported that whitefly incidence was associated with nitrogen content of leaf. Its population had increased with the increase in nitrogen content in leaf as a result of DDT application on cotton.

Ripper and George (1965) found that whitefly population increased proportionally with the increase in nitrogen content of cotton leaves because of stimulating effect of higher nitrogen content on fecundity of whitefly.

Tester (1977) reported that there was low nitrogen level in two susceptible varieties of soybean viz., (P1) 227687 and (P1) 229358.

Abdelrahman and Saleem (1978) found increased whitefly population in the plots fertilized with high nitrogenous fertilizer as a result of reduction in life cycle of whitefly.

Weisser (1980) reported that whitefly population exhibited an increasing trend with the increase in leaf nitrogen following DDT application.

Harbough *et al.* (1982) observed that high dosages of nitrogenous fertilizers increased nitrogen content of *Crysenthemum* leaves and ultimately increased fertility of whitefly resulting in higher incidence.

Wilson *et al.* (1988) studied fecundity and total developmental time of mite, *T. utricael*,on grapevine leaves having different nitrogen content under field condition and reported that mite population had responded significantly to increasing nitrogen content of leaf. They further reported that fecundity of mite was increased and total developmental time was reduced significantly due to higher nitrogen content of leaf.

Md Ilyas (1988) reported that nitrogen content of leaf and whitefly incidence were also highly significant and positively correlated.

Rote (1989) indicated that there was highly significant positive association between nitrogen content of leaf and whitefly population indicating increase in whitefly population with an increase in leaf nitrogen.

2.8.2 Vitamin 'C'

Vanderzant and Davich (1961) and Vanderzant *et al.* (1962) found that ascorbic acid was necessary for proper development of the boll weevil *Anthonomus grandis* Boheman. When adults (but not larvae) were fed with 100 mg of ascorbic acid / 100 g of diet, the egg hatch was normal; however, 50 mg/100 g of diet reduced the hatch.

The weight of adult *Anthonomous grandis* Boheman and the length of the developmental period were normal over 4 generations when adult and larval diets were formulated with 7.50 - 393.75 mg of ascorbic acid per 100 g of diet. Approximately 500 adults were produced in each generation. When both diets were prepared without ascorbic acid only 10 adults were produced in the 2nd generation and none thereafter (Hudspeth *et al.*, 1969).

2.8.3 Sugar

Tester (1977) demonstrated that two plant introductions have higher sterol and carbohyderate concentration than susceptible varieties to soybean insects.

Adult whiteflies were fed artificially, via a parafilm membrane, on media solution consisting of different buffers at various pH values, with or without sucrose. The preferred sucrose concentration in the media was 5-15%; adding 10% more sucrose to the medium increased somewhat the accepted range of pH, although it did not change the preferred pH (Magal *et al.*, 1982).

There was a statistically significant positive correlation between the average number of larvae of *B. tabaci* on the 'maximal leaf' on the one hand, and reducing sugars and total sugars on the other hand. (Rimon, 1984).

Sundermurthy *et al.* (1986) found that sugar content of cotton leaf did not have any significant relationship with whitefly population.

Venugopal Rao *et al* (1990) found that sugar content of cotton leaf did not show any significant relationship with whitefly build up.

2.8.4 Micronutrients

Venugopal Rao *et al.* (1990) found that cultivars which showed resistant reaction against whitefly had higher contents of phosphorus and magnecium and lower of nitrogen and iron than their counterparts. But the other parameters like sugar, protein, potassium, calcium and copper did not show any significant relationship with whitefly build up. Similar results were observed by Sundermurthy *et al.* (1986) and Anonymous (1987).

2.9 Biochemical parameters

Plant biochemicals that have adverse effects on insect feeding behavious may thereby reduce the probability for survival, particularly among species in which the larval forms are incapable of locating a more suitable host. Insect mortality may then result from starvation or semi starvation, combined with unfavourable environmental forces. A distinction needs to be drawn between resistance to feeding and resistance that acts by interferring with the physiological process of the insect (Beck, 1965).

2.9.1 Gossypol

Gossypol, tannins and phenols are present in varying amount in plants and block the availability of nutrients to insects (Reese and Schmidt, 1986).

Elewa *et al.* (1978) reported that glandless cotton were found to be more susceptible than glanded ones to infestation by *B. tabaci*.

Antibiotic effects of gossypol are positively due to reduced nutritional quality or non availability of nutrients or enzyme inhibition, which lead to the prolonged development and reduced growth of the insect (Sharma *et al.*, 1982).

Baloch *et al.* (1982) reported that glandless, nectariless and gossypol free varieties proved susceptible to whitefly.

Khalifa and Gameel (1983) tested cotton varieties against whitefly and they found that high gossypol content supported significantly small population of *B. tabaci*.

Patil *et al.* (1986) reported lower population of whitefly adults on pigmented cultivars as compared to DCH-32.

Butter and Vir (1989) worked out correlation and found that the adult population of *B. tabaci* and

gossypol glands on stem internodes were positively correlated.

Ajankar (1992) observed that there was highly significant positive correlation between density of gossypol glands on stem internode and boll bract and whitefly incidence. However, there was no significant correlation between density of gossypol glands on leaf lamina and whitefly incidence.

2.9.2 Phenol

Increase in phenolics was reported to be responsible for disease resistance in cotton seedlings (Ramasami and Shanmugham, 1977).

Bhat *et al.* (1981) and Zummo *et al.* (1984) reported the variations in the levels of phenols, tannins and proteins in cotton cultures, showing differential reaction to sucking and bollworm pests.

Phenolic compounds are known to impart resistance in many crop plants against pest and diseases. Ilango and Uthamasamy (1989) reported that there was higher precentage of total phenol in resistant variety (JK 260) of cotton to bollworms.

Phenol contents were higher in resistant group than in highly susceptible, susceptible and moderately resistance (Supriya, MERS 17, G Cot 12, G Cot 100 and L 389) groups. But its relation ($r = -0.1427$) with whitefly incidence was not significant.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The field evaluation of germplasm entries and pot culture studies were coducted at Cotton Research Station of Marathwada Agricultural University at Nanded and Parbhani. The chemical analysis were carried at the Department of Biochemistry, College of Agricultural Technology, Parbhani. The material used and methods adopted are described here.

3.1 Preliminary Field Screening of Cotton Germplasm Against Whitefly

Germplasm maintained by Cotton Research Station, M.A.U., Nanded was utilized for the study. Two hundred entries each were screened from *Gossypium hirsutum* and *arboreum* groups. The experiment was conducted during 1988. The number of adults on the 2nd (top leaf), sixth (middle leaf) and tenth leaf from the top (lower leaf) were recorded from two plants in each germplasm line. The results pooled together and mean number of adults on upper, middle and lower leaf were calculated.

3.2 Rapid Leaf Screening of Cotton Germplasm

The general population level of *B. tabaci* on cotton at Parbhani was very low during 1989 and hence selection pressure on the entries during the field screening was very low. To avoid the lower population of whiteflies on the leaf and also for a accurate evaluation of preference/non-preference character of the host plant

from the test entries, a rapid leaf screening method devised by Ranjeet(1987)was used. Since whiteflies prefer to lay eggs on the first fully opened leaf from the top, such leaves of cotton cultivars were excised from the plants and immediately brought to the laboratory. The petioles were immersed in small vial filled with water and entry numbers were tagged on the leaves. A wooden cage (75 cm x 45 cm x 30 cm) covered with black muslin cloth was placed over the leaves in the vials and females of *B. tabaci* were released into the cage at the rate of 10 females per leaf. Black muslin cloth was used to prevent the general tendency of the whiteflies to ascend to the top of the cage due to their strong phototrophic response and to aid them in settling on the leaves. Whiteflies were released during evening hours to facilitate their easy settling on the leaves. Each entry was replicated twice. The whiteflies were allowed to oviposit for 24 hours and average number of eggs laid per leaf were worked out. The results were analysed as a CRD using $\sqrt{x+1}$ transformation.

Check entries were also subjected to laboratory screening in confinement to find out the preference/non preference for egg laying under no choice condition. The test entries were grown in pots in cloth house with two plants/pot replicated four times. When the plants attained ninety days age, which is the most preferred stage for egg laying (Berlinger *et al.*, 1983). The plants in each of the pots were covered using polythene cylindrical cages with

PLATE 1 : SPECIALLY DESIGNED CLOTH HOUSE FOR BIOLOGICAL STUDY OF *Bemisia tabaci*

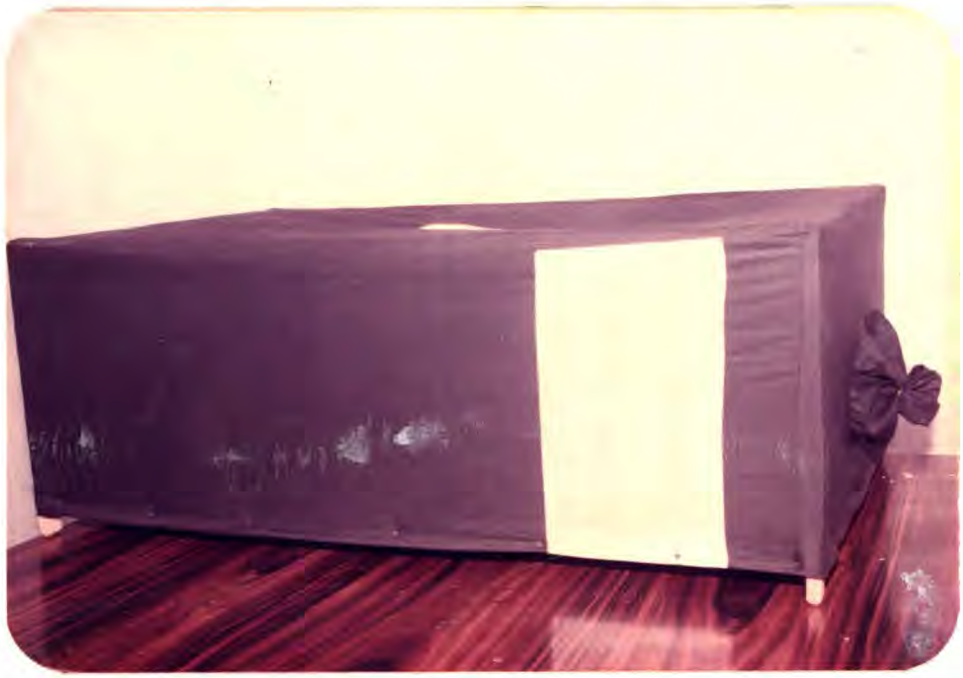


PLATE 2 : SPECIALLY DESIGNED WOODEN CAGES COVERED BY BLACK MUSLIN CLOTH FOR EGG LAYING BEHAVIOUR OF Bemisia tabaci UNDER CHOICE CONDITION.

PLATE 3 : SPECIALLY DESIGNED CYLINDRICAL POLYTHENE SHEET TO COVER A POT FOR EGG LAYING BEHAVIOUR OF Bemisia tabaci UNDER NO-CHOICE CONDITION.

the muslin cloth on top. Adult female whiteflies were released in individual cages during late evening at the rate of 10 whiteflies per leaf. Oviposition was allowed for 24 hours and the number of eggs laid were noted on all the leaves in the cages and averaged out per leaf. The results were analysed as a CRD using $\sqrt{x + 1}$ transformation.

3.3 Field Screening of Germplasm Selected from Preliminary Field Screening

32 cultivars were selected from preliminary field screening including some commercially grown cultivars since whiteflies have assumed epidemic propertion in many of the cotton growing tracts. Observations on whitefly incidence were recorded at 30 days interval on five plants selected at random from the net plot. Adults and nymphs of whiteflies were counted seperately from three leaves (top, middle and bottom) per plant (Sippel *et al.*, 1983). Adult population was counted by rotating leaf gently by holding the petiole in between thumb and index finger, so as not to disturb the adult whiteflies resting on the lower side of the leaf (Rote, 1989). The nymphs of whiteflies were counted with the help of 10 x lens. Observations were recorded during morning hours between 6.00 and 8.00 a.m. when the whitefly adults were less mobile. The data on whitefly adults and nymphs were transformed to $\sqrt{x + 1}$ formula of transformation and analysed statistically.

3.4 Egg Incubation Period and Duration of Development of *B. tabaci* on Different Cultivars

Total developmental period (from egg to adult) of whitefly was studied seperately in each cultivar to find out the reaction of whiteflies to exposure to these types and evaluate the antibiosis component available, if any. Two plants from each cultivar were selected and one fully expanded leaf from each plant at apex was tagged. Plastic cages specially designed for studying the life cycle of whitefly were placed on the plants (Borad, 1991) and each leaf was covered in such a way that whitefly adults could not come out. The leaf was cleaned earlier to ensure that no egg, larva or pupa of whitefly remained on it before releasing whitefly adults. Approximately fifty adults of whitefly were released in each cage and kept for 24 hours. Thereafter, the adults were removed from the cages and the leaves were examined for further development upto the emergence of adults. The results were analysed as CRD using $\sqrt{x + 1}$ transformation.

3.5 Morphological Studies

3.5.1 Hair density

The hair density per cm^2 on leaves of all the cultivars was recorded at 90 day after germination. Three fully matured leaves were selected at random from each cultivar and leaves were brought to the laboratory for estimating the hair density. Number of hair present in the

field visible in magnification were counted at 5 spots per leaf and transformed into density i.e. number of hair per cm^2 and averaged out. The real leaf area visible in magnification is known from its real diameter with a real scale.

3.5.2 Hair length

The matured leaves of each cultivar were brought to the laboratory and the length of the hair was measured with the help of occular micrometer by cutting the transverse section of leaf . Five samples were taken from each cultivar for measurement at 200 X magnification and averaged out.

3.5.3 Leaf area

Leaf area of each cultivar was measured with the help of electric leaf area meter. Upper, middle and lower leaf of five plants selected from each cultivar were collected and brought to the laboratory for estimating the leaf area.

3.5.4 Number of stomata

Three fully matured leaves were selected at random from each genotypes. The frequency of stomata (No. of stomata per sq cm) at 200 x magnification was worked out in five different microscopic field by using "Fevicol" sticker (Nayeem and Dalvi, 1989). The number of stomata per cm^2 are observed and transformed similarly as hair density (3.5.1 above).

3.6 Physiological, Nutritional and Biochemical Studies

3.6.1 Glassware and chemicals

"Corning" and "Borosil" glasswares were used throughout the experiments. Glasswares were cleaned with detergent and again rinsed throughly in tap water and finally with distilled water and were dried thoroughly.

3.6.2 Preparation of reagents and solution

3.6.2.1 Ascorbic acid standard solution

100 mg of ascorbic acid was accurately wighed and made upto 100 ml with 2% HPO_3. 4 ml of this solution was diluted to 100 ml with 2% HPO_3 (1 ml = 0.04 mg of ascorbic acid).

3.6.2.2 Indophenol reagent

100 mg of 2,6-dichlorophenol-indo phenol dye and 84 mg of sodium bicarbonate were dissolved in hot (85-95^{o}C) distilled water, cooled and made upto 100 ml. The solution was filtered and diluted 25 ml to 500 ml with distilled water.

3.6.2.3 Ethanol extract

One gram of fresh leaf samples were crushed to fine paste in few ml of boiling alcohol and the extract was filtered through Whatman No.1 filter paper. The paste was again resuspended in few ml of boiling alcohol and again filtered. The final volume of the extract was made to 10 ml. This extract was used for estimation of gossypol and sugar etc.

3.6.2.4 Ammonium molybdate solution

Twenty five g of ammonium molybdate was dissolved in 300 ml distilled water containing 200 ml diluted H_2SO_4.

3.6.2.5 Arsenomolybdate colour reagent

Solution A : In 445 ml of distilled water 2.5 g of ammonium molybdate was dissolved and to this 2.1 ml concentrated Na_2SO_4 was added.

Solution B : 0.3 g of sodium arsenate was dissolved in 2.5 ml distilled water.

Solution A and soultion B were mixed and stored inbrown bottle at 37°C for about 30 hours before use.

3.6.2.6 Catechol standard solution

Dilutions were made with distilled water to get 10 mg to 80 mg catechol per ml. This solution was stored at room temperature.

3.6.2.7 Copper reagent

Copper reagent A : Sodium carbonate 2.5 g, potassium sodium tartarate (Rochelle salt) 2.5 g, sodium carbonate 2 g and 20 g sodium sulphate (unhydrous) were disolved seperately in small quantities of distilled water and volume made upto 100 ml with distilled water, filtered and stored at room temperature.

Copper reagent B : Copper sulphate 5.7 g was dissolved in 50 ml distilled water to which one drop of concentrated H_2SO_4 was added.

25 parts of reagent A and 1 part of reagent B were mixed just before use.

3.6.2.8 Folin-ciocalten reagent

The commercialy prepared reagent (2N) was mixed with equal quantity of distilled water and stored in amber colour bottle at $2^{o}C$.

3.6.2.9 Sodium carbonate

20 g of sodium carbonate was dissolved in distilled water and the volume was made upto 100 ml.

3.6.2.10 Ammonium molybdate-sulphuric acid reagent

25 g ammonium molybdate was dissloved in 300 ml water. 75 ml concentrated H_2SO_4 diluted to 200 ml was then added to the ammonium molybdate solution.

3.6.2.11 Hydroquinone solution

0.5 g hydroquinone was dissolved in 100 ml water and 1 drop of concentrated H_2SO_4 was added to retard the oxidation.

3.6.2.12 Standard phosphate solution

0.4394 g pure dry KH_2PO_4 was dissolved in water and diluted to 1 litre. 10 ml of this solution was diluted to 100 ml to give working standard solution. (1 ml = 0.01 mg phosphorus).

3.6.2.13 Reagents for gossypol estimation

Solution A : 715 ml of ethanol was diluted to 1000 ml with distilled water and to this 0.2 ml glacial acetic acid and 200 ml ether (peroxide free) were added.

Solution B : 3 g of ascorbic acid was dissloved in 45 ml of solution A.

3.6.3 Estimation of pH of leaf

The pH of cell sap was estimated at 90 and 120 days after germination. The leaves from four replications were collected, mixed through and treatment wise pH of leaf was estimated. Each sample of ten grams was crushed in a blender, mixed with 50 ml distilled water and pH of crude extract was estimated by using a pH meter (Toshniwal pH meter Cat. No. CL 46). The pH of leaf extract was estimated twice and averaged out as suggested by Berlinger *et al.* (1983).

3.6.4 Estimation of chlorophyll of leaf

The a, b and total chlorophyll content were estimated at 90 and 120 days after germination.

2 g leaf tissues were homogenised with few ml of pure acetone. It was filtered through filter paper (Whatman No.1) with the addition of 80 per cent acetone. The filtration was repeated with 80 per cent acetone till the pulp and filter paper lost green colour. Volume of the filterate was made upto 100 ml by adding 80 per cent acetone (Arnon, 1949). The optical density of the chlorophyll extract was recorded with spectrometer set at 645 and 663 nm against 80 per cent acetone solvent blank. The quantity of chlorophyll present (mg/g of tissue) in the extract was calculated from the equations given below.

$$\text{Chlorophyll a} = (1.27 \times D\ 663) - (2.69 \times D\ 645) \times \frac{V}{1000} \times \frac{1}{W}$$

$$\text{Chlorophyll b} = (2.69 \times D\ 645) - (4.68 \times D\ 663) \times \frac{V}{1000} \times \frac{1}{W}$$

$$\text{Total chlorophyll} = (1.27 \times D\ 663) - (2.69 \times D\ 645) \times \frac{V}{1000} \times \frac{1}{W}$$

Where,

D = optical density at 645 and 663 W/L

V = The final volume of the 80 per cent acetone chlorophyll extract.

W = Fresh weight in grams of the tissue extracted.

3.6.5 Estimation of nitrogen

Nitrogen content of leaf was estimated at 90 and 120 days after germination. Fully expanded leaves from each net plot were plucked and brought to the laboratory and kept in an oven for drying. The dried leaves were finally powdered in grinder and fine leaf powder was used for estimaion of nitrogen. It was estimated by Kjeldahl's method (Jackson, 1967).

3.6.6 Estimation of calcium

An aliquot (25 ml) of the mineral solution was diluted to about 150 ml with distilled water. A few drops of methyl red were added and the mixture neutralisd with ammonia till the pink colour changed to yellow. The solution was heated to boiling and 10 ml of ammonium oxalate were added. The mixture was then allowed to boil

for a few minutes and glacial acetic acid added till the colour became distinctly pink. The mixutre was kept aside in a warm place, and when the precipitate settled down, the supernatant was tested. The precipitate was then filtered through Whatman No. 40 or 42 filter paper, and washed with warm water till free of oxalate. The precipitate was transferred to a beaker by piercing a hole in the filter paper and pouring over it dilute (2 N) sulphuric acid (about 5-10 ml). The solution was then heated at about 70^{o}C and titrated against N/100 $KMnO_4$ solution.

1 ml of N/100 $KMnO_4$ = 0.2004 mg of calcium.

3.S.7 Determination of total phosphorus

To an aliquot 0.1 ml of the mineral solution are added to 1 ml of ammonium molybdate, 1 ml of hydroquinone and 1 ml of Na_2SO_3 solutions in this order mixing well after each addition. The volume is then made up to 15 ml with water and the solution throughly mixed. After 30 minutes. The optical density of this solution is measured in a photoelectric colorimeter, against a reagent blank (prepared in the same way as the test except that the test solution is omitted) using a red filter (660 m/u). The phosphorus content of the sample is read off from standard curve prepared with standard phosphate solution (range 0.01-0.1 mg P) following the same procedure as described above.

$$\text{Phosphorus (mg/g)} = \frac{\text{Graph reading (x mg)}}{\text{Volume taken}} \times \frac{\text{volume of mineral solution (ml)}}{\text{Weight of sample (g)}}$$

3.6.8 Estimation of ascorbic acid

The requisite volume of standard ascorbic acid solution - 1,2, 2.5, 3.4 and 5 ml were pipetted to dry test tubes and made upto 5 ml with the requisite amount of 2% HPO_3. 10 ml of dye was added with a rapid delivery pipette. After shaking, reading was taken within 15 to 20 seconds. Spectrometer was set to 100% transmission using a blank consisting of 5 ml of 2% HPO_3 solution and 10 ml of water. The red colour was measured at 518 nm. Standard curve was obtained by plotting absorbance against concentration.

For each sample 5 ml of the extract was taken in a dry test tube towhich 10 ml of dye was added and measured as in standard.

The concentration of ascorbic acid from the standard curve was noted and the ascorbic acid content in the sample was calculated as given below.

$$\text{mg of ascorbic acid per 100 g/ml of sample} = \frac{\text{Ascorbic acid sample}}{\text{1 ml of solution taken for estimation}} \times \frac{\text{Volume made up}}{\text{Volume of sample taken}} \times 1000 \times 100$$

3.6.9 Estimation of sugars

3.6.9.1 Reducing sugars

To 0.1 ml of ethanol extract, distilled water was added to adjust the volume of 1 ml. The copper reagent mixture was added and the tubes were kept in boiling water for 20 minutes. Later, they were taken out, cooled and 1 ml of ammonium molybdate colour reagent was added. The volume was made up to 25 ml with distilled water. After adjusting the colorimeter with blanks (all reagents except tissue extract) absorbance was recorded at 520 nm. The estimates are expressed as Mg of reducing sugars per g of dry sample from standard curve (Nelson 1944).

3.6.9.2 Total sugars

The ethanol extract was used for the estimation of total sugars. The extract (0.5 ml) was taken in test tubes and 2 ml of 1 N H_2SO_4 was added. The tubes were kept in water bath at 49^{o}C for 30 minutes and then cooled. One drop of methyl red indicator and 2 ml of 1N NaOH were added. The volume was made upto 1 ml with distilled water. One ml of copper reagent mixture was added and kept in boiling water for 20 minutes. After cooling 1 ml of Nelson's arsenomolybdate reagent was added and volume was made to 25 ml with distilled water. After adjusting the colorimeter with blank (all reagents except ethanol extract) the colour intensity was read at 520 nm. Total sugars were calculated using the standard curve obtained

from various concentration of glucose solution. The results for quantity of total sugars were expressed in mg/g of dry sample.

3.6.10 Measurement of total phenols

The alcohol extract of plant tissue was used to estimate total phenol content colorimetrically using Folin-Ciocalteau reagent (Bray and Thorpe, 1954).

To 0.1 ml extract, 0.9 ml of distilled water was added. One ml of 1 N Folin-Ciocalteau reagent and 2 ml of 20 per cent sodium carbonate solution were added to diluted extract. After shaking the tube vigorously it was boiled for one minute on boiling water both. The tubes were cooled in running tap water. The colour intensity was measured by spectrophotometer at 645 nm. A blank containing all reagents except extract was used to adjust absorbance to zero. For standazrd curve same procedure was followed by using standard solution of catechol of various concentraion and from the recorded OD values standard curve was plotted. The phenol catechol equivalents from standard curve of catechol and expressed in mg/g of dry sample.

3.6.11 Determination of gossypol

3.6.11.1 Free gossypol

0.1 g of sample was transferred to a 250 ml glassstoppered flask. 3 ml of solution B and 0.5 ml of concentrated HCl were added to this and mixed gently.

After about 3 minutes for the decolourization of the chlorophyll. 30 ml of ethyl ether was added and swirl the flask in warm water until the ether boils sufficiently to expel the air. The stopper was inserted with a twisting motion. The flask was shaken vigorously for a 10 minutes on a mechanical shaker. The extract was filtered under reduced pressure through a filter paper disc. The flask was washed and then filtered with small portion of ethyl ether without pouring the small amount of water layer on the filter. This procedure prevented the transfer of any anthocyanins into filterate. The filterate was transferred to a 50 ml volumetric flask and made to 50 ml with a solution A. Immediately 5 ml aliquot was pipetted in triplicate to 25 ml volumetric flask containing 5 ml of solution A. 0.5 ml of freshly distilled aniline was quickly added to two of the flasks, reserving the aliquot in the third flask for the reference solution. The flasks containing the sample and reference were placed into water bath heated to 75^{o}C for 40 minutes. A cap was placed over the flask containing the reference solution to prevent contamination with aniline vapour. After cooling, the referenc and samples were diluted to 25 ml with solution A. The absorbance was determined at 445 mm using aniline as a reference. (Smith , 1966)

The gossypol content of the sample was calculated from a standard absorbance concentration curve prepared by converting pure gossypol dissolved in soultion A to the dianiline derivative.

Standard curve: The standard curve was prepared by dissolving 25 mg of gossypol in a few ml of ether in a 100 ml volumetric flask. This was diluted to 100 ml with solution A and mixed. 10 ml of this solution was diluted to 100 ml in a volumetric flask with solution A and mixed. From this, aliquots in triplcate were pipetted into 25 ml volumetric flasks covering a range of 0.025 to 0.200 mg of gossypol and diluted the smaller aliquots to 5 ml with solution A. One aliquot was diluted from each replicate to 25 ml with solution A, it was mixed and reserved as a reference solution. The gossypol in the remaining aliquots converted to dianilinogossypol as previously described and absorbance was at 445 mm using the appropriate reference.

The free gossypol was calculated from the following equation

$$\%\ \text{Free gossypol in sample} = \text{absorbance} \times \frac{1}{a} \times \frac{100\ \text{mg of sample}}{\text{the aliquot used}}$$

Where a = absorbance mg of gossypol as dianilinogossypol in 25 ml of solution A = 3.064

3.6.11.2 Bound gossypol

The extracted residue from the free gossypol determination was transferred to a 250 ml glass stoppered flask. To this 2 ml of solution a and 2 ml of freshly distilled aniline, were added and placed on the metal top of a steam bath (not directly exposed to the steam) and heated for 45 to the steam) and heated for 45 minutes to

convert the gossypol to dianilinegossypol. The flask was removed from the steam bath. To this , 50 ml of redistilled hexane was added. The flask was warmed by swirling in hot water (60-70^{o}C) to expel air. The stopper was inserted with a twisiting motion, and then shaken vigorously for 30 minutes on a mechanical shaker. With the funnel covered with watch glass, a portion of the extract was filtered through a Whatman filter paper No. 4 into a small narrow neck flask. The absorbance of the filterate was estimated at 440 mm using hexane as the reference solution. Bound gossypol was calculated from the following equation.

$$\% \text{ gossypol} = \frac{\text{absorbance} \times 2 \times \frac{1}{a} \times 100}{\text{weight of sample in mg}}$$

Where a = absorbance / mg of gossypol as dianilinogossypol in 25 ml of hexane = 3.172

Standard curve : The standard absorbance curve was prepared by dissolving 25 mg of pure gossypol in 25 ml of ethyl ether in a 100 ml volumetric flask and then diluted to volume with hexane and mixed. 10 ml of the solution was transferred to a 100 ml volumetric flask and diluted to volume with hexane and used as the gossypol standard. Aliquots were taken converted to dianilinogossypol and determined for leaves except hexane was used as the solvent and the absorbance was determined at 440 mm. (Smith, 1966)

3.7 Anatomical studies

For the anatomical studies, infestation free plants were selected at ramdom from each genotypes after 90 days of sowing. The second leaf from the top on the main stem was selected for studies. One leaflet was fixed in FAA (Formaldehyde : Acetic Acid : Alcohol 70% 5:5:90). The leaflets were cut into 0.5 cm x 1 cm rectangular segments and were processed by following the steps as below.

Steps in tissue processing for blocks

Leaf segment ---> 70% Ethanol (overnight) ----> 90% Ethanol (4 hours)

↓

100% Ethanol (6 hours) <-- 100% Ethanol (6 hours) <-- 100% Ethanol (6 hours) <-- 100% Ethanol (6 hours)

↓

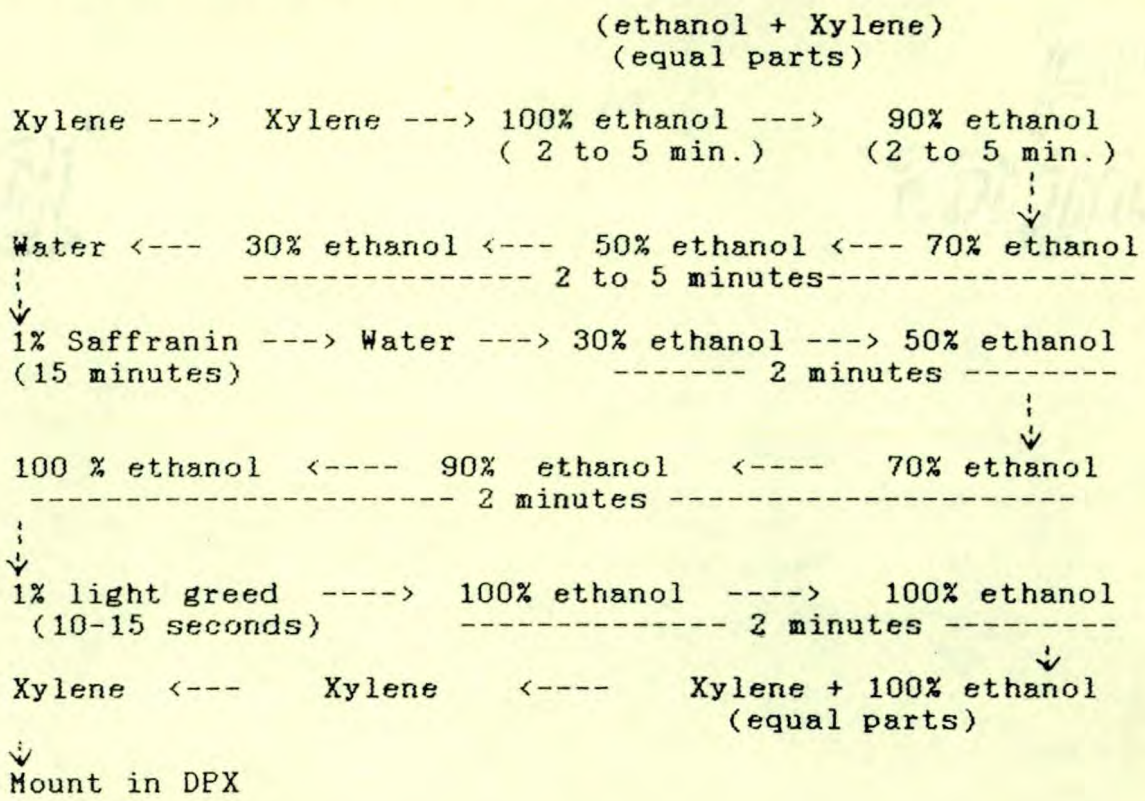
100 % Ethanol + Xylene (Equal parts, 4 hours) ----> Xylene (12 hours) -------->

↓

Xylene + soild paraffin (equal parts, 4 hours) <--- Melted paraffin (changed for evry 8 hrs till traces of xylene removes at 60° in incubator) <--- Embeded in paraffin blocks

The section of 10 µm thickness were cut using rotary microtome. Thin sections were mounted on glass microslides in Mayer's egg albumin (Sass, 1951).

Steps in staining with saffranin and light green



The masurement of various cell were taken using occular micrometer at 100 x magnification in five different microscopic fields.

3.8 Correlation and Regression of Whitefly Abundence with Different Characters of the Test Entries.

Morphological characters such as number of stellate hairs on the leaf, length of stellate hairs, leaf area and number of stomata and physiological characters like pH of cell sap and total chlorophyll content of leaf, nutritional parameters like nitrogen, phosphorus, calcium,

sugars and vitamin C, biochemical parameters like phenol and gossypol content of leaf have been reported to interfere with normal ovipisitional preferences of whiteflies and development of nymph and adult of *B. tabaci*. Hence, genotypic correlations and regressions of these characters and whitefly population were worked out.

EXPERIMENTAL FINDINGS

4. EXPERIMENTAL FINDINGS

Four hundred genetically diverse genotypes of cotton were screened critically against whitefly for their resistance reaction at Cotton Research Station, Nanded.

Based on preliminary screening 32 resistant and susceptible genotypes comprising of *G. hirsutum*, *G. arboreum* and hybrids of *hirsutum* x *hirsutum* and *hirsutum* x *barbadense* were selected for detail studies. Some of the lines have been reported to be resistant to *B. tabaci* earlier and they were also included for confirmation. The results of present investigation are presented under following heads.

4.1 Behaviour of whitefly during the entire season.

4.2 Ovipositional preference /non preference of *B. tabaci* under choice and no-choice conditon.

4.3 Egg incubation period and development time from egg to adult on different cultivars.

4.4 Stability of cotton cultivars for resistance against whitefly.

4.5 Impact of morphological, anatomical, physiological, nutritional and biochemical characters of plant on incidence of whitefly.

4.6 Correlation and regression studies.

4.7 Behaviour of *B. tabaci* in relation to cotton species.

4.1 Behaviour of whitefly during the entire season

The experiment was conducted to screen 32 cultivars against whitefly during kharif 1989-90 and 1990-91. The results are presented below.

4.1.1 Adult population of *B. tabaci* during 1989-90 and 1990-91.

The data presented in Table 1 revealed that the adult population per leaf varied from 2.22 to 8.94 adults/ leaf at 90 days during 1989-90. The lowest population of *B. tabaci* adults was recorded on *desi* cultivars viz. Namdeo, Rohini, Eknath and Jyoti followed by LK 861, PF, PONF, NH 210 and NH 360. These cultivars were significantly superior over rest of the cultivars. Cultivars LRA 5166, Pournima, DHY 286, NHH 44 and PKV HY.2 showed highest mean population.

Obsertation recorded at 120 days after germination (1989-90) indicated significant differences among 32 genotypes for adult population of *B.tabaci* (Table 1). The lowest population was recorded on cultivars viz. American Nectariless, LPS 141, LK 861, OKRA, PF, PNF, PONF, NH 210, NH 360, Eknath, Rohini, Namdeo and Jyoti. NHH 44, PKV Hy.2, Gland less, PH 93, LRA 5166, Pournima, DHY 286 and NS 15 harbored highest population i.e. more than 6 adults per leaf.

Table 1: Reaction of selected cotton cultivars against *B. tabaci* adults

Variety	Number of whitefly adults per leaf				Mean
	1989		1990		
	Days after germination				
	90	120	90	120	
DS 28	6.64 (2.76)	5.00 (2.44)	10.59 (3.40)	8.54 (3.08)	7.69 (2.94)
NS 15	7.11 (2.78)	6.76 (2.78)	12.95 (3.73)	9.34 (3.21)	9.04 (3.16)
AM.NECT	5.52 (2.55)	3.74 (2.17)	8.82 (3.13)	5.95 (2.43)	6.01 (3.16)
G 67	6.57 (2.75)	5.32 (2.51)	8.73 (3.11)	8.38 (2.89)	7.23 (2.65)
AC 738	7.76 (2.95)	5.99 (2.64)	10.9 (3.44)	8.46 (3.07)	8.28 (3.04)
BN 1	6.55 (2.74)	4.66 (2.37)	9.39 (3.22)	8.46 (3.07)	7.27 (2.87)
DHY 286	8.30 (3.04)	7.06 (2.83)	10.54 (3.39)	8.99 (3.16)	8.72 (3.11)
AK 32	6.59 (2.75)	4.96 (2.44)	8.03 (3.03)	6.71 (3.16)	6.57 (2.75)
MCU 5	6.92 (2.81)	4.63 (2.37)	9.87 (3.29)	8.16 (3.02)	7.40 (2.89)
POURNIMA	8.72 (3.11)	6.74 (2.78)	8.63 (3.10)	7.11 (2.84)	7.80 (2.96)
LPS 141	4.15 (2.26)	2.86 (1.96)	7.12 (2.84)	4.37 (2.31)	4.62 (2.37)
LK 861	3.79 (2.18)	2.16 (1.77)	6.98 (2.82)	3.60 (2.14)	4.13 (2.26)
LRA 5166	8.01 (3.00)	6.13 (2.67)	12.02 (3.72)	8.94 (3.15)	8.99 (3.16)
SUMAN	6.45 (2.72)	3.48 (2.11)	8.93 (3.15)	6.86 (2.80)	6.43 (2.72)
SUPRIYA	6.54 (2.74)	5.23 (2.49)	8.85 (3.13)	6.99 (2.82)	6.90 (2.81)
PH 93	6.98 (2.82)	6.21 (2.68)	10.44 (3.38)	7.29 (2.87)	7.73 (2.95)
GLANDLESS	7.73 (2.95)	6.33 (2.70)	11.93 (3.59)	8.67 (3.10)	8.99 (3.16)
OKRA	4.02 (2.24)	2.99 (1.99)	6.44 (2.72)	3.88 (2.20)	4.33 (2.30)
PF	3.25 (2.06)	2.67 (1.91)	5.68 (2.58)	2.81 (1.95)	3.60 (2.14)
PNF	3.87 (2.20)	2.37 (1.83)	4.78 (2.40)	2.91 (1.97)	3.48 (2.11)
PONF	2.72 (1.92)	1.91 (1.70)	4.87 (2.42)	2.15 (1.77)	2.91 (1.97)
NH 210	2.66 (1.91)	2.25 (1.80)	3.46 (2.11)	3.38 (2.09)	2.94 (1.98)
NH 360	2.67 (1.91)	2.11 (1.76)	3.23 (2.05)	3.86 (2.20)	2.97 (1.99)
H 4	6.88 (2.80)	5.95 (2.63)	11.31 (3.50)	8.60 (3.09)	8.18 (3.02)
NHH 44	8.60 (3.09)	6.92 (2.81)	11.23 (3.49)	9.65 (3.26)	9.10 (3.17)
PKV HY.2	8.94 (3.15)	6.59 (2.75)	10.82 (3.43)	10.34 (3.36)	9.18 (3.19)
DCH 32	6.43 (2.72)	4.78 (2.40)	8.02 (3.00)	6.90 (2.81)	6.53 (2.74)
NHB 12	6.49 (2.73)	4.96 (2.44)	8.47 (3.07)	6.32 (2.70)	6.56 (2.74)
EKNATH	2.54 (1.88)	2.31 (1.81)	3.50 (2.12)	2.47 (1.86)	2.71 (1.92)
ROHINI	2.39 (1.84)	1.93 (1.71)	3.83 (2.19)	2.39 (1.84)	2.63 (1.90)
NAMDEO	2.22 (1.79)	2.28 (1.81)	2.19 (1.78)	1.64 (1.62)	2.08 (1.75)
JYOTI	2.77 (1.94)	2.10 (1.76)	3.55 (2.13)	2.53 (1.87)	2.74 (1.93)
SE ±	.39	.39	.52	.48	4.28
CD at 5%	.79	.79	1.06	.98	1.18

Note : Figures in parentheses indicate transformed values.

Incidence of adult whitefly during 1990-91 (90 days) indicated that adult population varied from 2.19 adults per leaf (Namdeo) to 12.95 adults per leaf (NS 15) (Table 1). The lowest population varied in between 2.19 to 3.83 adults per leaf and was recorded on Namdeo, NH 360, NH 210, Eknath, Jyoti and Rohini. Cultivars PF and PNF showed higher population mean of whitefly as compared to year 1989. Highest population of more than 10 adults per leaf was recorded on NHH 44, PKV Hy.2, H 4, Gland less, PH 93, LRA 5166, DHY 286, AC 738, NS 15 and DS 28.

Comparison of the number of *B. tabaci* adults at 120 days (1990-91) on 32 genotypes (Table 1) showed that all pigmented and *arboreum* strains except one of the asiatic genotype Namdeo (1.64 adults per leaf) had significantly lower adults over their counterparts. The cultivar Pournima which recorded highest population at 90 and 120 days (1989) and 90 days (1990) showed moderate numbers of whitefly. The highest population of more than 8 adults per leaf was recorded on PKV Hy. 2, NHH 44, H 4, DS 28, NS 15, G 67, AC 738, BN 1, DHY 286, MCU 5, LRA 5166 and Glandless.

4.1.2 Nymph population of *B.tabaci* during 1989-90 and 1990-91

At 90 days (1989-90) singificant differences among 32 genotypes (Table 2) for nymph population were evident. The population varied from 2.34 nymph / leaf (Namdeo) to 11.68 nymph/ leaf (PKV Hy.2). NHH 44 and PKV

Table 2: Reaction of selected cottor cultivars against *B. tabaci* nymphs

Variety	Number of whitefly nymphs per leaf				Mean
	1989		1990		
	Days after germination				
	90	120	90	120	
DS 28	6.80 (2.79)	8.66 (3.10)	11.74 (3.56)	18.57 (4.42)	11.44 (3.52)
NS 15	8.41 (3.06)	10.72 (3.42)	15.99 (4.12)	22.48 (4.84)	14.40 (3.92)
AM.NECT	5.08 (2.46)	6.03 (2.65)	7.98 (2.99)	10.48 (3.38)	7.39 (2.89)
G 67	6.59 (2.75)	10.27 (3.35)	8.60 (3.09)	18.65 (4.43)	11.02 (3.46)
AC 738	8.23 (3.03)	10.12 (3.33)	9.46 (3.23)	13.52 (3.81)	10.33 (3.36)
BN 1	6.60 (2.75)	7.38 (2.89)	8.26 (3.04)	10.26 (3.35)	8.12 (3.01)
DHY 286	9.49 (3.23)	10.15 (3.33)	12.83 (3.71)	14.65 (5.06)	14.28 (3.90)
AK 32	5.53 (2.55)	6.72 (2.77)	8.88 (3.14)	10.33 (3.36)	7.86 (2.97)
MCU 5	5.39 (2.52)	7.68 (2.94)	12.60 (3.68)	19.78 (4.55)	11.36 (3.51)
POURNIMA	8.60 (3.09)	9.57 (3.25)	11.34 (3.51)	23.44 (4.94)	13.23 (3.77)
LPS 141	4.09 (2.25)	4.73 (2.39)	5.67 (2.58)	6.59 (2.75)	5.27 (2.50)
LK 861	3.54 (2.13)	3.92 (2.21)	6.13 (2.67)	7.52 (2.91)	5.27 (2.50)
LRA 5166	7.86 (2.97)	8.76 (3.12)	13.52 (3.81)	20.26 (4.61)	12.60 (3.68)
SUMAN	5.51 (2.55)	5.63 (2.57)	6.02 (2.64)	11.34 (3.51)	7.12 (2.84)
SUPRIYA	6.83 (2.79)	7.09 (2.84)	8.50 (3.08)	12.10 (3.61)	8.63 (3.10)
PH 93	7.55 (2.92)	8.36 (3.05)	10.19 (3.34)	12.53 (3.67)	9.65 (3.26)
GLANDLESS	8.30 (3.04)	7.85 (2.97)	9.66 (3.26)	13.87 (3.85)	9.92 (3.30)
OKRA	4.16 (2.27)	3.77 (2.18)	4.86 (2.42)	6.02 (2.64)	4.70 (2.38)
PF	3.36 (2.08)	4.07 (2.25)	5.62 (2.57)	6.58 (2.75)	4.90 (2.42)
PNF	3.26 (2.06)	3.06 (2.01)	3.40 (2.09)	5.21 (2.49)	3.73 (2.17)
PONF	2.88 (1.96)	1.86 (1.69)	3.26 (2.06)	3.71 (2.17)	2.92 (1.97)
NH 210	3.36 (2.08)	3.11 (2.02)	2.15 (1.77)	4.14 (2.26)	3.19 (2.04)
NH 360	3.08 (2.01)	3.20 (2.04)	2.22 (1.79)	4.17 (2.27)	3.16 (2.03)
H 4	7.88 (2.97)	9.07 (3.17)	10.25 (3.35)	21.52 (4.74)	12.18 (3.63)
NHH 44	10.71 (3.42)	13.32 (3.78)	15.09 (4.01)	23.75 (4.97)	15.71 (4.08)
PKV HY.2	11.68 (3.56)	14.13 (3.88)	16.09 (4.13)	24.49 (5.04)	16.59 (4.19)
DCH 32	5.66 (2.58)	7.31 (2.88)	6.22 (2.68)	12.22 (3.63)	7.85 (2.97)
NHB 12	6.20 (2.68)	7.40 (2.89)	6.90 (2.81)	11.31 (3.50)	7.95 (2.99)
EKNATH	2.94 (1.98)	2.76 (1.93)	3.12 (2.02)	3.49 (2.11)	3.07 (2.01)
ROHINI	2.88 (1.96)	2.61 (1.90)	2.98 (1.99)	3.00 (2.00)	2.86 (1.96)
NAMDEO	2.34 (1.82)	2.47 (1.86)	2.59 (1.89)	3.16 (2.02)	2.64 (1.90)
JYOTI	2.81 (1.95)	2.63 (1.90)	2.78 (1.90)	3.13 (2.03)	2.83 (1.95)
SE+	.56	.59	.58	.43	1.18
CD at 5%	1.15	1.22	1.99	.87	3.27

Note : Figures in parentheses indicate transformed values.

Hy.2 harbored significantly higher number of whitefly nymph and they were significantly superior over rest of the cultivars. Lowest population of nymph was recorded on PONF and all asiatic cotton varieties.

Results from Table 2 indicate that, at stage of 120 days (1989-90) all *arboreum* strains, Namdeo (2.47), Rohini (2.61), Jyoti (2.63) and Eknath (2.76) and one hirsutum pigmented variety PONF (1.86) recorded lower nymph population per leaf. The *hirsutum* cotton varieties LK 861 (3.92), OKRA (3.77), PNF (3.06), NH 210 (3.11) and NH 360 (3.20) also recorded lower nymph population over rest of the tetraploid genotypes. Recommended hybrids viz. NHH 44 (13.32) and PKV Hy.2 (14.13) recorded highest population of whitefly nymph and significantly differed over rest of the cultivars. NS 15 (10.72), G 67 (10.27), AC 738 (10.12) and DHY 286 (10.15) also recorded significantly higher population per leaf but were at par with Pournima (9.57), a presently recommended straight variety for Marathwada region.

In respect of nymph population during 1990-91 season at 90 days it was observed that the cultivar NH 210, NH 360, Rohini, Namdeo and Jyoti recorded significantly low population of whitefly nymph and were significantly superior over rest of the genotypes. On the contrary the highest population per leaf was recorded on NS 15, LRA 5166, NHH 44 and PKV Hy.2 which were statistically at par with DS 28 DHY 286, MCU 5 and Pournima.

The incidence of whitefly nymph at 120 days during the same year was also studied. Analysis of varience indicated significant differences amongst genotypes. Among all genotypes NS 15, Pournima, NHH 44, PKV Hy.2 and DHY 286 recorded highest population per leaf i.e. 22.48, 23.44, 23.75, 24.49 and 24.65, respectively. On the other hand PONF and all *arboreum* strains recorded lower population with infestation level less than 4 nymphs/leaf. The cultivars DS 28 (18.57),G 67 (18.65), MCU 5 (19.78) and LRA 5166 (20.26) also recorded significantly higher population while PF, PNF, NH 210, NH 360, OKRA, LPS 141 and LK 861 were moderate and recorded population higher than *arboreum* but lower than rest of the cultivars.

4.1.3 Mean adult population of *B. tabaci* during 1989-90 and 1990-91

Results depicted in Table 1 revealed that there were significant differeces among 32 genotypes for adult population of *B. tabaci*. Mean sum of squares due to environment x genotypes was highly significant revealing the predominace of environment in harbouring population. It was low during 1989-90 than in 1990-91. After advance age of crop the population decreased during both the years. Between the two years, 1990-91 was rather favourable for whitefly build up. Amongst genotypes, PKV Hy.2 and NHH 44 recorded highest population mean during both the years while all *desi* cotton varieties invariably

recorded lowest population mean, even under favourable as well as unfavourable years.

4.1.4 Mean nymph population of *B. tabaci*. during 1989-90 and 1990-91

Perusal of Table 2 revealed that mean sum of squares at each stages of crop as well as for individual environment, variety and variety x environment components were highly significant for nymphal population of *B. tabaci*. It indicate that the genotype selected for present investigation possess substantial genetic variability and thereby expressed differential reactions. Intensity of pest also changed with the change in environment or stage of the crop.

Nymph intensity was significantly higher at 120 days during 1990-91 as compared to 90 and 120 days (1989) and 90 days (1990). Strains like NS 15, DHY 286 and Pournima of *G. hirsutum* and intra *hirsutum* hybrids like PKV Hy.2 and NHH 44 recorded significantly higher nymphal population over rest of the genotypes. Nymphs of *B. tabaci* showed non preferential behaviour for LPS 141, LK 861, Suman, AK 32, American Nectariless, NH 210, NH 360, three pigmented varieties, two inter specific hybrids and all asiatic cotton varieties. It is interesting to note that nymphs of *B. tabaci* preferred PKV Hy.2 under favourable as well as unfavourable environments while Namdeo, a diploid cotton even under favourable environment was not preferred by the pest.

4.2 Ovipositional preference / non preference of *B.tabaci* on different cultivars under choice and no-choice condition

Table 3 revealed that the intensity of egg laying on genotypes was varied and most of them showed significant differences among each other. Lower number of eggs were observed on Namdeo (2.2 eggs/leaf) and it was at par with NHB 12, NH 210, Pourinma, AC 738 and all *arboreum* strains. AK 32 (14.70 eggs/leaf) had significantly higher eggs which was at par with NS 15, G 67, MCU 5, LK 861, LRA 5166, Gland less, PF, H 4, NHH 44 and PKV Hy 2. Pubescent varieties like AC 738, DHY 286 and Pourinma had significantly fewer eggs while the resistant genotypes LK 861 (10.68) had more number of eggs than its counterpart LPS 141 (8.95).

During 1990, the results for egg laying indicated significant difference among 32 genotypes (Table 3). Mean sum of squares due to genotypes was highly significnt revealing the presence of substantial genetic variability. All *desi* cotton varieties had fewer eggs and at par with NHB 12, DCH 32, NH 360, PONF, PNF, OKRA, PH 93, LK 861, LPS 141, Pourinma, MCU 5, BN 1, American nectariless and NS 15.

Table 3 : Average number of eggs laid per leaf under choice and no choice conditions during 1989 and 1990

Varieties	Choice	No choice
DS 28	9.88	5.17
NS 15	7.99	6.57
AME.Nect.	6.42	4.90
G 67	9.40	6.49
AC 738	9.68	4.07
BN I	7.06	4.05
DHY 286	10.97	6.68
AK 32	14.70	4.43
Pournima	7.70	6.58
LPS 141	5.24	6.56
LK 861	4.66	3.95
LRA 5166	12.41	4.21
Suman	9.71	6.39
Supriya	9.00	3.82
PH 93	7.19	7.55
Glandless	11.40	6.04
Okra	6.13	2.29
PF	9.68	2.82
PNF	7.57	7.52
PONF	6.79	4.45
NH 210	8.45	4.16
NH 360	7.42	4.50
H 4	3.96	5.17
NHH 44	12.37	3.96
PKV Hy. 2	10.41	6.58
DCH 32	6.76	7.62
NHB 12	7.04	5.69
Eknath	3.83	3.51
Rohini	4.84	4.19
NAMDEO	3.51	3.34
JYOTI	4.32	3.11
SE ±	1.73	1.22
CD at 5%	4.79	3.39

Pournima recorded consistant performance and it was lowest in egg number while LK 861 which had higher eggs during 1989, however it was not preferred by *B.tabaci* for egg laying during subsequent year. NHH 44 had significantly higher egg number than rest of the cultivars and was at par with LRA 5166, Glandless and AK 32.

Under no-choice conditions, cultivar Namdeo recorded lowest number of eggs (1.43 eggs/leaf) and at par with DS 28, American nectariless, BN 1, AK 32, LPS 141, LK 861, Glandless, Okra, PONF, NH 360, H 4,DCH 32 and NHB 12 and all *arboreum* strains. G 67 and PKV Hy.2 on the contrary were significantly superior over rest of the cultivars and recorded highest number of eggs.

During 1990, Glandless (2.29) recorded lowest number of eggs and was at par with okra, two pigmented and all asiastic cotton cultivars. The hybrid PKV Hy.2 indicated similar trend and preferred most by *B.tabaci* even under no choice condition.

4.3 Biology of *B.tabaci* on different cultivars

4.3.1 Egg incubation period of *B.tabaci*

Table 4 revealed the lowest incubation period on all intra specific hybrids and was significantly superior over rest of the cultivars. Pournima and DCH 32 also recorded low incubation period and were at par with each other. Okra (5.92) recorded highest incubation period

Table 4 : Egg incubation period and Development time of *B. tabaci* on different cotton cultivars

Variety	Egg incubation period (Days)	Development time (Days)
DS 28	4.10 (2.25)	25.9 (5.18)
NS 15	4.00 (2.23)	26.2 (5.21)
AME.NECT.	4.40 (2.32)	25.4 (5.13)
G 67	4.10 (2.25)	25.3 (5.12)
AC 738	4.10 (2.25)	22.0 (4.79)
BNI	4.90 (2.42)	24.6 (5.05)
DHY 286	4.80 (2.40)	24.1 (5.00)
AK 32	4.90 (2.42)	25.5 (5.14)
MCU 5	4.60 (2.36)	25.6 (5.15)
Pournima	3.70 (2.16)	21.8 (4.77)
LPS 141	4.40 (2.32)	26.7 (5.26)
LK 861	5.30 (2.50)	26.1 (5.20)
LRA 5166	4.80 (2.40)	25.5 (5.14)
Suman	5.20 (2.48)	27.0 (5.29)
Supriya	5.10 (2.46)	26.5 (5.24)
PH 93	5.10 (2.46)	25.5 (5.14)
G.less	4.80 (2.40)	25.6 (5.15)
OKRA	5.92 (2.62)	26.1 (5.20)
PF	5.40 (2.52)	25.4 (5.13)
PNF	5.30 (2.50)	25.5 (5.14)
PONF	5.50 (2.54)	25.1 (5.10)
NH 210	4.80 (2.40)	23.8 (4.97)
NH 360	4.20 (2.28)	24.1 (5.00)
H 4	3.50 (2.12)	21.7 (4.76)
NHH 44	3.40 (2.09)	21.8 (4.77)
PKV Hy.2	3.30 (2.07)	21.9 (4.78)
DCH 32	3.90 (2.21)	23.6 (4.95)
NHB 12	4.10 (2.25)	23.2 (4.91)
Eknath	5.90 (2.62)	26.5 (5.24)
Rohini	5.80 (2.60)	26.7 (5.26)
Namdeo	5.90 (2.62)	26.2 (5.21)
Jyoti	5.60 (2.56)	26.1 (5.10)
S.E.±	0.89	1.62
C.D. at 5%	2.62	4.31

Figures in parentheses indicate transformed values.

and it was significantly higher over rest of the cultivars. Eknath, Namdeo, Jyoti and Rohini also recorded high incubation period and were at par with LK 861, Suman, Supriya, PH 93 and all pigmented strains.

4.3.2 Development time of *B.tabaci* from egg to adult emergence

The Table 4 indicated significant differences in development time of *B.tabaci* on different genotypes. H 4 recorded lowest development time (21.7 days) and was at par with PKV Hy 2, NHH 44 and Pourinma. AC 738 also recorded low development time and it was at par with NHB 12, DCH 32, NH 210 and NH 360.

Highest development time was recorded on Suman (27 days) and it was significantly superior over rest of the cultivars. Rohini also recorded more development time and it was at par with LK 861, LPS 141, NS 15, Supriya, Okra and all *arboreum* strains.

4.4 Stability of genotypes against infestation of *B. tabaci*

The stability of resistance over different location and populations and durability in the face of selection for resistance breaking biotypes, has long been a concern (Painter, 1951). Geographical differences were found in the adaption of greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), to sweet peppers (Lenteren *et*

al., 1989). Inconsistencies in resistance could be due to differences in the behaviour or physiology of pest, or to interaction of environmental factors with the expression of resistance (Stoner, 1992).

4.4.1 Analysis of varience

Pooled analysis of varience for egg, nymph and adult are presented in Table 5,6 and 7. It revealed that large portion of variation for adult and nymph was attributed to genotypes and environment. The genotypes and environment components when tested against genotype x environment, environment component was predominent. These results satisfied the basic requirement for such study, since they indicate the average performance of genotype with respect to adult and nymph which varied significantly under different environments.

The magnitude of environment variation is considerably high for adults and nymphs. This indicates that the environment had major role in whitefly infestation either in a form of nymph or adult. The variation due to genotype x environment interaction was found to be highly significant for most of the characters. This suggested that genotypes were unable to maintain consistent performance under different environments.

4.4.2 Grading environments

Eberhart and Russell (1966) suggested that the performance value of large group of variety provided an abstract measure of environment. In present investigation this method was used qualitatively to grade environments.

Table 5 : Analysis of varience for adult

SOURCE OF VARIATION	df	SUM OF SQUARES	MEAN SQUARES	F RATIO
Varieties	31	699.61381	22.56819	14.845
Env.+ (Var.* Env.)	96	290.29240	3.02388	1.989
Environments	3	223.00687	74.33562	236.023
Var.* Env.	93	67.28553	0.72350	2.297
Environments (Lin.)	1	223.00687	223.00687	146.688
Var.*Env (Lin.)	31	47.12869	1.52028	4.827
Pooled deviation	64	20.15685	0.31495	
POOLED ERROR	384	45.20632	0.11772	
TOTAL	127	989.90609	7.79454	

Table 6 : Analysis of varience for nymph

SOURCE OF VARIATION	df	SUM OF SQUARES	MEAN SQUARES	F RATIO
Varieties	31	1140.80089	36.80003	23.996
Env.+ (Var.* Env.)	96	182.39008	1.89990	1.239
Environments	3	120.50598	40.16866	179.250
Var.* Env.	93	61.88410	0.66542	2.969
Environments (Lin.)	1	120.50598	120.50598	78.576
Var.*Env. (Lin.)	31	47.54219	1.53362	6.844
Pooled deviation	64	14.34192	0.22409	
POOLED ERROR	384	67.42690	0.17559	
TOTAL	127	1323.19099	10.41883	

Table 7 : Analysis of varience for egg

SOURCE OF VARIATION	df	SUM OF SQUARES	MEAN SQUARES	F RATIO
Varieties	31	38.51409	1.24239	32.010
Env.+ (Var.* Env.)	96	35.92386	0.37421	9.642
Environments	3	32.96364	10.98788	400.231
Var.* Env.	93	2.96022	0.03183	1.159
Environments (Lin.)	1	32.96364	32.96364	849.314
Var.*Env. (Lin.)	31	1.20317	0.03881	1.414
Pooled deviation	64	1.75705	0.02745	
POOLED ERROR	384	7.33858	0.01911	
TOTAL	127	74.43794	0.58613	

Thus, a comparison of any environment mean with grade mean helped to grade environment . In present investigation, 90 and 120 days crop age during 1989 and 1990 were treated as four environments viz. E I (90 days, 1989) E II (120 days, 1989),E III (90 days, 1990) and E IV (120 days, 1990) ; because microclimatic conditions during the age of 90 days under rainfed conditions is completely different from that of conditions prevailing at 120 days of cotton crop. Morevoer, crop at 90 days is in green stage while it reaches to physiological maturity at 120 days.

The environment at 120 days (1990) followed by environment at 90 days (1990) indexed as most favourable environment for egg, nymph and adult population of whitefly. This is evident as these two environments for two stages of whitefly recorded positive and highest environmental index values except III for nymph. The negative environment index values indicate unfavourable from the point of view of pest development. It suggest that for epidemic development of pest use E IV is adhesive.

4.4.3 Regression analysis of phenotypic stability

The four environments used in the study provided a sufficient range of variability. The variation for genotypes is highly significant for adult and nymph. Significant difference among variety mean for two parameters was evident as revealed by the large varience

ratio of MSI /MS3. Mean squares for pooled deviation from regression are significant for these two parameters.

Genotype x environment (Lin.) variation is observed to be significant for egg, nymph and adult parameters. The low MS2/MS3 ratio or non significant genotype x environment (Lin). variation indicate that there are no significant differences amongst genotype for their regression on environment index for egg, nymph and adult.

4.4.4 Stability of genotypes

Adaptability of 32 genotypes was studied under four environments. In the present study, highly susceptible genotypes viz. PKV Hy. 2, NHH 44 and straight variety NS 15, a parent of recommended hybrid (NHB 12) were highly attacked by the adult whitefly. These genotypes recorded bi value more than one, either significant or non significant. Varieties like PONF, NH 210 and all four varieties of *desi* cotton recorded least whitefly population with regression coefficient value significantly less than unity. Out of 32 genotypes six genotypes recorded regression coefficient value significantly higher than unity while seven genotypes possessed bi value significantly less than one. These genotypes with below and above average stability, respectively recorded infestation level higher than population mean. It suggests that genotypes with above average stability may not show increased infestation level

even under favourable environment for pest. Ninteen genotypes recorded regression coefficient value nearer to unity thereby indicating that their reaction against adult infestation my remain consistent even under favourable as well as unfavourable conditions.

The distribution of 32 genotypes in four quadrants was 5, 15, 5 and 7 in QI,QII, QIII and QIV respectively.

The genotypes falling in Q IV are important because they have less infestation level and bi value is less than unity. These genotypes may not show increased infestation level even under favourable environment.

4.4.5 Stability of population of *B. tabaci*

In respect of adult population, eight and eleven genotypes recorded regression coefficient value significantly less and higher than unity, respectively. From resistance point of view, those eight genotypes are most desirable as the infestation level due to adult may not elevate even with change in the environment or even under availability of favourable environments. Three *hirsutum* cultivars and four *arboreum* cultivars of above average stability recorded infestation level below population mean. Amongst those three *hirsutum* cultivars PF, PONF and PNF are worth mentioning due to their non-significant S^2di values. It suggests that stability for resistance may not disturb in these genotypes.

Table 8 : Stability of different genotypes for egg population of *B. tabaci*

Varieties	Mean	S^2di	Bi
DS 28	3.52	0.08	0.77
NS 15	4.04	0.03	0.96
AM.NECT.	3.30	0.01	1.04
G 67	3.62	0.03	0.84
AC 738	3.97	0.08	0.97
BN 1	4.15	-0.07	0.82
DHY 286	3.62	0.18	0.92
AK 32	3.63	0.03	0.89
MCU 5	4.12	0.02	1.06
POURNIMA	2.94	-0.04	0.84
LPS 141	2.70	-0.08	1.12
LK 861	4.06	-0.01	1.02
LRA 5166	3.27	-0.01	0.84
SUMAN	3.59	0.03	1.00
SUPRIYA	4.00	-0.01	0.89
PH 93	3.72	-0.01	0.64
GLANDLESS	3.30	-0.01	1.07
OKRA	3.68	-0.01	1.14
PF	3.56	-0.01	1.03
PNF	3.59	0.07	0.86
PONF	2.76	-0.01	0.91
NH 210	2.84	0.07	1.26
NH 360	3.60	-0.01	1.09
H 4	3.94	-0.03	0.80
NHH 44	4.13	-0.01	0.76
PKV Hy.2	3.34	-0.01	0.90
DCH 32	3.35	0.05	0.94
NHB 12	2.29	-0.01	0.81
EKNATH	2.30	0.08	1.43
ROHINI	2.51	-0.01	1.36
NAMDEO	2.38	-0.01	1.25
JYOTI	2.38	0.01	1.43
S.E.±	0.239		
C.D. at 5%	0.475		

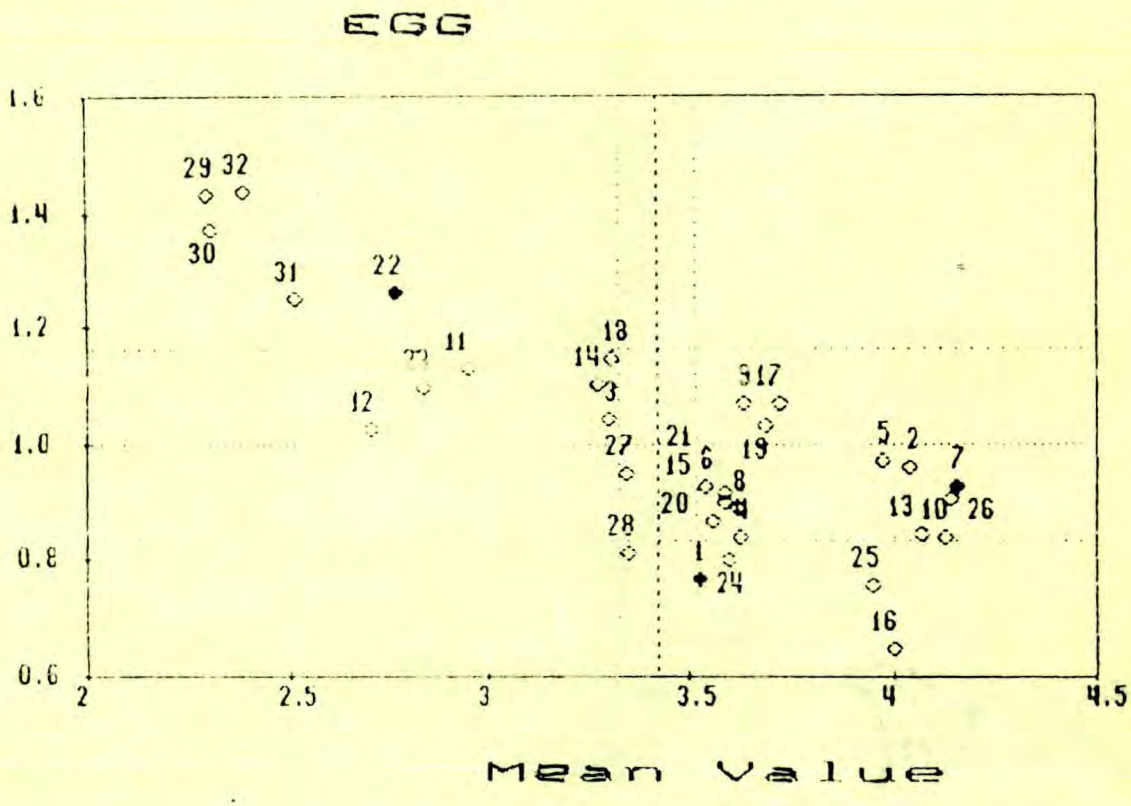


Fig. 1 : Relationship between regression coefficient and Egg population of B. tabaci.

Table 9 : Stability of different genotypes for nymphal population of *B. tabaci*

Varieties	Mean	S^2di	Bi
DS 28	11.44	-0.01	0.76
NS 15	14.40	0.42	1.62
AM.NECT.	7.38	0.12	0.07
G 67	11.02	-0.12	0.75
AC 738	10.33	0.09	2.22
BN 1	8.12	0.03	1.56
DHY 286	14.28	0.03	1.76
AK 32	7.86	-0.08	1.82
MCU 5	11.36	0.76	1.13
POURNIMA	13.23	0.17	1.84
LPS 141	5.27	-0.12	0.52
LK 861	5.27	-0.16	0.76
LRA 5166	12.60	0.27	1.03
SUMAN	7.12	-0.16	0.74
SUPRIYA	8.63	0.28	0.92
PH 93	9.65	0.09	1.93
GLANDLESS	9.92	0.29	2.39
OKRA	4.70	-0.02	0.83
PF	4.90	-0.06	0.54
PNF	3.73	-0.05	0.84
PONF	2.92	-0.16	0.35
NH 210	3.19	-0.09	0.37
NH 360	3.16	-0.15	0.43
H 4	12.18	0.22	1.31
NHH 44	15.71	-0.14	1.16
PKV Hy.2	16.59	-0.11	1.09
DCH 32	7.85	0.63	1.23
NHB 12	7.95	0.14	1.11
EKNATH	3.07	-0.15	0.25
ROHINI	2.86	-0.14	0.09
NAMDEO	2.64	-0.17	0.32
JYOTI	2.83	-0.15	0.16
S.E. ±	0.650		
C.D. at 5%	1.291		

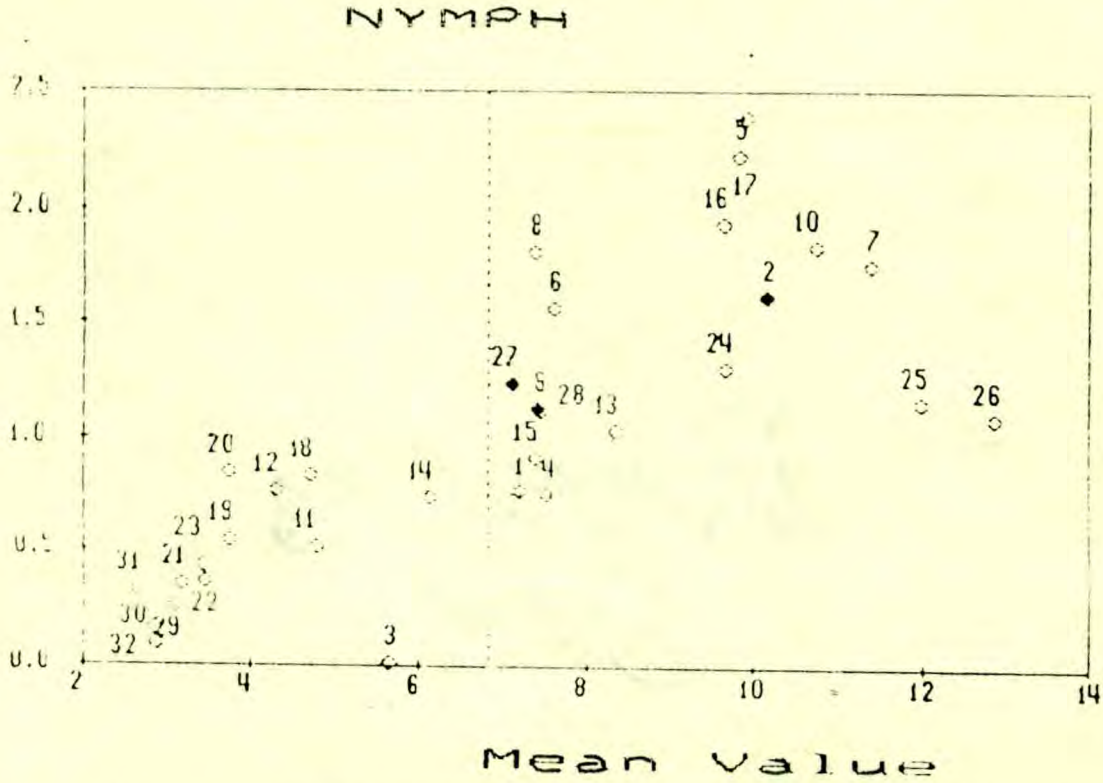


Fig. 2 : Relationship between regression coefficient and Nymph population of B. tabaci.

Table 10 : Stability of different genotypes for adult population of *B. tabaci*

Varieties	Mean	S^2di	Bi
DS 28	7.69	0.24	1.55
NS 15	9.04	0.98	1.77
AM.NECT.	6.01	-0.09	1.37
G 67	7.23	0.62	0.96
AC 738	8.28	-0.11	1.33
BN 1	7.27	0.64	1.29
DHY 286	8.72	-0.09	0.94
AK 32	6.57	-0.01	0.80
MCU 5	7.40	0.20	1.41
POURNIMA	7.80	0.79	0.43
LPS 141	4.62	-0.01	1.16
LK 861	4.13	0.17	1.30
LRA 5166	8.99	0.05	1.86
SUMAN	6.43	0.29	1.43
SUPRIYA	6.90	-0.11	0.98
PH 93	7.73	0.26	1.17
GLANDLESS	8.66	0.03	1.55
OKRA	4.33	0.09	0.93
PF	3.60	0.46	0.82
PNF	3.48	0.28	0.60
PONF	2.91	0.37	0.80
NH 210	2.94	-0.09	0.33
NH 360	2.97	0.38	0.31
H 4	8.18	0.22	1.51
NHH 44	9.10	0.01	1.17
PKV Hy.2	9.18	0.86	1.12
DCH 32	6.53	0.01	0.86
NHB 12	6.56	-0.01	0.93
EKNATH	2.71	-0.05	0.32
ROHINI	2.63	-0.04	0.52
NAMDEO	2.08	0.01	-0.03
JYOTI	2.74	-0.07	0.38
S.E.±	0.538		
C.D.at 5%	1.069		

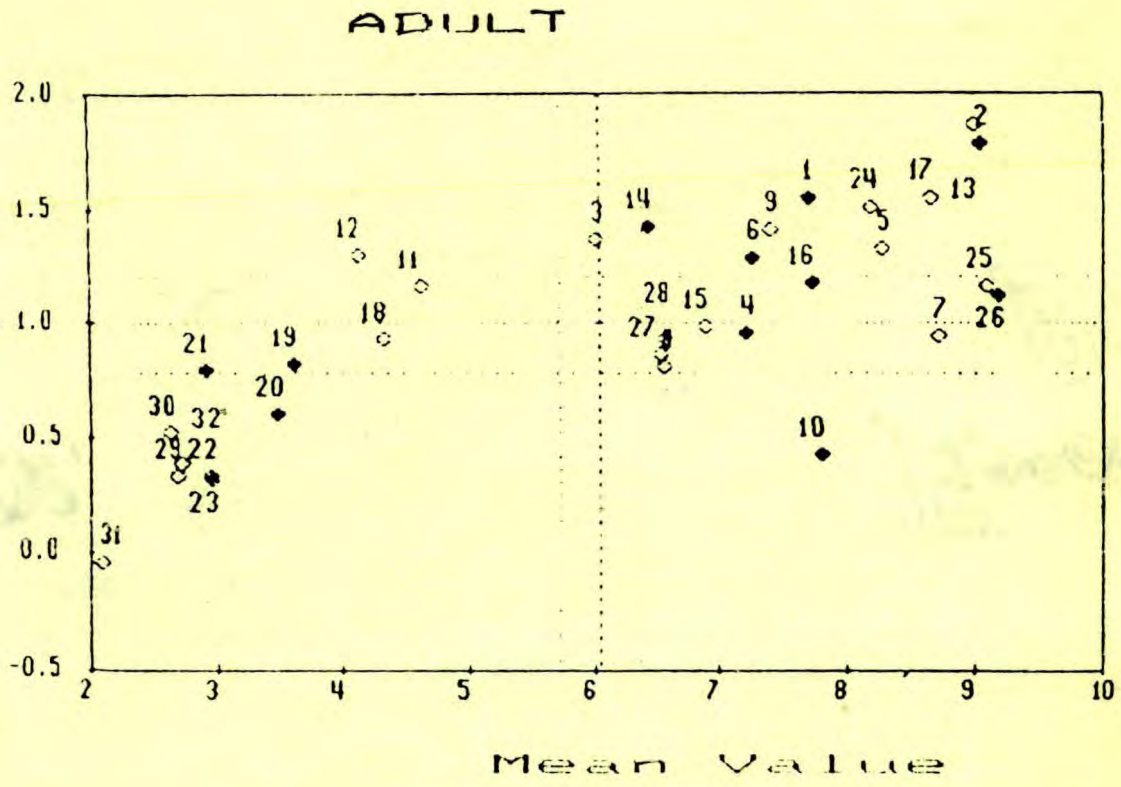


Fig. 3 : Relationship between regression coefficient and Adult population of B. tabaci.

Eleven genotypes, which recorded below average stability (regression coefficient value more than unity) showed adult infestation at par or less than population mean. Strains like LPS 141, LK 861, which expressed high level of resistance ability are undesirable and their resistance ability may be disturbed with change in the environment or they are resistant under specific conditions. A look at graph (Fig. 7) clearly shows that under unfavourable conditions, these two strains recorded adult population of 3.50 per leaf (LPS 141) and 2.97 per leaf (LK 861), however, with availability of favourable conditions, infestation level increased to the level of 5.74 per leaf(LPS 141) and 5.29 per leaf (LK 861). In other words, it can be said that these two cultivars are very sensitive to environments.

Average stability (bi =1) was expressed by 13 out of 32 genotypes. Amongst these 13 genotypes, only four genotypes recorded infestation level less than population mean while it was numerically or significantly higher adult population in rest of the genotyes. It suggests that genotypes having higher mean and bi equal to unity may show high level of infestation even under favourable conditions and hence while rcommending such genotypes either for general cultivation or for using as parents in crossing programme, it is necessary to take due care. Popular hybrids viz. NHH 44 and PKV Hy.2 recorded non-significant bi but high population (Fig. 8).

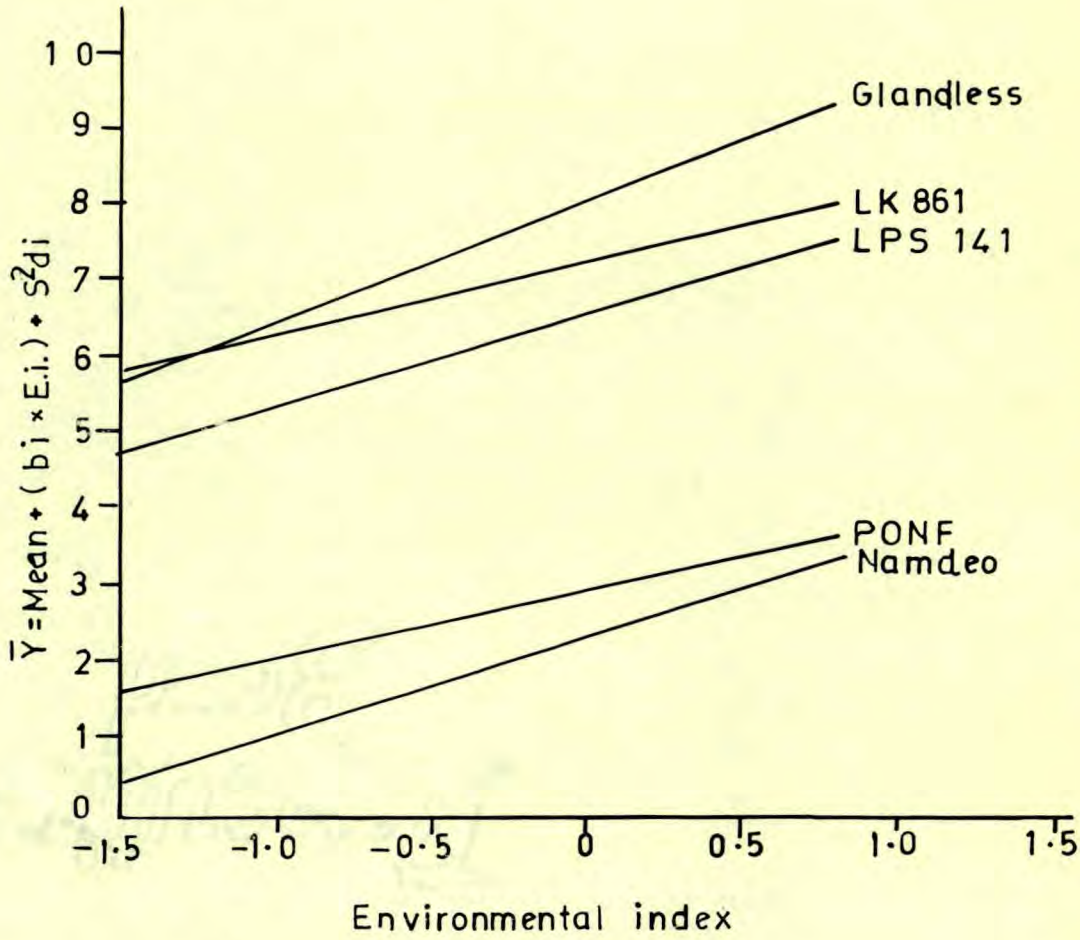


Fig 4. Stability of genotypes for egg population of whitefly

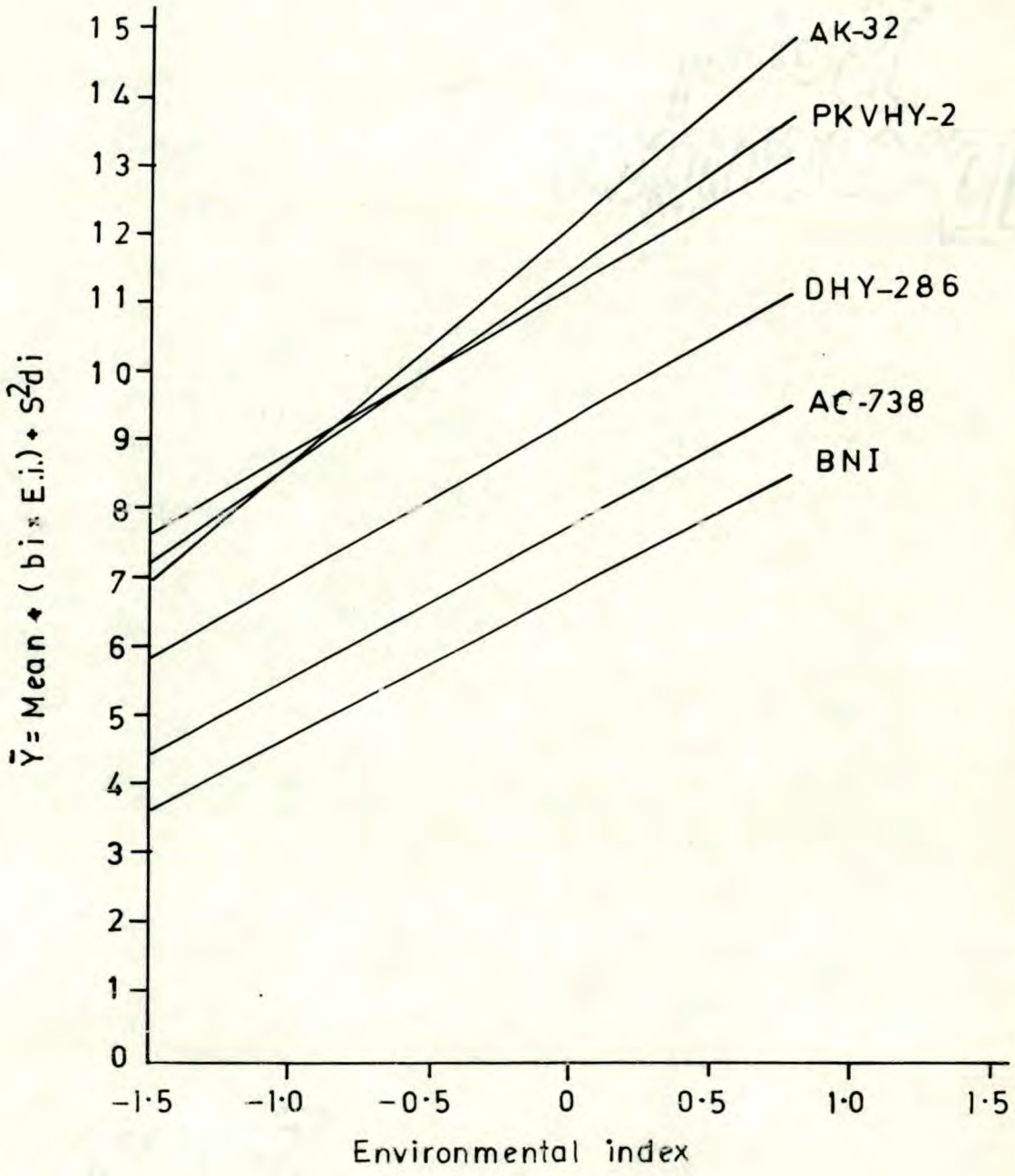


Fig 5. Stability of genotypes for egg population of whitefly

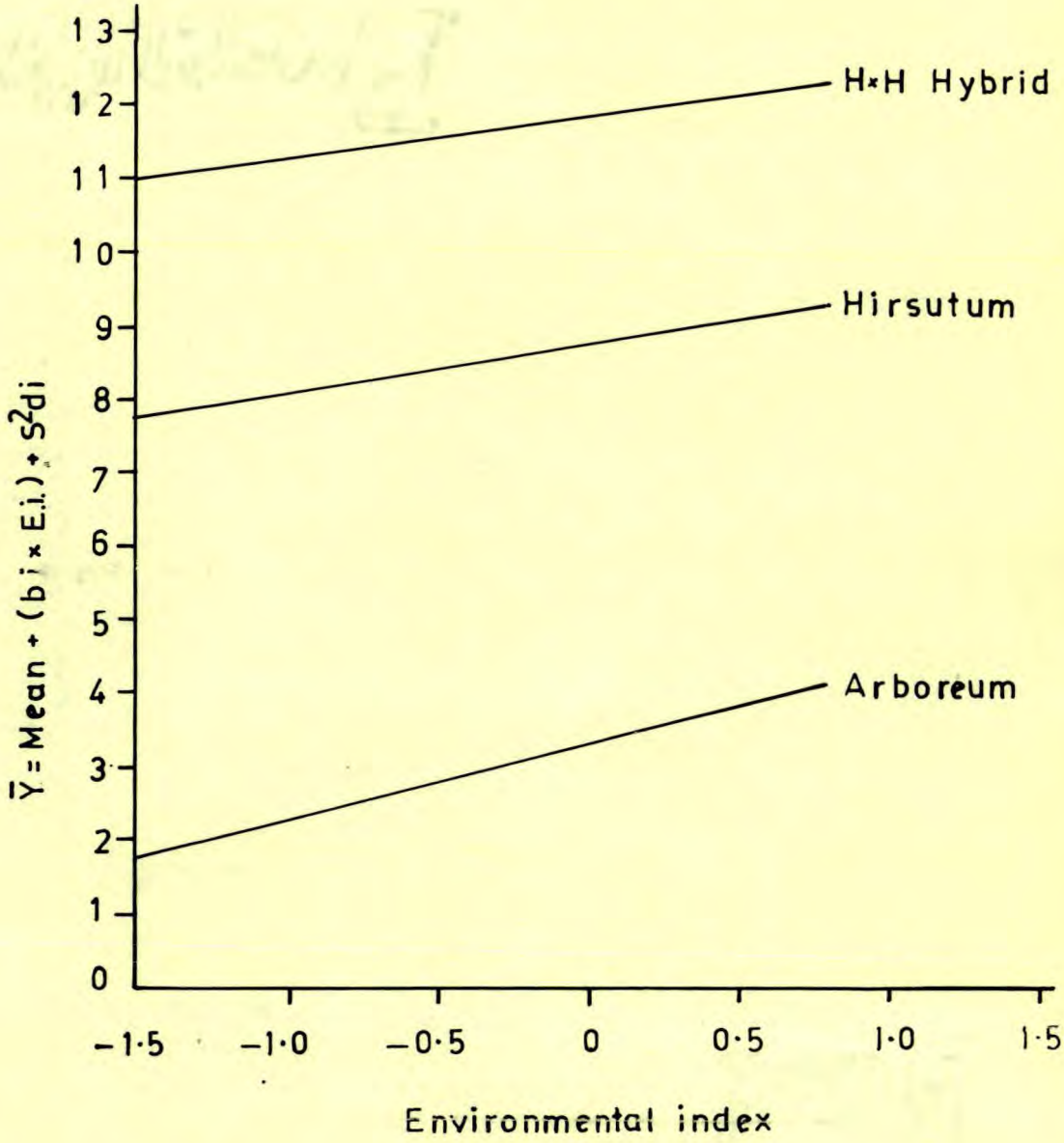


Fig 6. Stability of genotypes for egg population of whitefly

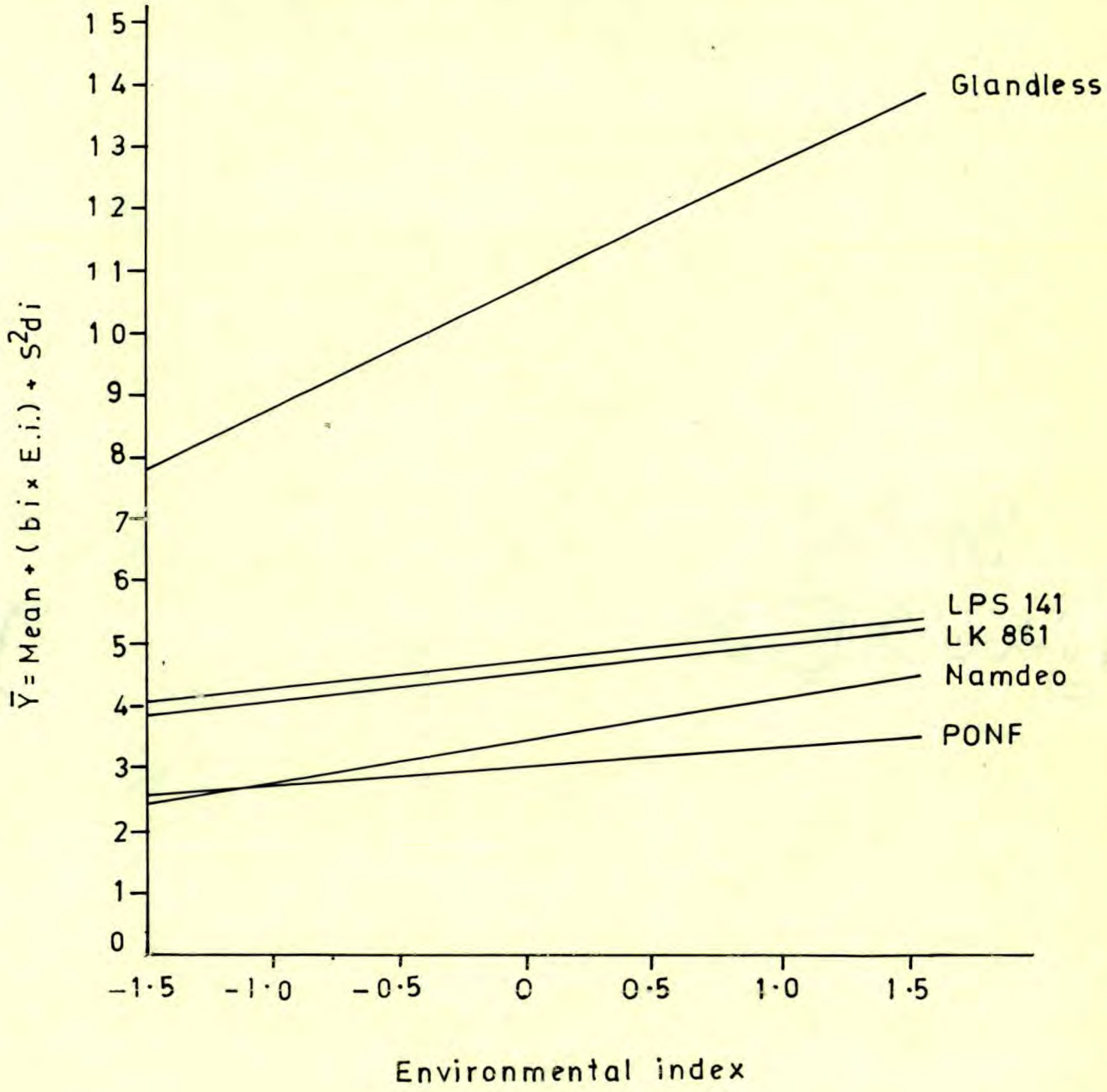


Fig 7. Stability of genotypes for nymphal population of whitefly

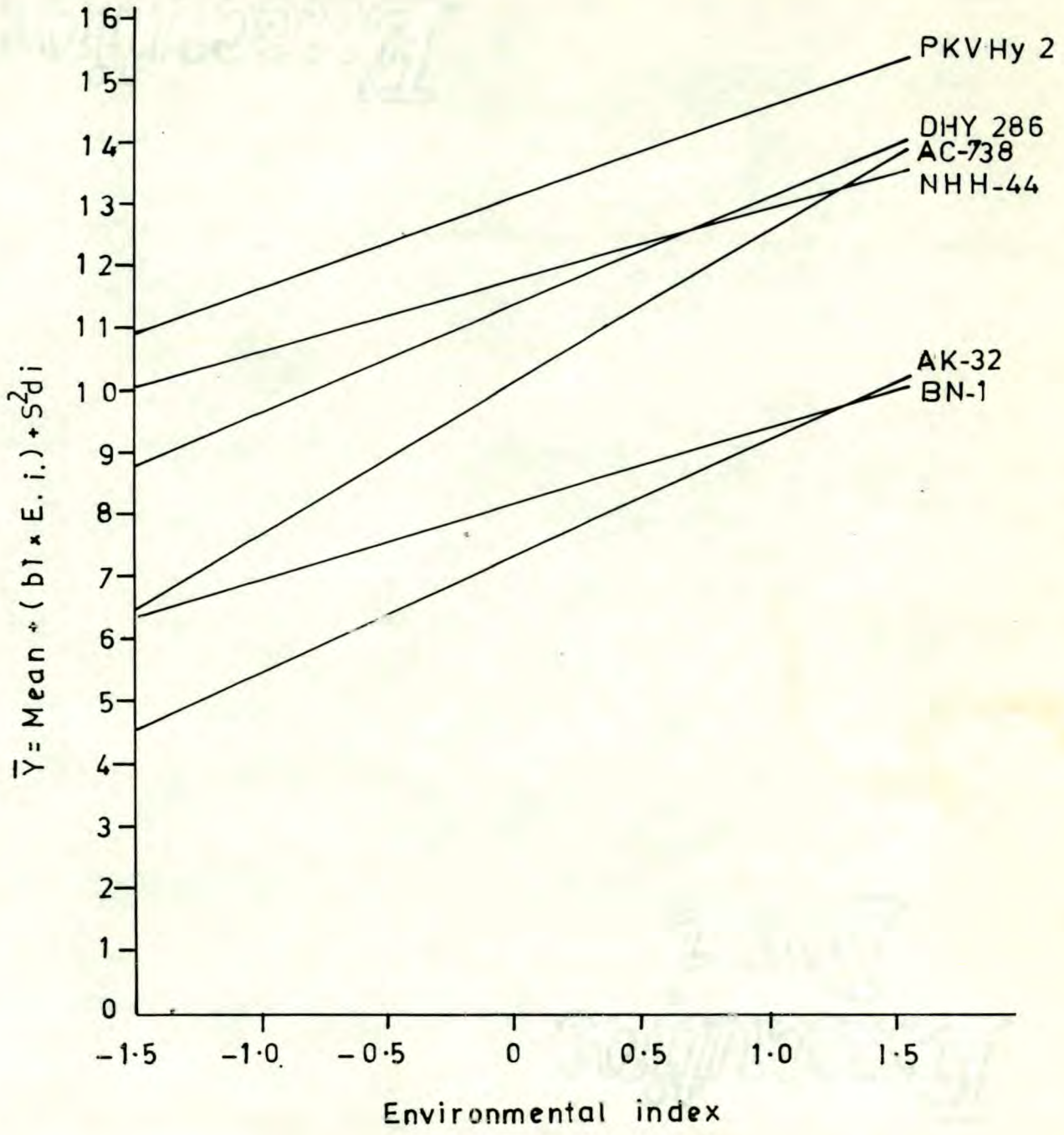


Fig 8. Stability of genotypes for nymphal population of whitefly

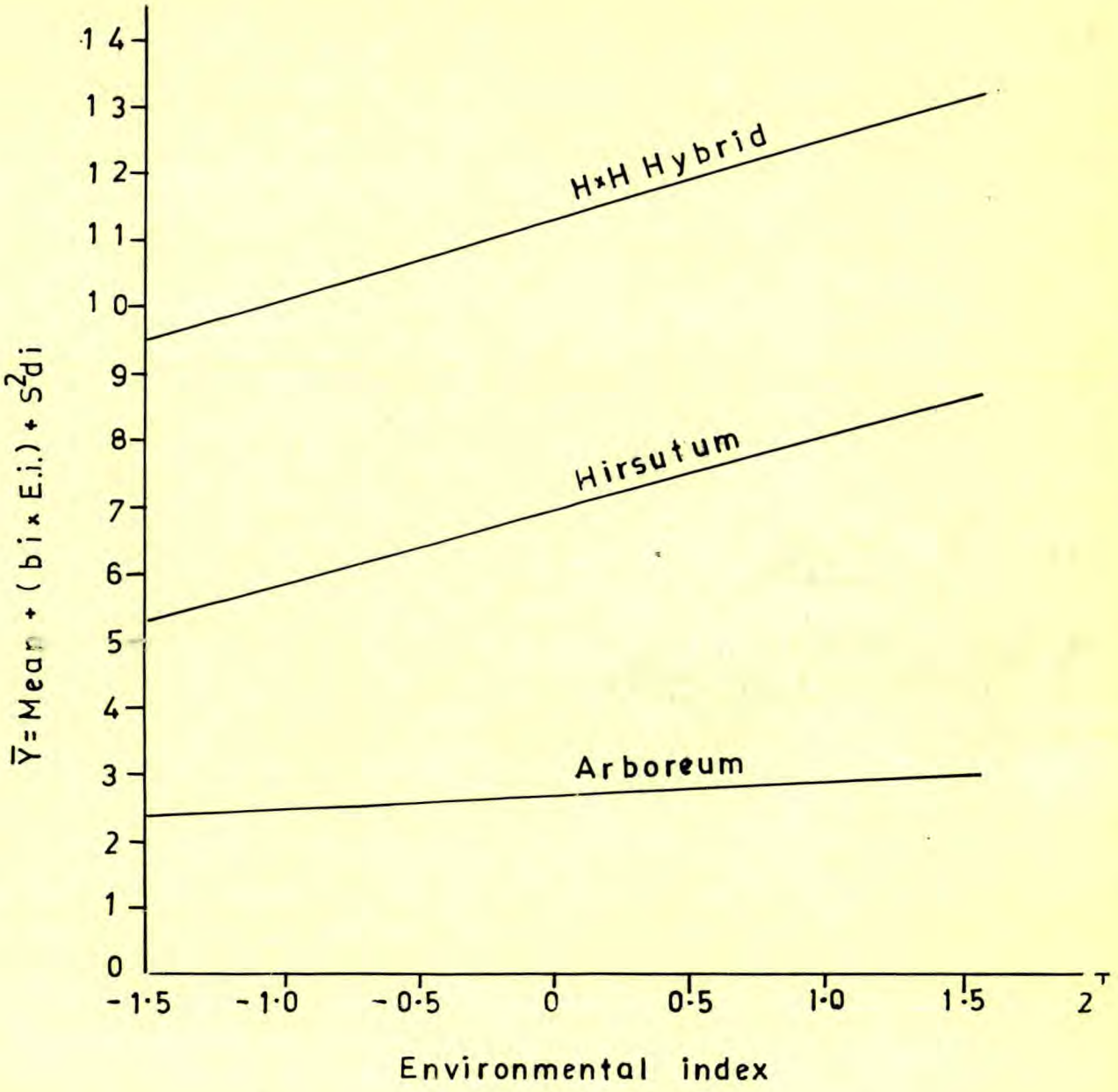


Fig 9. Stability of genotypes for nymphal population of whitefly

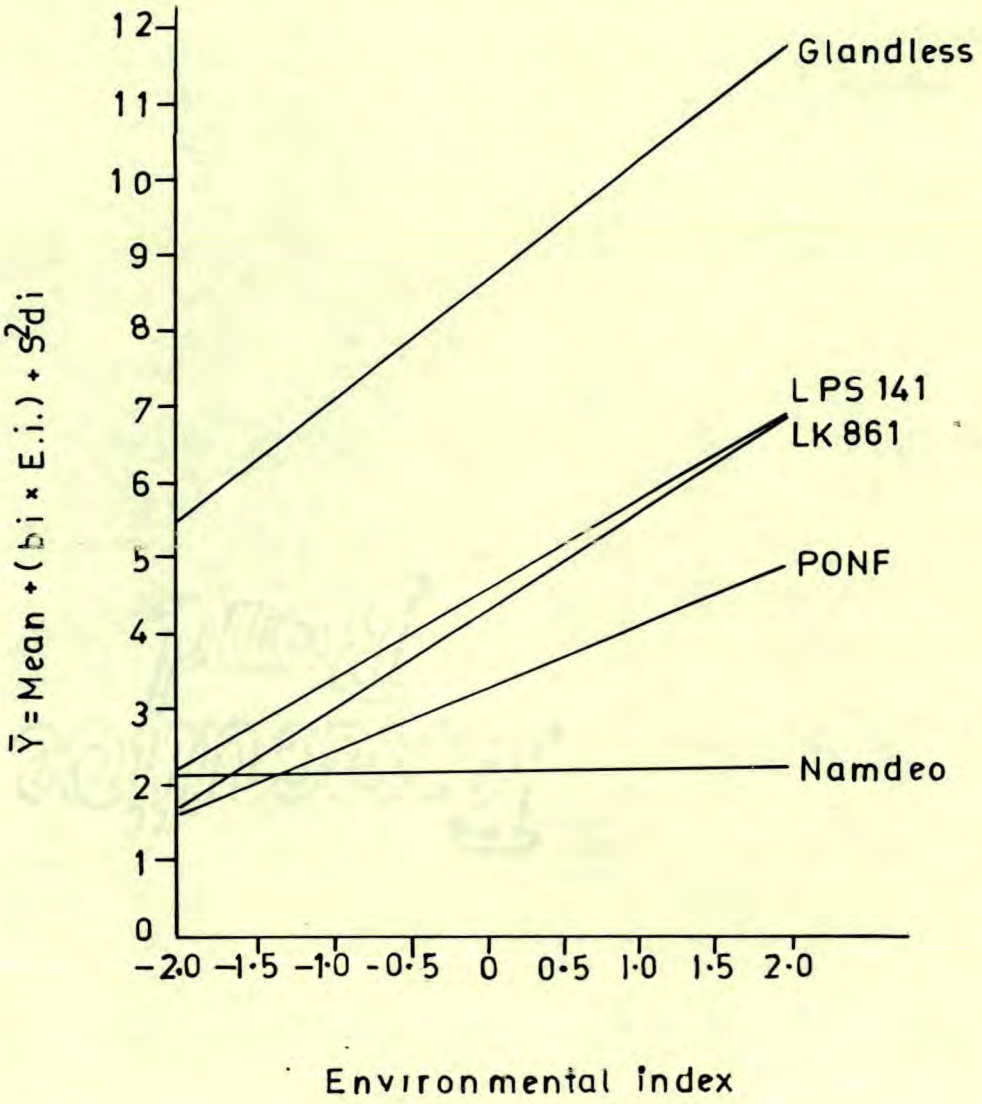


Fig 10 Stability of genotypes for adult population of whitefly

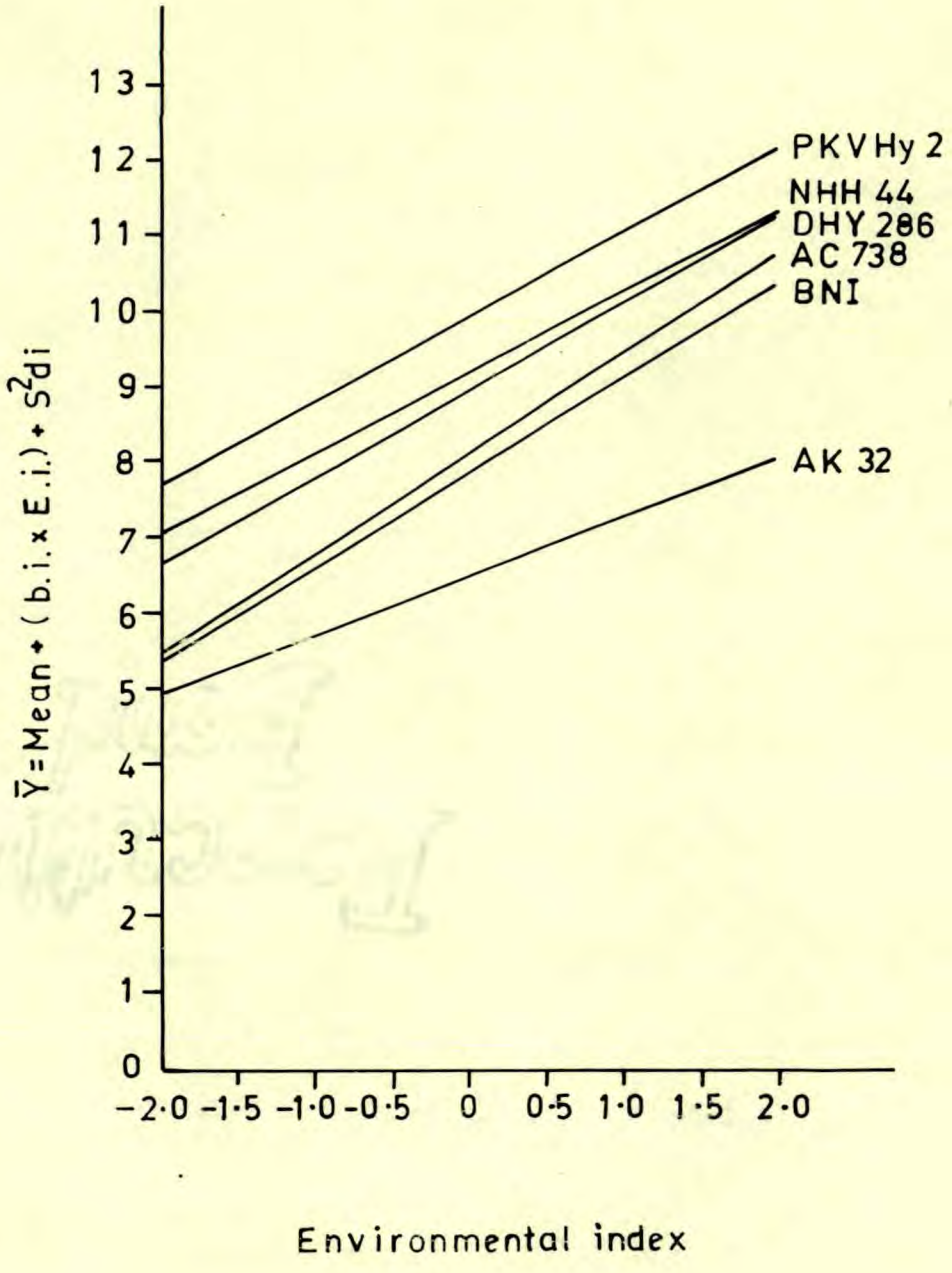


Fig 11 Stability of genotypes for adult population of whitefly

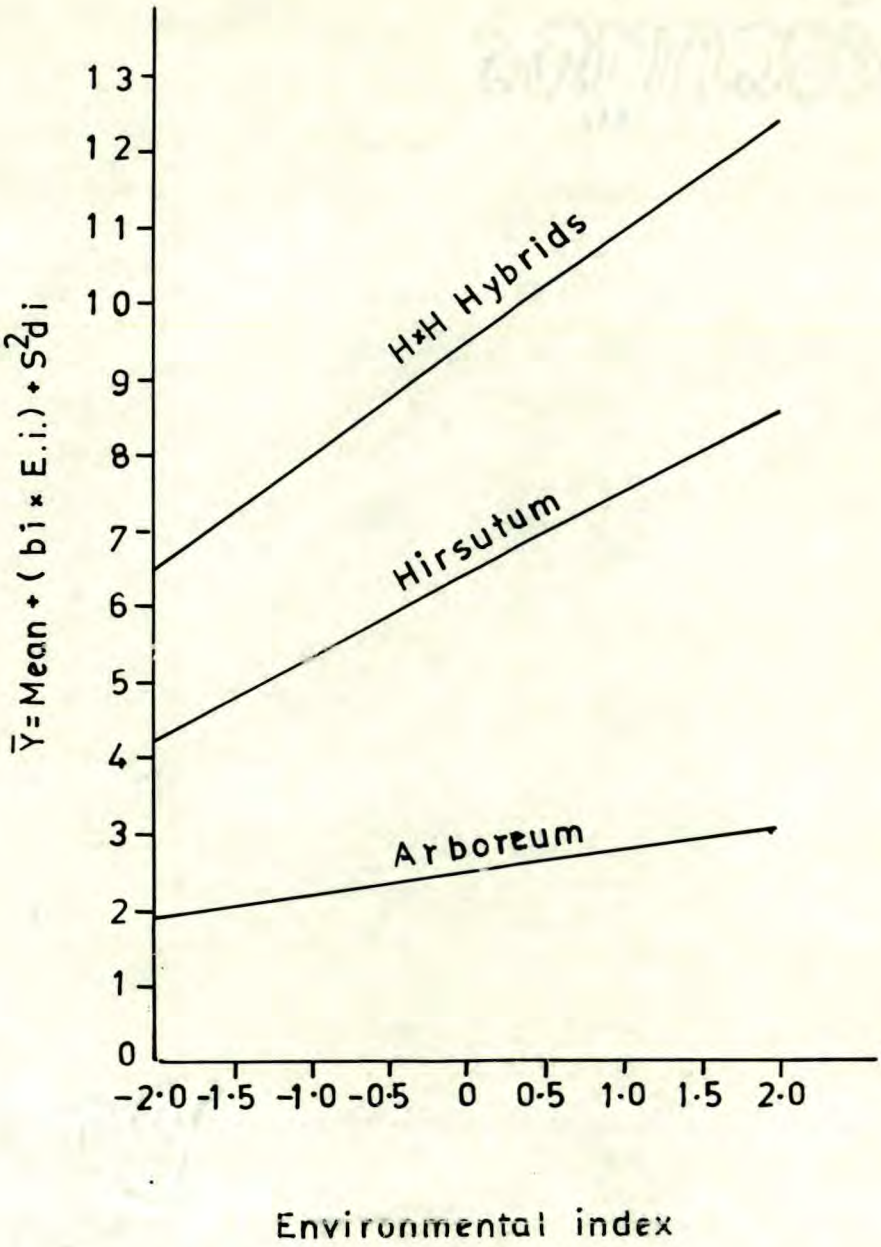


Fig 12. Stability of genotypes for adult population of whitefly

Stability of 32 genotypes was also evaluated for whitefly population. Data presented in Table 9 and Fig. 11 pointed out that 8,10 and 14 geenotypes recorded average (bi = 1), below average (bi > 1) and above average (bi < 1.00) stability, respectively. All *arboreum* genotypes may show least nymph infestation even under favourable and unfavourable conditions. Amongst *hirsutum* group, may be variety or hybrid, LPS 141, LK 861, PF and PONF cultures recorded significantly low nymph population. LPS 141 and LK 861, which recorded below average stability for adult, while it was above average stability for nymph. This indicate contradictory behaviour of genotypes and suggests that the characters contributing for resistance against nymph and adult are altogether different. Likewise, NHH 44 and PKV Hy.2 which showed below average stability against adult possessed average stability (bi = 1) for nymph population. However, PF, PONF and PNF and *arboreum* cultures expressed low mean coupled with regression coefficient value significantly less than unity (above average).

A comparison of *arboreum* (above average) with *hirsutum* (below average) depicted in Fig. 3,6 and 9 revealed that intensity of whitefly population increased with change in the environment in *hirsutum* and intra specific *hirsutum* hybrids but such trend was not observed with *desi* cultivars.

Data presented in Table 9 indicated that none of the genotypes, having bi value equal to unity, recorded nymph population significantly less than population mean (6.81 nymph/leaf). These genotypes under all kinds of environments may show high level of infestation. Fig. 11 indicates that 8,9 and 15 genotypes occupied position in QI, QII and QIII respectively. Most of the genotypes clustered either in QII and QIV for nymph as well as adult.

As regards eggs, only one *hirustum* culture recorded regression coefficient value significantly higher than unity, thereby indicating below average stability performance. Cultivars like DS 28, Pournima, LRA 5166, PH 93, H 4, NHH 44 and NHB 12 possessed above average stability as evidenced from bi values significantly higher than unity. Amongst these H 4, NHH 44 and NHB 12 hybrids recorded egg number at par with population. These genotypes may not show higher level of infestation even under favourable conditions. Their performance just coincide with that expressed by *arboreum* cultivars (Table 8).

4.5 Impact of different characteristic of plant on development of whitefly

4.5.1 Morphological characters and their impact on infestation level

Morphological characters like leaf area, number of stomata, hair-length and hair density have been studied in 32 genotypes at 90 and 120 days during 1989-90 and 1990-91 to understand their impact on development of whitefly.

4.5.1.1 Leaf Area

The data presented in Table 11 the presence of substantial variation due to genotypes as well as environments. Variation due to genotype x environment was highly significant indicating differential expression per leaf area with change in environment. Year 1990-91 may be 90 days or 120 days showed pronounced effect on leaf area. It was 57.4 cm^2 in 1990 at 120 days which was significantly higher over leaf area expressed in 90 days (1990), 120 days (1989) and 90 days (1989) by a margin of 9, 12.1 and 18 per cent respectively. Pooled mean of 32 genotypes was 50.9 cm^2 and ranged from 27.2 cm^2 (Jyoti) to 85.14 cm^2 (NHB 12). Perusal of Table 11 reveals that 18 and 12 genotypes recorded statstically less and higher values for leaf area respectively over population mean (50.9 cm^2). Hybrid NHB 12, H 4, DCH 32 and varieties like

Table 11. Leaf area of selected cotton cultivars exhibiting different degree of susceptibility to *B. tabaci*

Variety	Leaf area (cm^2)			
	1989		1990	
	Days after germination			
	90	120	90	120
DS 28	55.18	58.163	67.931	67.033
NS 15	57.42	61.327	68.511	74.052
AM.NECT	32.32	36.385	40.720	48.877
G 67	68.70	72.220	75.177	83.279
AC 738	37.89	40.193	47.340	52.055
BN 1	36.97	40.063	45.563	50.621
DHY 286	42.51	43.862	51.188	54.075
AK 32	43.20	45.480	49.803	57.331
MCU 5	40.17	42.732	50.222	55.182
POURNIMA	41.67	45.297	52.683	54.485
LPS 141	45.18	47.660	55.658	56.285
LK 861	51.75	53.105	55.982	61.563
LRA 5166	41.20	44.450	51.433	54.195
SUMAN	53.60	54.885	62.807	65.496
SUPRIYA	49.91	50.870	56.161	61.782
PH 93	42.50	44.765	48.611	53.024
GLANDLESS	51.78	53.483	61.293	66.550
DKRA	23.16	26.870	33.369	38.957
PF	38.72	40.012	46.583	51.138
PNF	39.57	41.335	44.C05	53.507
PONF	25.08	27.923	34.735	37.357
NH 210	42.30	45.015	52.695	54.334
NH 360	41.05	45.925	51.955	55.370
H 4	75.05	78.560	83.813	85.544
NHH 44	48.84	50.690	55.764	60.201
PKV HY.2	50.17	50.087	61.765	66.828
DCH 32	70.23	73.295	75.C82	87.427
NHB 12	79.38	82.120	87.415	87.672
EKNATH	26.17	28.278	34.191	36.162
ROHINI	22.46	24.460	28.663	34.407
NAMDEO	23.38	26.700	31.893	37.245
JYOTI	22.72	22.792	29.645	33.918
SE±	1.29	1.36	1.34	1.43
CD at 5%	2.56	2.71	2.67	2.85

G 67, NS 15 and DS 28 recorded significantly higher leaf area over rest of the genotypes. However, LRA 5166 and PKV Hy 2 as well as NH 360, AK 32 and LPS 141 showed at par values for leaf area.

Genetic correlation and regression studies between leaf area and whitefly population at different stages were worked out seperately. The correlation cofficient and regression equations are presented in Table 12.

Table 12 : Correlation coefficient and regression equations between whitefly adult population and leaf area.

Year	Days After Planting	`r' values	Regression equation
1988	90	0.509**	$\bar{Y}$ = 2.182 + 0.074 X
1989	120	0.488**	$\bar{Y}$ = 1.536 + 0.060 X
1990	90	0.549**	$\bar{Y}$ = 1.852 + 0.117 X
1990	120	0.580**	$\bar{Y}$ = -0.070 + 0.108 X
Mean		0.517**	$\bar{Y}$ = 1.206 + 0.094 X

** Significant (P = 0.01), * Significant (P = 0.05).

From the results, it is evident that there was highly significant positive correlation between whitefly population and leaf area during both the years.

4.5.1.2 Stomata / cm^2

Variation due to treatments at both stages in both years as well as variation to environment and varieties in pooled analysis were highly significant (Table 13). Environmental index value for stomata

Table 13. Number of stomata in selected cotton cultivars exhibiting different degree of susceptibility to *B. tabaci*

Variety	Stomata / cm^2			
	1989		1990	
	Days after germination			
	90	120	90	120
DS 28	245.32	258.467	262.313	273.899
NS 15	265.878	257.620	287.038	288.438
AM.NECT	138.175	151.165	152.345	180.594
G 67	234.763	237.162	242.982	261.015
AC 738	234.197	241.750	259.706	270.967
BN 1	320.117	349.408	334.346	371.935
DHY 286	200.543	201.193	224.576	222.021
AK 32	158.245	165.607	169.574	192.219
MCU 5	189.403	180.098	214.764	209.492
POURNIMA	145.455	142.827	166.634	161.032
LPS 141	158.355	155.852	182.499	172.077
LK 861	142.280	151.217	151.103	167.694
LRA 5166	204.927	209.400	226.604	228.318
SUMAN	192.503	176.630	216.551	199.048
SUPRIYA	189.192	177.095	202.943	200.554
PH 93	220.807	236.895	228.584	248.587
GLANDLESS	240.182	254.160	266.866	287.418
DKRA	237.605	236.645	262.068	269.760
PF	177.305	176.757	197.557	204.439
PNF	179.707	178.680	185.410	207.318
PONF	215.410	215.682	236.935	231.267
NH 210	251.682	234.550	281.278	251.184
NH 360	249.465	271.825	265.670	288.984
H 4	233.010	231.837	267.827	249.909
NHH 44	256.492	231.837	267.670	249.909
PKV HY.2	250.732	237.802	272.974	264.816
DCH 32	196.583	205.212	201.646	237.229
NHB 12	122.945	130.083	135.929	144.020
EKNATH	251.335	251.140	268.526	275.940
ROHINI	295.272	302.300	311.990	319.314
NAMDEO	313.840	320.795	326.509	343.350
JYOTI	263.672	260.918	290.351	288.318
SE±	1.65	1.06	1.23	1.58
CD at 5%	3.29	2.98	2.62	3.10

parameters indicated unfavourable effects during 1989-90 as compared to year 1990-91. The highest number of stomata / cm^2 was recorded in 1990-91 at 120 days and it was followed by at 90 days (1990) (235.6 / cm^2) which was significantly less over mean value at 120 days (1990) and significantly higher over mean values at 90 days (1989) and 120 days (1989). Weighted mean was 228.2 cm^2 and ranged between 174.2 cm^2 (AK 32) and 350.8 cm^2 (BN 1). Popular recommended *hirsutum* variety, Pournima recorded lowest number of stomata (152.8 cm^2) while recommended *arboreum* variety Namdeo and BN 1, a parent of NHH 44 recorded highest value for this parameter.

Genetic correlation and regression studies between number of stomata and whitefly population at different stages were worked out seperately. The correlation cofficient and regression equations are presented in Table 14.

Table 14 : Correlation coefficient and regression equations between whitefly adult population and stomta/cm^2

Year	Days After Planting	`r´ values	Regression equation
1989	90	-0.168**	$\bar{Y}$ = 7.169 - 0.006 X
1989	120	-0.093	$\bar{Y}$ = 6.063 - 0.003 X
1990	90	-0.128**	$\bar{Y}$ = 9.766 - 0.007 X
1990	120	-0.054	$\bar{Y}$ = 6.810 - 0.002 X
Mean		-0.135**	$\bar{Y}$ = 6.472 - 0.001 X

** Significant (P = 0.01), * Significant (P = 0.05).

Table 15. Hair length in selected cotton cultivars exhibiting different degree of susceptibility to *B. tabaci*

Variety	Hair length (microns)			
	1989		1990	
	Days after germination			
	90	120	90	120
DS 28	195.35	204.033	201.704	212.196
NS 15	379.318	385.105	394.429	410.554
AM.NECT	98.51	104.275	116.171	122.433
G 67	292.898	310.313	291.577	325.659
AC 738	359.185	346.985	380.189	389.759
BN 1	209.31	217.158	227.975	230.697
DHY 286	228.15	237.878	256.259	249.751
AK 32	532.84	564.595	555.977	591.748
MCU 5	310.803	318.622	344.915	343.875
POURNIMA	178.92	188.805	205.587	197.278
LPS 141	277.415	289.683	310.049	292.097
LK 861	290.120	307.540	298.263	310.361
LRA 5166	398.39	413.965	427.350	421.284
SUMAN	228.63	241.583	263.634	255.139
SUPRIYA	258.23	273.365	278.386	288.574
PH 93	449.46	473.845	471.707	467.480
GLANDLESS	468.332	486.325	522.284	519.606
OKRA	332.450	353.628	352.194	382.392
PF	503.302	447.355	523.104	475.952
PNF	354.420	365.665	343.739	391.271
PONF	354.583	307.443	371.875	311.875
NH 210	174.242	170.420	191.554	179.552
NH 360	211.555	160.045	220.099	169.903
H 4	404.928	397.250	408.162	394.119
NHH 44	453.285	483.008	454.033	488.053
PKV HY.2	770.45	789.197	810.591	817.575
DCH 32	270.26	293.120	281.247	319.573
NHB 12	236.165	252.305	239.214	251.450
EKNATH	132.11	148.085	157.922	162.848
ROHINI	139.79	152.030	162.124	171.585
NAMDEO	213.303	203.167	219.147	216.661
JYOTI	141.46	152.060	165.513	168.334
SE±	2.82	1.57	1.88	1.62
CD at 5%	5.61	3.13	4.48	3.22

From the result it is evident that there was highly negative correlation between whitefly population and number of stomata per cm^2 .

4.5.1.3 Hair length (in micron)

Substantial genetic diversity amongst 32 genotypes for hair length at 90 and 120 days of both years was noted and it showed marked differences for expression of the character (Table 15). Wider range was expressed for hair length by 32 genotypes and it was maximum in AK 32 (573.7μ) while it was lowest (113.1μ) in American necteriless as against population mean of 321.0 μ.

Genetic correlation and regression studies between hair length and whitefly population at different stages were worked out seperately. The correlation cofficient and regression equations are presented in Table 16.

Table 16 : Correlation coefficient and regression equations between whitefly adult population and Hair length.

Year	Days After Planting	'r' values	Regression equation
1989	90	0.425*	$\bar{Y}$ = 3.619 + 0.006 X
1989	120	0.470*	$\bar{Y}$ = 2.470 + 0.006 X
1990	90	0.435*	$\bar{Y}$ = 5.030 + 0.009 X
1990	120	0.439*	$\bar{Y}$ = 3.480 + 0.008 X
Mean		0.498**	$\bar{Y}$ = 3.560 + 0.007 X

** Significant (P = 0.01), * Significant (P = 0.05).

From the results it is observed that there was significantly positive correlation between whitefly population and hair length.

4.5.1.4 Hair density

Analysis of variance for hair density in individual environment as well as pooled are depicted in Table 17.

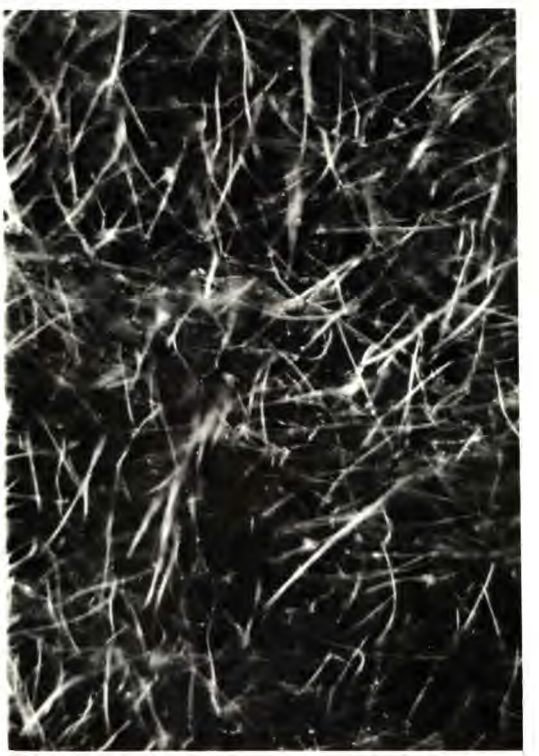
Highest hair density was to the tune of 35.2/cm^2 at 120 days (1990) which was significantly higher by margin of 27.3%, 56.3% and 56.9% , respectively over rest of the stages. The overall population mean for hair density was 26.9/cm^2 and ranged between 3.6 and 51.42/cm^2. Out of 32 genotypes, 13 and 14 genotypes recorded significantly higher and lower values for hair density when compared with population mean of 26.9 / cm^2. Most of the genotypes exhibited similar trend at all the stages of both years except LPS 141 and LK 861.

Genetic correlation and regression studies between hair density and whitefly population at different stages were worked out seperately. The correlation cofficient and regression equations are presented in Table 18.

NAMDEO

LK 861

NHH 44



PKV HY 2

PLATE 4 : HAIR DENSITY ON LEAF LAMINA OF DIFFERENT COTTON CULTIVARS.

NAMDEO

LK 861

NHH 44

PKV HY 2

PLATE 5 : HAIR DENSITY ON LEAF MIDRIB OF DIFFERENT COTTON CULTIVARS.

ROHINI

NH 360

DHY 286

LRA 5166

PLATE 6 : HAIR DENSITY ON LEAF LAMINA OF DIFFERENT COTTON CULTIVARS.

ROHINI

NH 360

DHY 286

LRA 5166

PLATE 7 : HAIR DENSITY ON LEAF MIDRIB OF DIFFERENT COTTON CULTIVARS.

DCH 32

G 67

NS 15

PLATE 8 : HAIR DENSITY ON LEAF LAMINA OF DIFFERENT COTTON CULTIVARS.

DCH 32

G 67

NS 15

PLATE 9 : HAIR DENSITY ON LEAF MIDRIB OF DIFFERENT COTTON CULTIVARS.

Table 17. Hair density ir selected cotton cultivars exhibiting different degree of susceptibility to *B. tabaci*

Variety	Hair density /cm^2			
	1989		1990	
	Days after germination			
	90	120	90	120
DS 28	15.52	18.405	21.380	31.962
NS 15	29.928	33.225	42.605	50.050
AM.NECT	1.148	0.718	4.760	2.548
G 67	21.423	26.743	29.392	40.353
AC 738	34.182	31.923	41.608	46.656
BN 1	12.78	17.945	22.663	31.083
DHY 286	39.980	42.118	48.042	52.296
AK 32	18.96	21.670	25.561	35.236
MCU 5	17.05	20.920	25.394	35.578
POURNIMA	35.68	40.690	47.428	48.846
LPS 141	5.925	6.778	8.944	14.687
LK 861	9.01	14.230	13.805	26.266
LRA 5166	18.71	23.013	27.538	34.211
SUMAN	15.533	17.728	22.510	29.381
SUPRIYA	8.092	10.967	14.062	24.373
PH 93	29.78	32.838	36,701	42.716
GLANDLESS	8.57	11.425	16.116	22.908
OKRA	20.925	17.135	25.182	30.060
PF	15.12	17.873	22.921	28.777
PNF	19.60	23.153	23.601	35.964
PONF	28.980	17.050	34.126	30.867
NH 210	1.620	2.505	5.290	12.046
NH 360	0.982	1.000	3.538	9.168
H 4	22.85	25.655	31.714	40.048
NHH 44	30.322	38.870	41.320	55.363
PKV HY.2	39.072	45.275	52.903	62.454
DCH 32	2.805	3.865	8.629	17.507
NHB 12	11.675	16.595	18.570	29.260
EKNATH	35.475	41.320	47.535	56.583
ROHINI	28.93	28.430	37.901	42.461
NAMDEO	32.360	40.128	47.772	55.188
JYOTI	33.217	28.860	41.432	42.527
SE±	3.21	1.18	2.30	1.31
CD at 5%	6.37	2.35	4.65	2.61

Table 18 : Correlation coefficient and regression equations between whitefly adult population and Hair density.

Year	Days After Planting	'r' values	Regression equation
1989	90	0.195*	$\bar{Y}$ = 4.920 + 0.032 X
1989	120	0.383**	$\bar{Y}$ = 3.090 + 0.056 X
1990	90	0.111	$\bar{Y}$ = 7.371 + 0.023 X
1990	120	0.236**	$\bar{Y}$ = 4.500 + 0.046 X
Mean		0.244**	$\bar{Y}$ = 4.760 + 0.047 X

** Significant (P = 0.01), * Significant (P = 0.05).

From the results it is concluded that there was highly positive correlation between whitefly population and hair density.

4.5.2 Study of anatomical characters in different cultivars

Substantial diversity and significant differences were observed for palisade cell, mesophyll cells and distances between epidermis and phloem amongst 32 genotypes under study (Table 19).

The average length of palisade cells varied from 77.49 µ (Jyoti) to 102.76 µ (DCH 32). The two intersepcific hybrids DCH 32 and NHB 12 recorded highest length of palisade cells and at par with three susceptible *hirsutum* hybirds (H 4, NHH 44 and PKV Hy.2) and two

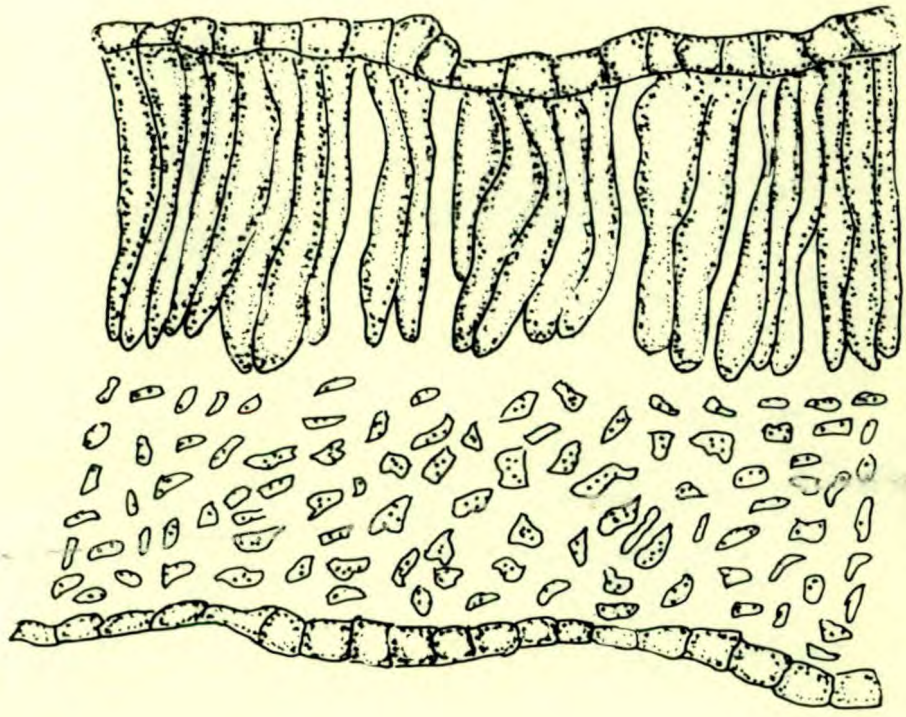


Fig.13 T.S. of leaf of LPS 141. X 240

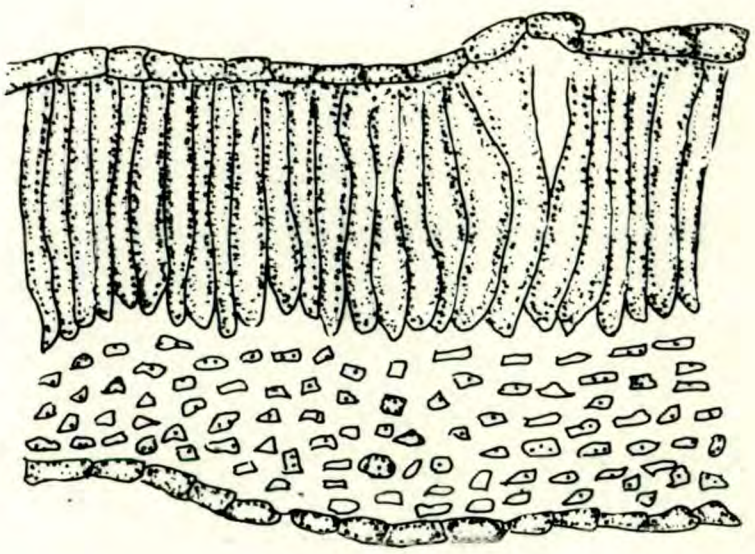


Fig.14 T.S. of leaf of LK 861. X 240

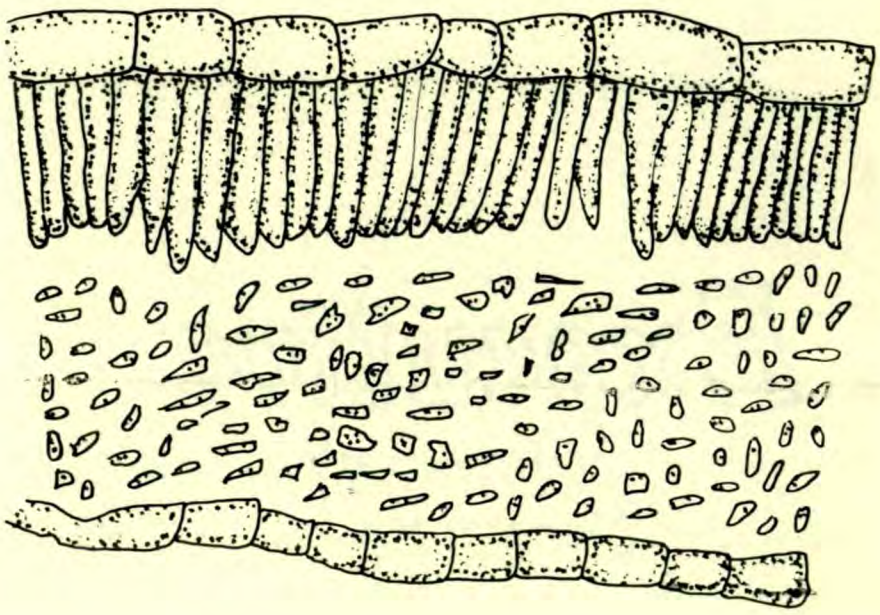


Fig.15 T. S. of leaf of PKVHy-2. X 240

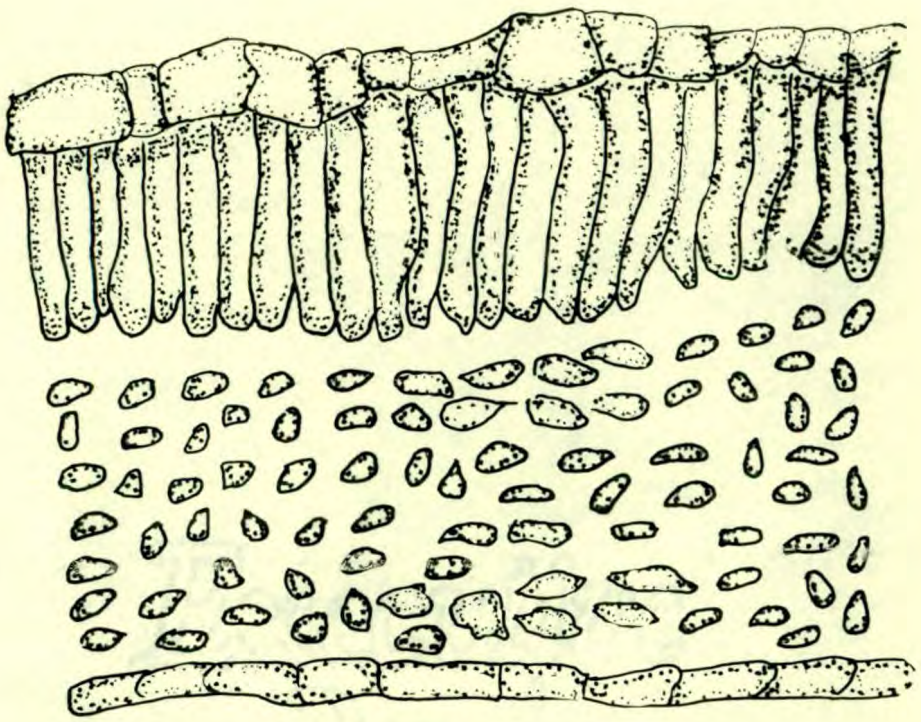


Fig.16 T.S. of leaf of NHH-44. X240

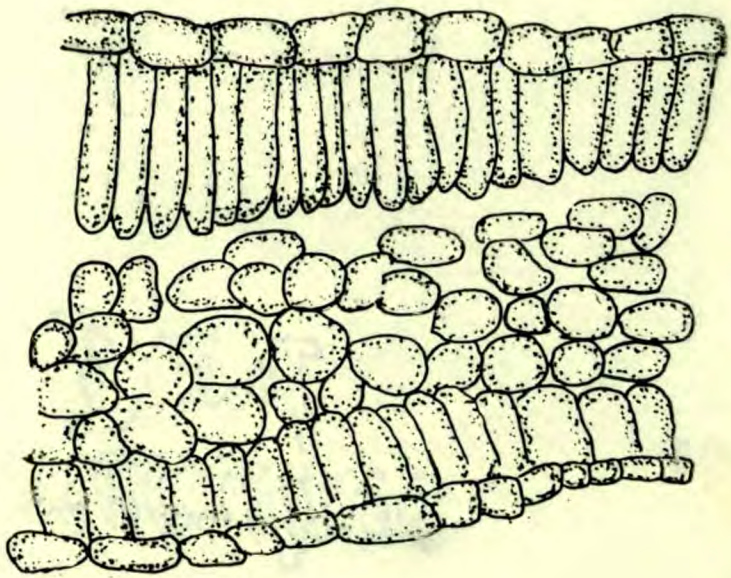


Fig.17 T.S. of leaf of Namdeo. X240

Table 19 : Anatomical characters in selected cotton cultivars exhibiting different degrees of susceptibility to *B. tabaci*.

Variety	size of cells (micron)		Distance between epidermis and phloem (micron)
	Palisade	Mesophyll	
DS 28	80.91	77.62	94.32
NS 15	71.70	75.84	81.01
AME.Nect.	82.93	76.38	114.15
G 67	81.01	82.69	82.93
AC 738	82.78	87.89	87.89
BN I	80.03	78.41	92.59
DHY 286	81.99	89.72	98.37
AK 32	80.16	80.42	96.41
MCU 5	78.72	91.64	87.04
Pournima	84.89	90.22	92.56
LPS 141	96.12	72.44	110.63
LK 861	96.71	74.44	109.62
LRA 5166	83.57	92.55	93.50
Suman	87.08	86.76	91.93
Supriya	81.47	87.16	99.47
PH 93	91.83	71.15	104.49
Glandless	87.15	82.51	91.82
Okra	89.06	79.24	88.28
PF	84.89	80.68	87.69
PNF	87.27	81.63	88.66
PONF	86.64	82.61	87.95
NH 210	92.69	81.33	98.67
NH 360	96.04	81.68	96.86
H 4	96.91	101.75	92.52
NHH 44	97.41	92.79	98.68
PKV Hy. 2	94.33	98.52	96.39
DCH 32	102.76	80.83	96.93
NHB 12	102.35	83.33	97.39
Eknath	78.31	53.86	104.76
Rohini	77.90	55.79	106.26
NAMDEO	80.93	56.63	107.84
JYOTI	77.49	50.67	102.67
SE ±	4.11	2.30	3.60
CD at 5%	12.60	6.92	9.88

resistant hirsutum genotyes (LK 861 and LPS 141). All *arboreum* varieties recorded lowest length of palisade cells and were at par with most of *hirsutum* varieties.

The highest length of mesophyll cells was recorded in H 4 (101.75 µ) and it was at par with PKV Hy.2 (98.52 µ). The *desi* cotton varieties had lowest length of mesophyll cells which was significantly superior over rest of the genotypes. The resistant genotype LPS 141 and LK 861 recorded medium length of mesophyll cells but significantly heigher over rest of the cultivars except DS 28, NS 15, American nectariless and BN I.

The mean distance between epidermis to phloem varied from 81.01 µ (NS 15) to 114.15 µ (American Nectariless). The two resistant strains LK 861 and LPS 141 recorded higher distance betwen epidermis to phloem and it was at par with PH 93 and all asiatic cotton varieties.

4.5.3 Impact of physiological characters under varied environmental conditions

An attempt has been made to understand the impact of cell contents i.e. chlorophyll a, b,total chlorophyll and pH of cell sap on sensitivity of genotype, pest development and genotype behaviour in relation with pest.

4.5.3.1 Chlorophyll 'a'

Component chlorophyll 'a' was estimated in 32 genotypes at 90 and 120 days during 1989 and 1990. Statistical analysis presented in Table 20 revealed significant difference among the genotypes. Magnitude of chlorophyll a was relatively less during 1989-90 at both the stages viz, 90 and 120 days as compared to rest of the treatments. Pooled mean for chlorophyll component was 1.55 and ranged between 1.74 (H 4) and 1.29 (NS 15). Out of 32 genotypes, 14 recorded significantly higher chlorophyll a content over population mean. It was revealed that two straight varieties viz, MCU 5 and PF and intra *hirsutum* hybrid H 4 recorded significantly higher value over rest of the genotypes. The study also indicated that the diploid variety Namdeo recorded chlorophyll a higher than recommended popular tetraploid hybrid NHH 44.

Genetic correlation and regression studies between chlorophyll a and whitefly population at different stages were worked out seperately. The correlation cofficient and regression equations are presented in Table 21.

Table 20. Chlorophyll a content in selected cotton cultivars exhibiting different degree of susceptibility to *B. tabaci*

Variety	Chlorophyll a content (mg/g)			
	1989		1990	
	Days after germination			
	90	120	90	120
DS 28	2.327	2.318	2.518	2.549
NS 15	2.167	2.185	2.348	2.442
AM.NECT	2.431	2.422	2.634	2.694
G 67	2.243	2.257	2.439	2.504
AC 738	2.233	2.239	2.548	2.497
BN 1	2.378	2.341	2.587	2.586
DHY 286	2.418	2.456	2.651	2.697
AK 32	2.376	2.381	2.571	2.640
MCU 5	2.548	2.590	2.793	2.864
POURNIMA	2.540	2.598	2.775	2.822
LPS 141	2.547	2.652	2.794	2.780
LK 661	2.316	2.345	2.503	2.570
LRA 5166	2.337	2.341	2.561	2.577
SUMAN	2.382	2.354	2.615	2.600
SUPRIYA	2.442	2.479	2.646	2.729
PH 83	2.395	2.373	2.584	2.593
GLANDLESS	2.496	2.495	2.769	2.624
OKRA	2.447	2.451	2.680	2.725
PF	2.606	2.611	2.835	2.878
PNF	2.344	2.349	2.526	2.612
PONF	2.526	2.530	2.754	2.752
NH 210	2.390	2.351	2.631	2.582
NH 360	2.539	2.561	2.750	2.790
H 4	2.662	2.618	2.682	2.828
NHH 44	2.539	2.486	2.738	2.718
PKV HY.2	2.565	2.561	2.784	2.820
DCH 32	2.414	2.418	2.593	2.690
NHB 12	2.409	2.518	2.606	2.721
EKNATH	2.427	2.427	2.641	2.678
ROHINI	2.378	2.381	2.590	2.615
NAMDEO	2.558	2.566	2.761	2.811
JYOTI	2.414	2.426	2.649	2.682
SE±	0.07	0.01	0.08	0.05
CD at 5%	0.14	0.02	0.16	0.09

Table 21 : Correlation coefficient and regression equations between whitefly adult population and chlorophyll a.

Year	Days After Planting	'r' values	Regression equation
1989	90	-0.102	$\bar{Y}$ = 6.520 - 2.020 X
1989	120	-0.091	$\bar{Y}$ = 5.000 - 1.490 X
1990	90	-0.181	$\bar{Y}$ = 11.120 - 4.780 X
1990	120	-0.175	$\bar{Y}$ = 9.060 - 4.270 X
Mean		0.149	$\bar{Y}$ = 4.600 + 2.630 X

** Significant (P = 0.01), * Significant (P = 0.05).

From above table it is found that there was non-significant correlation between whitefly population and chlorophyll a.

4.5.3.2 Chlorophyll `b'

Perusal of Table 22 revealed presence of substantial genetic variability for chlorophyll b. Maximum chlorophyll `b' was observed from the samples collected at 120 days during 1990-91 which showed two fold increase in value over 1989-90 at 90 and 120 days of the crop. Chlorophyll b expressed fully at 120 days rather than at 90 days. In ranking PKV Hy 2 and LK 861 were on the top and bottom respectively. The trend also indicated that intra/inter species hybrids showed a heterotic effects for chlorophyll b, over their respective parents as well as popular varieties like Pournima, H 4, LPS 141 were at par

Table 22. Chlorophyll b in selected cotton cultivars exhibiting different degree of susceptibility to *B. tabaci*

Variety	Chlorophyll b content (mg/g)			
	1989		1990	
	Days after germination			
	90	120	90	120
DS 28	1.327	1.379	1.586	1.710
NS 15	1.191	1.192	1.480	1.557
AM.NECT	1.401	1.427	1.674	1.808
G 67	1.239	1.255	1.504	1.607
AC 738	1.232	1.255	1.530	1.620
BN 1	1.331	1.359	1.608	1.707
DHY 286	1.329	1.379	1.632	1.723
AK 32	1.365	1.354	1.628	1.719
MCU 5	1.497	1.510	1.813	1.890
POURNIMA	1.566	1.545	1.875	1.872
LPS 141	1.566	1.580	1.886	1.898
LK 861	1.190	1.245	1.449	1.574
LRA 5166	1.239	1.247	1.533	1.586
SUMAN	1.278	1.248	1.580	1.597
SUPRIYA	1.333	1.324	1.606	1.677
PH 93	1.314	1.341	1.574	1.661
GLANDLESS	1.431	1.446	1.741	1.826
OKRA	1.384	1.382	1.687	1.670
PF	1.544	1.541	1.483	1.904
PNF	1.268	1.280	1.519	1.648
PONF	1.466	1.450	1.766	1.776
NH 210	1.328	1.316	1.639	1.650
NH 360	1.522	1.421	1.803	1.755
H 4	1.657	1.516	1.927	1.830
NHH 44	1.497	1.456	1.764	1.791
PKV HY.2	1.604	1.781	1.906	1.086
DCH 32	1.319	1.381	1.569	1.761
NHB 12	1.408	1.317	1.674	1.630
EKNATH	1.334	1.339	1.671	1.694
ROHINI	1.278	1.290	1.560	1.629
NAMDEO	1.431	1.441	1.704	1.790
JYOTI	1.531	1.361	1.655	1.723
SE±	0.09	0.02	0.03	0.06
CD at 5%	0.18	0.04	0.06	0.12

but significantly superior over rest of the genotypes except PKV Hy 2 which was significantly higher.

Genetic correlation and regression studies between chlorophyll b and whitefly population at different stages were worked out seperately. The correlation cofficient and regression equations are presented in Table 23.

Table 23 : Correlation coefficient and regression equations between whitefly adult population and chlorophyll b.

Year	Days After Planting	'r' values	Regression equation
1989	90	0.052	$\bar{Y}$ = 5.290 + 0.948 X
1989	120	0.093	$\bar{Y}$ = 3.770 + 1.510 X
1990	90	-0.041	$\bar{Y}$ = 8.680 - 0.981 X
1990	120	0.077	$\bar{Y}$ = 4.810 + 1.810 X
Mean		0.279	$\bar{Y}$ = 3.900 + 3.960 X

** Significant (P = 0.01), * Significant (P = 0.05).

From above results it is evident that non-significant correlation existed between whitefly population and chlorophyll b.

4.5.3.3 Total chlorophyll

Estimates of total chlorophyll ranged from 1.50 (PKV Hy 2) and 0.63 (NS 15). The overall population mean was 1.09 and 13 genotypes recorded significantly higher values over population mean. Hybrid PKV Hy 2, H 4 and PF ranked

Table 24: Total chlorophyll in selected cotton cultivars exhibiting different degree of susceptibility to *B. tabaci*

Variety	Total chlorophyll (mg/g)			
	1989		1990	
	Days after germination			
	90	120	90	120
DS 28	3.654	3.697	4.103	4.258
NS 15	3.358	3.376	3.864	3.998
AM.NECT	3.832	3.849	4.308	4.502
G 67	3.556	3.551	4.014	4.111
AC 738	3.464	3.495	3.988	4.117
BN 1	3.710	3.699	4.194	4.293
DHY 286	3.747	3.810	4.283	4.395
AK 32	3.742	3.734	4.199	4.359
MCU 5	4.045	4.100	4.606	4.754
POURNIMA	4.106	4.132	4.649	4.683
LPS 141	4.113	4.154	4.680	4.689
LK 861	3.528	3.591	3.974	4.145
LRA 5166	3.575	3.588	4.084	4.163
SUMAN	3.660	3.602	4.195	4.197
SUPRIYA	3.775	3.001	4.252	4.403
PH 93	3.708	3.715	4.158	4.254
GLANDLESS	3.927	3.941	4.477	4.595
OKRA	3.817	3.833	4.353	4.486
PF	4.150	4.152	4.678	4.782
PNF	3.612	3.628	4.045	4.260
PONF	3.967	3.979	4.494	4.528
NH 210	3.717	3.667	4.270	4.233
NH 360	4.061	3.982	4.554	4.545
H 4	4.319	4.183	4.789	4.705
NHH 44	4.036	3.941	4.502	4.509
PKV HY.2	4.169	4.279	4.699	4.906
DCH 32	3.738	3.797	4.167	4.449
NHB 12	3.842	3.834	4.305	4.350
EKNATH	3.762	3.766	4.258	4.372
ROHINI	3.656	3.671	4.150	4.243
NAMDEO	3.989	4.006	4.465	4.600
JYOTI	3.766	3.787	4.305	4.405
SE±	0.19	0.15	0.20	0.16
CD at 5%	0.37	0.29	0.39	0.32

1st, 2nd and 3rd in order of merit. These three genotypes also showed superior performance either for chlorophyll a or b component.

Genetic correlation and regression studies between chlorophyll b and whitefly population at different stages were worked out seperately. The correlation cofficient and regression equations are presented in Table 25.

Table 25 : Correlation coefficient and regression equations between whitefly adult population and total chlorophyll.

Year	Days After Planting	`r´ values	Regression equation
1989	90	-0.011	$\bar{Y}$ = 5.740 - 0.109 X
1989	120	-0.003	$\bar{Y}$ = 4.370 - 0.025 X
1990	90	-0.103	$\bar{Y}$ = 9.800 - 1.348 X
1990	120	-0.047	$\bar{Y}$ = 6.980 - 0.586 X
Mean		0.228	$\bar{Y}$ = 4.050 - 1.824 X

** Significant (P = 0.01), * Significant (P = 0.05).

From the results it is evident that there was weak postive correlation between whitfly population and total chlorophyll.

4.5.3.4 pH of cell sap

Perusal of Table 26 revealed that except at 120 days (1990), all the three environments were unfavourable and recorded pH values nearer to 7. Highest value for pH was observed at 120 days (1990) and were ranged from 7.2

Table 26. pH content in selected cotton cultivars exhibiting different degree of susceptibility to *B. tabaci*

Variety	pH			
	1989		1990	
	Days after germination			
	90	120	90	120
DS 28	5.750	5.565	6.364	7.837
NS 15	6.606	7.055	7.051	8.780
AM.NECT	5.333	5.905	6.128	7.681
G 67	5.615	6.807	6.280	8.326
AC 738	6.123	7.280	7.232	8.976
BN 1	5.938	7.618	6.765	9.089
DHY 286	6.155	7.122	7.277	8.527
AK 32	6.202	7.405	6.877	9.080
MCU 5	6.193	7.712	7.380	9.508
POURNIMA	6.180	6.930	7.275	8.194
LPS 141	5.997	6.918	7.187	8.104
LK 861	5.763	7.162	6.331	8.345
LRA 5166	5.982	7.255	7.026	8.596
SUMAN	6.090	6.590	7.226	8.066
SUPRIYA	5.983	6.907	6.775	8.427
PH 93	6.342	6.945	6.959	8.067
GLANDLESS	5.965	6.217	7.117	7.988
OKRA	5.768	6.632	6.850	8.439
PF	5.595	6.912	6.604	8.523
PNF	5.770	7.130	6.268	8.870
PONF	6.038	6.883	7.071	8.113
NH 210	5.782	5.915	6.895	7.219
NH 360	5.628	6.263	6.449	7.580
H 4	5.710	6.450	6.497	7.598
NHH 44	5.298	7.647	6.681	8.784
PKV HY.2	6.550	7.843	7.590	9.480
DCH 32	5.780	6.255	6.307	8.050
NHB 12	5.943	6.762	6.665	7.784
EKNATH	6.330	7.293	7.231	8.840
ROHINI	6.350	7.100	7.231	8.427
NAMDEO	6.838	7.012	7.626	8.486
JYOTI	7.137	7.650	8.309	9.283
SE±	0.08	0.02	0.10	0.06
CD at 5%	0.19	0.05	0.21	0.13

to 9.5 whereas 6.3 to 8.3, 5.9 to 7.6 and 5.5 to 7.1 in 90 days (1990) , 120 days (1989) and 90 days (1989) respectively.

A *desi* cotton variety Jyoti recorded highest overall mean for pH while DCH 32 recorded lowest value. Except PKV Hy 2, other four top ranking genotypes were from *G.arboreum* type. Probably high values for pH content in *arboreum* varieties and low values in hybrids of tetraploid cotton might be cause for non preference by pest for diploid cotton.

Genetic correlation and regression studies between pH and whitefly population at different stages were worked out seperately. The correlation cofficient and regression equations are presented in Table 27.

Table 27 : Correlation coefficient and regression equations between whitefly adult population and pH.

Year	Days After Planting	`r' values	Regression equation
1989	90	-0.056	$\bar{Y}$ = 7.650 - 0.327 X
1989	120	0.154	$\bar{Y}$ = 0.322 + 0.581 X
1990	90	-0.131	$\bar{Y}$ = 13.880 - 0.844 X
1990	120	0.156	$\bar{Y}$ = -0.253 + 0.761 X
Mean		0.056	$\bar{Y}$ = 4.900 + 0.162 X

** Significant (P = 0.01), * Significant (P = 0.05).

It is found that there was non-significant correlation between whitfly population and pH (Table 27).

4.5.4 Impact of nutritional parameters under varied environmental condition

4.5.4.1 Nitrogen

Analysis of variance and performance for nitrogen content is given in Table 28. Nitrogen content in 32 genotypes ranged from 1.42 (PF) to 2.89 (PKV Hy 2) with overall mean of 2.35. Six and fourteen genotypes recorded significantly lower and higher nitrogen estimation when compared with population mean. Highest estimates was recorded at 120 days (1990) (3.63) while it was lowest at 120 days (1989) (1.51). Cultivars viz, NHH 44 and PKV Hy 2 had highest nymphal count recorded high nitrogen content.

Cultivars Eknath, Rohini, (desi) PF, PNF (*hirsutum*) recorded relatively lower values as compared to that of preferred one.

Genetic correlation and regression studies between nitrogen and whitefly population at different stages were worked out seperately. The correlation cofficient and regression equations are presented in Table 29.

Table 28 : Nitrogen content in selected cotton cultivars exhibiting different degree of susceptibility to *B. tabaci*

Variety	Nitrogen (%)			
	1989		1990	
	Days after germination			
	90	120	90	120
DS 28	1.620	2.16	2.834	3.637
NS 15	1.730	2.21	3.108	3.934
AM.NECT	1.543	2.31	2.833	3.751
G 67	1.587	2.28	2.820	3.684
AC 738	1.780	2.17	3.211	3.964
BN 1	1.738	1.90	3.043	3.837
DHY 286	1.745	2.39	3.180	3.798
AK 32	1.783	2.42	3.020	3.923
MCU 5	1.660	2.47	3.118	3.370
POURNIMA	2.025	2.97	3.457	3.994
LPS 141	1.473	2.20	2.297	3.346
LK 861	1.452	2.11	2.651	3.428
LRA 5166	1.348	2.32	2.739	3.375
SUMAN	1.478	2.09	2.910	3.590
SUPRIYA	1.555	2.19	2.846	3.683
PH 93	1.620	2.22	2.641	3.576
GLANDLESS	1.665	2.91	3.112	3.917
OKRA	1.572	1.89	2.991	3.806
PF	0.563	1.31	1.926	2.601
PNF	0.498	1.23	1.724	2.916
PONF	0.768	1.120	2.141	3.153
NH 210	1.310	1.253	2.766	3.302
SB 298	1.452	1.390	2.777	3.444
H 4	1.855	2.93	3.140	3.706
NHH 44	1.955	2.85	3.223	3.867
PKV HY.2	2.058	2.99	3.460	4.120
DCH 32	1.707	1.680	2.876	3.967
NHB 12	1.540	1.502	2.802	3.429
EKNATH	1.615	1.575	2.951	3.733
ROHINI	1.640	1.542	2.970	3.605
NAMDEO	1.597	1.492	2.891	3.618
JYOTI	1.518	1.467	2.948	3.356
SE±	0.10	0.11	0.10	0.13
CD at 5%	0.19	0.23	0.20	0.26

Table 29 : Correlation coefficient and regression equations between whitefly adult population and nitrogen

Year	Days After Planting	'r' values	Regression equation
1989	90	0.505**	$\bar{Y}$ = 0.967 + 3.030 X
1989	120	0.552**	$\bar{Y}$ = -0.466 + 3.190 X
1990	90	0.413**	$\bar{Y}$ = -1.640 + 3.358 X
1990	120	0.494**	$\bar{Y}$ = -7.660 + 3.805 X
Mean		0.418**	$\bar{Y}$ = 3.110 + 1.225 X

** Significant (P = 0.01), * Significant (P = 0.05).

From the result it is evident that there was significantly positive correlation existed between whitfly population and nitrogen.

4.5.4.2 Phosphorus

Substantial genetic diversity for phosphorus content is existing for 32 genotypes (Table 30). Environment also played vital role in changing the level of phosphorus content and thereby affect on intenstity of whitefly . Phosphorus content of a cultivar changed with change in environment.

The overall population mean for phosphorus was 3.93 mg/gm. Hybrid DCH 32 recorded very high estimates (4.26 mg/gm) while DHY 286 was the lowest (2.59 mg/gm) in order of merit. Hybrid DCH 32 recorded significantly higher value over population mean while rest of the cultivars recorded either at par or significantly less phosphorus.

Table 30. Phosphorus content in selected cotton cultivars exhibiting different degree of susceptibility to *B. tabaci*

Variety	Phosphorus (mg/g)			
	1989		1990	
	Days after germination			
	90	120	90	120
DS 28	2.010	2.918	4.155	5.999
NS 15	3.118	3.300	5.520	6.729
AM.NECT	2.717	2.983	4.965	6.474
G 67	2.095	3.013	4.262	6.282
AC 738	3.135	3.127	5.629	6.526
BN 1	1.195	2.053	4.195	5.286
DHY 286	1.963	2.054	4.422	5.252
AK 32	2.670	2.861	5.034	6.235
MCU 5	2.277	2.270	4.790	5.697
POURNIMA	2.905	2.837	5.379	5.922
LPS 141	2.188	2.178	4.703	5.227
LK 861	2.055	3.080	4.163	6.103
LRA 5166	1.565	3.120	3.969	6.260
SUMAN	2.720	2.705	5.219	5.942
SUPRIYA	3.015	3.055	5.262	6.325
PH 93	2.535	2.955	4.672	5.932
GLANDLESS	1.873	2.193	4.351	5.637
OKRA	1.733	2.457	4.172	5.927
PF	1.973	3.155	4.371	6.374
PNF	2.985	3.072	5.012	6.505
PONF	1.300	2.088	3.68[illegible]	5.168
NH 210	2.135	2.000	4.665	5.116
NH 360	2.683	2.563	4.991	5.682
H 4	2.112	2.023	4.363	5.042
NHH 44	2.173	3.425	4.403	6.543
PKV HY.2	2.227	2.873	4.637	6.214
DCH 32	4.390	3.488	6.355	7.006
NHB 12	2.883	2.815	5.078	5.719
EKNATH	2.685	2.678	5.011	5.963
ROHINI	2.678	2.767	4.993	5.900
NAMDEO	2.430	2.563	4.686	5.797
JYOTI	2.543	2.979	5.031	6.138
SE±	0.06	0.02	0.07	0.06
CD at 5%	0.12	0.05	0.14	0.13

Behaviour of genotypes under varied environment indicated consistent performance of varieties from *arboreum* group followed by three *hirsutum* varieties. These genotypes though recorded relatively less values maintained their position in all kinds of environment

Genetic correlation and regression studies between phosphorus and whitefly population at different stages were worked out seperately. The correlation cofficient and regression equations are presented in Table 31.

Table 31 : Correlation coefficient and regression equations between whitefly adult population and phosphorus

Year	Days After Planting	'r' values	Regression equation
1989	90	0.077	$\bar{Y}$ = 4.930 + 0.293 X
1989	120	0.190	$\bar{Y}$ = 2.110 + 0.820 X
1990	90	-0.047	$\bar{Y}$ = 9.310 - 0.270 X
1990	120	0.153	$\bar{Y}$ = 1.100 + 0.845 X
Mean		0.274*	$\bar{Y}$ = 4.040 + 0.505 X

** Significant (P = 0.01), * Significant (P = 0.05).

It is found that there is positive corrrelation between whitefly population and phosphorus (Table 31).

4.5.4.3 Calcium

Lowest estimates for calcium was recorded at 120 days (1989) (23.74 mg/gm) followed by at 90 days (1989) (24.79 mg/gm) (Table 32). This indicates that the year 1989-90 in comparision with 1990-91 had inhibited for

Table 32. Calcium content in selected cotton cultivars exhibiting different degree of susceptibility to *B. tabaci*

Variety	Calcium (mg/g)			
	1989		1990	
	Days after germination			
	90	120	90	120
DS 28	20.100	19.022	22.824	23.865
NS 15	34.455	32.958	38.855	39.566
AM.NECT	17.632	16.225	21.568	22.568
G 67	30.550	29.350	33.199	35.013
AC 738	29.427	28.473	34.294	34.806
BN 1	18.413	17.403	21.895	22.846
DHY 286	20.380	19.270	24.961	24.560
AK 32	32.882	32.160	35.602	38.491
MCU 5	34.120	33.357	39.556	40.189
POURNIMA	31.930	30.890	36.800	35.457
LPS 141	25.298	21.632	30.324	26.166
LK 861	21.650	20.360	24.218	24.944
LRA 5166	23.403	18.340	27.809	23.434
SUMAN	36.208	34.320	41.470	39.815
SUPRIYA	22.490	21.522	25.912	27.125
PH 93	26.775	25.285	29.427	29.473
GLANDLESS	17.417	16.660	21.999	22.969
DKRA	20.778	19.400	25.306	25.877
PF	33.630	31.882	38.170	38.664
PNF	28.165	27.560	30.202	34.061
PONF	24.070	23.503	28.445	28.125
NH 210	29.632	27.738	35.033	32.456
NH 360	31.107	30.383	34.849	35.137
H 4	27.115	26.735	30.455	30.886
NHH 44	24.950	23.358	28.181	28.311
PKV HY.2	21.132	20.260	25.416	26.167
DCH 32	31.512	31.140	33.432	38.150
NHB 12	31.408	30.170	34.388	32.452
EKNATH	9.255	9.455	13.278	15.024
ROHINI	7.942	7.582	11.656	12.793
NAMDEO	8.403	8.045	11.964	13.475
JYOTI	21.022	25.485	25.870	31.490
SE±	1.24	0.62	1.27	0.92
CD at 5%	2.46	1.24	2.53	1.84

expression of calcium content. Pooled mean for calcium content was 26.59 mg/gm. Genotypes showed a wider range for this component i.e. from 9.9 mg/gm in Rohini to 37.95 mg/gm in Suman. All *G.arboreum* varieties except Jyoti recorded very low calcium content.

In general calcium level in hybrid was lower as compared to their parents and popular variety Pournima. Susceptible cultivars were having level of calcium in the range of moderate to very high.

Genetic correlation and regression studies between calcium and whitefly population at different stages were worked out seperately. The correlation cofficient and regression equations are presented in Table 33.

Table 33 : Correlation coefficient and regression equations between whitefly adult population and calcium.

Year	Days After Planting	`r' values	Regression equation
1989	90	0.311*	$\bar{Y}$ = 3.400 + 0.090 X
1989	120	0.200*	$\bar{Y}$ = 3.160 + 0.050 X
1990	90	0.268*	$\bar{Y}$ = 4.940 + 0.107 X
1990	120	0.240*	$\bar{Y}$ = 3.580 + 0.087 X
Mean		0.324*	$\bar{Y}$ = 2.930 + 0.116 X

** Significant (P = 0.01), * Significant (P = 0.05).

From the result it is found that there was significant positive correlation between whitefly incidence and calcium content in leaf.

4.5.4.4 Vitamin C

Estimates for vitamin C are given in Table 34. Variation due to varieties was highly significant. Estimates of vitamin C at 120 days (1990) was 15.61 mg/100 gm which showed significant superiority at 90 days (1990), 120 days (1989) and 90 days (1989) by margin of 23.2%, 47.9% and 50.6% , respectively.

The overall mean for vitamin C content was 12.31 mg/100 gm. A reported resistant genotype LPS 141 recorded highest vitamin C content (26.43 mg/100 gm) and it was significantly superior over rest of the cultivars. G 67 followed by Okra and PF, had very less amount of vitamin c.

Genetic correlation and regression studies between vitamin c and whitefly population at different stages were worked out seperately. The correlation cofficient and regression equations are presented in Table 35.

Table 34 : Correlation coefficient and regression equations between whitefly adult population and vitamin c.

Year	Days After Planting	'r' values	Regression equation
1989	90	-0.189	$\bar{Y}$ = 6.480 - 0.080 X
1989	120	-0.224	$\bar{Y}$ = 5.200 - 0.079 X
1990	90	-0.133	$\bar{Y}$ = 9.030 - 0.078 X
1990	120	-0.194	$\bar{Y}$ = 7.740 - 0.102 X
Mean		-0.070	$\bar{Y}$ = 6.490 - 0.035 X

** Significant (P = 0.01), * Significant (P = 0.05).

Table 35. Vitamin C content in selected cotton cultivars exhibiting different degree of susceptibility to *B. tabaci*

Variety	Vitamin C (mg/100 g)			
	1989		1990	
	Days after germination			
	90	120	90	120
DS 28	1.445	12.498	13.185	17.098
NS 15	6.385	5.413	8.778	10.747
AM.NECT	12.225	11.582	14.306	17.313
G 67	1.378	0.978	3.499	6.030
AC 738	8.762	9.415	11.386	14.816
BN 1	11.262	10.235	13.429	15.264
DHY 286	7.270	8.188	9.854	13.128
AK 32	9.815	10.340	11.729	15.722
MCU 5	11.432	12.350	14.297	17.995
POURNIMA	8.340	9.467	10.923	14.139
LPS 141	25.333	24.510	28.888	28.556
LK 861	18.305	17.388	19.632	21.676
LRA 5166	9.225	8.538	11.762	13.362
SUMAN	10.358	9.677	13.088	14.715
SUPRIYA	9.448	10.328	11.562	15.446
PH 93	6.698	7.6655	8.625	12.167
GLANDLESS	12.323	13.600	15.176	19.362
DKRA	18.757	20.808	21.711	26.924
PF	2.415	2.525	4.752	7.811
PNF	2.420	2.382	4.410	7.635
PONF	3.247	3.442	5.615	8.220
NH 210	7.295	8.492	10.017	13.219
NH 360	9.403	10.465	11.653	15.189
H 4	8.356	9.455	10.469	13.895
NHH 44	6.400	7.175	8.495	11.988
PKV HY.2	5.760	4.700	8.184	9.895
DCH 32	16.225	18.065	19.429	24.079
NHB 12	17.325	17.237	19.161	21.060
EKNATH	11.283	11.450	13.585	16.626
ROHINI	12.425	12.318	14.701	17.057
NAMDEO	14.605	14.310	16.677	19.349
JYOTI	13.693	13.660	16.544	19.024
SE±	0.11	0.15	0.14	0.17
CD at 5%	0.21	0.29	0.28	0.35

From the above table it is evident that there was negative corelation between whitfly population and vitamin c.

4.5.4.5 Total sugar

It was estimated at 90 and 120 days during 1989-90 and 1990-91. Table 36 revealed that *desi* varieties estimated lower values during 1989 while NS 15, American nectariless, G 67, LRA 5166, Pournima, H 4 and DCH 32 recorded higher values during 1990.

Genetic correlation and regression studies between total sugar and whitefly population at different stages were worked out seperately. The correlation cofficient and regression equations are presented in Table 37.

Table 36 : Correlation coefficient and regression equations between whitefly adult population and total sugar.

Year	Days After Planting	`r´ values	Regression equation
1989	90	-0.146	$\bar{Y}$ = 6.650 - 0.165 X
1989	120	-0.166	$\bar{Y}$ = 5.310 - 0.158 X
1990	90	-0.156	$\bar{Y}$ = 10.590 - 0.259 X
1990	120	-0.127	$\bar{Y}$ = 10.020 - 0.300 X
Mean		0.124	$\bar{Y}$ = 5.160 + 0.101 X

** Significant (P = 0.01), * Significant (P = 0.05).

From the result it is found that non-significant correlation existed between whitefly population and total sugar.

Table 37 : Total sugar content in selected cotton cultivars exhibiting different degree of susceptibility to *B. tabaci*

Variety	Total sugars (mg/g)			
	1989		1990	
	Days after germination			
	90	120	90	120
DS 28	6.565	7.442	7.006	7.008
NS 15	6.175	8.165	7.145	8.368
AM.NECT	8.150	8.130	5.868	8.429
G 67	6.818	4.905	6.389	8.810
AC 738	6.847	7.878	7.922	6.997
BN 1	9.398	8.213	7.150	7.059
DHY 286	7.318	7.230	6.548	7.996
AK 32	7.970	7.960	5.538	7.076
MCU 5	9.142	7.195	5.358	7.174
POURNIMA	6.370	7.358	6.476	8.903
LPS 141	6.872	7.837	6.090	7.286
LK 861	7.125	8.037	6.444	7.422
LRA 5166	6.435	8.338	6.390	8.001
SUMAN	6.148	7.112	6.223	6.962
SUPRIYA	7.733	7.650	5.438	7.553
PH 93	8.878	7.898	6.350	7.216
GLANDLESS	8.957	7.862	6.176	7.206
OKRA	8.855	7.798	8 023	7.211
PF	7.677	5.817	7.836	7.330
PNF	6.125	5.160	7.207	7.544
PONF	7.315	5.225	6.420	8.642
NH 210	7.120	7.878	6.381	7.440
NH 360	6.298	6.230	7.116	6.819
H 4	7.363	8.240	6.050	8.555
NHH 44	7.485	7.367	6.123	6.984
PKV HY.2	8.425	8.258	5.498	6.356
DCH 32	7.578	8.628	6.656	8.217
NHB 12	7.480	7.890	5.031	6.934
EKNATH	3.938	4.923	6.785	7.870
ROHINI	5.207	5.213	6.035	7.854
NAMDEO	4.437	4.495	6.092	7.344
JYOTI	3.870	3.815	4.969	7.848
SE±	0.09	0.03	0.12	0.09
CD at 5%	0.18	0.06	0.24	0.17

4.5.4.6 Reducing sugar

Perusal of Table 39 revealed significant differences amongst varieties for each environment. It indicated that the genotype selected possess substantial genetic diversity for reducing sugar.

Genetic correlation and regression studies between reducing sugar and whitefly population at different stages were worked out seperately. The correlation cofficient and regression equations are presented in Table 38.

Table 38 : Correlation coefficient and regression equations between whitefly adult population and reducing sugar.

Year	Days After Planting	'r' values	Regression equation
1989	90	-0.145	$\bar{Y}$ = 6.790 - 0.415 X
1989	120	-0.063	$\bar{Y}$ = 4.760 - 0.151 X
1990	90	-0.085	$\bar{Y}$ = 9.340 - 0.336 X
1990	120	-0.220	$\bar{Y}$ = 9.810 - 0.753 X
Mean		0.110	$\bar{Y}$ = 5.100 + 0.265 X

** Significant (P = 0.01), * Significant (P = 0.05).

From the above table it is evident that there was non-significant correlationship between whitefly population and reducing sugar.

Table 39: Reducing sugars content in selected cotton cultivars exhibiting different degree of susceptibility to *B. tabaci*

Variety	Reducing sugars (mg/g)			
	1989		1990	
	Days after germination			
	90	120	90	120
DS 28	4.760	5.717	4.731	4.753
NS 15	4.150	6.065	4.341	5.377
AM.NECT	4.143	5.140	3.230	4.431
G 67	4.910	5.813	3.930	4.990
AC 738	4.680	5.572	2.889	4.823
BN 1	4.755	6.747	4.847	4.904
DHY 286	5.112	5.262	4.380	5.386
AK 32	5.213	5.235	3.235	4.491
MCU 5	4.860	4.822	3.108	4.118
POURNIMA	4.150	5.117	4.402	5.144
LPS 141	4.555	5.577	3.842	4.573
LK 861	4.950	5.983	3.881	4.967
LRA 5166	4.565	6.302	4.800	5.376
SUMA[illegible]	4.200	5.092	4.402	4.249
SUPRIYA	4.985	4.950	4.055	5.135
PH 93	4.800	4.773	3.778	4.725
GLANDLESS	4.657	4.663	3.947	5.007
OKRA	4.800	4.767	5.080	5.171
PF	4.820	4.730	5.067	5.132
PNF	4.115	4.085	4.007	5.406
PONF	4.827	3.882	4.062	5.867
NH 210	4.117	4.040	3.394	4.102
NH 360	4.158	4.128	3.273	4.198
H 4	4.763	4.755	3.829	4.712
NHH 44	4.265	2.338	3.322	4.415
PKV HY.2	4.810	5.715	4.015	4.958
DCH 32	4.888	5.942	4.747	5.886
NHB 12	4.943	4.975	3.972	4.852
EKNATH	2.443	3.418	4.577	5.624
ROHINI	3.875	2.878	3.998	4.949
NAMDEO	2.090	2.052	3.170	4.209
JYOTI	2.660	2.632	3.917	4.873
SE±	0.04	0.10	0.04	0.11
CD at 5%	0.08	0.21	0.09	0.21

4.5.4.7 Non reducing sugar

Table 41 indicates significant values for various sources of variation. Among 32 lines level of non reducing sugar ranged from 8.9 (PF) to 3.0 (Jyoti). Sugar content in recommended hybrids though at par or significantly superior over population mean.

Genetic correlation and regression studies between non reducing sugar and whitefly population at different stages were worked out seperately. The correlation cofficient and regression equations are presented in Table 40.

Table 40 : Correlation coefficient and regression equations between whitefly adult population and non reducing sugar.

Year	Days After Planting	'r' values	Regression equation
1989	90	-0.106	$\bar{Y}$ = 6.160 - 0.155 X
1989	120	-0.177	$\bar{Y}$ = 5.060 - 0.215 X
1990	90	-0.145	$\bar{Y}$ = 9.920 - 0.314 X
1990	120	-0.179	$\bar{Y}$ = 8.590 - 0.305 X
Mean		0.125	$\bar{Y}$ = 5.310 + 0.143 X

** Significant (P = 0.01), * Significant (P = 0.05).

The result bring to the notice for the absence of perfect relationship between non reducing sugar and infestation level. This is evident as strains which showed relatively higher susceptibility to the pest possess higher / lower values than their population means.

Table 41: Non-reducing sugars content in selected cotton cultivars exhibiting different degree of susceptibility to *B. tabaci*

Variety	Non-reducing sugars (mg/g)			
	1989		1990	
	Days after germination			
	90	120	90	120
DS 28	1.805	1.725	2.334	2.254
NS 15	2.027	2.085	2.806	2.975
AM.NECT	2.008	2.990	2.639	3.999
G 67	1.908	2.093	2.460	3.820
AC 738	2.168	2.305	3.03?	2.174
BN 1	2.642	1.465	2.303	3.156
DHY 286	2.180	1.967	2.052	2.610
AK 32	2.758	2.567	2.304	2.424
MCU 5	2.285	3.092	2.253	3.057
POURNIMA	2.220	2.240	2.074	3.759
LPS 141	2.317	2.260	2.248	2.714
LK 861	2.175	2.060	2.562	2.459
LRA 5166	1.780	1.785	1.589	2.377
SUMAN	1.947	2.028	1.821	2.720
SUPRIYA	2.748	2.700	1.384	2.432
PH 93	2.078	3.125	2.573	2.491
GLANDLESS	2.283	3.200	2.229	2.198
OKRA	2.055	3.030	2.943	2.040
PF	2.860	1.087	2.772	2.198
PNF	2.010	1.080	3.200	2.144
PONF	2.487	1.335	1.359	2.767
NH 210	3.002	3.837	2.987	3.337
NH 360	2.140	2.102	3.842	2.620
H 4	2.600	3.485	2.220	3.843
NHH 44	3.220	2.180	2.802	2.718
PKV HY.2	3.165	2.543	1.482	1.398
DCH 32	2.690	2.885	1.910	2.068
NHB 12	2.537	2.915	1.059	2.083
EKNATH	1.495	1.505	2.208	2.247
ROHINI	2.330	2.335	2.036	2.905
NAMDEO	2.007	2.193	2.644	2.885
JYOTI	1.210	1.183	1.052	2.974
SE±	0.12	0.09	0.13	0.11
CD at 5%	0.24	0.19	0.26	0.22

4.5.5 Impact of biochemical characters under varied environmental conditions

4.5.5.1 Gossypol content of leaf

Total gossypol content in leaf was 0.25 and 0.23 at 90 days and 120 days (1989) respectively, which were at par with each other but significantly less at90 and 120 days (1990) means. The overall mean was 0.37 and all genotypes showed variation for total gossypol content in the range from 0.92 (Suman) to 0.23 (NHB 12) (Table 43). Highest estimates was observed at 120 days during 1990-91 while lowest at 120 days of 1989-90.

Genetic correlation and regression studies between Total gossypol and whitefly population at different stages were worked out seperately. The correlation cofficient and regression equations are presented in Table 42.

Table 42 : Correlation coefficient and regression equations between whitefly adult population and total gossypol.

Year	Days After Planting	`r' values	Regression equation
1989	90	0.002	$\bar{Y}$ = 5.640 + 0.026 X
1989	120	0.213	$\bar{Y}$ = 4.920 - 2.371 X
1990	90	-0.011	$\bar{Y}$ = 8.090 - 0.161 X
1990	120	-0.051	$\bar{Y}$ = 6.660 - 0.854 X
Mean		-0.082	$\bar{Y}$ = 5.680 + 0.987 X

** Significant (P = 0.01), * Significant (P = 0.05).

Table 43. Total gossypol content in selected cotton cultivars exhibiting different degree of susceptibility to *B. tabaci*

Variety	Total gossypol (%)			
	1989		1990	
	Days after germination			
	90	120	90	120
DS 28	0.302	0.293	0.410	0.642
NS 15	0.145	0.145	0.273	0.525
AM.NECT	0.148	0.147	0.269	0.534
G 67	0.292	0.291	0.402	0.660
AC 738	0.213	0.211	0.347	0.590
BN 1	0.192	0.193	0.313	0.557
DHY 286	0.190	18764	0.324	0.548
AK 32	0.184	0.184	0.299	0.562
MCU 5	0.238	0.263	0.378	0.650
POURNIMA	0.148	0.150	0.280	0.502
LPS 141	0.231	0.229	0.371	0.574
LK 861	0.291	0.285	0.396	0.628
LRA 5166	0.279	0.334	0.413	0.688
SUMAN	0.286	0.297	0.418	0.520
SUPRIYA	0.258	0.401	0.378	0.768
PH 93	0.119	0.122	0.233	0.467
GLANDLESS	0.079	0.078	0.210	0.460
OKRA	0.267	0.272	0.404	0.664
PF	0.201	0.204	0.331	0.589
PNF	0.208	0.215	0.314	0.598
PONF	0.202	0.207	0.333	0.556
NH 210	0.248	0.239	0.390	0.590
NH 360	0.220	0.220	0.343	0.573
H 4	14579	0.142	0.265	0.486
NHH 44	0.231	0.232	0.348	0.586
PKV HY.2	0.178	0.132	0.308	0.505
DCH 32	0.174	0.171	0.282	0.558
NHB 12	0.120	0.117	0.238	0.456
EKNATH	0.262	0.265	0.387	0.635
ROHINI	0.255	0.262	0.279	0.616
NAMDEO	0.265	0.257	0.385	0.622
JYOTI	0.164	0.162	0.299	0.535
SE±	0.007	0.056	0.002	0.056
CD at 5%	0.014	0.111	0.016	0.111

From the results it is found that there was weak negative correlation existed between whitefly population and total gossypol.

4.5.5.2 **Free gossypol**

Free gossypol content is depicted in Table 45. It ranged from 0.72 (Supriya) to 0.12 (PONF). Except Suman and Supriya marginal differences for the component among the rest of the cultivars were observed. Suman and Supriya maintained their position and exhibited consistent performance whereas inconsistent performance was expressed by rest of the cultivars. This suggest probable change in behaviour of genotypes against pest with change in the environment.

Genetic correlation and regression studies between free gossypol and whitefly population at different stages were worked out seperately. The correlation cofficient and regression equations are presented in Table 44.

Table 44 : Correlation coefficient and regression equations between whitefly adult population and free gossypol.

Year	Days After Planting	'r' values	Regression equation
1989	90	0.070	$Y = 5.540 + 0.985 X$
1989	120	-0.049	$\bar{Y} = 4.450 - 1.070 X$
1990	90	0.051	$\bar{Y} = 7.820 + 1.030 X$
1990	120	0.037	$\bar{Y} = 5.780 + 1.200 X$
Mean		0.170	$\bar{Y} = 5.480 + 3.170 X$

** Significant (P = 0.01), * Significant (P = 0.05).

Table 45: Free gossypol content in selected cotton cultivars exhibiting different degree of susceptibility to *B. tabaci*

Variety	Free Gossypol (%)			
	1989		1990	
	Days after germination			
	90	120	90	120
DS 28	0.104	0.105	0.196	0.309
NS 15	0.069	0.071	0.172	0.292
AM.NECT	0.067	0.069	0.165	0.293
G 67	0.105	0.110	0.199	0.324
AC 738	0.088	0.089	0.194	0.309
BN 1	0.106	0.109	0.205	0.321
DHY 286	0.063	0.064	0.169	0.275
AK 32	0.058	0.062	0.154	0.280
MCU 5	0.093	0.093	0.202	0.316
POURNIMA	0.072	0.077	0.178	0.282
LPS 141	0.134	0.135	0.245	0.336
LK 861	0.102	0.103	0.193	0.304
LRA 5166	0.086	0.141	0.191	0.348
SUMAN	0.143	0.152	0.253	0.365
SUPRIYA	0.172	0.325	0.270	0.539
PH 93	0.035	0.041	0.131	0.243
GLANDLESS	0.049	0.052	0.155	0.275
OKRA	0.075	0.080	0.181	0.305
PF	0.045	0.557	0.148	0.276
PNF	0.052	0.059	0.144	0.280
PONF	0.039	0.046	0.142	0.251
NH 210	0.089	0.091	0.199	0.297
NH 360	0.078	0.082	0.178	0.288
H 4	0.079	0.081	0.177	0.282
NHH 44	0.056	0.057	0.154	0.265
PKV HY.2	0.069	0.077	0.173	0.295
DCH 32	0.113	0.113	0.202	0.339
NHB 12	0.069	0.072	0.166	0.269
EKNATH	0.081	0.089	0.182	0.304
ROHINI	0.069	0.078	0.169	0.285
NAMDEO	0.076	0.082	0.175	0.294
JYOTI	0.008	0.092	0.195	0.310
SE±	0.007	0.057	0.007	0.056
CD at 5%	0.014	0.112	0.015	0.112

From the result it is found that there was weak positive correlation between whitefly population and free gossypol.

4.5.5.3 **Bound gossypol**

Wider range for bound gossypol was observed as NHB 12 recorded lowest value while Suman maintained its top position as in free and total gossypol (Table 47).

Fifteen, out of 32 genotypes recorded significantly higher estimates for bound gossypol when compared with overall population mean (0.19). Most of the *G.arboreum* varieties except Jyoti and few promising breeding lines (okra, PF, PNF, PONF) recorded performance matchable with each other.

Genetic correlation and regression studies between bound gossypol and whitefly population at different stages were worked out seperately. The correlation cofficient and regression equations are presented in Table 46.

Table 46 : Correlation coefficient and regression equations between whitefly adult population and bound gossypol.

Year	Days After Planting	'r' values	Regression equation
1989	90	-0.077	$Y = 5.840 - 1.240 X$
1989	120	-0.233	$\bar{Y} = 4.820 - 3.220 X$
1990	90	-0.072	$\bar{Y} = 8.310 - 1.580 X$
1990	120	-0.091	$\bar{Y} = 6.700 - 1.870 X$
Mean		-0.041	$\bar{Y} = 6.200 - 0.791 X$

** Significant (P = 0.01), * Significant (P = 0.05).

Table 47 : Bound gossypol content in selected cotton cultivars exhibiting different degree of susceptibility to *B. tabaci*

Variety	Bound Gossypol (%)			
	1989		1990	
	Days after germination			
	90	120	90	120
DS 28	0.199	0.188	0.213	0.332
NS 15	0.076	0.074	0.101	0.233
AM.NECT	0.081	0.079	0.103	0.240
G 67	0.186	0.181	0.203	0.336
AC 738	0.125	0.122	0.153	0.281
BN 1	0.086	0.083	0.109	0.238
DHY 286	0.127	0.122	0.155	0.273
AK 32	0.126	0.124	0.145	0.282
MCU 5	0.145	0.144	0.176	0.306
POURNIMA	0.076	07377	0.102	0.220
LPS 141	0.097	0.094	0.126	0.238
LK 861	0.189	0.182	0.203	0.323
LRA 5166	0.193	0.193	0.222	0.340
SUMAN	0.123	0.145	0.165	0.155
SUPRIYA	0.086	0.076	0.108	0.229
PH 93	0.083	0.081	0.102	0.224
GLANDLESS	0.030	0.026	0.055	0.185
OKRA	0.192	0.188	0.223	0.355
PF	0.156	0.150	0.183	0.313
PNF	0.157	0.156	0.170	0.318
PONF	0.163	0.162	0.191	0.305
NH 210	0.159	0.148	0.191	0.294
NH 360	0.142	0.138	0.166	0.285
H 4	0.066	0.061	0.088	0.204
NHH 44	0.175	0.175	0.195	0.321
PKV HY.2	0.109	0.054	0.135	0.211
DCH 32	0.061	0.058	0.080	0.219
NHB 12	0.051	0.045	0.073	0.186
EKNATH	0.181	0.176	0.205	0.331
ROHINI	0.186	0.183	0.209	0.330
NAMDEO	0.189	0.176	0.210	0.328
JYOTI	0.076	0.069	0.103	0.226
SE±	0.001	0.003	0.002	0.004
CD at 5%	0.002	0.006	0.004	0.008

From the result it is evident that weak negative correlation existed between whitefly population and bound gossypol.

4.5.5.4 Phenol

The overall population mean for phenol content was 5.23. Genotype PNF recorded very high phenol content of 10.09 while Pournima recorded very low value of 3.74. Hybrids recorded very less amount of Phenol than the population mean. Genotypes like PF, Jyoti, PONF showed phenol content significantly higher over population mean (Table 49). Very high estimates of 8.07 was recorded at 120 days (1990),while it was lowest (3.45) at 90 days (1989).

Genetic correlation and regression studies between phenol and whitefly population at different stages were worked out seperately. The correlation cofficient and regression equations are presented in Table 48.

Table 48 : Correlation coefficient and regression equations between whitefly adult population and phenol.

Year	Days After Planting	`r' values	Regression equation
1989	90	-0.614	$\bar{Y}$ = 8.670 - 0.875 X
1989	120	-0.626	$\bar{Y}$ = 6.980 - 0.747 X
1990	90	-0.584	$\bar{Y}$ = 15.000 - 1.170 X
1990	120	-0.634	$\bar{Y}$ = 14.760 - 1.066 X
Mean		-0.150	$\bar{Y}$ = 6.950 - 0.173 X

** Significant (P = 0.01), * Significant (P = 0.05).

Table 49. Phenol content in selected cotton cultivars exhibiting different degree of susceptibility to *B. tabaci*

Variety	Total Phenol (mg/g)			
	1989		1990	
	Days after germination			
	90	120	90	120
DS 28	2.733	3.755	4.977	7.124
NS 15	2.273	3.297	4.791	7.050
AM.NECT	2.855	3.943	5.230	7.803
G 67	3.815	4.920	6.058	8.520
AC 738	2.075	3.165	4.666	6.886
BN 1	2.798	3.870	5.203	7.419
DHY 286	2.078	3.102	4.676	6.608
AK 32	3.908	4.870	6.170	8.614
MCU 5	2.200	3.178	4.845	6.963
POURNIMA	2.170	3.055	4.754	6.441
LPS 141	3.557	4.670	6.275	7.942
LK 861	3.487	4.602	5.658	7.880
LRA 5166	2.300	3.233	4.857	6.680
SUMAN	3.652	4.803	6.325	8.358
SUPRIYA	2.632	3.772	5.012	7.364
PH 93	2.730	3.842	4.985	7.085
GLANDLESS	3.260	4.275	5.933	8.130
OKRA	3.077	4.077	5.698	7.944
PF	7.807	8.922	10.474	12.919
PNF	8.400	9.313	10.271	13.271
PONF	6.360	7.260	9.012	10.504
NH 210	3.680	4.805	6.425	8.169
NH 360	3.272	4.278	5.713	7.672
H 4	2.348	3.390	4.726	6.657
NHH 44	2.537	3.760	4.890	7.182
PKV HY.2	2.345	3.300	4.891	6.970
DCH 32	2.150	3.133	4.350	6.963
NHB 12	2.582	3.783	4.910	6.931
EKNATH	3.705	4.755	6.168	8.379
ROHINI	4.287	5.233	6.739	8.636
NAMDEO	3.847	5.105	6.219	8.658
JYOTI	5.650	6.815	5.395	6.552
SE±	0.11	0.06	0.13	0.08
CD at 5%	0.21	0.13	0.26	0.16

From the result it is concluded that there was negative correlation between whitefly population and phenol content of leaf.

4.6 Correlation and regression studies

Genoptypic correlation were workedout for adult and nymph of whitefly with 17 characters related with resistance / susceptibility of a genotype in each environment as well as by pooling the data. However the results pertaining at 120 days (1990) were only presented because this environment recorded high environmental index value as well as high infestation level for adult and nymph. The study revealed that the association of adults with leaf area, hair length, nitrogen content was highly significant and positive. These parameters also recorded either strong / weak positive genetic association for nymph. Stomata number, chlorophyll a, vit. c, phenol, free gossypol, bound gossypol and total gossypol showed negative but weak association with adult and nymph of whitefly. Negative association of these characters with adults and nymph suggested that increase in their level may result in reducing population may be nymph or adult. Strong positive association of leaf area, hair length, N content, with adult and nymph may be cause for increasing the population with increase in the value of parameters.

Total chlorophyll and chlorophyll b had a negative relationship with adult but positive for nymph.

Table 50 : Genotypic correlations between leaf characters and *B. tabaci*

Characters	Egg	Nymph	Adult
Leaf area	0.389	0.513	0.571
Number of stomata	-0.241	-0.080	-0.125
Hair length	0.603	0.543	0.480
Hair density	0.240	0.388	0.597
Palisade cells	-	-0.010	0.042
Mesophyll cells	-	0.384	0.403
Phloem dist.	-	-0.298	-0.193
Chlorophyll a	-0.432	-0.368	-0.597
Chlorophyll b	0.401	0.716	0.402
Total chlorophyll	0.483	0.739	-0.543
pH	0.007	0.130	0.048
Nitrogen	0.195	0.641	0.580
Phosphorus	0.040	0.113	0.118
Calcium	0.440	0.238	0.274
Vitamin C	-0.476	-0.242	-0.195
Phenol	-0.296	-0.638	-0.658
Reducing sugar	0.117	-0.097	-0.145
Non redu. sugar	0.122	-0.107	-0.169
Total sugar	0.136	-0.127	-0.193
Free gossypol	-0.110	-0.001	0.071
Bound gossypol	-0.143	-0.155	-0.115
Total gossypol	-0.119	-0.119	-0.049

Likewise, reducing sugar, non reducing sugar and total sugar showed strong or weak but invariably negative association with nymph and adult. Free gossypol had positive association with adult but weak negative association with nymph.

The correlation studies with anatomical characters revealed that the average length of palisade cells ranged from 77.49 µ (Jyoti) to 102.76 µ (DCH 32). Statistically non significant correlation existed between palisade cells and the population of whitefly adult and nymph. The trend noted indicated shortest thickness in asiatic cotton and two susceptible varieties of *hirsutum* cotton viz. MCU 5 and AC 738. However, the interspecific hybrids showed highest length of palisade cells (Table 19).

The correlation between mesophyll cells and population of whitefly adults as well as nymph was positively correlated and treatment differences were highly significant (Table 50). The r value between adullt population and mesophyll cell was 0.403 and between nymph population and mesophyll cells was 0.384. The average length of mesophyll cells ranged from 50.67 µ (Jyoti) and 101.75 µ (H 4).In *arboreum* varieties the length of mesophyll cells was lowest.

Results (Table 50) indicated negative correlation between epidermis to phloem and population of whitefly and nymph. The r values between adult population of whitefly

and distance between epidermis to phloem was -0.193 and between nymph population of whitefly and distance between epidermis to phloem was -0.298. The average values varied from 81.01 μ (NS 15) to 114.15 μ (American nectariless). However, all *arboreum* strains recorded higher distance between epidermis and phloem and at par with LK 861 and LPS 141.

4.7 Behaviour of the pest in relation with the species

Genus *gossypium* consist of 32 species out of which four are only cultivated species. India is unique country wherein, all four species are cultivated out of these four cultivated species, two species *hirsutum* and *barbadense* are tetraploid (2n = 4x = 52) while *arboreum* is deploid (2n = 26). An attempt in present investigation has been made to understand behaviour of whitefly in relation to species of *arboreum hirsutum* and intra and inter species tetraploid hybrids. Data collected from earlier experiment is categorised according to species and mean performance from egg, nymph and adult are depicted in Table 51.

For adult infestation, highest incidence was noticed in intra *hirsutum* hybrids and it was followed by *hirsutum* varieties. Very negligible incidence was evident in *arboreum* species. in respect of nymph population , the trend was just similar to that noticed for adult whitefly. Nymph population to the extent of 24.65 per leaf was

Table 51 : Species wise classification showing relationship between leaf characters and *B. tabaci*

Characters	G.hirsutum	G.arboreum	Hybrid (H x H)	Hybrid (H x B)
Leaf area	48.98	28.31	64.36	80.91
No. of Stomata	213.99	290.29	239.98	171.59
Hair length	331.17	169.31	555.79	271.40
Hair density	23.70	39.08	40.22	12.42
chlorophyll 'a'	2.51	2.55	2.67	2.54
chlorophyll b	1.50	1.49	1.71	1.49
Total chlorphyll	4.01	3.04	4.40	4.04
pH	6.87	7.39	7.08	6.61
Nitrogen	2.14	2.21	2.55	2.26
Phosphorus	3.68	3.79	3.62	4.54
Calcium	28.49	14.02	25.76	32.89
Vitamin C	11.07	14.08	8.08	18.82
Phenol	4.76	5.63	3.66	3.62
Reducing sugar	3.30	3.31	3.16	3.88
Non-reducing sugar	4.46	3.37	5.45	7.35
Total sugar	7.77	6.75	8.58	11.29
Free	0.15	0.13	0.12	0.14
Bound	0.17	0.16	0.11	0.06
Total	0.33	0.29	0.23	0.20
Egg	8.95	3.66	12.11	6.69
Nymph	8.28	2.85	14.82	7.90
Adult	6.26	2.54	8.82	6.54

recorded on *hirsutum* while incidence was more or less similar in intra *hirsutum* hybrids and inter species hybrids (H x B). Number of egg per leaf was considerably low in genotypes of deploid species while it was 2 to 3 fold increase in rest of the groups. Amongst tetraploid species, *hirsutum* varieties showed relatively higher tolerence against egg laying. Data presented in Table 51 revealed that female of whitefly preferred genotypes of *hirsutum x hirsutum* followed by *hirsutum x barbadense* for egg laying.

Relation of various morphological, anatomical, physiological, nutritional and biochemical parameters was studied in relation with preference of the species by the pest. Scrutiny of data in this direction revealed that intra *hirsutum* hybrids were very much liked by the whitefly. These hybrids recorded highest mean values for leaf area, number of stomata, hair length, hair density, chlorophyll and nitrogen content while they contains average values of pH of cell sap, Phosphorus, calcium, and sugar. Vitamin c , phenols and gossypom in genotypes of intra *hirsutum* hybrids were low as compare to rest of species.

5. DISCUSSION

A major problem encountered in modern Indian Agriculture, particularly in cotton monoculture areas of Maharashtra, is with the emrgence of new primary pest like whitefly *Bemisia tabaci* Genn. which was formerly of scondary importance. Since chemical control against this pest is expensive, environmentally disruptive and largely ineffective, growing of resistant or tolerant variety of cotton to whitefly could be the possible alternative.

In present investiagtion, an attempt has been made to study the mechanism of resistance and to identify most important source of resistance by studying various morphological, physiological, nutritional, biochemical and anatomical characters of cotton plant. The results obtained in these studies are discussed here.

5.1 Intensity of Whitefly Incidence and Impact of Environment Thereon :

The biotic and abiotic factors operating in a particular ecosystem are the deciding factors that govern development of pest in space and time. The abiotic factors like temperature and rainfall have profound influence on the sucessful development of *B. tabaci*. The environmental conditions in various stages of crop varies and changes from year to year, thereby, affecting favourably or

unfavourably on pest development. Microclimatic and physiological conditions under rainfed condition at the age of 90 days is completely different from that of conditions prevailing at 120 days of cotton crop. Likewise, year 1989-90 and 1990-91 were totally different from each other due to the variation in amount and pattern of rainfall distribution. Likewise, testing of genotypes under choice and no choice conditions provides precise and reliable information about resistance ability of cultivar.It is therefore, worthwhile to understand the impact of these conditions on development of *B. tabaci* as well as on stability of resistant genotype. In present investigation the performance of selected 32 genotypes was tested under four varied conditions against whitefly. Results indicated that the population of *B. tabaci* fully developed and heavily loaded on host plant during 1990-91 at 120 days as compared to the rest of the environments. Environment during 90-91 at 120 days was quite congenial, not only for increasing adult population but also favoured in increasing nymphal population. The joint effect of season and physiological stage of crop favoured heavy load of whitefly.

Effect of environment on intensity of *B. tabaci* was studied by Venugopal Rao (1987), who reported prolonged developmental period of 7.5 days from 13 to 25 days and attributed it towards decrease of 5^{o}C in maximum

temperature and 4% rise in relative humidity. The present investiagation revealed that in addition to the direct influence of environment on pest, the seasonal factor and physiological stage also exercise influence directly or indirectly on host physiology which also alter development pattern of whitefly. Similar views were also expressed by Mound and Halsey (1978) which confirms results of the present investigation.

5.2 Varietal Resistance to Cotton Whitefly

Growing resistant variety is most important and long lasting component in pest management programme and would enhance the effectiveness of other component involved in the strategy. In the preliminary field screening, conducted during 1987-88, 400 strains of diverse origin and possessing diverse morphological features were screened. Based on their performance, finally 32 genotypes consisting of *hirsutum* varieties, intra and inter specific tetraploid hybrids and asiatic cotton varieties were selected and studied in detail for understanding cause of either high or low infestation of whitefly. (Appendix I)

In understanding the reaction of these 32 genotypes against pest, various parameters have been considered. Lines were evaluated on the basis of infestation level for egg, nymph and adult under

individual environment at 90 and 120 days, for two years besides under choice and no choice conditions . Moreover, screening based either on individual parameters for egg/nymph/adult has certain limitations and may show contradictory and inconsistant performance. Many criteria like determination of number of adults or larvae, eggs ovipisited, yield losses, measuring length of insect life cycle, number of surviving plants etc. are used to evaluated resistance. Some of these measure only one factor, the others may measure the combined effect (s) of all factors. Often comparisions are made with a known resistant/susceptible cultivar (Dahms, 1972). To get more realistic picture of a cultivar for its resistance ability, ranking of genotypes individually for egg, nymph and adult was done and score obtained by each genotype under each condition was aggregated. On the basis of aggregate score the cultivars were grouped into resistant, moderately resistant, susceptible and highly susceptible group. Likewise mean infestation observed in asiatic cotton group has been considered as a base for identification of resistant genotype. Use of asiatic cotton as a base for identification of a genotype resistant to whitefly seems to be more scientific strategy in getting precise results. This may be the first case wherein infestation level in asiatic cotton has been considered as criteria for identifying/measuring resistance ability of *hirsutum* cotton genotypes.

5.2.1 Classification of Genotypes Based on Individual Parameters Egg, Nymph and Adult Population of *B.tabaci*

Grouping of genotypes was done by using pooled data. Genotypes for adult population were classified considering the range of 0-1 (Resistant), 2-3 (moderately resistant, 4-5 (susceptible) and 5 and above (Highly susceptible). In present investigation out of 32 genotypes, 8 strains recorded adult population in the range of 0-1 with population mean of 0.9 adults/leaf. Amongst these strains PF, PNF, PONF, LPS 141, LK 861 and Okra showed high level of resistance (Table 54). Mean infestation level of Group.I (0-1) is just at par with the infestation level observed in *desi* cotton cultivars which are well known for their inherent resistance ability. Out of 8 resistant genotypes, three genotypes viz. PF, PNF and PONF recorded adult population just at par with *desi* cotton cultivars. Likewise, highly susceptible group consisted of six genotypes which recorded high level of infestation. These highly susceptible cultivars expressed higher hair density, longer hair length, pH above 7 and low phenol content as compared to level observed either in resistant *hirsutum* or *arboreum* cultivars. Mound (1965) reported pH of cell sap, Khalifa and Gameel (1983) hair density, Magal *et al.* (1982) pH and Butter and Vir (1989) hair density and hair length as factors for imparting resistance. Amongst susceptible five cultivars,

Table 52 : Comparison of leaf characters based on egg of *B. tabaci*

Characters	Highly susceptible	Susceptible	Moderately resistant	Resistant	Desi
Leaf area	51.01	52.84	57.56	50.66	28.31
No. of Stomata	229.08	224.68	186.64	209.79	280.29
Hair length	417.25	361.45	249.65	242.12	169.31
Hair density	38.70	22.10	13.60	7.04	39.08
chlorophyll 'a'	2.50	2.55	2.52	2.55	2.55
chlorophyll b	1.52	1.54	1.49	1.53	1.49
Total chlorphyll	4.02	4.10	4.02	3.09	3.45
pH	7.13	6.85	6.53	6.60	7.39
Nitrogen	2.41	2.05	2.20	2.05	2.21
Phosphorus	3.85	3.56	4.03	3.51	3.79
Calcium	27.54	27.66	28.71	34.06	14.02
Vitamin C	8.57	8.91	16.54	16.26	14.08
Phenol	3.54	5.43	4.12	4.75	5.63
Reducing sugar	3.34	3.42	3.09	2.99	3.31
Non-reducing sugar	4.12	5.08	5.35	4.83	3.37
Total sugar	7.48	8.51	8.47	7.82	6.75
Free gossypol	0.12	0.17	0.14	0.15	0.13
Bound gossypol	0.12	0.13	0.25	0.15	0.16
Total gossypol	0.24	0.31	0.40	0.30	0.29
Egg population	15.58	12.26	10.24	7.38	5.15

Table 53 : Comparison of leaf characters based on nymph of *B. tabaci*

Characters	Highly susceptible	Susceptible	Moderately resistant	Resistant	Desi
Leaf area	55.41	59.44	48.20	43.72	28.31
No. of Stomata	232.04	218.16	172.50	209.95	290.29
Hair length	424.02	318.04	179.23	311.71	169.31
Hair density	36.47	19.09	11.20	14.88	39.08
chlorophyll `a'	2.55	2.50	2.50	2.57	2.55
chlorophyll b	1.56	1.48	1.47	1.54	1.49
Total chlorphyll	4.11	3.98	3.98	4.12	3.45
pH	7.03	6.91	6.41	6.69	7.39
Nitrogen	2.45	2.24	2.15	1.81	2.21
Phosphorus	3.75	3.85	3.93	3.50	3.79
Calcium	27.25	28.35	27.93	31.01	14.02
Vitamin C	9.19	12.23	12.07	12.18	14.08
Phenol	3.65	4.02	4.52	6.18	5.63
Reducing sugar	3.25	3.27	1.69	3.71	3.31
Non-reducing sugar	4.37	4.64	3.83	5.77	3.37
Total sugar	7.62	7.95	5.53	9.48	6.75
Free gossypol	0.11	0.20	0.15	0.12	0.13
Bound gossypol	0.10	0.13	0.47	0.16	0.16
Total gossypol	0.21	0.34	0.63	0.29	0.29
Nymph population	13.91	10.56	6.78	4.14	2.85

Table 54 : Comparison of leaf characters based on adult of *B. tabaci*.

Characters	Highly susceptible	Susceptible	Moderately resistant	Resistant	Desi
Leaf area	53.90	55.40	61.31	43.72	28.31
No. of Stomata	239.53	234.12	171.60	209.85	290.29
Hair length	461.22	326.20	293.79	311.71	169.31
Hair density	39.28	26.20	14.25	14.88	38.08
chlorophyll 'a'	2.51	2.53	2.51	2.57	2.55
chlorophyll b	1.52	1.53	1.49	1.54	1.49
Total chlorphyll	4.03	4.07	4.00	4.11	3.45
pH	7.17	6.89	6.65	6.69	7.39
Nitrogen	2.38	2.34	2.24	1.81	2.21
Phosphorus	3.73	3.66	4.19	3.50	3.79
Calcium	25.69	27.19	31.20	31.01	14.02
Vitamin C	8.02	10.38	14.60	12.18	14.08
Phenol	3.53	3.91	4.28	6.18	5.63
Reducing sugar	3.51	3.06	2.78	2.71	3.31
Non-reducing sugar	4.28	4.10	5.27	5.77	3.37
Total sugar	7.81	7.17	8.10	9.48	6.75
Free gossypol	0.12	0.18	0.14	0.12	0.13
Bound gossypol	0.14	0.11	0.24	0.16	0.16
Total gossypol	0.26	0.30	0.38	0.29	0.29
Adult	8.86	8.77	5.37	5.62	2.54

recommended and popular hybrids viz. NHH 44 and PKV Hy.2 were at par with each other and harboured highest adult population. In field trials of present investigation thes genotypes expressed stunted growth and shedding of fruiting bodies. This may be attributed towards lack of getting sufficient nutrition which might have been utilized by whitefly. Similar views in their study were also reported by Husain and Trehan (1933).

In respect of nymph population , eight cultures showed mean population in the range of 1-2 and 2-3 nymphs per leaf (Table 53) and have been *desig*nated as resistant and moderately resistant genotypes, respectively. The resistant genotypes were same as observed for adults.The susceptible cultures had fairly high (3-5 and 6-10 nymphs/leaf) population. Amongst highly susceptible cultivars, NHH 44, PKV Hy.2 and other ten genotypes were favoured by nymphs.

Using the criteria of egg / leaf, it was observed that resistant group had 7.38 as against 10.24, 12.26 and 15.58 in moderately resistant, susceptible and highly susceptible groups, respectively (Table 52). The susceptible group includes the cultivars like PKV Hy.2, NHH 44, PH 93, Pournima, NS 15, DHY 286, LRA 5166 and AC 738. The study revealed that hybrids NHH 44 and PKV Hy.2 invariably recorded high infestation level for adult, nymph and egg. One of the parents of both hybrids also

showed high susceptibility for all the three parameters. The study also enlightened that these two recommended hybrids did not resist whitefly at any stage of life cycle. On the contrary, strains like PF, PNF, LK 861 and LPS 141 for all three parameters; Okra for adults and nymphs exhibited higher level of resistance. Venugopal Rao *et al.* (1990) also reported LK 861 and LPS 141 as resistant cultivars which confirms the results of present investigation. Asiatic cotton cultivars, however, exhibited resistance ability against all three stages of *B. tabaci*.

5.2.2 Performance on the Basis of Aggregate Ranking

Screening based on individual parameter (egg/nymph/adult) may show inconsistent performance of a genotype. DCH 32, interspecific hybrid which has been grouped under susceptible category (based on nymph) showed relatively higher level of resistance when adult and egg population was taken into consideration. Like wise, Okra showed high level of resistance when adult and nymph population was considered while it was moderately resistant to susceptible when egg was used as a base. Inconsistant performance with individual parameter may become unreliable for identifying genotype as resistant due to which breeder become handicaped while planning resistance breeding programme for want of precise and reliable information.

To overcome this problem, an attempt has been made considering all the three parameters i.e. adult, nymph and egg simultaneously. This has been done by screening performance for each parameters on merit basis and aggregating the score obtained by genotype for individual parameter. This helped to get reliable and precise information about performance of a genotype for resistance ability against whitefly. Perusal of Table 55 revealed that the genotypes having aggregate rank in the range of 1-9 were considered as resistant cultures. Genotypes with score from 10-19 and 20 and above were considered as susceptible and highly susceptible lines, respectively.

Eleven genotypes got ranking from 1 to 9. Amongst these LPS 141, LK 861, Okra, PF, PNF, and PONF were worth to mention as they recorded infestation level at par with *desi* cotton varieties and ranked in order to merit. These observations coincided with observations recorded at various AICCIP center. Field screening at different centres of AICCIP in Andhra Pradesh revealed that LPS 141, LK 861, D 53, MERS 17, 2F etc. were resistant to whitefly (AICCIP, 1986). Venugopal Rao (1987) reported that LK 861, LPS 141, D 53, NHV 1, 2F, A 102, JK 97 FBRN, MERS 17 and JK 286 were promising in recording low whitefly incidence and fell in resistant cluster. In the present investigation, strains like LK 861, LPS 141, Okra, PF and PONF indicated similar trend.

Okra and cultivars like PF, PONF showed relatively high level of resistance. This may probably because the decrease in shades and humidity associated with the Okra leaf canopy which is less favourable to this pest (Jones, 1982). This indicate that the reduced canopy helped in better air movement, providing lower relative air humidity and probably high temperature. The overall effect of this rendered the environment less favourable to whitefly. Ozgur and Sekeroglu (1986) were also of the same opinion. Khalifa and Gameel (1983) however, were of the opinion that open canopy permits more insectisides to reach the whitefly, particularly late in the season.

Resistance ability of above genotypes was attributed towards increased vitamin C and phenol content and decreased level of stomata numbers and hair density. But the other parameters like leaf area, chlorophyll, phosphorus, calcium, sugar and gossypol did not show any significant effect in checking whitefly build up. Sippel *et al.* (1987) and Butler and Henneberry (1984) also reported that low hair density confer resistance to cotton whitefly. However, Bhat *et al.* (1981) and Zummo *et al.* (1984) reported variation in the level of phenols, tannins and proteins in cotton cultures, showing differential reaction to sucking and bollworm pests. It is interesting to note that when aggregate ranking criteria was adopted none of the hybrids or their parents occupied a position in resistant category.

In summarizing results of screening of genotypes for resistance against whitefly, the present investigation revealed that for individual parameters i.e. nymph, egg and adult as well as considering all three parameters simultaneously, strains like PF, PONF, LK 861, LPS 141, Okra showed very high level of resistance while NHH 44, PKV Hy.2, Pournima, LRA 5166, AC 738 may be grown with full plant protection due to their susceptibility.

The study also enlightened that *hirsutum* identified as moderately resistant or resistant against pest, however, very rarely compete with asiatic cotton cultures i.e. Rohini, Namdeo, Eknath, Jyoti either based on individual or simultaneously for all the three paramters. This impress that though *hirsutum* cultivars, recorded relatively lower level of infestation, they cannot match with *arboreum* cultures for their resistance ability. Resistance ability of these cultivars, either change in the environment or nutrition balance. Hence, it is a prerequiste to have *hirsutum* culture that can match with *arboreum* cultures for resistance otherwise so far identified resistant genotypes may require application of insecticides, however, the frequency of spraying may be lower.

Asiatic cotton are well adapted to vagaries of environments prevailing in the country. These cultivars, over the time showed inherent ability to resist against sucking pest complex which included whitefly, also

expressed similar trend in present investigation. Moreover, though pest visited the *arboreum* plants, they did not cause the damage. All these evidence lead to conclude that *desi* cotton possess inherent ability to stand against pest even in epidemic out break. However, the aspect of developing *hirsutum* variety at par with *arboreum* has rarely been considered by earlier workers. This may probably be the first attempt in comparing *hirsutum* cultivar with *arboreum* cultivars for knowing their resistance ability. This criteria provides firm and scientific footing for identifying *hirsutum* genotype having resistance ability just matchable with *arboreum*.

Scrutiny of data collected revealed that *arboreum* cultivars recorded mean population of 0.38, 0.49 and 5.14 for egg, nymph and adult, respectively. As against infestation level in *G. arboreum* group, *hirsutum*, intra species and inter species tetraploid hybrids recorded adult population of 3.2, 5.4 and 2.9, respectively (Table 55). Likewise, egg/leaf, it was 12.4, 14.5 and 10.5 in *hirsutum* varieties, intra species and inter species hybrids, respectively. These observations lead to conclude that none of the tetraploid groups, may be varieties or hybrids, has ability to match or surpass over the performance of *arboreum* cultivars.

When individual genotype were examined, it was observed that only five out of 27 cultures recorded adult population nearer to that of *arboreum*. Amongst these cultivars PF, PNF and PONF are worth to mention. Likewise,

for nymph only PNF reached nearer to level of *arboreum*. It is surprising to note that none of the cultures of tetraploid cotton was comparable with *arboreum* for eggs/leaf. All are favoured by pest for egg laying. While summarizing the results, it can be concluded that PF, PONF and PNF cultures of *hirsutum* group recorded infestation level practicaly at par with *arboreum* cultures for nymph and adult population. Moreover, the same cultures in earlier screening also recorded similar encouraging performance under individual as well as joint test. It indicates that these three cultures may possess greater ability to resist against *B. tabaci*.

Several other workers in their study also identified *hirsutum* genotypes resistant against whitefly. However, no one has so far studied /evaluated their performance over location, years, environment, various physiological conditions. Hence resistance ability of such genotypes may be unstable and may break-down with change in the conditions. It is therefore, necessary to evaluate their performance from stability point of view.

5.2.3 Stability Performance of Genotypes Showing Resistance Ability Against Whitefly

In present investigation the four environments created (90 and 120 days during 1989-90 and 1990-91) provided sufficient range of whitefly for evaluation of stable genotype. Blum (1969) also created such three

distinct environments for screening sorghum genotypes against shootfly. Such genotype x environment interaction lead to sucessful evaluation of stable genotypes against *B. tabaci* which could be used in future breeding programme.

In any resistant breeding programme, a genotype having regression coefficient (bi) value less than one (above average stability) with minimum sensitivity to change with the change in environment (S^2di) and low mean would be *desi*rable. Such cultivars with bi less than unity should be considered as resistant and least sensitive to change in environment and may show consistant performance even with change in conditions.

Scrutiny of data from this point of view revealed that 8,14 and 1 genotypes recorded above average stability for egg, nymph and adult respectively. This is evident as they recorded regression coefficient value (bi) significantly less than unity. Their stable resistance ability may not disturb with change in environment, as is evident from non significant S^2di. All these genotypes recorded infestation level either at par or less than population mean.

It is revealed that Okra, PF, PNF, PONF exhibited high degree of phenotypic stability. The cultivars LPS 141 and LK 861 showed high level of resistance when screened on the basis of ranking criteria.

However their resistant ability may change with change in environment. The breeder may not use strain like NS 15, AC 738, BN 1, MCU 5, PH 93 and Glandless as a parent in crossing programme because they recorded below average stability (bi more than unity).

Popular hybrids NHH 44, PKV Hy.2 and H 4 recorded below average stability for adult and nymph while all *desi* cultivars indicated above average stability for egg, nymph and adult. Culture G 67 and Supriya recorded bi value less than unity for all life stages of whitefly.

The study clearly revealed that strains like PF, PNF, Okra, G 67 and Supriya are worth using as parents in breeding programme. Moreover, it will be worth crossing these parents with each other, so that desirable genes may not dissipiate with advancing generation.

5.3 Basis of Resistance

In earlier chapters efferts were made to understand the behaviour of pest under varied environments and reaction of genotypes against pest with change in the condition. It was observed that certain genotypes showed resistance ability under particular conditions and its ability affected with change in the environment. Stability parameter analysis, therefore, was to measure resistance ability. Such exercise helped to identify genotypes showing resistance ability stable over years, conditions.

An attempt in the present topic has been made to findout the basis of resistance or susceptibility of a genotype against whitefly. This aspect has been studied by estimating genotypic correlation of egg, nymph and adult with various morphological, physiological, nutritional, biochemical and anatomical parameters.

5.3.1 Basis of Resistance in Relation with Different Characteristics of Cotton Leaf

In respect of morphological characters viz. leaf area, stomata frequency, hair length and density, mean performance over environments (pooled) is depicted in Table 55. It indicated that leaf area in 32 genotypes varied from 17.2 cm^2 (Jyoti of asiatic cotton) to 75.9 cm^2 (G 67); while stomata frequency ranges in between 153.9 (Pournima) to 343.9 (BN I). Hair length and hair density was maximum in Glandless of upland cotton (499.9/cm^2) and Eknath of indegeneous cotton (46.4 cm^2) while American nectariless recorded lowest values for both the parameters. Amongst these parameters, leaf area and hair length showed significant positive genotypic association with adult, nymph and egg while remaining three parameters had weak association either in positive or negative direction. This indicated that increase either in leaf area or hair length may lead to increase in intensity of pest. Butter and Vir (1989) found that leaf area had weak negative correlation and hair length had positive correlations with egg, nymphs and adult population of *B.*

Table 55 :Comparison of leaf characters based on Aggregate Rank

characters	Resistant	Susceptible
Leaf area	39.44	55.17
Number of stomata	243.52	229.70
Hair length	246.30	408.36
Hair density	25.03	36.12
Chlorophyll a	0.55	0.55
Chlorophyll b	0.52	0.57
Total chlorophyll	1.08	1.13
pH	7.10	7.22
Nitrogen	2.21	2.60
Phosphorus	3.82	3.94
Calcium	22.70	28.18
Vitamin C	14.37	10.36
Phenol	6.25	4.16
Reducing sugar	3.68	3.52
Non reducing sugar	5.16	4.79
Total sugar	8.87	8.32
Free gossypol	0.150	0.14
Bound gossypol	0.190	0.14
Total gossypol	0.350	0.29

tabaci. Significant positive correlation of hair length and whitefly population is also reported by Md. Ilyas (1988). It is therefore, suggested to breed a genotype having leaf area and hair length in the range of 27 cm^2 to 55 cm^2 and from 154 μ to 231 μ, respectively. This is evident as these genotypes having leaf area and hair length in the above range were least preferred by pest, may be egg laying, nymph and adult population devlopment.

Genotypic correlation studies between chlorophyll a,b and total did not show strong association either with adult, nymph or egg. Range of variability for these parameters was also narrow. Non significant association and inconsistant trend of pH with egg, nymph and adult was observed in present investigation. However, these results did not coincide with the findings of Md. Ilyas (1988) who reported significant positive association of pH of cell sap but negative correlation between chlorophyll and whitefly infestation. Husain *et al.* (1936) first observed that there was correlation between whitefly incidence and pH of cotton leaves. They reported that whitefly population had increased on the cotton having higher pH of leaves. Magal *et al.* (1982) found old leaves with 6.8 pH were significantly more attractive to whitefly as compared to young leaves having pH values of 5.9. In present investigation, resistant *hirsutum* cultivars and *arboreum* varieties recorded mean pH of 6.69 and 7.39, respectively, are in the line of Magal *et al.* (1982).

However, non significant relatioship of pH of cell sap and whitefly population observed in present investigation confirm the findings of Rote (1989).

In respect of biochemical components, they have adverse effects on insect feeding behaviour. Because, they may reduce the probablity for survival, particularly among species in which the larval forms are incapable of locating a more susceptible host. Insect mortality may then result from starvation or semi stravation, confined with unfavourable forces. In present investigation amongst the three nutritional components viz. nitrogen, phosphorus and calcium, range of variability for nitrogen and phosphorus content was narrow while wider range for calcium content was evident i.e. Rohini and Suman recorded lowest (3.9 mg/gm) and highest values (37.9 mg/gm). Low level of calcium content was observed in popular hybrids like H 4, NHH 44, PKV Hy.2 as compared with their parents and resistant genotypes like PF, NH 210, NH 360. As calcium gives toughness to cell wall it revealed from the present study that the susceptibility of intra specific hybrids could be due to low calcium level. The relationship was strong and positive for egg, nymph and adult with nitrogen and phosphorus thereby indicating that increase in N content may lead to increased susceptibility. Similar results were also reported by Joyce (1958) and Joyce and Robert (1959), which confirm the findings of present investigation. Ripper and George

(1965) attributed it towards stimulating effect of higher nitrogen content on fecundity of whitefly. However, Abdelrehmman and Saleem (1978) attributed it towards reduction in period of life cycle of whitefly. The trend observed in present investigation for nitrogen coincided with the findings of Joyce (1958), Joyce and Robert (1959), Ripper and George (1965), Abdelrahman and Saleem (1978), Weisser (1980), Md. Ilyas (1988) and Rote (1989) but contradictary for phosphorus (Venugopal Rao *et al.*, 1990). The non significant relationship with calcium confirms the findings of Venugopal Rao *et al.* (1990) and Sunderamurthy *et al.* (1986).

Vitamin C amd phenol component exhibited nagative association but significant by phenol with adult and nymph and by vitamin C with egg number. Okra and PNF for Vit. C and LPS 141 and PNF for phenol recorded highest and lowest values respectively. It indicates that lower magnitude of vitamin C and higher phenol content may individually or jointly contribute for increasing resistance level. The study also suggested that total phenolic compounds and its different constituents may show greater variation, depending upon the presence or absence of resin glands. These results are in the line reported by Venugopal Rao *et al.* (1990).

Free, bound or total gossypol content seems to have less influence either in increasing or decreasing intensity of pest. This is evident as it showed very weak

and non significant association with adult, nymph and egg. Non significant association observed in present investigation did not coincide with the observation reported by Elewa *et al.* (1978), Baloch *et al.* (1982) Khalifa and Gameel (1983). Sharma *et al.* (1982) reported gossypol content in the range of 0.03 % (Empire) to 0.72% (HG 6) in *hirsutum* group and 0.42% to 0.62% in *G. arboreum*. In present investigation total gossypol content showed narrow range of variability.

The resistant cultures recorded leaf area (39.44 cm^2), number of stomata (243.52 /cm^2); hair length (246.30 /u); hair density (25.03 cm^2); pH (7.10) and nitrogen content (2.21%) significantly higher than the mean values recorded by susceptible group and their values were matchable with *arboreum* cotton either for one or more characters.

To bring the level of resistance in *G. hirsutum* at par with *arboreum* cotton which is being considered as resistant, the breeder should evolve a variety with leaf area around 28 cm^2 ; stomata number of 290/cm^2 and optimum level of other different biochemical parameters given in Table 55. This would give a ready recknor to a breeder for incorporating charaters contributing resistance against whitefly.

5.3.2 Basis of Resistance in Relation with Leaf Anatomy

Lot of information is available indicating basis of resistance against whitefly. Review of literature indicated that hair density, hair length, leaf thickness, leaf area and gossypol glands on stem internodes affected population of *B. tabaci* on cotton (Butter and Vir, 1989). However, contradictory results had been reported regarding various biochemical parameters Husain *et al.* (1936); Rote (1989), Tester (1977), Sharma *et al.* (1982), Khalifa and Gameel (1983). Nymph and adults of *B. tabaci* suck the cell sap from lower surface by inserting their sharp stylet in the leaf tissue. In *G. arboreum*, compact layer of lower palisade is existing which may prohibit the stylet of pest to enter in tissue . Such layer in *hirsutum* is completely wanting due to which *B.tabaci* prefer and feed from lower surface. It leads to conclude that there must be something other than morphological / physiological/ biochemical constituents which contribute resistance against *B. tabaci*. Moreover, the earlier workers could not explain the basis of resistance ability in asiatic cotton. Leaf anatomy plays probably a pivotal factor in deciding resistance ability of *arboreum* cotton. This is because *B. tabaci* has to penetrate its stylet and ovipositer into the tissue for feeding and egg laying, respectively. Therefore, anatomical structure of leaf has got a great significance on their feeding as well as egg laying habit, that ultimately results into preference or

non-preference of host. Saini and Gadkari (1957) and Krishnaswamy and Andel (1977) studied leaf anatomy of diploid and tetraploid cotton and pointed out the basic difference in structure of leaf. They stated that lower palisade layer in *hirsutum* is completely absent while it is well developed in asiatic cotton. Considering feeding habit of *B. tabaci*, the lower palisade layer might be playing an important role in deciding resistance. Moreover, thickness of epidermis might be interfering with feeding, oviposition and development of *B. tabaci*. Therefore, in present investigation the leaf anatomical parameters viz. thickness of palisade, spongy tissue, distance of phloem from abaxial epidermis were studied in these 32 genotypes of different species and their performance is presented in Table 19.

Results indicated that the resistant group had maximum distance between epidermis to phloem (107.96 µ) which was significantly superior over mean of susceptible group. Susceptible varieties NS 15 and AC 738 recorded highest nymphal population on the lower surface. Hargreaves (1915) suggested two reasons for this; i.e. thinness of lower cuticle and nearness of phloem from lower surface. In present investigation, the above genotype had very close distance with phloem. Venugopal Rao (1990) proved that in resistant group, distance between abaxial epidermis and phloem were higher which

strongly supported results of present investigation. The study also indicated shorter thickness either of palisade/ mesophyll might act as a barrier for probosis of *B. tabaci*.

Correlation studies of whitefly population with distance to phloem indicated negative effect while significantly positive relation with mesophyll thickness. Similar results were reported by Venugopal Rao (1990). Puri *et al.* (1993 explained the role of leaf anatomy on incidence of whitefly and were of the opinion that genotypes having shorter distance to phloem tissue could help in easy penetration of stylets as compared to cultivars with longer distance. These findings are in the line of present investigation and support strongly.

It would be worth if breeder evolve a resistant genotype having phloem distance from abaxial epidermal layer in the range of 102.67 μ to 114.15 μ and mesophyll layer thickness of 50 μ to 56 μ, as well as incroporate abaxial palisade layer.

5.4 Practical Utility of the Present Investigation

Use of chemical have certain limitations and therefore, research programme was mainly oriented in identifying resitant culture from 400 germ plasm. It was also intended to know about basis of resistance and understand the effect of the age of the crop on development of pest.

The investigation brought out certain vital points which have practical utility directly in adopting cotton cultivation and indirectly to be adopted while planning of programme for management of whitefly.

The investigation clearly indicated that for studying whitefly may be egg, nymph and adult, appropriate stage is 120 days age of the crop rather than 90 days. Considering all three life stages simultaneously strains PF, PONF, PNF and Okra withstood in order of merit. These strains revealed lower infestation level than rest of the *hirsutum* genotypes though higher than *arboreum* cultivars.

It is suggested to use *arboreum* as a check while evaluating resistant ability of *hirsutum* genotypes. The study also caution that insecticides should not be recommended unless and until it is effective to reduce infestation level at par with infestation level noted in *arboreum* cultivars which have inherent capacity of resistance.

The study warranted that before reconsidering any variety as resistant, it's stability may be tested under natural and artifical environment over years and location.

These studies enlightened that nitrogen, phenol, calcium, hair length, density, pH, vitamin C are the factors that contribute [illegible] increasing resistance rather than reducing, non-reducing and total sugars and phosphorus etc.

Amongst anatomical characets phloem distance plays maximum role in imparting resistance. Abaxial palisade layer which is absent in *hirsutum* cotton plays crucial role in determining resistance and susceptibility of a genotype hence it is suggested to incorporate this character from *arboreum* to *hirsutum* by adopting appropriate breeding methodology. The investigation pointed out that LK 861, LPS 141, as resistant genotypes are very sensitive and their ability of resistance may be disturbed with change in environment hence, while recommending such genotypes this point should also be considered. Most of the recommemded popular hybrids invariably expressed susceptibility to all stages of whitefly; hence these hybrids should not be cultivated without use of appropriate insecticides.

The study indicated that one of the parents of these hybrids invariably recorded susceptibility to either eeg, nymph and adult The approach of screening material by "aggregating score" technique is more reliable for getting precise information about resistance ability of genotypes, hence screening should be done considering all the parameters simultaneously.

Stability parameter study helped in identifying certain genotypes with above average stability (low population and non significant S^2 di). If these genotypes satisfy yield potential, they should be considered for cultivation. They may be used in breeding programme too.

The study pointed out that it will not be impossible to breed a variety resistant to whitefly, in future, however, understanding the genetic nature of resistance is a prerequisite and planning in this direction will be rewarding.

6 SUMMARY

The present investigation was aimed at study of various aspects of whitefly to understand the basis of resistance in a genotype against whitefly. The material for this study included 32 cotton cultivars of diploid, tetraploid varieties, intra and intersepcific hybrids and some pigmented varieties.

Thirty-two genotyes were tested under four distinct levels of whitefly by collecting adult, nymph and egg data for two years at two physiological stages of crop. In addition, these cultivars were evaluated under choice and no-choice conditions. Besides these aspects attempt was made to study developmental aspects by catagorizing these 32 genotypes into mainly resistant and susceptible groups.

In addition, data for 22 observations i.e. morphological (4), physiological (4), nutritional components (7), biochemical components (4) and leaf anatomical parameters (3) were collected from each environment except for leaf anatomical parameters which were conducted for only one year.

Twenty two observations were subjected mainly to four biometrical approaches i.e. (1) screening of genotypes based on performance in individual environment, aggregating scores obtained by each geontype under four

conditions by considering simultaneously egg, nymph and adult stages (2) evaluating performance of *hirsutum* cotton genotypes considering asiatic cotton as a base (3) stability parameters model of Eberhart and Russell (4) genotypic correlation.

The study revealed that magnitude of varience in respect of egg, nymph and adult in different groups increased with availability of favourable environments. The results of present study indicated the need for screening of breeding material and recommended cultivars under high whitefly population.

In aggregate scoring as well as screening genotypes by using yard stick of resistance level *arboreum*, cultivars viz. PF, PONF, PNF, Okra, LK 861, LPS 141 are worth to mention as they recorded low infestation for egg, nymph and adult.

All susceptible genotypes recorded below average stability thereby indicates the possitbility of high magnitude of damage under high level of whitefly population. The distribution of genotypes for three parameters in different quadrants indicated that susceptible and resistant genotypes could be considered as unstable and stable to changing whitefly population.

The tendency of most of the resistant genotypes to concentrate in IV and III quadrant indicated above average stability with mean infestation level less and

higher than population mean. The study also pointed out that most of the recommended hybrids showed very high susceptiblity either for one or all three parameters. One of these parents invariabily recorded high susceptibility, thereby suggesting that character is under control by genetical factors and probably involved a dominant gene action.

Crossing of amongst genotypes of below average stability coupled with low infestation level may show segregantion with high resistance ability and hence suggested to breeders.

Amongst all characters related with resistance, distance between epidermis and phloem, length of spongy cells, leaf area, hair density, hair length, nitrogen, calcium, vitamin C and phenol were more related rather than their counterparts.

It is also suggested that abaxial palisade layer character, available in *arboreum* may be incorporated in *hirsutum*. Such *hirsutum* genotype may provide resistance not only against whitefly but also sucking pest complex of cotton.

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APPENDIX I

Average number of adults of whitefly per leaf on four hundred genetically diverse genotypes.

NAME OF VARIETY	DATES OF OBSERVATIONS				
	15/9/88	1/10/88	15/10/88	1/11/88	15/11/88
NHB12	2.50	2.08	1.33	8.20	16.43
1883/1	2.83	2.41	1.66	8.53	16.76
H4	1.60	16.18	19.11	10.45	5.29
1912/9	2.17	1.75	1.00	7.87	16.10
1889/3	2.93	17.51	20.44	11.78	6.62
PKVHY-2	6.20	2.12	6.16	19.38	27.68
SUMAN	2.11	8.37	9.68	2.42	5.58
1915/4	0.27	14.85	17.78	9.11	3.96
BC F1 (2)	7.72	3.59	7.63	20.85	29.15
SUPRIYA	2.66	7.97	22.75	2.86	18.16
80/676	4.78	0.65	4.69	17.91	26.21
PH93	8.13	5.21	9.98	3.25	10.92
1321/8/8	2.90	9.16	10.47	3.21	6.37
DCH-32	8.48	2.33	8.37	6.38	4.59
NHH-44	10.23	5.21	8.52	32.48	37.27
1321/18/2	1.32	7.58	8.89	1.63	4.79
LRA5166	1.08	2.94	4.16	7.65	18.87
1321/4/6	3.53	8.84	23.62	3.73	19.03
1321/8/7	1.79	7.10	21.88	1.99	17.29
POURNIMA	4.89	8.37	6.16	12.72	7.95
1321/14/11	10.24	7.32	12.09	5.36	13.03
NH210	6.65	10.11	12.52	3.76	2.31
NH360	2.44	12.78	3.17	8.51	6.64
1321/12/8	6.02	3.10	7.87	1.14	8.81
1321/9/8	10.35	4.20	10.24	8.25	6.46
1321/9/21	6.61	0.46	6.50	4.51	2.72
1321/16/14	12.80	7.78	11.09	35.05	39.84
1321/16/5	2.82	5.71	1.03	5.04	9.55
1324/1/4	1.65	4.65	4.73	8.81	19.44
1324/2/6	0.51	1.23	3.59	6.49	18.30
1324/4/11	7.95	12.98	9.66	18.81	11.01
1324/6/5	1.83	3.76	3.54	6.63	4.89
1324/6/17	1.55	6.13	7.47	1.44	3.81
NH 284	0.73	2.35	6.65	0.98	2.99
NH 325	1.77	5.60	2.55	1.74	7.35
NH 352	1.31	1.54	2.09	1.42	6.89
PKV081	9.97	3.32	5.05	2.16	5.90
PAH 118	7.39	1.30	2.47	0.74	3.32
PAH 156	9.20	2.96	6.36	7.56	12.64
PAH 182	3.44	1.74	0.60	3.58	6.88
PAH 261	2.73	1.81	4.05	3.26	8.38
G 2932	1.81	1.03	3.13	1.12	7.46
PH 99	4.59	4.98	2.54	2.30	6.59
KH-101-2238	2.13	3.80	0.08	0.92	4.13

DC1 120	4.36	2.02	7.65	11.06	11.51
JLH-109	0.50	1.50	3.79	1.84	7.65
79BH-5-3	8.29	6.39	3.84	2.68	5.29
KD (CA-KD)	4.63	0.73	0.18	0.50	1.63
N1SD-2	5.12	3.03	5.37	1.85	4.42
1883/3	2.83	2.41	1.66	8.53	16.76
1913/2	2.17	1.75	1.00	7.87	16.10
1891/3	2.93	17.51	20.44	11.78	6.62
1915/5	0.27	14.85	17.78	9.11	3.96
BC1F1 (3)	7.72	3.59	7.63	20.85	29.15
80/216	4.78	0.65	4.69	17.91	26.21
1321/8/13	2.90	9.16	10.47	3.21	6.37
1321/18/1	1.32	7.58	8.89	1.63	4.79
1321/1/3	3.53	8.84	23.62	3.73	19.03
1321/8/3	1.79	7.10	21.88	1.99	17.29
1321/14/12	10.24	7.32	12.09	5.36	13.03
1321/12/9	6.02	3.10	7.87	1.14	8.81
1321/9/12	10.35	4.20	10.24	8.25	6.46
1321/14/7	6.61	0.46	6.50	4.51	2.72
1321/16/13	12.80	7.78	11.09	35.05	39.84
1321/16/4	5.11	2.12	6.08	7.33	3.56
1324/1/3	1.65	4.65	4.73	8.81	19.44
1324/3/8	0.51	1.23	3.59	6.49	18.30
1324/4/9	7.95	12.98	9.66	18.81	11.01
1324/6/6	1.83	3.76	3.54	6.63	4.89
1324/6/18	1.55	6.13	7.47	1.44	3.81
N 289	0.73	2.35	6.65	0.98	2.99
NH 330	1.77	5.60	2.55	1.74	7.35
NH 355	1.31	4.54	2.09	1.42	6.89
SRT-1	9.97	3.32	5.05	2.16	5.90
PAH 122	7.39	1.30	2.47	0.74	3.32
PAH 158	9.20	2.96	6.36	7.56	12.64
PAH 202	3.44	1.74	0.60	3.58	6.88
PAH 268	2.73	1.81	4.05	3.26	8.38
JLH 106	1.81	1.03	3.13	1.12	7.46
AKH 84635	4.59	4.98	2.54	2.30	6.59
B-82 BH-1	2.13	3.80	0.08	0.92	4.13
DC1 121	4.36	2.02	7.65	11.06	11.51
PH-23	0.50	1.50	3.79	1.84	7.65
PH 39	8.29	6.39	3.84	2.68	5.29
LRK-516	4.63	0.73	0.18	0.50	1.63
1883/2	2.83	2.41	1.66	8.53	16.76
1915/3	2.17	1.75	1.00	7.87	16.10
1912/3	2.93	17.51	20.44	11.78	6.62
1915/6	0.27	14.85	17.78	9.11	3.96
BC1F1 (4)	7.72	3.59	7.63	20.85	29.15
80/679	4.78	0.65	4.69	17.91	26.21
1321/8/14	2.90	9.16	10.47	3.21	6.37
1321/4/3	1.32	7.58	8.89	1.63	4.79

1321/4/20	3.53	8.84	23.62	3.73	19.03
1321/8/1	1.79	7.10	21.88	1.99	17.29
1321/14/13	10.24	7.32	12.09	5.36	13.03
1321/12/10	6.02	3.10	7.87	1.14	8.81
1321/9/18	10.35	4.20	10.24	8.25	6.46
1321/14/2	6.61	0.46	6.50	4.51	2.72
1321/16/12	12.80	7.78	11.09	35.05	39.84
1321/16/3	5.66	6.12	8.07	25.02	7.08
1324/1/9	1.65	4.65	4.73	8.81	19.44
1324/3/7	0.51	1.23	3.59	6.49	18.30
1324/4/6	7.95	12.98	9.66	18.81	11.01
1324/6/7	1.83	3.76	3.54	6.63	4.89
NH 317	1.55	6.13	7.47	1.44	3.81
NH 302	0.73	2.35	6.65	0.98	2.99
NH 332	1.77	5.60	2.55	1.74	7.35
NH 364	1.31	1.54	2.09	1.42	6.89
PKV081	9.97	3.32	5.05	2.16	5.90
PAH 135	7.39	1.30	2.47	0.74	3.32
PAH 161	9.20	2.96	6.36	7.56	12.64
PAH 209	3.44	1.74	0.60	3.58	6.88
PAH 272	2.73	1.81	4.05	3.26	8.38
JLH 158	1.81	1.03	3.13	1.12	7.46
AKH 8432	4.59	4.98	2.54	2.30	6.59
B-82 BH-2	2.13	3.80	0.08	0.92	4.13
DC1 114	4.36	2.02	7.65	11.06	11.51
NH-293	0.50	1.50	3.79	1.84	7.65
NH 208	8.29	6.39	3.84	2.68	5.29
1MH 2721	4.63	0.73	0.18	0.50	1.63
1886/4	2.83	2.41	1.66	8.53	16.76
1915/4	2.17	1.75	1.00	7.87	16.10
1912/7	2.93	17.51	20.44	11.78	6.62
1916/5	0.27	14.85	17.78	9.11	3.96
BC1F1 (5)	7.72	3.59	7.63	20.85	29.15
BC1F1 -(8)	4.78	0.65	4.69	17.91	26.21
1321/8/17	2.90	9.16	10.47	3.21	6.37
1321/4/7	1.32	7.58	8.89	1.63	4.79
1321/6/10	3.53	8.84	23.62	3.73	19.03
1321/14/5	1.79	7.10	21.88	1.99	17.29
1321/13/6	5.90	3.32	11.51	7.65	1.03
1321/12/11	6.02	3.10	7.87	1.14	8.81
1321/9/20	12.36	4.09	12.19	0.56	1.46
1321/14/1	6.61	0.46	6.50	4.51	2.72
1321/16/11	3.81	1.42	3.26	8.38	29.15
1321/16/2	0.80	2.16	5.29	7.65	3.96
1324/2/5	1.65	4.65	4.73	8.81	19.44
1324/3/6	0.51	1.23	3.59	6.49	18.30
1324/4/5	7.95	12.98	9.66	18.81	11.01
1324/6/8	1.83	3.76	3.54	6.63	4.89
NH 268	1.55	6.13	7.47	1.44	3.81

NH 304	0.73	2.35	6.65	0.98	2.99
NH 340	1.77	5.60	2.55	1.74	7.35
NH 369	1.31	1.54	2.09	1.42	6.89
PH 36	9.97	3.32	5.05	2.16	5.90
PAH 138	7.39	1.30	2.47	0.74	3.32
PAH 163	9.20	2.96	6.36	7.56	12.64
PAH 216	3.44	1.74	0.60	3.58	6.88
PAH 276	2.73	1.81	4.05	3.26	8.38
JLH 168	1.81	1.03	3.13	1.12	7.46
AKH 8413	4.59	4.98	2.54	2.30	6.59
DC1 131	2.13	3.80	0.08	0.92	4.13
DC1 116	4.36	2.02	7.65	11.06	11.51
WH-21	0.50	1.50	3.79	1.84	7.65
WH 216	8.29	6.39	3.84	2.68	5.29
1MH-2725	4.63	0.73	0.18	0.50	1.63
1889/3	2.83	2.41	1.66	8.53	16.76
1883/1	2.17	1.75	1.00	7.87	16.10
1912/9	2.93	17.51	20.44	11.78	6.62
1916/3	0.27	14.85	17.78	9.11	3.96
BC1F1 (6)	7.72	3.59	7.63	20.85	29.15
BC1F1 (10)	4.78	0.65	4.69	17.91	26.21
1321/8/19	2.90	9.16	10.47	3.21	6.37
1321/4/12	1.32	7.58	8.89	1.63	4.79
1321/6/3	3.53	8.84	23.62	3.73	19.03
1321/14/6	1.79	7.10	21.88	1.99	17.29
1321/13/8	10.24	7.32	12.09	5.36	13.03
1321/11/2	6.02	3.10	7.87	1.14	8.81
1321/9/22	10.35	4.20	10.24	8.25	6.46
1321/16/23	6.61	0.46	6.50	4.51	2.72
1321/16/10	12.80	7.78	11.09	35.05	39.84
1324/1/10	16.70	5.75	1 .05	15.07	14.76
1324/2/4	1.65	4.65	4.73	8.81	19.44
1324/3/1	0.51	1.23	3.59	6.49	18.30
1324/4/4	7.95	12.98	9.66	18.81	11.01
1324/6/11	1.83	3.76	3.54	6.63	4.89
NH 312	1.55	6.13	7.47	1.44	3.81
NH 305	0.73	2.35	6.65	0.98	2.99
NH 342	1.77	5.60	2.55	1.74	7.35
NH 372	1.31	1.54	2.09	1.42	6.89
1512/1/3	9.97	3.32	5.05	2.16	5.90
PAH 141	7.39	1.30	2.47	0.74	3.32
PAH 165	9.20	2.96	6.36	7.56	12.64
PAH 237	3.44	1.74	0.60	3.58	6.88
PAH 280	2.73	1.81	4.05	3.26	8.38
NH 381	1.81	1.03	3.13	1.12	7.46
AKH 8435	4.59	4.98	2.54	2.30	6.59
DC1 134	2.13	3.80	0.08	0.92	4.13
DC1 122	4.36	2.02	7.65	11.06	11.51
KH-98-2105	0.50	1.50	3.79	1.84	7.65

G 2987	8.29	6.39	3.84	2.68	5.29
1MH 2934	4.63	0.73	0.18	0.50	1.63
1891/3	2.83	2.41	1.66	8.53	16.76
1883/3	2.17	1.75	1.00	7.87	16.10
1916/1	2.93	17.51	20.44	11.78	6.62
1324/6/19	0.27	14.85	17.78	9.11	3.96
BC1F1 (7)	7.72	3.59	7.63	20.85	29.15
BC1F2	4.78	0.65	4.69	17.91	26.21
1321/7/4	2.90	9.16	10.47	3.21	6.37
1321/4/24	1.32	7.58	8.89	1.63	4.79
1321/8/2	3.53	8.84	23.62	3.73	19.03
1321/14/8	1.79	7.10	21.88	1.99	17.29
1321/12/4	10.24	7.32	12.09	5.36	13.03
1321/9/5	6.02	3.10	7.87	1.14	8.81
1321/9/13	10.35	4.20	10.24	8.25	6.46
1321/16/22	6.61	0.46	6.50	4.51	2.72
1321/16/9	2.87	5.78	1.04	5.07	9.85
1324/1/7	17.75	4.66	2.07	6.00	6.77
1324/2/3	1.65	4.65	4.73	8.81	19.44
1324/4/22	0.51	1.23	3.59	6.49	18.30
1324/4/3	7.95	12.98	9.66	18.81	11.01
1324/6/12	1.83	3.76	3.54	6.63	4.89
N 269	1.55	6.13	7.47	1.44	3.81
NH 312	0.73	2.35	6.65	0.98	2.99
NH 345	1.77	5.60	2.55	1.74	7.35
NHH 302	1.31	1.54	2.09	1.42	6.89
1512/1/2	9.97	3.32	5.05	2.16	5.90
PAH 146	7.39	1.30	2.47	0.74	3.32
PAH 168	9.20	2.96	6.36	7.56	12.64
PAH 212	3.44	1.74	0.60	3.58	6.88
G 1630	2.73	1.81	4.05	3.26	8.38
NH 382	1.81	1.03	3.13	1.12	7.46
AKH 8603	4.59	4.98	2.54	2.30	6.59
DC1 108	2.13	3.80	0.08	0.92	4.13
G-84-909	4.36	2.02	7.45	11.06	11.51
KH-100-2237	0.50	1.50	3.79	1.84	7.65
AKH-938	8.29	6.39	3.84	2.68	5.29
NHS-1412	4.63	0.73	0.18	0.50	1.63
1912/3	2.83	2.41	1.66	8.53	16.76
1883/2	2.17	1.75	1.00	7.87	16.10
1913/2	2.93	17.51	20.44	11.78	6.62
1324/6/9	0.27	14.85	17.78	9.11	3.96
80/216/4	7.72	3.59	7.63	20.85	29.15
BC1F1 (9)	4.78	0.65	4.69	17.91	26.21
1321/6/5	2.90	9.16	10.47	3.21	6.37
1321/4/26	1.32	7.58	8.89	1.63	4.79
1321/8/15	3.53	8.84	23.62	3.73	19.03
1321/14/9	1.79	7.10	21.88	1.99	17.29
1321/12/5	10.24	7.32	12.09	5.36	13.03

1321/9/6	6.02	3.10	7.87	1.14	8.81
1321/9/14	10.35	4.20	10.24	8.25	6.46
1321/16/21	6.61	0.46	6.50	4.51	2.72
1321/16/7	8.70	6.76	17.06	32.08	5.84
1324/1/6	6.86	17.65	12.09	11.09	21.86
1324/2/2	1.65	4.65	4.73	8.81	19.44
1324/4/20	0.51	1.23	3.59	6.49	18.30
1324/5/1	7.95	12.98	9.66	18.81	11.01
1324/6/15	1.83	3.76	3.54	6.63	4.89
N 274	1.55	6.13	7.47	1.44	3.81
NH 316	0.73	2.35	6.65	0.98	2.99
NH 347	1.77	5.60	2.55	1.74	7.35
GODAVARI	1.31	1.54	2.09	1.42	6.89
1512/1/4	9.97	3.32	5.05	2.16	5.90
PAH 151	7.39	1.30	2.47	0.74	3.32
PAH 172	9.20	2.96	6.36	7.56	12.64
PAH 242	3.44	1.74	0.60	3.58	6.88
G(t) 1093	2.73	1.81	4.05	3.26	8.38
NH 383	1.81	1.03	3.13	1.12	7.46
KH-94-2166	4.59	4.98	2.54	2.30	6.59
DC1 108	2.13	3.80	0.08	0.92	4.13
ADB-10050	4.36	2.02	7.65	11.06	11.51
AKH-8247	0.50	1.50	3.79	1.84	7.65
SURAT	8.29	6.39	3.84	2.68	5.29
N1SD-5	4.63	0.73	0.18	0.50	1.63
1912/7	2.83	2.41	1.66	8.53	16.76
1886/4	2.17	1.75	1.00	7.87	16.10
1915/3	2.93	17.51	20.44	11.78	6.62
BC-1F1 (1)	0.27	14.85	17.78	9.11	3.96
80/216	7.72	3.59	7.63	20.85	29.15
1321/8/15	4.78	0.65	4.69	17.91	26.21
1321/6/6	2.90	9.16	10.47	3.21	6.37
1321/1/1	1.32	7.58	8.89	1.63	4.79
1321/8/9	3.53	8.84	23.62	3.73	19.03
1321/14/10	1.79	7.10	21.88	1.99	17.29
1321/12/7	10.24	7.32	12.09	5.36	13.03
1321/9/7	6.02	3.10	7.87	1.14	8.81
1321/9/17	10.35	4.20	10.24	8.25	6.46
1321/16/15	6.61	0.46	6.50	4.51	2.72
1321/16/6	9.81	5.67	16.09	23.02	18.72
1324/5/5	2.80	7.78	11.09	35.05	9.84
1324/2/1	1.65	4.65	4.73	8.81	19.44
1324/4/14	0.51	1.23	3.59	6.49	18.30
1324/5/2	7.95	12.98	9.66	18 81	11.01
1324/6/16	1.83	3.76	3.54	6.63	4.89
N 280	1.55	6.13	7.47	1.44	3.81
NH 318	0.73	2.35	6.65	0.98	2.99
NH 351	1.77	5.60	2.55	1.74	7.35
CPH 5567	1.31	1.54	2.09	1.42	6.89

PAH 115	9.97	3.32	5.05	2.16	5.90
PAH 152	7.39	1.30	2.47	0.74	3.32
PAH 176	9.20	2.96	6.36	7.56	12.64
PAH 253	3.44	1.74	0.60	3.58	6.88
G 2984	2.73	1.81	4.05	3.26	8.38
PH 9.	1.81	1.03	3.13	1.12	7.46
KH-95-2018	4.59	4.98	2.54	2.30	6.59
DC1 118	2.13	3.80	0.08	0.92	4.13
G COT 10	4.36	2.02	7.65	11.06	11.51
G4406	0.50	1.50	3.79	1.84	7.65
G 4231	8.29	6.39	3.84	2.68	5.29
N1SD-3	4.63	0.73	0.18	0.50	1.63
NA-266	1.36	3.11	1.46	1.15	1.68
NAMDEO	0.68	2.00	0.78	0.99	1.00
EKNATH	0.11	2.00	4.00	0.16	2.00
85/142	0.00	0.89	0.10	0.83	0.32
NA 319	0.20	2.81	4.09	0.32	2.09
ROHINI	0.37	1.00	0.13	0.71	0.65
JYOTI	1.00	0.31	1.00	2.00	0.52
NA 259	0.02	1.19	3.91	0.00	1.91
NA 332	0.45	1.23	0.21	1.42	0.73
NA 334	0.29	0.77	0.05	0.00	0.57
NA 109	1.51	0.62	1.51	2.19	1.03
NA 136	0.49	0.00	0.49	1.81	0.01
PA-85/139	1.36	3.11	1.46	1.15	1.68
85/162	0.00	0.89	0.10	0.83	0.32
85/162	0.20	2.81	4.09	0.32	2.09
PA 85/89	0.02	1.19	3.91	0.00	1.91
NA 336	0.45	1.23	0.21	1.42	0.73
NA 339	0.29	0.77	0.05	0.00	0.57
NA 110	1.51	0.62	1.51	2.19	1.03
NA 347	0.49	0.00	0.49	1.81	0.01
NA-341	1.36	3.11	1.46	1.15	1.68
NA 317	0.00	0.89	0.10	0.83	0.32
PA-85/85	0.20	2.81	4.09	0.32	2.09
NA 325	0.02	1.19	3.91	0.00	1.91
PA 168	0.45	1.23	0.21	1.42	0.73
PA 85/160	0.29	0.77	0.05	0.00	0.57
NA 308	1.51	0.62	1.51	2.19	1.03
NA 311	0.49	0.00	0.49	1.81	0.01
NA-263	1.36	3.11	1.46	1.15	1.68
PA-168	0.00	0.89	0.10	0.83	0.32
NA 326	0.20	2.81	4.09	0.32	2.09
PA 166	0.02	1.19	3.91	0.00	1.91
NA 340	0.45	1.23	0.21	1.42	0.73
NA 341	0.29	0.77	0.05	0.00	0.57
PA 86/22	1.51	0.62	1.51	2.19	1.03
PA-106	1.36	3.11	1.46	1.15	1.68
NA-260	0.00	0.89	0.10	0.83	0.32

PA-85/88	0.20	2.81	4.09	0.32	2.09
NA 268	0.02	1.19	3.91	0.00	1.91
NA 337	0.45	1.23	0.21	1.42	0.73
SM 6	0.29	0.77	0.05	0.00	0.57
PA 86/11	1.51	0.62	1.51	2.19	1.03
PA-85/141	1.36	3.11	1.46	1.15	1.68
NA-318	0.00	0.89	0.10	0.83	0.32
PA 85/11	0.20	2.81	4.09	0.32	2.09
PA-85/97	0.02	1.19	3.91	0.00	1.91
NA 335	0.45	1.23	0.21	1.42	0.73
RS 51	0.29	0.77	0.05	0.00	0.57
PA 86/13	1.51	0.62	1.51	2.19	1.03
NA-319	1.36	3.11	1.46	1.15	1.68
NA 328	0.00	0.89	0.10	0.83	0.32
PA 85/95	0.20	2.81	4.09	0.32	2.09
NA 265	0.02	1.19	3.91	0.00	1.91
PA 85/151	0.45	1.23	0.21	1.42	0.73
NA 305	0.29	0.77	0.05	0.00	0.57
PA 86/16	1.51	0.62	1.51	2.19	1.03
NA-315	1.36	3.11	1.46	1.15	1.68
NA 340	0.00	0.89	0.10	0.83	0.32
NA 228	0.20	2.81	4.09	0.32	2.09
NA 262	0.02	1.19	3.91	0.00	1.91
PA 85/168	0.45	1.23	0.21	1.42	0.73
PA 140	0.29	0.77	0.05	0.00	0.57
NA 349	1.51	0.62	1.51	2.19	1.03
NA-306	1.36	3.11	1.46	1.15	1.68
PA 106	0.00	0.89	0.10	0.83	0.32
NA 305	0.20	2.81	4.09	0.32	2.09
PA 85/96	0.02	1.19	3.91	0.00	1.91
PA 129	0.45	1.23	0.21	1.42	0.73
NA 299	0.29	0.77	0.05	0.00	0.57
NA 316	1.51	0.62	1.51	2.19	1.03
NA-269	1.36	3.11	1.46	1.15	1.68
PA 140	0.00	0.89	0.10	0.83	0.32
NA 327	0.20	2.81	4.09	0.32	2.09
PA 156	0.02	1.19	3.91	0.00	1.91
PA 85/150	0.45	1.23	0.21	1.42	0.73
NA 106	0.29	0.77	0.05	0.00	0.57
NA 137	1.51	0.62	1.51	2.19	1.03
PA 85/160	1.36	3.11	1.46	1.15	1.68
NA 349	0.00	0.89	0.10	0.83	0.32
NA 329	0.20	2.81	4.09	0.32	2.09
NA 262	0.02	1.19	3.91	0.00	1.91
NA 333	0.45	1.23	0.21	1.42	0.73
PA 82/82	0.29	0.77	0.05	0.00	0.57
NA 348	1.51	0.62	1.51	2.19	1.03
PA 85/75	1.36	3.11	1.46	1.15	1.68
PA 168	0.00	0.89	0.10	0.83	0.32

NA 80	0.20	2.81	4.09	0.32	2.09
PA 85/1	0.02	1.19	3.91	0.00	1.91
NA 342	0.45	1.23	0.21	1.42	0.73
NA 107	0.29	0.77	0.05	0.00	0.57
NA 345	1.51	0.62	1.51	2.19	1.03
PA-140	1.36	3.11	1.46	1.15	1.68
86/142	0.00	0.89	0.10	0.83	0.32
PA 85/9	0.20	2.81	4.09	0.32	2.09
PA 85/44	0.02	1.19	3.91	0.00	1.91
NA 338	0.45	1.23	0.21	1.42	0.73
NA 108	0.29	0.77	0.05	0.00	0.57
NA 140	1.51	0.62	1.51	2.19	1.03