SELECTION FOR MOSAIC RESISTANCE IN PUMPKIN (*Cucurbita moschata* Poir)

By

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THESIS

Submitted in partial fulfilment of the
requirement for the degree

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DECLARATION

I hereby declare that the thesis entitled "SELECTION FOR MOSAIC RESISTANCE IN PUMPKIN (Cucurbita moschata Poir)" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara,
17 -10-1992.

LATHA, P.

Dedicated to
my loving parents

CERTIFICATE

Certified that this thesis entitled "Selection for mosaic resistance in pumpkin (Cucurbita moschata Poir)" is a record of research work done independently by **Mrs.Latha, P.,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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We, the undersigned members of the Advisory Committee of **Mrs.Latha, P.**, a candidate for the degree of Master of Science in Horticulture, agree that the thesis entitled "Selection for mosaic resistance in pumpkin (Cucurbita moschata Poir)" may be submitted by Mrs.Latha, P., in partial fulfilment of the requirement for the degree.

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my loving parents

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Introduction

INTRODUCTION

Pumpkin (Cucurbita moschata Poir) is a popular summer vegetable of Kerala which is grown for its mature and immature fruits. Its young leaves, flowers and fruits are rich in carotene, the precursor of Vitamin A. The crop is specially noted for its low cost of production and long keeping quality of fruits. In spite of its popularity, very little effort has been made for the genetic improvement of the crop. Yield of pumpkin remains low due to poor genetic stock and inadequate management practices. The cultivation of pumpkin suffered a set back during the last few years due to severe outbreak of mosaic diseases, particularly yellow vein mosaic and pumpkin mosaic (Balakrishnan, 1988).

For years, eradication of overwintering hosts of the viruses, altering planting dates and chemical protection against the insect vectors have been the principal means of control. Standardization of ideal time of sowing specific to each zone has great relevance for achieving maximum productivity by avoiding diseases. Cultivation of resistant varieties is the most efficient method of control of diseases, particularly those caused by viruses. None of the available pumpkin cultivars or varieties so far available or reported in the country possesses resistance to mosaic. Therefore, development of high yielding, carotene rich, mosaic resistant variety should be the primary aim of pumpkin improvement in the country. CM 214, a line from Nigeria, had proved its resistance to yellow vein mosaic and pumpkin mosaic (Suresh Babu, 1989). But its fruits are warty and is highlyerratic in bearing due to poor fruit setting and low seed germination.

Yield is an artefact of several contributing characters like average fruit weight, number of fruits/plant, earliness etc. The knowledge of the type of gene action for the expression of a character is helpful in formulating the breeding strategy for the ultimate improvement of the crop.

In the present study, an attempt is made to standardize the ideal time of sowing for pumpkin. The adapted variety Ambili was also crossed to the mosaic resistant line CM 214 (Nigerian Local) to identify mosaic resistant and high yielding segregants, to understand the gene action of economic characters and to unravel inheritance pattern of mosaic resistance and discrete characters by developing F_1, F_2, BC_1 and BC_2 generations. The mosaic resistant line CM 214 was also subjected to rigorous selection for improvement in fruit characters and yield.

Review of Literature

REVIEW OF LITERATURE

Pumpkin (*Cucurbita moschata* Poir) is an underexploited, but popular vegetable of Kerala. Mosaic is the most dreadful disease affecting the successful cultivation of the crop in the State. Very little work has been done for the genetic improvement of the crop particularly to mosaic resistance. Because of the limited informations on these lines in pumpkin, works on other vegetable crops are reviewed under the following heads:

A. Important viral diseases of cucurbits

B. Seasonal influence on mosaic incidence, vector population and yield

C. Source and inheritance of mosaic resistance in cucurbits

D. Inheritance of qualitative characters and gene action of quantitative characters in cucurbits

E. Improvement through selection

A. Important viral diseases of cucurbits

Several viruses causing diverse symptoms have been reported in cucurbits. The important viral diseases causing serious damage to pumpkin are yellow vein mosaic, pumpkin mosaic, watermelon mosaic, cucumber mosaic, bottle gourd mosaic, zucchini yellow mosaic, squash mosaic etc. Reports on various viral diseases in cucurbits are listed in Table 1.

Table 1. Important viral diseases of cucurbits

Viruses/Viral diseases reported	Crop	Authority
Pumpkin mosaic	Pumpkin	Shankar *et al*., 1972 Umamaheswaran, 1985 Balakrishnan, 1988
	Vegetable marrow	Reddy and Nariani, 1963
	Cucurbita maxima	Singh, 1981
Yellow vein mosaic	Pumpkin	Capoor and Ahmed, 1975 Bhargava and Bhargava, 1977 Jayashree, 1984 Balakrishnan, 1988
Bottle gourd mosaic (Cucumis virus-3)	Bottle gourd	Vasudeva and Lal, 1943 Dubey, 1977
	Cucurbits	Hariharasubramanian and Badami, 1964
Bottle gourd mosaic (Cucumis virus 2B and 2C)	Bottle gourd	Raychaudhari and Nariani, 1977
Cucumis virus-1	Snake gourd	Dubey *et al*., 1974 Joseph and Menon, 1978 Joseph and Menon, 1981

Contd.

Table 1. Continued

Viruses/viral diseases reported	Crop	Authority
Cucumber mosaic virus	Cucumber	Aharoni *et al.*, 1977 Lele and Mukerji, 1979
	Muskmelon	Sharma *et al.*, 1980 Sharma *et al.*, 1987
	Summer squash	Saugar and Raj, 1988
Cucumber yellows	Cucumber	Zenbayashi *et al.*, 1984
Zucchini yellow mosaic virus	Cucurbits	Lecoq and Pitrat, 1984 Gleason and Provvidenti, 1990
	Cucurbita pepo	Provvidenti, 1984
	Squash, *Luffa* spp. and *Cucumis metuliferus*	Provvidenti and Gonsalves, 1984
	Cucumber and courgette	Greber *et al.*, 1987
	Cucurbita pepo var. *melopepo*	Crosslin *et al.*, 1988
	Pumpkin and watermelon	Abdulsalam *et al.*, 1988
	Cucumber and melon	Ghorbani, 1988
	Cucumis melo	Blua and Perring, 1989
	Watermelon	Fernandes *et al.*, 1991

Contd.

Table 1. Continued

Viruses/Viral diseases reported	Crop	Authority
Cucumber vein yellowing virus	*Cucumis sativus*	Yilmaz *et al*., 1989
Watermelon mosaic virus	Summer squash	Demski and Chalkley, 1972 Bishnoi *et al*., 1985
	Pumpkin	Qureshi and Mayee, 1979 Roy and Mukhopadhyay, 1979 Singh, 1987
	Bottle gourd	Demski and Chalkley, 1974 Singh, 1989
	Cucurbita maxima	Tripathi and Joshi, 1985 Singh and Bhargava, 1987
	Cucumber	Makkouk and Lesemann, 1980
Squash mosaic virus	Squashes and pumpkins	Freitag, 1956
	Cantaloup and watermelon	Nelson *et al*., 1965
Squash leaf curl virus	Squash	Flock and Mayhew, 1981

Contd.

Table 1. Continued

Viruses/Viral diseases reported	Crop	Authority
	Cucurbita maxima, *C. moschata* and *C. pepo*	Cohen *et al.*, 1983
Melon mosaic virus	Pumpkin and muskmelon	Jaganathan and Ramakrishnan, 1971

Reddy and Nariani (1963) reported a mosaic caused by cucumis virus 1 in vegetable marrow which was transmitted by Aphis gossypii, A. craccivora and Myzus persicae. The symptoms of this mosaic were characterized by typical mosaic pattern of light and dark green with reduction in leaf and fruit size and delay in flowering. Shankar et al. (1972) described the symptoms of pumpkin mosaic in Cucurbita moschata. The leaves showed mosaic mottling, late unfolding of young leaves and complete chlorosis followed by green vein banding. The older leaves had dark green blisters with the rest of the lamina being chlorotic. Flowering was delayed and flower and fruit size were reduced. They observed that the virus was transmitted by Aphis gossypii and through sap. The virus resembled cucumis virus 3 causing bottle gourd mosaic (Vasudeva and Lal, 1943) and the cucumis virus 1 causing mosaic of vegetable marrow (Reddy and Nariani, 1963). Umamaheswaran (1985) observed severe mottling and disfiguration of leaves of C. moschata infected with pumpkin mosaic. Dark green vein banding, irregular chlorotic spots and mottling with mild green blisters were other symptoms. Plant stunting and sparse flowering and fruit setting were also noticed.

Bottle gourd mosaic in Lagenaria siceraria caused by cucumis virus 2B and 2C was characterized by irregular light green and dark green mottling of leaves which later enlarged and coalesced to give mosaic appearance, green vein banding, blistering, puckering and finally distortion of leaves (Raychaudhari and Nariani, 1977). This virus was sap transmissible and also insect transmissible by red pumpkin beetle. Joseph and Menon (1981) noticed a complete failure of fruit set in snake gourd infected by cucumber mosaic virus (CMV). Saugar and Raj (1988) reported the occurrence of filiform disease in summer squash by a strain of CMV which was transmitted by Myzus persicae.

Capoor and Ahmed (1975) described a mosaic in pumpkin designated as pumpkin yellow vein mosaic which affected Cucurbita pepo, C. moschata and C. maxima. It was neither seed borne nor seed transmissible but was transmitted in nature by the whitefly, Bemisia tabaci in a semipersistent manner. Bhargava and Bhargava (1977) confirmed the whitefly transmission of pumpkin yellow vein mosaic (PYVM) and they recorded 60% incidence of PYVM in C. moschata. The symptoms of yellow vein mosaic were described by Jayashree (1984). Initial symptoms were faint yellowing of finer veins, finally developing into characteristic vein yellowing. In advanced stages, large chlorotic areas appeared on leaves making the yellow network of veins inconspicuous. Reduction of leaf size, retardation of growth, shortening of internodes, production of very few female flowers etc., were the other symptoms.

Lecoq and Pitrat (1984) observed mosaic, leaf deformation, plant stunting, necrosis and fruit alterations in cucurbits infected by zucchini yellow mosaic virus (ZYMV). In C. pepo, Provvidenti (1984) noticed distortion of fruits or knobbed fruits and complete loss of crop with early infection. Similar symptoms by ZYMV in different cucurbits were reported by Provvidenti and Gonsalves (1984), Greber et al. (1987), Crosslin et al. (1988) and Ghorbani (1988). Abdulsalam et al. (1988) reported that ZYMV was transmissible in a nonpersistent manner by Aphis gossypii and Myzus persicae. Blua and Perring (1989) recorded 76-94% reduction in yield of marketable fruits of Cucumis melo by ZYMV infection.

Yilmaz et al. (1989) identified a cucumber vein yellowing virus from diseased Cucumis sativus cv. Cool Green which was easily transmitted in a semipersistent manner by Bemisia tabaci.

Reddy and Nariani (1963) reported filiform type of symptoms in vegetable marrow which was caused by a strain of watermelon mosaic virus (WMV). This was characterized by severe distortion and filiformy of leaves, vein clearing of young leaves, chlorosis, prominent dark green blisters etc. The veins and veinlets extended beyond the margins and interveinal areas were reduced. There was delayed flowering and reduction in flower and fruit size. Demski and Chalkley (1972) recorded

9-43% loss of crop of summer squash infected by WMV. In watermelon, Demski and Chalkley (1974) reported 19-73% reduction in yield and more than 55% reduction in fresh weight due to WMV infection.

Filiform symptoms by WMV were also reported by Qureshi and Mayee (1979) in several other cucurbits like Lagenaria siceraria, Cucurbita moschata, Cucumis melo and Luffa spp. The host range of WMV was found to be restricted to Cucurbitaceae (Qureshi and Mayee, 1979; Ahmed, 1981 and Bishnoi et al., 1985). Roy and Mukhopadhyay (1979) reported the incidence of WMV in C. moschata which was transmitted in a nonpersistent manner by Aphis gossypii and also by mechanical contact. Makkouk and Lesemann (1980) reported the transmission of this virus through Myzus persicae in the stylet borne manner. Symptoms of WMV were also described by Tripathi and Joshi (1985) in C. maxima, Singh (1987) in pumpkin and Singh (1989) in bottle gourd. Hernandez et al. (1989) reported the incidence of papaya ringspot potyvirus, watermelon mosaic 1 potyvirus, squash mosaic virus and zucchini yellow mosaic in Cucurbita moschata, marrows, melons and watermelon.

Infection of squash mosaic virus in squashes and pumpkin was characterized by vein clearing and chlorotic spotting of young leaves and they tended to curl upward (Freitag, 1956).

Regular marginal projections of the veins were seen due to retarded development of interveinal tissues and in advanced stages enations developed from the lower surface of leaves. Similar symptoms of squash mosaic virus were observed in cantaloup and watermelon by Nelson et al. (1965). Grogan et al. (1959) observed an increased incidence of squash mosaic virus in places where the population of cucumber beetles was abundant.

Flock and Mayhew (1981) described the occurrence of squash leaf curl in cucurbits for the first time. The symptoms were leaf curl, enations, thickening of veins, stunting and high plant mortality and the virus was transmitted by *Bemisia tabaci*. Cohen et al. (1983) reported squash leaf curl virus (SLCV) in *C. maxima*, *C. moschata* and *C. pepo*. Dodds et al. (1984), Dolores and Valdez (1988) and McCreight and Kishaba (1991) also observed SLCV to be exclusively whitefly transmissible.

Hariharasubramanian and Badami (1964) reported the occurrence of a virus causing mild chlorosis, mottling and blistering of leaves and stunting in cucurbits and it resembled bottle gourd mosaic virus. In bitter gourd, this virus caused long narrow projections of leaf apices called 'Shoestrings' and it was transmitted by aphids in a nonpersistent manner.

The incidence of melon mosaic virus was reported by Jaganathan and Ramakrishnan (1971) in pumpkin (*C. moschata*) and muskmelon which caused leaf mottling and malformations, dark green vein banding, plant stunting and sparse flowering and fruit setting.

The biochemical changes following viral infection were also noticed by many workers. Mandahar and Singh (1971) and Ghosh (1978) reported destruction of both the chlorophylls by pumpkin mosaic of Cucurbita moschata. In cucumber, CMV caused a reduction in gibberellin like substances and an increase in abscissic acid which resulted in retardation of hypocotyl growth (Aharoni et al., 1977).

Lele and Mukerji (1979) observed an overall decrease in photosynthetic rate and increase in respiratory rate in cucumber following CMV infection. The peroxidase activity was considerably higher in infected leaves. Singh (1981) also reported an increased peroxidase activity in C. maxima after inoculation with pumpkin mosaic virus. A reduction in dry weight was noticed in muskmelon leaves infected by CMV (Sharma et al., 1980). Amount of total chlorophyll, chlorophyll 'a' and chlorophyll 'b', total sugars, reducing and non-reducing sugars were also lower in infected leaves than healthy leaves. Sharma et al. (1987) recorded an increased level of protein in muskmelon following CMV infection.

Pandey and Joshi (1989) observed a reduction in the chlorophyll content and number of chloroplasts, both in palisade and spongy cells in bitter gourd leaves infected by cucumis virus 3. Chlorophyllase activity was higher in infected leaves due to disruption of chloroplast in chlorosis induced tissues.

In muskmelon infected by WMV-1, Erdiller and Ertunc (1987) recorded a reduction in respiration rate and the content of starch, sugars and inorganic and total nitrogen and an increase in protein content. Reduction in total, reducing and non-reducing sugars and starch by WMV-1 infection was reported in muskmelon by Singh and Bhargava (1987).

B. Seasonal influence on mosaic incidence, vector population and yield

Among the different environmental factors, rising temperature is the most probable cause of change in symptom expression of diseases. Symptom development, beyond initial stages, either increased or decreased in response to temperatures, apparently depending on the particular host-virus complex rather than upon either entity alone.

Cheo and Pound (1952) observed a greatest concentration of cucumber mosaic virus 1 (CMV-1) in spinach at 28°C. At 16°C the plants developed symptoms slowly. They also found that the multiplication of CMV-1 in spinach was favoured by longer day length and high light intensity. Temperature of 28°C or above were found to be lethal to all cucumber virus-1 infected plants of spinach while low temperature retarded disease development in susceptible plants and inhibited symptom expression in resistant plants (Pound and Cheo, 1952).

Bancroft (1958) measured the concentration of squash mosaic virus in leaves of pumpkin and squash under various conditions of light intensity and temperature. They found that at low temperature, the leaves of short day plants contained much more virus than those of long day plants whereas the virus made the greatest initial increase at high temperatures during long days.

In bhindi, Chelliah et al. (1975) observed a negative correlation between yellow vein mosaic incidence and relative humidity (RH) and there existed a highly positive correlation between the disease incidence, whitefly population and temperature.

High mortality of pumpkin plants infected by squash leaf curl transmitted by *Bemisia tabaci* at temperatures above 32.2°C was reported by Flock and Mayhew (1981). No distinct symptoms were developed when temperature was less than 21°C and enations and other symptoms developed between 26.6 and 32.2°C.

In okra, very low population of whiteflies and thereby a low incidence of yellow vein mosaic were recorded in the crop sown in middle of August (24-29°C and 90-95% RH) showing the influence of planting time on mosaic incidence (Keshwal and Jain, 1983).

According to Vicente et al. (1988), the reduced population of Bemisia tabaci and hence the lower incidence of bean golden mosaic gemini virus in bean plants (Phaseolus vulgaris) in winter were mainly due to lower temperature. In tomato, incidence of shoestring disease caused by PV-Y was greatly influenced by mean air temperature and relative humidity (Chowfla et al., 1989). They found that higher temperature (20°C) coupled with low RH (56.5%) and lower temperature (15.8°C) with high RH (64.2%) favoured disease initiation suggesting a specific temperature requirement of the virus for its synthesis and multiplication.

Kassanis (1957) reported that most plant viruses multiplied less rapidly as the temperature rose from 30°C and some ceased to multiply at temperatures around 36°C. Complete masking of the symptoms of watermelon mosaic viruses 1 and 2, cucumber mosaic virus and squash mosaic virus was observed in muskmelon at 18.3°C (Foster and Webb, 1965).

In Cucurbita pepo, Pink and Walkey (1985a) observed a reduced symptom severity with increase in temperature. In cultivars Cinderella and Cobham Bush Green, increased light intensity also resulted in a decrease in the symptoms.

Whiteflies (Bemisia tabaci Genn.) are the important vectors of different viruses such as yellow vein mosaic virus, squash leaf curl virus etc. Whitefly population is greatly influenced by the environmental factors mainly temperature. Pruthi and Samuel (1942) reported that the higher temperatures during summer influenced the fecundity of B. tabaci resulting in an increased spread of tobacco leaf curl disease. Generally, whitefly population and thereby disease incidence are found to be high at high temperature. Trehan (1944) reported that the rate of development and reproduction of B. tabaci were positively correlated with temperatures upto 45°C. At high temperature females outnumbered males and thus resulted in an increased spread of cotton leaf curl during summer.

B. tabaci is a potent vector of cassava mosaic. Studies on population dynamics of whitefly on cassava in Kerala by Lal (1981) revealed that a comparatively stable maximum temperature of 29.4-32.9°C favoured the incidence of whiteflies. Seif (1981) found that the interaction of atmospheric temperature and relative humidity was highly correlated with the development of white-flies in cassava. He noticed that a maximum mean temperature and minimum mean rainfall during January-March coincided with maximum mean number of adult whiteflies.

Though whiteflies were present throughout the year, Lal and Pillai (1982) observed a peak population during January, March and June in cassava. They also reported that the whitefly population was positively and significantly correlated with the increase in maximum temperature. Singh and Butter (1988) noticed a positive correlation between whitefly population and temperature and rain fall, but there was a negative correlation between population and RH. Reddy et al. (1989) observed a heavy build up of whiteflies in cotton at 27.2°C temperature and 71.2% RH. They also noticed a suppression of the pest population by heavy rainfall and found that a temperature range of 29-33°C was congenial for rapid multiplication and spread of whiteflies.

Temperature was found to affect the development of eggs of whiteflies. Verma et al. (1990) observed improper development below 10°C and above 36°C and the optimum rate of adult development was found between 20 and 30°C.

Seasonal influence on yield may be through different ways such as the influence on sex differentiation, pollen germination, fruit set etc. Temperature and photoperiod were found to have great influence on sex differentiation and thereby yield of cucurbits (Matsuo, 1968; Zatyko, 1968 and Cantliffe, 1981). Matsuo

(1968) reported that in many varieties of cucumber, low temperature and short days promoted female differentiation.

Failure of the pollen grains to germinate and thus to set fruits will influence the yield. Masui et al. (1971) found that the germination rate of the pollen grains of Cucumis melo was decreased when maintained at high temperature, i.e., at 45°C when kept for 5-30 h, germination rate dropped from 87.3% to 69.9%. In cucumber, Matlob and Kelly (1972) observed that high temperature of 80-100°F before or during pollination resulted in the failure of pollen tube growth. Yakimenko (1984) reported the influence of sowing date and variety on the number of female flowers produced and hence yield in cucumber.

Delaying planting of Cucumis melo var. flexuosus was found to decrease the plant dry weight, average fruit weight and total fruit yield significantly (Mohammed et al., 1989). Benzioni et al. (1991) also reported the influence of time of sowing on emergence, growth, flowering, fruit number and fruit size in Cucumis metuliferus.

C. Source and inheritance of mosaic resistance in cucurbits

Information on the pattern of inheritance of resistance is necessary to select the suitable method for developing a resistant variety. Shifriss et al. (1942) investigated the genetical control of virus symptoms in cucumber and reported that three complementary genes controlled the ability or the failure to produce chlorosis at the cotyledon stage whereas in the true leaf stage, they observed a constant changing of the ratio suggesting the role of several gene modifiers in the genetical control of viral symptoms (Table 2).

From the analysis of the data of F_1, F_2 and backcross generations involving resistant and susceptible varieties of cucumber, Wasuwat and Walker (1961) found that resistance to cucumber mosaic virus (CMV) was governed by a single dominant gene. Kooistra (1969) reported that a high degree of resistance to cucumis virus-1 in cucumber was characterized by intermediate inheritance and seemed to be based on three genes each carrying a partial resistance.

In melons, resistance to CMV was found to be controlled by three recessive factors (Karchi et al., 1975). They also observed a very low virus concentration in the resistant than in the susceptible parent and that of the F_1 hybrid was intermediate indicating incomplete dominance of susceptibility.

Lecoq and Pitrat (1980) reported that resistance to one of the CMV strains in a resistant line of Cucumis melo was governed by a single dominant gene and they also found that

Table 2. Inheritance of resistance to mosaic in cucurbits

Virus/Crop	Pattern of inheritance of resistance	Authority
1. Cucumber mosaic virus		
Pumpkin	Quantitative inheritance	Pink and Walkey, 1985b
	Two unlinked recessive genes	Pink, 1987
Cucumber	Three complementary genes + modifiers	Shifriss *et al*., 1942
	Three genes with partial resistance	Kooistra, 1969
	Single dominant gene	Wasuwat and Walker, 1961
	Quantitative inheritance	Meyer *et al*., 1987
Melon	Three recessive genes	Karchi *et al*., 1975
	Single dominant gene	Lecoq and Pitrat, 1980
	Two recessive genes	Velich and Tobias, 1985
2. Zucchini yellow mosaic virus		
Cucurbita moschata	Partial dominance	Provvidenti, 1986
	Single dominant gene	Munger and Provvidenti, 1987 Paris *et al*., 1988
Cucumber	Single recessive gene	Yang *et al*., 1986 Provvidenti, 1987

Contd.

Table 2. Continued

Virus/Crop	Pattern of inheritance of resistance	Authority
Cucurbita ecuadorensis	Single major gene	Robinson *et al*., 1988
	Quantitative inheritance	Paran *et al*., 1989
Citrullus lanatus	Single recessive gene	Provvidenti, 1991
3. Watermelon mosaic virus		
Cucumis metuliferus	Single dominant gene	Provvidenti and Robinson, 1977
C. sativus	Single recessive gene	Wang *et al*., 1984
4. Papaya ringspot virus		
C. ecuadorensis	Polygenic resistance	Herrington *et al*., 1989
5. Melon mosaic virus		
Cucumber	Single dominant gene	Cohen *et al*., 1971
6. Muskmelon necrotic virus		
Muskmelon	Single recessive gene	Coudriet *et al*., 1981
7. Cucumber green mottle mosaic virus		
Muskmelon	Polygenes with recessive nature	Rajamony *et al*., 1990

this gene controlled the resistance of melon to *Aphis gossypii*, the vector of CMV, by non-preference.

Rosemeyer and Bemis (1981) found the *Cucurbita foetidissima* was resistant to cucumber mosaic virus, watermelon mosaic virus and tomato ringspot virus. Wild species of *Cucurbita* viz., *C. martinezii*, *C. lundelliana* and *C. ecuadorensis* were found to be resistant to CMV and hence they could be successfully hybridized with *C. pepo* for transferring CMV resistance (Washek, 1983). Pink and Walkey (1985b) reported that resistance to CMV in pumpkin cultivar Cinderella was quantitative. But in muskmelon, resistance to CMV was controlled by two recessive genes (Velich and Tobias, 1985). Meyer *et al*. (1987) also observed quantitative resistance to CMV in cucumber which was found to be influenced by genotype, effective inoculum dose, plant age, and virulence of the virus isolate used. They also noticed a negative correlation between degree of quantitative resistance and virus concentration in the leaves.

Yang *et al*. (1986) reported that the resistance to zucchini yellow mosaic virus (ZYMV) in cucumber was controlled by single dominant gene. Provvidenti (1986) identified an additional source of resistance to ZYMV in a Nigerian squash (*C. moschata*) and reported that this resistance was partially dominant. Munger and Provvidenti (1987) found that a single gene when homozygous in *C. moschata* conferred a high level of resistance to ZYMV in a cross between Nigerian Local (resistant) and Waltham Butternut (susceptible). From the F_1, F_2 and reciprocal backcross populations, it was demonstrated that resistance to Connecticut strain of ZYMV in a ZYMV resistant cultivar of cucumber was conferred by a single recessive gene (Provvidenti, 1987). Paris et al. (1988) found the resistance to ZYMV to be controlled by a single dominant gene in the resistant inbred line of C. moschata cultivar Menina in crosses involving susceptible Waltham Butternut and Menina.

Cucurbita ecuadorensis which was reported to be resistant to ZYMV was crossed with C. maxima cv. Buttercup by Robinson et al. (1988) and from the segregation data it was clear that the resistance to ZYMV in C. ecuadorensis was conferred by a single major gene. They also found that varying degrees of symptom expression in heterozygous plants was due to the presence of modifying genes influencing the major gene.

Quantitative inheritance of ZYMV resistance was reported in C. ecuadorensis by Paran et al. (1989). Several genes with major effects along with genes of minor effects seemed to control ZYMV resistance. They also found the additive, dominance and their interactions to be significant with major contribution from additive effects. Provvidenti (1991) observed a high level of resistance to Florida strain of ZYMV in Citrullus lanatus which was controlled by a single recessive gene.

Provvidenti and Robinson (1977) reported that the resistance to watermelon mosaic virus-1 (WMV-1) in Cucumis metuliferus was governed by a single completely dominant gene in a cross between PI 292190 (resistant) x ACC 2459 (susceptible). Similar results were obtained in the case of Papaya ringspot virus (PRSV) also (Provvidenti and Gonsalves, 1982). On artificial inoculation they observed identical reaction of both PRSV and WMV-1 suggesting that the genes for resistance to PRSV were closely linked to or the same as that for WMV-1 and both are known to be closely related serologically. In Cucumis sativus cv. Surinam, resistance to WMV-1 was reported to be monogenic recessive when crossed with the susceptible Wisconsin 2757 (Wang et al., 1984).

Resistance can also be due to low rate of multiplication of the virus and such type of resistance to WMV-II was seen in a WMV-II resistant breeding line of melon (Moyer et al., 1985). The inheritance of resistance to PRSV type W in C. ecuadorensis appeared to be controlled by a polygenic system and the analysis of means of generations revealed that additive gene effects were predominant (Herrington et al., 1989).

In Cucumis sativus cv. Kyoto-3-feet, Cohen et al. (1971) observed a single dominant factor for the control of resistance to melon mosaic. They also noticed a low concentration of the virus in resistant plants.

Studies on inheritance of resistance to cucumber green mottle mosaic virus showed that resistance was governed by polygenes with recessive nature, i.e., the susceptibility was incompletely dominant (Rajamony *et al*., 1990). Various reports on inheritance of mosaic resistance in cucurbits are summarized in Table 2.

D. Inheritance of qualitative characters and gene action of quantitative characters in cucurbits

Information on inheritance or gene action of a character whether qualitative or quantitative, is a pre-requisite for selecting a particular method of breeding.

1) Inheritance of discrete characters

Leaf surface of genus *Cucurbita* is characterized by silvery patches. Scarchuk and Lent (1965) reported that the air spaces in the palisade tissue were responsible for the silver grey colouration since the palisade cells are not in close contact. This silvery leaf or mottled leaf character was found to be controlled by a single dominant gene designated as 'M' in *C. maxima*, *C. pepo* and *C. moschata* (Scott and Riner, 1946; Scarchuk, 1954; Coyne, 1970 and Robinson *et al*., 1976) (Table 3).

According to Shifriss (1981), the expression of silvery trait vary with (1) the time during plant development at which it is first manifested (2) the extent of its distribution over

Table 3. Inheritance of discrete characters in cucurbits

Character/Crop	Pattern of inheritance	Authority
Silvery leaf trait		
Cucurbita moschata	Single dominant gene	Coyne, 1970
C. maxima	"	Scott and Riner, 1946
C. pepo	"	Scarchuk, 1954
Cucurbita spp.	"	Robinson *et al.*, 1976
	Modifier genes	Shifriss, 1982
	Single partially dominant gene + modifier genes	Ribeiro and Costa, 1989
Colour of mature fruits		
C. pepo	Two independent modifier genes	Shifriss and Paris, 1981
Green fruit skin colour		
C. pepo	Single dominant gene	Robinson, 1987
Orange fruit skin colour		
C. pepo	Two complementary genes	Shifriss, 1987
Orange flesh colour		
C. pepo	Two complementary genes	Paris, 1988

the leaf (3) its intensity and (4) the environment. Shifriss (1982) reported the role of modifier genes in the expression of gene M, i.e., these modifier genes either acted separately or interacted to extend or intensify the expression. Shifriss (1984) observed that the extreme high temperature under field conditions did not reduce the expressivity and hence many of the C. moschata cultivars which are largely of tropical adaptation have distinctly mottled leaf.

Ribeiro and Costa (1989) reported partial dominance of mottled leaf character in C. moschata. The continuous variation in the mottled expression in the F_2 showed the involvement of modifier genes along with the partially dominant gene.

New fruit colours such as orange or green were found to appear at maturity. In C. pepo some varieties at maturity bear green fruits while some others produce yellow fruits. Shifriss and Paris (1981) reported that two independent modifier genes are involved in the pigmentation of a cross between C. pepo var. Table King (green fruits) and Precocious Small Sugar (yellow fruits). These genes designated as Ep-1 and Ep-2 were found to act cumulatively in extending the pigmentation.

Robinson (1987) crossed C. moschata cv. Long Neopolitan having mottled dark and light green fruit skin with the cultivar Butternut having buff coloured skin. The green skin colour was found controlled by a single dominant gene.

In *Cucurbita pepo*, the inheritance of flesh colour was studied by Paris (1988) and found that the orange flesh colour was conditioned by two complementary genes B and L-2 in a cross between cv. Vegetable Spaghetti (pale flesh) and cv. Precocious Fordhook Zucchini (orange flesh). In watermelon, Henderson (1989) reported that orange flesh colour was dominant to yellow, but recessive to red flesh colour.

2) Gene action of important polygenic characters

Gopalakrishnan (1979) suggested that selection of plants considering yield *per se* was more efficient than selection for component characters in pumpkin (*C. moschata*). Additive gene action was observed for female flowers/plant, average fruit weight, fruits/plant and carotene content in pumpkin (Gopalakrishnan *et al*., 1980).

Doijode and Sulladmath (1981) from their studies of 13 crosses involving nine varieties reported additive, dominance and epistasis in the control of number of days to opening of the first female flower in pumpkin. Though additive, dominance and epistasis were significant for days to fruit maturity, additive and additive x additive interactions were the predominant (Doijode and Sulladmath, 1982). Doijode and Sulladmath (1984) observed complementary gene interaction for days to fruit maturity and partial dominance for fruit size and cavity size index, flesh thickness, TSS and fruit weight in pumpkin. Doijode et al. (1985) reported additive gene action for seed number, seed weight/ fruit, hundred seed weight and seed size index in a 7 x 7 diallel and recurrent selection was recommended as the breeding method.

Additive gene action affected earliness, fruit weight and TSS in watermelon while number of fruits and yield were governed by non-additive gene action (Sachan and Premnath, 1976). But Brar and Nandpuri (1978) reported additive component of variance for number of fruits. They also recorded a low heritability for yield and thus dominant gene action was seen associated with yield.

In cucumber, significant additive genetic variance was noticed for early flowering (Miller and Quisenberry, 1976). Hormuzdi and More (1989) found the additive genetic component to play an important role in the expression of days to anthesis, average fruit weight, fruit length, fruit diameter, vine length and early yield in cucumber. Rastogi and Deep (1990) recorded high heritability and genetic advance for fruit yield per plant, average fruit weight, number of female flowers and number of fruits/plant.

In muskmelon, additive component was highly significant for days to first female flower anthesis, fruit number/vine and TSS whereas dominance was prominent for fruit weight, flesh thickness and total yield (Singh et al., 1976). Swamy and Dutta (1987) described the role of dominance in the genetic control of seed weight per fruit and hundred seed weight in muskmelon and predominance of additive effects for earliness was reported by Abadia et al. (1988). Lawande and Patil (1990) reported that dominance component was more pronounced for number of fruits/vine, fruit weight, fruit diameter and yield per vine in bitter gourd. Reports on gene action of different economic quantitative characters in cucurbits are listed in Table 4.

E. Improvement through selection

Knowledge about the genetic parameters like variability, heritability, genetic advance etc. is helpful in formulating a suitable breeding method. Selection of plants considering yield *per se* was found to be more efficient in *Cucurbita moschata* Poir than selection for component characters (Gopalakrishnan, 1979). Gopalakrishnan et al. (1980) suggested selection for the improvement of female flowers/plant, average fruit weight, fruits/plant and carotene content in pumpkin.

Recurrent selection was recommended as the breeding method for the improvement of characters like seed number, seed weight/fruit, hundred seed weight and seed size index in pumpkin by Doijode et al. (1985) while Singh et al. (1988) reported selection as the best method for improving yield, fruit size, fruit weight and hundred seed weight. According to Borthakur and Shadeque (1990), selection of plants considering female flowers/plant, weight of fruit, fruit size index and flesh thickness was more effective in pumpkin.

In watermelon, Thakur and Nandpuri (1974) suggested selection for characters like seeds/kg of fruit weight, hundred seed weight, weight/fruit and number of fruits/plant to improve yield. Vashistha et al. (1983) also recommended simple selection of yield components to improve yield and TSS percentage.

In cucumber, selection based on earliness, average fruit weight, fruit length, fruit diameter, vine length and early yield was suggested by Hormuzdi and More (1989) whereas Rastogi and Deep (1990) recommended selection for fruit yield/plant, fruit weight, female flowers/plant and fruits/plant.

Vijay (1987) reported that selection was more effective for improving fruits/vine, flesh thickness and yield/vine in muskmelon.

Table 4. Gene action of polygenic characters in cucurbits

Crop/Character	Gene action	Authority
1. Pumpkin		
Days to first female flower anthesis	Additive, dominance and epistasis	Doijode and Sulladmath, 1981
Female flowers/plant	Additive	Gopalakrishnan et al., 1980 Borthakur and Shadeque, 1990
Fruits/plant	Additive	Gopalakrishnan et al., 1980
Average fruit weight	Additive	Gopalakrishnan et al., 1980 Singh et al., 1988 Borthakur and Shadeque, 1990
	Partial dominance	Doijode and Sulladmath, 1984
	Additive and dominance	Doijode and Sulladmath, 1985
Yield	Additive	Singh et al., 1988
Flesh thickness	Partial dominance	Doijode and Sulladmath, 1984
	Additive and dominance	Doijode and Sulladmath, 1985
	Additive	Borthakur and Shadeque, 1990
Seed number	Additive	Doijode et al., 1985
Hundred seed weight	Additive	Doijode et al., 1985 Singh et al., 1988

Contd.

Table 4. Continued

Crop/Character	Gene action	Authority
Seed size index	Additive	Doijode *et al.*, 1985
Fruit size and cavity size indices	Additive	Singh *et al.*, 1988 Borthakur and Shadeque, 1990
	Partial dominance	Doijode and Sulladmath, 1984
	Additive and dominance	Doijode and Sulladmath, 1986
2. Watermelon		
Yield	Non-additive	Sachan and Premnath, 1976
	Dominance	Brar and Nandpuri, 1978
No. of fruits/plant	Additive	Thakur and Nandpuri, 1974 Brar and Nandpuri, 1978
	Non-additive	Sachan and Premnath, 1976
Average fruit weight	Additive	Thakur and Nandpuri, 1974 Sachan and Premnath, 1976 Vashistha *et al.*, 1983
	Dominance and dominance x dominance epistasis	Sharma and Chaudhari, 1988
Seeds/kg fruit weight	Additive	Thakur and Nandpuri, 1974

Contd.

Table 4. Continued

Crop/Character	Gene action	Authority
Hundred seed weight	Additive	Thakur and Nandpuri, 1974
Earliness	Additive	Sachan and Premnath, 1976
	Dominance and dominance x dominance epistasis	Sharma and Chaudhari, 1988
Length of vine	Additive	Vashistha *et al.*, 1983
3. Cucumber		
Days to anthesis	Additive	Miller and Quisenberry, 1976 Hormuzdi and More, 1989
No. of female flowers/plant	Additive	Solanki and Seth, 1980 Rastogi and Deep, 1990
Average fruit weight	Additive	Hormuzdi and More, 1989 Rastogi and Deep, 1990
No. of fruits/plant	Additive	Rastogi and Deep, 1990
Fruit length	Additive	Hormuzdi and More, 1989
Fruit diameter	Additive	Hormuzdi and More, 1989 Mariappan and Pappaiah, 1990

Contd.

Table 4. Continued

Crop/Character	Gene action	Authority
Fruit yield/plant	Additive	Rastogi and Deep, 1990
Number and weight of seeds/fruit	Additive	Mariappan and Pappaiah, 1990
Vine length	Additive	Solanki and Seth, 1980 Hormuzdi and More, 1989
4. Muskmelon		
Days to first female flower anthesis	Additive	Singh et al., 1976 Abadia et al., 1988
Yield/plant	Dominance	Singh et al., 1976
	Additive	Swamy et al., 1985 Vijay, 1987
No. of fruits/vine	Additive	Singh et al., 1976 Vijay, 1987
Average fruit weight	Dominance	Singh et al., 1976
	Additive	Chhonkar et al., 1979 Swamy et al., 1985
Flesh thickness	Dominance	Singh et al., 1976
	Additive	Chhonkar et al., 1979 Swamy et al., 1985 Vijay, 1987

Contd.

Table 4. Continued

Crop/Character	Gene action	Authority
Hundred seed weight	Dominance	Swamy and Dutta, 1987
5. Bitter gourd		
Yield/plant	Additive	Srivastava and Srivastava, 1976 Singh et al., 1977 Mangal et al., 1981 Chaudhari et al., 1991
	Dominance	Lawande and Patil, 1990
Average fruit weight	Additive	Srivastava and Srivastava, 1976 Mangal et al., 1981 Chaudhari et al., 1991
	Dominance	Lawande and Patil, 1990
No. of fruits/plant	Additive	Srivastava and Srivastava, 1976 Singh et al., 1977 Mangal et al., 1981 Chaudhari et al., 1991
	Dominance	Lawande and Patil, 1990
Fruit length	Additive	Lawande and Patil, 1990
Fruit diameter	Dominance	Lawande and Patil, 1990

Contd.

Table 4. Continued

Crop/Character	Gene action	Authority
Seed weight/fruit	Additive	Chaudhari *et al*., 1991
Length of vine	Additive	Mangal *et al*., 1981 Chaudhari *et al*., 1991
6. Pointed gourd		
Yield/plant	Additive	Singh *et al*., 1985
Fruit length	Additive	Singh *et al*., 1985
Fruit diameter	Additive	Singh *et al*., 1985
7. Ribbed gourd		
Days to flower	Additive	Kadam and Kale, 1987
Fruits/vine	Additive	Abusaleha and Dutta, 1990a
Average fruit weight	Additive	Reddy and Rao, 1984
Fruit yield	Additive	Reddy and Rao, 1984 Abusaleha and Dutta, 1990a
Fruit length	Additive	Abusaleha and Dutta, 1990a
Vine length	Additive	Abusaleha and Dutta, 1990a

Contd.

Table 4. Continued

Crop/Character	Gene action	Authority
8. Sponge gourd		
Yield/vine	Additive	Abusaleha and Dutta, 1990b
Fruits/vine	Additive	Abusaleha and Dutta, 1990b
Vine length	Additive	Abusaleha and Dutta, 1990b
9. Bottle gourd		
Fruit weight	Additive	Sirohi et al., 1988
Fruit length	Additive	Sirohi et al., 1988

Materials and Methods

MATERIALS AND METHODS

The present studies were conducted in the vegetable research plots of Department of Olericulture, College of Horticulture, Vellanikkara during November 1990 - April 1992. The experimental field is located at an altitude of 23 M above MSL and is situated between 10°32' N latitude and 76°16' E longitude. Geographically it falls in the warm humid tropical climatic zone. The meteorological data for the seasons under experimentation are presented in Appendix I.

The experiments consisted of the following:

A. Seasonal influence on vector population, mosaic incidence and yield in pumpkin

B. Studies on gene action of economic quantitative characters and inheritance pattern of discrete characters and mosaic resistance in pumpkin

C. Improvement of mosaic resistant line CM 214 through selection

A. Seasonal influence on vector population, mosaic incidence and yield in pumpkin

To study the seasonal influence on vector population, mosaic incidence and yield in pumpkin, the locally adapted high yielding variety Ambili developed in the Kerala Agricultural University was sown at bimonthly intervals starting from March

1991. In addition to the schedule of bimonthly sowing, an additional crop was also raised in October since October sowing was practised by the traditional growers of pumpkin. The seven treatments were as follows:

Treatment 1	-	Sowing in March
Treatment 2	-	Sowing in May
Treatment 3	-	Sowing in July
Treatment 4	-	Sowing in September
Treatment 5	-	Sowing in October
Treatment 6	-	Sowing in November
Treatment 7	-	Sowing in January

Sowing was done on sixteenth day of respective months. The experiment was laid out in a randomised block design with four replications. There were five pits/treatment/replication with three plants/pit. Pits were taken at a spacing of 4.5 M x 2 M and the cultural operations were done as per Package of Practices Recommendations (Kerala Agricultural University, 1989).

1. Observations recorded

a. Whitefly population

The number of adult whiteflies (*Bemisia tabaci* Genn.), the vector of yellow vein mosaic, was counted at fortnightly intervals. Whitefly population on all the plants were counted in the early morning when they were less active.

b. Mosaic incidence

Incidence of mosaic diseases was recorded as and when the symptoms appeared. Based on the symptoms expressed the mosaic diseases were assigned to yellow vein mosaic, pumpkin mosaic, bottle gourd mosaic, watermelon mosaic and cucumber mosaic (Table 5, Plates 1 to 5).

c. Economic quantitative characters

(i) Fruit yield/plant (kg)

(ii) Fruits/plant

(iii) Average fruit weight (kg)

(iv) Hundred seed weight (g)

(v) Days to first female flower anthesis

(vi) Days to first fruit set

(vii) Length of vine (m)

2. Statistical analysis

The data were analysed for analysis of variance as per Panse and Sukhatme (1967).

Table 5. Typical symptoms of mosaic diseases in pumpkin

Disease	Reported by	Symptoms
1. Yellow vein mosaic	Jayashree, 1984	Faint yellowing of veins and veinlets later becoming characteristic yellow net work of veins, reduction of leaf size, stunted growth.
2. Pumpkin mosaic	Umamaheswaran, 1985	Dark green vein banding, light green and dark green patches of leaf lamina, mild green blisters, plant stunting, severe mottling and disfiguration.
3. Bottle gourd mosaic	Raychaudhari and Nariani, 1977	Irregular light green and dark green mottling of leaves later coalescing to give mosaic appearance, green vein banding, severe puckering and distortion of leaves.
4. Watermelon mosaic	Reddy and Nariani, 1963	Severe distortion and filiformy of leaves, vein clearing of young leaves, chlorosis, dark green blisters, reduced interveinal area with the veins and veinlets extending beyond the margins.
5. Cucumber mosaic	Bhargava and Bhargava, 1977	Chlorotic spots, green blisters, wrinkling, mosaic mottling, curled margins, yellowing and reduction in leaf size.

Plate 1. Yellow vein mosaic ⟶


YELLOW VEIN MOSAIC

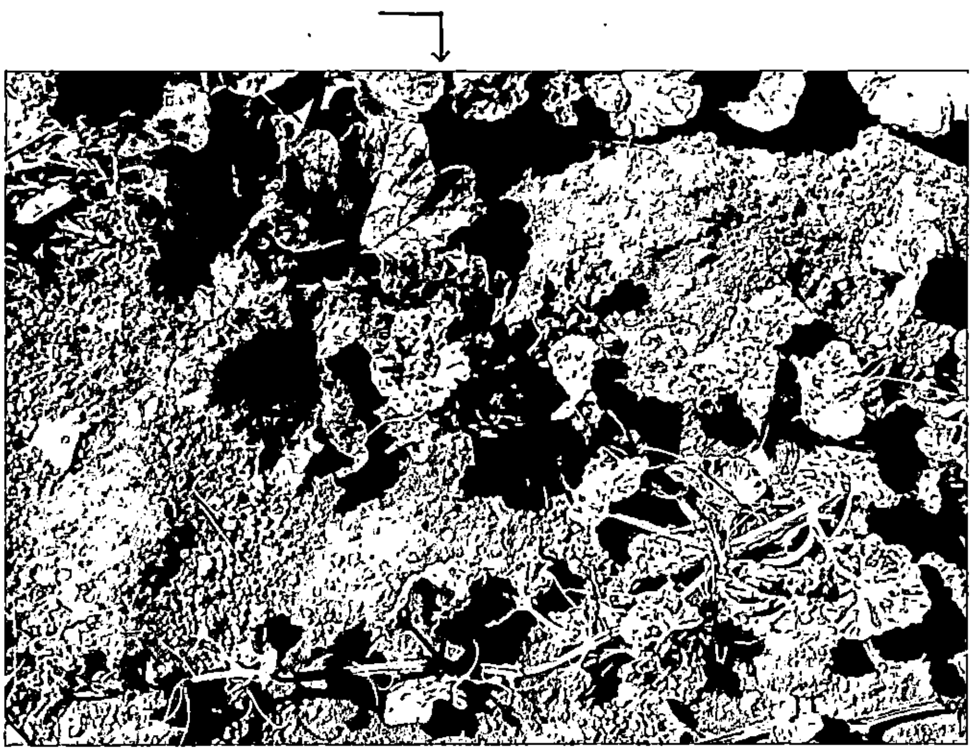
Plate 2. Pumpkin mosaic ⟶

Plate 3. Bottle gourd mosaic ⟶

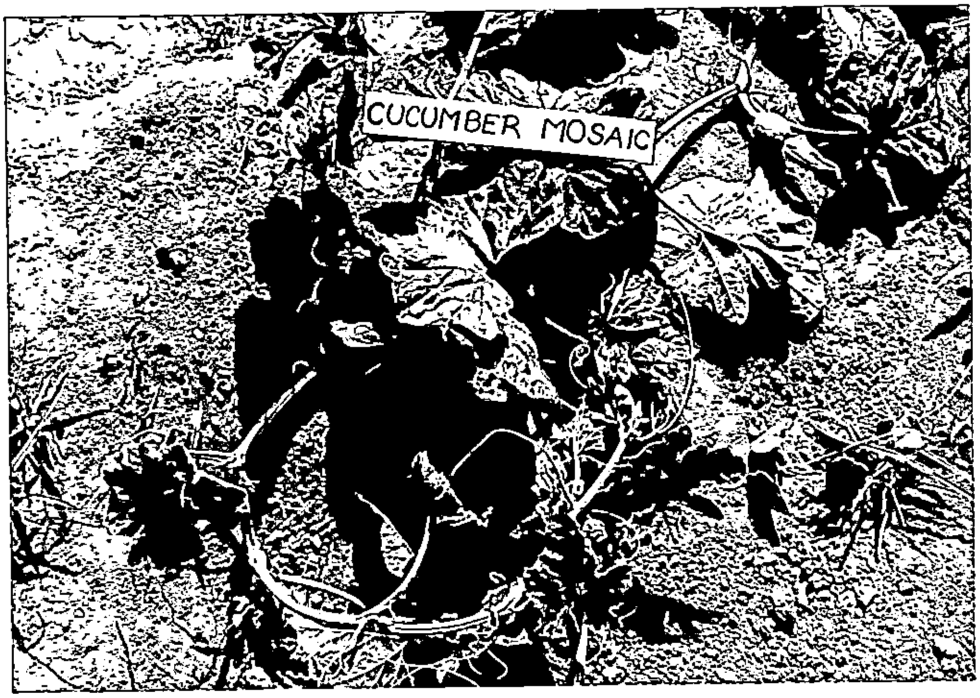
Plate 4. Watermelon mosaic ⟶

Plate 5. Cucumber mosaic ⟶


PUMPKIN MOSAIC




WATERMELON MOSAIC


CUCUMBER MOSAIC

B. Studies on gene action of economic quantitative characters and inheritance pattern of discrete characters and mosaic resistance in pumpkin

The experimental material consisted of F_1, F_2, BC_1 and BC_2 generations of cross between the susceptible variety Ambili and the resistant accession CM 214 (Nigerian Local). The salient features of Ambili and CM 214 are presented in Table 6 (Plates 6 and 7).

Parental population, F_1 and segregating generations of Ambili and CM 214 were sown during June 1991. Twenty five plants each under P_1, P_2 and F_1, 200 plants in F_2 and 100 plants each under BC_1 and BC_2 generations were maintained during the study.

1. Gene action of economic quantitative characters in pumpkin

a. Observations recorded

All the plants of the parental, F_1, F_2 and backcross generations were observed for the following characters:

(i) Fruit yield/plant (kg)

(ii) Fruits/plant

(iii) Average fruit weight (kg)

(iv) Fruit length (cm)

(v) Fruit diameter (cm)

Table 6. Salient features of the parents, Ambili and CM 214

Character/ Particulars	Ambili	CM 214
1. Source	Kerala Agricultural University	NBPGR, New Delhi
2. Resistance to mosaic	Susceptible to pumpkin mosaic and yellow vein mosaic (Suresh Babu, 1989)	Resistant to pumpkin mosaic and yellow vein mosaic (Suresh Babu, 1989)
3. Fruit surface	Smooth	Warty
4. Colour of mature fruit	Orange/buff	Green
5. Seed colour and appearance	Cream and bold	Light brown and half-filled
6. Seed germination	> 90%	< 10%
7. Silvery leaf trait	Present	Absent
8. Colour of flesh	Orange or deep yellow	Light yellow

Plate 6. Parent 1, Ambili ⟶

Plate 7. Parent 2, CM 214 ⟶


AMBILL


CM 2

(vi) Flesh thickness (cm)

(vii) Seeds/fruit

(viii) Hundred seed weight (g)

(ix) Seed length (cm)

(x) Seed diameter (cm)

(xi) Days to first female flower anthesis

(xii) Days to first fruit set

(xiii) Female flowers/plant

(xiv) Length of main vine (m)

b. Statistical analysis

(i) Scaling tests

Estimates of additive (D) and dominance (H) components of genetic variance were made using the means and variances of six populations viz., P_1, P_2, F_1, F_2, BC_1 and BC_2. Scaling tests suggested by Mather (1949) were carried out to detect the presence of non-allelic interaction.

$$A = 2\bar{B}_1 - \bar{P}_1 - \bar{F}_1$$

$$V(A) = 4V(\bar{B}_1) + V(\bar{P}_1) + V(\bar{F}_1)$$

$$B = 2\bar{B}_2 - \bar{P}_2 - \bar{F}_1$$

$$V(B) = 4V(\bar{B}_2) + V(\bar{P}_2) + V(\bar{F}_1)$$

$$C = 4\bar{F}_2 - 2\bar{F}_1 - \bar{P}_1 - \bar{P}_2$$

$$V(C) = 16V(\bar{F}_2) + 4V(\bar{F}_1) + V(\bar{P}_1) + V(\bar{P}_2)$$

$$D = 2\bar{F}_2 - \bar{B}_1 - \bar{B}_2$$

$$V(D) = 4V(\bar{F}_2) + V(\bar{B}_1) + V(\bar{B}_2)$$

The fitness of model depended on two conditions viz., additivity of gene effects and independence of heritable components from non-heritable components.

ii) Generation mean analysis

Three parameter model

In the absence of non-allelic interaction, three parameter model as suggested by Jinks and Jones (1958) was used.

$$m = \tfrac{1}{2}\bar{P}_1 + \tfrac{1}{2}\bar{P}_2 + 4\bar{F}_2 - 2\bar{B}_1 - 2\bar{B}_2$$

$$V(m) = \tfrac{1}{4}V(\bar{P}_1) + \tfrac{1}{4}V(\bar{P}_2) + 16V(\bar{F}_2) + 4V(\bar{B}_1) + 4V(\bar{B}_2)$$

$$d = \tfrac{1}{2}\bar{P}_1 - \tfrac{1}{2}\bar{P}_2$$

$$V(d) = \tfrac{1}{4}V(\bar{P}_1) + \tfrac{1}{4}V(\bar{P}_2)$$

$$h = 6\bar{B}_1 + 6\bar{B}_2 - 8\bar{F}_2 - \bar{F}_1 - 3/2\bar{P}_1 - 3/2\bar{P}_2$$

$$V(h) = 36V(\bar{B}_1) + 36V(\bar{B}_2) + 64V(\bar{F}_2) + V(\bar{F}_1) + 9/4V(\bar{P}_1) + 9/4V(\bar{P}_2)$$

Six parameter model

In the presence of non-allelic interaction as indicated by the significance of scaling tests, six parameter model was used as given by Hayman (1958).

$$m = \bar{F}_2$$

$$V(m) = V(\bar{F}_2)$$

$$d = \bar{B}_1 - \bar{B}_2$$

$$V(d) = V(\bar{B}_1) + V(\bar{B}_2)$$

Silvery leaf trait of leaf lamina	-	Present/Absent
Appearance of fruit surface	-	Warty/Smooth
Rind colour of mature fruit	-	Green/Buff
Seed colour	-	Cream/Light brown

b. Statistical analysis

The agreement of the observed values with the expected was tested by the χ^2 test of goodness of fit with (n-1) degrees of freedom where 'n' is the number of classes (Panse and Sukhatme, 1978).

3. Inheritance of mosaic resistance

To study the inheritance of mosaic resistance, P_1, P_2, F_1, F_2, BC_1 and BC_2 generations of the cross involving mosaic resistant accession CM 214 and susceptible variety Ambili were artificially inoculated for pumpkin mosaic and yellow vein mosaic.

a. Artificial inoculation

(i) Pumpkin mosaic

Artificial induction of pumpkin mosaic was done during March-April 1992 by sap transmission under protected conditions. For this, the leaves showing typical symptoms of pumpkin mosaic were collected and macerated with distilled water at the rate of 1 ml g^{-1} of leaf tissue. The sap was strained through muslin cloth and taken in a petridish. Leaves of young seedlings at

k. Female flowers/plant

l. Length of vine (m)

From the base population, four promising plants were selected and selfed seeds were collected. The progenies of the selected plants were raised during October 1991 - February 1992. Observations on the above characters were again recorded. At each stage of selection, emphasis was laid on characters like appearance of fruit in particular to nonwarty nature, fruit set and yield.

Genetic gain was calculated utilizing the mean performance of progeny of selected plants and base population (Singh and Chaudhary, 1979).

Realised genetic gain = Mean performance of the progeny - Mean performance of base population

2-3 leaf stage were dusted with carborandum powder (600 mesh) and rubbed with cotton dipped in the sap from leaf base to the tip. Then the leaves were washed with distilled water to remove the excess sap and later the seedlings were kept for symptom expression.

(ii) Yellow vein mosaic

Whitefly (Bemisia tabaci), the vector of yellow vein mosaic, was used for transmission studies. After a period of half an hour fasting, the adult whiteflies were transferred to microcages and were allowed to feed on the yellow vein mosaic affected leaves of pumpkin for one hour. Then they were transferred to healthy pumpkin seedlings of three leaf stage and allowed to feed for 24 hours. After this inoculation feeding period, plants were sprayed with Rogor 0.03% to kill the whiteflies. Seedlings were then kept for observation.

b. Statistical analysis

The agreement of the observed values with the expected values was tested by the χ^2 test of goodness of fit with (n-1) degrees of freedom where 'n' is the number of classes (Panse and Sukhatme, 1978).

C. Improvement of mosaic resistant line CM 214 through selection

1. Germination studies

Seeds of CM 214 which had a low germination percentage were subjected to the following six treatments during October 1990.

Treatment 1 : Mechanical scarification - Seeds were rubbed against a rough surface to soften the seed coat

Treatment 2 : Soaking seeds in GA 50 ppm for half an hour

Treatment 3 : Soaking seeds in GA 250 ppm for half an hour

Treatment 4 : Removal of seed coat and soaking the seeds in distilled water overnight

Treatment 5 : Hot water treatment - soaking the seeds in hot water at 60°C for 10 minutes

Treatment 6 : Control - Soaking seeds in distilled water overnight

The experiment was done in a completely randomised design with 25 seeds/treatment/replication except for Treatment 4 where 28 seeds were used in each replication.

The treated seeds were kept in petridishes lined with moist filter paper for allowing germination.

Seeds of the progenies of selections made from the base population was again subjected to the above six treatments during February 1992. The experiment was done in a randomised block design with four replications. There were ten seeds/treatment/replication.

2. Improvement through selection

After removing the seed coat, 50 seeds of CM 214 were sown in petridishes during November 1990. The germinated ones were transferred to small poly bags filled with potting mixture and later shifted to the main field at three leaf stage. The developing fruits were alternately sprayed with a fungicide and an insecticide at fortnightly intervals to prevent fruit drop. The bulk population of the breeding line CM 214 was used as the base population for selection and a total of 36 plants formed the base population. Individual plants were observed for the following characters:

a. Fruit yield/plant (kg)
b. Fruits/plant
c. Average fruit weight (kg)
d. Fruit length (cm)
e. Fruit diameter (cm)
f. Flesh thickness (cm)
g. Seeds/fruit
h. Hundred seed weight (g)
i. Days to first female flower anthesis
j. Days to first fruit set

k. Female flowers/plant

l. Length of vine (m)

From the base population, four promising plants were selected and selfed seeds were collected. The progenies of the selected plants were raised during October 1991 - February 1992. Observations on the above characters were again recorded. At each stage of selection, emphasis was laid on characters like appearance of fruit in particular to nonwarty nature, fruit set and yield.

Genetic gain was calculated utilizing the mean performance of progeny of selected plants and base population (Singh and Chaudhary, 1979).

Realised genetic gain = Mean performance of the progeny - Mean performance of base population

Results

RESULTS

The data from the present investigations were analysed statistically and are presented under the following heads:

A. Seasonal influence on vector population, mosaic incidence and yield in pumpkin

B. Studies on gene action of economic quantitative characters and inheritance pattern of discrete characters and mosaic resistance in pumpkin

C. Improvement of mosaic resistant line CM 214 through selection

A. Seasonal influence on vector population, mosaic incidence and yield in pumpkin

1. Seasonal influence on vector population

To study the seasonal influence on vector population, the adapted variety Ambili was sown at bimonthly intervals. The population of whiteflies was minimum in plants sown in the month of May (2.22/plant) closely followed by July sowing (3.67/plant) (Table 7). Vector population was maximum in January sown crop (11.62/plant) which was on par with March sowing (10.64/plant). Crops sown in the months of September, October and November also had a comparatively good population of Bemisia tabaci (7.6 - 8.4/plant).

Table 7. Population of <u>Bemisia tabaci</u> per plant under different dates of sowing in pumpkin

Treatment (Month of sowing)	Whitefly population							
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	150 DAS	Mean
March	2.70	13.85	16.45	16.45	12.00	2.40	*	10.64
May	2.50	1.25	2.50	2.40	1.50	2.40	3.02	2.22
July	0.00	0.40	1.65	2.20	8.20	4.33	8.90	3.67
September	0.20	3.40	7.25	9.30	10.20	13.00	15.50	8.40
October	0.00	2.28	10.90	13.50	14.55	3.90	9.50	7.80
November	0.40	7.75	11.85	5.10	10.10	10.47	*	7.61
January	0.40	9.00	9.50	11.20	20.40	19.20	*	11.62
Mean	0.89	5.42	8.59	8.59	10.99	7.96	9.23	
CD (0.05)	1.18	1.28	2.28	2.26	2.34	2.17	1.74	0.89

DAS - Days after sowing

* Due to heavy incidence of mosaic, the plants were dried up

When vector population was counted at fortnightly intervals from the date of sowing, minimum incidence (0.89) was noticed 15 days after sowing (DAS) and gradually increased to 5.42 at 30 DAS, 8.59 at 45 DAS and 10.99 at 75 DAS in proportionate to the spread of the plant. However, depending on the weather conditions fluctuations in whitefly population was noticed. In March sowing, there was heavy build up of whitefly population during flowering and fruiting period which coincided with high temperature and low rain fall. But, with the starting of rain during the first week of June the population was found to reduce considerably. But in January sowing, heavy whitefly population was noticed during the entire cropping period. In crops sown in the month of November, January and March heavy build up of whitefly population and resultant mosaic incidence were noticed.

2. Seasonal influence on mosaic incidence

The pumpkin crop sown in different months were affected by symptoms of yellow vein mosaic, pumpkin mosaic, bottle gourd mosaic, cucumber mosaic and watermelon mosaic.

a) Yellow vein mosaic

Yellow vein mosaic disease was maximum in the January sown crop (65%) followed by November (60%) and March sowing

(51.67%) (Table 8). May sown crop was completely free from yellow vein mosaic. Pumpkin sown in July also had a comparatively low mosaic incidence (15%). Early expression of yellow vein mosaic occurred in January sown crop (28 days) followed by the crops sown in March and November (32 days). Maximum days for appearance of the disease was taken by July sown crop (60 days). In general, plants affected by yellow vein mosaic had poor flowering and negligible fruiting.

b) Pumpkin mosaic

Incidence of pumpkin mosaic was maximum in March and January sown crops (36.67% and 30% respectively) (Table 9). Crops sown in May, July and November were completely free from symptoms of pumpkin mosaic. The minimum number of days taken for disease expression also had a wide range with 25 days in January sown crop and 90 days in September sown crop. Even though the plants affected by pumpkin mosaic had retained fruits, yield reduction and malformation and reduction in size of fruits were noticed.

c) Bottle gourd mosaic

The incidence of bottle gourd mosaic was noticed in crops sown in all the months and it ranged from 3.33% in July sown crop to 20% in crop sown in October (Table 10). Early expression of the symptoms occurred in the crop sown in March (20 days)

Table 8. Incidence of yellow vein mosaic in different dates of sowing in pumpkin

Treatment (Month of sowing)	No. of plants affected	% of plants affected	Minimum number of days for symptom expression
March	31	51.67(45.95)*	32
May	0	0.00(0.0042)	--
July	9	15.00(22.78)	60
September	23	38.33(38.25)	40
October	18	30.00(33.22)	45
November	36	60.00(50.78)	32
January	39	65.00(53.73)	28
Mean			39.5
CD (0.05)		4.44	

* Data after angular transformation. Values in parentheses are transformed values.

Table 9. Incidence of pumpkin mosaic disease in different dates of sowing in pumpkin

Treatment (Month of sowing)	No. of plants affected	% of plants affected	Minimum number of days for symptom expression
March	22	36.67(37.27)*	42
May	0	0.00(0.0042)	--
July	0	0.00(0.0042)	--
September	8	13.33(21.42)	90
October	6	10.00(18.43)	63
November	0	0.00(0.0042)	--
January	21	30.00(33.22)	25
Mean			55
CD (0.05)		4.197	

* Data after angular transformation. Values in parentheses are transformed values.

Table 10. Incidence of bottle gourd mosaic in different dates of sowing in pumpkin

Treatment (Month of sowing)	No. of plants affected	% of plants affected	Minimum number of days for symptom expression
March	4	6.67(14.97)*	20
May	11	18.30(25.32)	30
July	2	3.33(10.52)	50
September	4	6.67(14.97)	55
October	12	20.00(26.57)	32
November	8	13.33(21.42)	25
January	3	5.00(12.92)	25
Mean			33.86
CD (0.05)		3.97	

* Data after angular transformation. Values in parentheses are transformed values

closely followed by those sown in November and January (25 days). The September and July sown crops took maximum number of days for the appearance of the symptoms (55 and 50 days after sowing respectively).

d) Watermelon mosaic

Watermelon mosaic was more serious during rainy seasons as evidenced by 45% disease incidence in May sowing and 36.67% in July sowing (Table 11). Crops sown during January and March were comparatively free from watermelon mosaic. The minimum number of days for the disease appearance ranged from 25 days in November sowing to 60 days in September sowing.

e) Cucumber mosaic

Incidence of cucumber mosaic was more in May sowing (30%) followed by November sowing (10%) (Table 12). The crops sown in January, March, July and September were free from cucumber mosaic. In May sowing even though cucumber mosaic incidence was more, the incidence took place only very late (70 days after sowing).

3. Seasonal influence on yield

The yield and the contributing characters were significantly influenced by different dates of sowing in pumpkin (Table 13, Appendix II).

Table 11. Incidence of watermelon mosaic in different dates of sowing in pumpkin

Treatment (Month of sowing)	No. of plants affected	% of plants affected	Minimum number of days for symptom expression
March	0	0.00(0.0042)	--
May	27	45.00(42.13)*	42
July	22	36.67(37.27)	40
September	6	10.00(18.43)	60
October	0	0.00(0.0042)	--
November	3	5.00(12.92)	25
January	0	0.00(0.0042)	--
Mean			41.75
CD (0.05)		3.08	

* Data after angular transformation. Values in the parentheses are transformed values.

Table 12. Incidence of cucumber mosaic in different dates of sowing in pumpkin

Treatment (Month of sowing)	No. of plants affected	% of plants affected	Minimum number of days for symptom expression
March	0	0.00(0.0042)	--
May	18	30.00(33.22)*	70
July	0	0.00(0.0042)	--
September	0	0.00(0.0042)	--
October	2	3.33(10.52)	30
November	6	10.00(18.43)	32
January	0	0.00(0.0042)	--
Mean			44
CD (0.05)		3.07	

* Data after angular trasnformation. Values in parentheses are transformed values.

Since the plants were affected by different types of mosaic diseases, the yield of pumpkin during the period of experimentation was in general low. But it exhibited statistically significant difference under different dates of sowing. Yield was maximum for October sown crop (7.06 kg/plant) closely followed by crop sown in September (6.83 kg/plant). Crop sown in May and November yielded 5.14 kg and 4.95 kg respectively. Since plants sown in March were totally affected by mosaic diseases no fruit could be harvested. The fruits/plant did not show significant difference due to different dates of sowing. The average fruit weight ranged from 1.68 kg in January sowing to 3.58 kg in July sowing. Crops sown during the month of May, July and October had bold seeds as indicated by maximum values for hundred seed weight (13-14 g).

Earliness as observed by days to first female flower anthesis and days to fruit set were also significantly influenced by dates of sowing. November sown crop was the earliest to flower (47.16 days) followed by October (48.78 days) and September (49.48 days) sown crops. Flowering in May sown crop coincided with heavy rainfall and fruit setting was delayed by 18 days after flowering.

The vegetative character like length of vine was also influenced by different dates of sowing. Length was maximum in July and October sown crops (5.95 m and 5.80 m respectively).

Table 13. Effects of different time of sowing on yield and other economic characters in pumpkin

Month of sowing	Yield/ plant (kg)	Fruits/ plant	Average fruit weight (kg)	Hundred seed weight (g)	Days to first female flower anthesis	Days to first fruit set	Length of vine (m)
March	-	-	-	-	55.75	--	4.45
May	5.14	1.75	2.91	13.90	58.30	76.31	4.97
July	6.80	1.86	3.58	13.84	51.49	55.31	5.95
September	6.83	2.16	3.16	11.13	49.48	53.25	4.06
October	7.06	2.25	3.14	13.40	48.78	52.20	5.80
November	4.95	1.71	2.73	10.55	47.16	55.04	2.69
January	2.28	1.37	1.68	10.50	56.53	62.96	1.79
CD (0.05)	3.12	0.90	0.81	2.58	4.77	6.54	0.88

Pumpkin sown during January had only a mean main vine length of 1.79 m.

B. Studies on gene action of economic quantitative characters and inheritance pattern of discrete characters and mosaic resistance in pumpkin

Observations on the parents, F_1, F_2 and backcross generations of the cross involving Ambili and CM 214 were utilized for deriving gene action of quantitative characters and inheritance pattern of discrete characters and mosaic resistance.

1. Gene action of economic quantitative characters in pumpkin

The performance of Ambili, CM 214, their F_1, F_2 and backcross generations is presented in Table 14.

The presence of non-allelic interaction was detected by ABCD scaling tests (Table 15). Simple additive-dominance model fitted only for two characters viz., flesh thickness and seeds/fruit. In all the remaining 12 quantitative characters non-allelic interaction was detected by the significance of either one of the scales.

The mean effect (m), additive effect (d), dominance effect (h) and additive x additive (i), additive x dominance (j) and dominance x dominance (l) epistasis effects for 14 quantitative characters are presented in Table 16.

Table 14. Mean performance of parents, F_1, F_2 and backcross generations of the cr
Ambili x CM 214

Character	P_1 (Ambili)	P_2 (CM 214)	F_1	F_2	BC_1	B
1. Fruit yield/plant (kg)	3.26	2.18	5.94	3.60	3.68	6
2. Fruits/plant	1.35	1.00	2.23	1.80	1.60	2
3. Average fruit weight (kg)	2.34	2.18	2.60	2.18	2.43	2
4. Fruit length (cm)	15.40	15.00	16.38	15.07	16.60	17.
5. Fruit diameter (cm)	18.20	17.78	18.29	16.70	18.28	19.
6. Flesh thickness (cm)	2.82	2.34	2.65	2.50	2.70	2.
7. Seeds/fruit	357.50	156.50	325.82	268.88	313.98	263.
8. Hundred seed weight (g)	15.30	7.65	14.84	13.20	12.87	16.
9. Seed length (cm)	1.70	1.40	1.58	1.61	1.49	1.
10. Seed diameter (cm)	0.88	0.87	0.90	0.82	0.74	0.
11. Days to first female flower anthesis	56.77	67.00	55.16	51.95	54.54	53.
12. Days to first fruit set	60.98	72.94	59.71	56.60	58.20	57.
13. Female flowers/plant	6.29	5.44	8.50	6.82	6.61	7.
14. Length of main vine (cm)	6.04	8.27	8.06	6.42	7.10	7.

Table 15. Scaling tests for non-allelic interaction for the characters in pumpkin

Character	Scales			
	A	B	C	D
Fruit yield/plant	S	S	NS	S
Fruits/plant	NS	S	NS	NS
Average fruit weight	NS	S	S	S
Fruit length	NS	S	NS	S
Fruit diameter	NS	S	S	S
Flesh thickness	NS	NS	NS	NS
Seeds/fruit	NS	NS	NS	NS
Hundred seed weight	S	S	NS	S
Seed length	S	S	NS	S
Seed diameter	S	NS	S	NS
Days to first female flower anthesis	NS	S	S	S
Days to first fruit set	S	S	S	S
Female flowers/plant	S	S	NS	NS
Length of main vine	NS	S	S	S

NS - Non-significant
S - Significant

Table 16. Components of total genetic effects for different quantitative characters in pumpkin

Character	m	d	h	i	j	l
1. Fruit yield/plant	3.63 ± 0.39*	-2.67 ± 0.40*	9.34 ± 1.85*	5.56 ± 1.74*	-3.22 ± 0.43*	-8.38 ± 2.59*
2. Fruits/plant	1.80 ± 0.01*	-0.61 ± 0.16*	1.46 ± 0.50*	0.41 ± 0.47	-0.79 ± 0.16*	-1.20 ± 0.80
3. Average fruit weight	2.18 ± 0.06*	-0.39 ± 0.12*	2.15 ± 0.40*	1.78 ± 0.33*	-0.47 ± 0.16*	-2.51 ± 0.69*
4. Fruit length	15.07 ± 0.45*	-0.74 ± 0.60	8.88 ± 2.48*	7.69 ± 2.15*	-0.93 ± 0.93	-12.53 ± 3.88*
5. Fruit diameter	16.72 ± 0.32*	-1.46 ± 0.42*	9.48 ± 1.60*	9.18 ± 1.52*	-1.67 ± 0.54	-12.66 ± 2.31*
6. Flesh thickness	1.79 ± 0.59*	0.24 ± 0.08*	2.08 ± 1.41			
7. Seeds/fruit	177.25 ± 91	100.50 ± 14.79*	219.44 ± 217.76			
8. Hundred seed weight	13.20 ± 0.57*	0.48 ± 0.80	9.89 ± 2.84*	6.52 ± 2.77*	-7.75 ± 0.85*	-13.21 ± 4.11*
9. Seed length	1.61 ± 0.03*	-0.09 ± 0.02*	-0.26 ± 0.14	-0.30 ± 0.14*	-0.23 ± 0.03*	0.40 ± 0.18*
10. Seed diameter	0.82 ± 0.03*	-0.13 ± 0.03*	-0.04 ± 0.13	-0.06 ± 0.12	-0.14 ± 0.03	-0.50 ± 0.16*
11. Days to first female flower anthesis	51.95 ± 0.49*	1.17 ± 0.66	1.30 ± 2.60	8.02 ± 2.37*	6.30 ± 1.025*	23.09 ± 3.96*
12. Days to first fruit set	56.60 ± 0.42*	0.88 ± 0.59	-2.61 ± 2.28	4.64 ± 2.06*	6.86 ± 0.88*	17.65 ± 3.5*
13. Female flowers/plant	6.82 ± 0.18*	-1.18 ± 0.33*	4.17 ± 1.04*	1.51 ± 0.98	-1.60 ± 0.39*	-1.52 ± 1.70
14. Length of main vine	6.42 ± 0.09*	-0.59 ± 0.14*	4.86 ± 0.51*	3.96 ± 0.45*	0.53 ± 0.20*	-3.17 ± 0.84*

a) Fruit yield/plant

Additive, dominance and interaction effects were significant for yield/plant. The dominance effect had maximum contribution (9.34) towards yield, while the additive effect was negative. Among the interactions, dominance x dominance effects had maximum value (-8.38).

b) Fruits/plant

For fruits/plant, additive, dominance and additive x dominance interactions were significant. Among these, dominance effect had maximum value (1.46). The other two effects were negative.

c) Average fruit weight

All the gene actions viz., additive, dominance and epistasis were significant for average fruit weight with the dominance x dominance interaction having the maximum value (-2.51). Among the main effects, dominance component was maximum (2.15).

d) Fruit length

Dominance effect and additive x additive and dominance x dominance interactions were significant for fruit length.

e) Fruit diameter

All the genetic effects, i.e., additive, dominance and interaction effects were significant for fruit diameter. Among the main effects, dominance gene action had maximum effect (9.48).

f) Flesh thickness

Simple additive-dominance model fitted for flesh thickness resulting in non-significance of scaling tests. The additive effect was significant indicating the prominent role of additive gene action for the control of flesh thickness in pumpkin.

g) Seeds/fruit

The absence of non-allelic interaction was indicated by the non-significance of the scaling tests. Additive gene effect was highly significant for this character (100.5).

h) Hundred seed weight

Dominance gene effects and epistasis, i.e., additive x additive, additive x dominance and dominance x dominance interactions affected hundred seed weight.

i) Seed length

Additive gene effects and epistasis had significant influence on seed length. Dominance x dominance interaction had maximum contribution towards seed length (0.40) and all the others had negative effects.

j) Seed diameter

In addition to the significant additive effect, seed diameter was also affected by interactions like additive x dominance and dominance x dominance. Both the main effects and interaction effects were negative for this character.

k) Days to first female flower anthesis

Presence of non-allelic interaction was detected for days to first female flower anthesis. All the three interactions viz., additive x additive, additive x dominance and dominance x dominance were significant while the main effects were non-significant.

l) Days to first fruit set

As in the case of days to first female flower anthesis, this character also had the same trend. Even though all the interactions were significant, the magnitude was more for dominance x dominance type of interaction (17.65).

m) Female flowers/plant

Additive, dominance and additive x dominance interactions were significant for the number of female flowers/plant. Among these, dominance gene effect had maximum value (4.17) and both additive and additive x dominance effects were negative (-1.18 and -1.60 respectively).

n) Length of main vine

Additive, dominance and epistasis effects were found significant for length of main vine. Among these, dominance effect was the highest (4.86) followed by additive x additive interaction (3.96).

2. The per se performance of the F_1 and segregating populations of Ambili x CM 214

During the evaluation of parents, F_1 and the segregating population of Ambili x CM 214 individual plant observations were made for identifying transgressive segregants with better yield, fruit appearance as well as resistance to mosaic. On an average, the F_1 outyielded standard variety Ambili by 45.12% (Plate 8). Some of the promising plants identified based on the mosaic resistance and per se performance are listed in Table 17 (Plates 9 to 12). All the selected plants were free from yellow vein mosaic, pumpkin mosaic, bottle gourd mosaic and cucumber mosaic and some were free from watermelon mosaic also.

3. Inheritance pattern of mosaic resistance in pumpkin

a) Yellow vein mosaic

All the plants of the susceptible variety Ambili exhibited

Table 17. *per se* performance of some superior plant types selected from the segregating population of Ambili x CM 214

Plant number	Yield/ plant (kg)	Fruits/ plant	Average fruit weight (kg)	Remarks
F_1 - 1 - 124	10.9	4	2.7	Free from YVM, PM, BM and CM, silvery leaf trait absent, fruits round, smooth, buff coloured and mottled with white and green patches, orange flesh, seeds light brown (Plate 9).
F_2 - 4 - 90	8.4	4	2.1	Free from mosaic, fruits round, smooth and buff coloured, deep orange flesh, seeds light brown and the plant took 32 days for first female flower anthesis.
BC_1 - 1 - 67	8.4	4	2.21	Free from YVM, BM, PM and CM, fruits round, smooth and buff coloured, flesh yellowish orange and seeds cream (Plate 11).
BC_1 - 1 - 68	7.9	3	2.63	Free from YVM, PM, BM and WM, fruits round, smooth and buff coloured, flesh orange and seeds cream.
BC_2 - 2 - 38	10.3	4	2.53	Free from YVM, PM, BM and CM, fruits round, green and moderately warty, flesh orange.
BC_2 - 3 - 85	10.1	4	2.55	Free from YVM, PM, BM and CM, fruits round, green and moderately warty, flesh orange.
BC_2 - 1 - 21	10.5	3	3.5	Free from YVM, PM, BM and CM, fruits flat round, green and moderately warty and flesh orange.
BC_2 - 1 - 26	11.06	4	2.8	Free from YVM, PM, BM and CM, fruits green, oblong and warty, seeds light brown and flesh orange (Plate 12).
BC_2 - 1 - 28	10.8	3	3.6	Free from PM, YVM, CM, BM and WM, fruits green, round and warty, flesh orange.
BC_2 - 1 - 30	10.2	3	3.4	Free from PM, YVM, BM, CM and WM, fruits green, round and warty, flesh orange.
BC_2 - 1 - 34	10.6	3	3.53	Free from PM, YVM, BM, CM and WM, fruits long, green and moderately warty, flesh orange and seeds light brown.
BC_2 - 1 - 42	11.7	3	3.2	Free from PM, YVM, BM, CM and WM, fruits long, green, moderately warty, flesh yellowish orange, seeds cream.

YVM - Yellow vein mosaic
PM - Pumpkin mosaic
CM - Cucumber mosaic
WM - Watermelon mosaic
BM - Bottle gourd mosaic


AMBILI x CM214 - F1

Plate 9. F_2-1-124 (A promising segregant of F_2 population of Ambili x CM 214) ⟶

Plate 10. A segregant with warty fruits in the F_2 population of Ambili x CM 214 ⟶

Plate 8. F_1 - Ambili x CM 214 ⟶

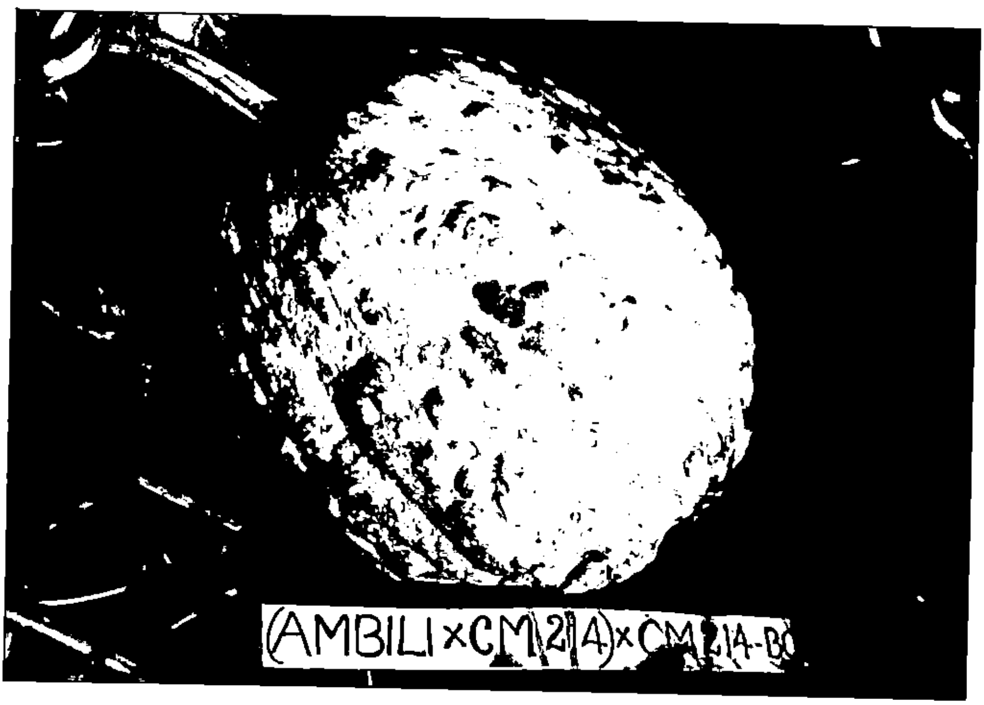

AMBILI ×CM 214-F2


AMBILI ×CM 214-F2

Plate 11. BC_1-1-67 (A promising segregant in ⟶
(Ambili x CM 214) x Ambili)

Plate 12. BC_2-1-26 (A promising segregant in ⟶
(Ambili x CM 214) x CM 214)


(AMBILI×CM 214)×AMBILI-BC


(AMBILI×CM 214)×CM 214-BC

typical yellow vein mosaic symptoms characterized by yellow net work of veins and veinlets and chlorotic interveinal areas on the lamina under artificial epiphytotic conditions by whitefly transmission. The accession CM 214 was completely resistant. In the F_1, out of the ten plants, nine were resistant (Table 18). In the F_2, a total of 100 plants segregated into 69 resistant and 31 susceptible in an expected ratio of 3:1 (χ^2 = 1.92, P = 0.1 - 0.2) and when the resistant F_1 was backcrossed to susceptible variety, 29 had resistance and 21 had susceptibility. In the backcross with resistant accession, out of the 50 plants, 43 were resistant (t = 2.82, P = 0.001 - 0.01).

b) Pumpkin mosaic

The adapted variety Ambili was completely susceptible to pumpkin mosaic and it exhibited typical mosaic symptoms of pumpkin mosaic under artificial inoculation of sap transmission (Table 19). Susceptible plants produced typical mosaic pattern of light green and dark green patches with dark green blisters. The resistant accession CM 214 was completely free from disease even under artificial inoculation. In the F_1, out of the ten plants, nine were susceptible and one resistant indicating dominance of susceptibility. Out of the 100 F_2 plants, 72 were susceptible and 28 resistant fitting in a monogenic Mendelian ratio of 3:1 (χ^2 = 0.48, P = 0.3 - 0.5). When the susceptible F_1 was back-

Table 18. Inheritance of resistance to yellow vein mosaic in pumpkin

Cross/ Generation	Observed number of plants			Expected ratio	χ^2	Probability
	Resistant	Susceptible	Total			
P_1 (Ambili)	0	10	10			
P_2 (CM 214)	10	0	10			
F_1	9	1	10			
F_2	69	31	100	3 : 1	1.92	0.1 - 0.2
BC_1	29	21	50	1 : 1	1.28	0.2 - 0.3
BC_2	43	7	50	1 : 0	2.82*	0.001-0.01

* t value

Table 19. Inheritance of resistance to pumpkin mosaic in pumpkin

Cross/ Generation	Observed number of plants			Expected ratio	χ^2	Probability
	Resistant	Susceptible	Total			
P_1 (Ambili)	0	10	10			
P_2 (CM 214)	10	0	10			
F_1	1	9	10			
F_2	28	72	100	3 : 1	0.48	0.3 - 0.5
BC_1	6	44	50	1 : 0	2.61*	0.01-0.02
BC_2	28	22	50	1 : 1	0.72	0.3 - 0.5

* t value

crossed to the susceptible parent, out of 50, 44 were susceptible. The susceptible F_1 when backcrossed with the resistant accession CM 214, BC_2 segregated into 28 resistant and 22 susceptible (χ^2 = 0.72, P = 0.3 - 0.5).

4. Inheritance of discrete characters

a) Silvery leaf trait of the leaf lamina

All the plants of Ambili were characterized by silvery patches at the intersects of veins and veinlets on leaf lamina and CM 214 was devoid of this character. All the F_1 plants had silvery leaf trait (Table 20). In the F_2, out of the 160 plants, 127 had silvery leaf trait while in 33 plants it was absent fitting in an expected genetic ratio of 13:3 (χ^2 = 0.34, P = 0.5 - 0.7). When F_1 was backcrossed to Ambili, silvery leaf character was present in 74 plants and absent in 6 plants. In the backcross with CM 214, out of the 80 plants, 45 plants possessed and 35 lacked silvery leaf trait fitting in a 1:1 ratio (χ^2 = 1.25, P = 0.2 - 0.3).

b) Warty appearance of the fruits

Ambili had fruits with smooth surface while fruits of CM 214 had prominent warty surface (Table 21). All the F_1 plants produced moderately warty fruits. In the F_2, a total of 94 plants segregated as 75 having smooth surfaced fruits and

Table 20. Inheritance of silvery leaf trait in pumpkin

Cross/ Generation	Observed number of plants			Expected ratio	χ^2	Probability
	Present	Absent	Total			
P_1 (Ambili)	24	0	24			
P_2 (CM 214)	0	24	24			
F_1	24	0	24			
F_2	127	33	160	13 : 3	0.34	0.5 - 0.7
BC_1	74	6	80	1 : 0	2.355*	0.02 - 0.05
BC_2	45	35	80	1 : 1	1.25	0.2 - 0.3

* t value

Table 21. Observations on inheritance of warty appearance of fruits in pumpkin

Cross/ Generation	Observed number of plants having		
	Warty fruits	Smooth fruits	Total
P_1 (Ambili)	0	12	12
P_2 (CM 214)	8	0	8
F_1	14	0	14
F_2	19	75	94
BC_1	18	28	46
BC_2	63	4	67

19 with warty fruits. When the F_1 was backcrossed to Ambili, warty fruits were produced by 18 plants and 28 plants produced smooth fruits whereas in the backcross with CM 214, 63 plants had warty fruits out of the total 67 plants.

c) Colour of mature fruits

All the plants of CM 214 and F_1 had green coloured fruits whereas orange or buff coloured fruits were produced by Ambili (Table 22). In the F_2, out of the total 94 plants, the mature fruits of 74 plants had buff colour and the remaining had green coloured fruits. In the backcross with Ambili, 26 out of the total 46, produced green fruits and in the backcross with CM 214, out of the 67 plants, 65 had green fruits.

d) Seed colour

Seeds of Ambili were cream coloured whereas those of CM 214 were light brown (Table 23). All the F_1 plants had light brown seeds. In the F_2, out of the 94 plants, 71 produced cream coloured seeds whereas in the backcross with Ambili, 25 out of the 46 had cream coloured seeds. In the backcross with CM 214, light brown seeds were produced by 64 plants out of a total of 67.

Table 22. Observations on inheritance of mature fruit colour in pumpkin

Cross/ Generation	Observed number of plants having		
	Green fruits	Buff fruits	Total
P_1 (Ambili)	0	12	12
P_2 (CM 214)	8	0	8
F_1	14	0	14
F_2	20	74	94
BC_1	20	26	46
BC_2	65	2	67

Table 23. Observations on inheritance of seed colour in pumpkin

Cross/ Generation	Observed number of plants having		
	Cream seeds	Light brown seeds	Total
P_1 (Ambili)	12	0	12
P_2 (CM 214)	0	8	8
F_1	0	14	14
F_2	71	23	94
BC_1	25	21	46
BC_2	3	64	67

C. Improvement of mosaic resistant line CM 214 through selection

1. Germination studies

Since the seed germination in CM 214 was highly erratic, the seeds were subjected to different treatments to induce germination. By soaking the seeds in distilled water, the germination percentage was only 8% (Table 24). In the remaining five treatments, germination was maximum in T_4 (71.4%) in which the seed coats were removed before soaking in water. When the seeds were treated with GA 50 ppm and 250 ppm, the germination percentage was equal to that of control (8%). Seeds subjected to mechanical scarification did not germinate at all.

When seeds of the progenies of selections made from base population were again subjected to the above treatments during February 1992, the germination percentage was found to increase in all the treatments (Table 24). Maximum germination (77.5%) was obtained when seeds were soaked after removing seed coat. The germination percentage in the remaining treatments including control ranged from 37.5% to 55%.

2. Improvement through selection

Out of the 36 plants of the base population of CM 214 raised during November 1990 - March 1991, eleven failed to set fruits. From the remaining, four were selected and selfed seeds were sown to raise the progeny during October 1991-February 1992.

Table 24. Germination percentage of base population and progenies of CM 214 under different treatments

Treatment	Percentage of germination	
	Base population during Nov. 1990	Progenies of selection during February 1992
T_1	0.0(0.01)	50.0
T_2	8.0(16.43)*	37.5
T_3	8.0(16.43)	47.5
T_4	71.4(57.68)	77.5
T_5	8.0(16.43)	52.5
T_6	8.0(16.43)	55.0
CD (0.05)	10.73	17.3

* Data after angular transformation. Values in parentheses are transformed values.

The means of the yield of base population and the four selected plants were 2.32 kg and 3.38 kg respectively (Table 25). As a result of selection, the yield was found to increase by 0.48 kg as indicated by the progeny yield of 2.8 kg. The genetic advance as percentage of mean for yield per plant was 20.69%. The number of fruits/plant, average fruit weight, fruit diameter, female flowers/plant and length of vine were found to increase marginally by adopting selection. Flesh thickness of CM 214 was increased from 1.81 cm to 2.03 cm with a genetic gain of 12.15%. There was considerable increase in the number of seeds/fruit as well as hundred seed weight as a result of selection (81.83 and 1.53 g respectively) and the genetic gain was 162.85% and 24.68% respectively. The fruit set was also improved after selection. The percentage of fruit set in the base population was 12.50% whereas it was increased to 13.6% in their progenies. Earliness in terms of days to first female flower anthesis and days to first fruit set was also noticed. The base population took 74.63 days for first female flower anthesis and 81.4 days for first fruit set whereas after selection the progenies took only 71.0 and 79.8 days respectively. The germination percentage was considerably increased in the progenies. From 8% in the parental population the germination was increased to 55% in the progenies. The size as well as appearance of fruits and seeds were also improved in the progenies. The number of half-filled and chaffy seeds was considerably reduced as evidenced by the

Table 25. Mean performance of base population, selected parents and their progeny of CM 214

Character	Base population ($\bar{X}_1$)	Selected parents ($\bar{X}_2$)	Progeny ($\bar{X}_3$)	Genetic gain ($\bar{X}_3$ - $\bar{X}_1$)
1. Yield/plant (kg)	2.32	3.38	2.80	0.48
2. Fruits/plant	1.13	1.50	1.40	0.27
3. Average fruit weight (kg)	2.06	2.34	2.09	0.03
4. Fruit length (cm)	14.31	15.00	14.06	-0.25
5. Fruit diameter (cm)	17.06	18.25	17.43	0.37
6. Flesh thickness (cm)	1.81	1.98	2.03	0.22
7. Seeds/fruit	50.25	61.25	132.08	81.83
8. Hundred seed weight (g)	6.20	5.80	7.73	1.53
9. Days to first female flower anthesis	74.63	73.25	71.03	-3.60
10. Days to first fruit set	81.38	80.75	79.80	-1.58
11. Female flowers/ plant	9.44	10.50	11.05	1.61
12. Length of vine (m)	7.50	7.08	7.52	0.02
13. Germination percentage	8.00	8.00	55.00	47.00
14. Fruit set (%)	12.50	14.90	13.60	1.10

increase in seed weight. The hundred seed weight of the base population was only 6.2 g while in the progenies it was 7.73 g.

Based on the _per se_ performance as well as the appearance of the fruits, five superior plants viz., CM 214-5-8, CM 214-8-9, CM 214-8-10, CM 214-11-4 and CM 214-11-6 were selected and selfed seeds were progressed for further improvement (Table 26). However, the fruits of these selections were still retaining their warty appearance and green colour.

Table 26. The *per se* performance of selections made from CM 214

Character	Selections made				
	CM 214-5-8	CM 214-8-9	CM 214-8-10	CM 214-11-4	CM 214-11-6
Yield/plant (kg)	4.50	5.70	5.30	5.40	5.70
Fruits/plant	2	3	3	2	3
Average fruit weight (kg)	2.25	1.90	1.76	2.70	1.90
Fruit length (cm)	15.5	14.0	15.0	15.5	14.0
Fruit diameter (cm)	15.5	17.0	16.6	20.0	18.0
Flesh thickness (cm)	2.10	2.00	2.30	2.20	2.15
Seeds/fruit	33	254	155	101.5	142.3
Hundred seed weight (g)	6.1	8.0	6.7	8.8	8.9
Days to first female flower anthesis	71	78	60	78	73
Days to first fruit set	84	82	78	82	79
Female flowers/plant	18	10	23	17	14
Length of vine (m)	7.5	7.0	8.0	7.6	8.3

Discussion

DISCUSSION

Pumpkin (Cucurbita moschata Poir) is one of the popular vegetables in the tropics. Introduced from South America by foreign navigators and emissaries, pumpkin is grown throughout the length and breadth of our country. Young leaves, flowers and fruits are rich in carotene, the precursor of Vitamin A. Low cost of production, long keeping quality of fruits and adaptability to a wide range of climatic conditions also favour the popularization of the crop. But yield in pumpkin remains low due to a conglomeration of reasons both genetic and environmental. Poor genetic stock, inadequate and improper management practices and incidence of pests and diseases, particularly mosaic are the main reasons for low productivity of the crop. Development of high yielding, carotene rich and mosaic resistant varieties and standardization of production technology are the pre-eminent goals of pumpkin improvement in the country.

The area under pumpkin is getting reduced day by day due to heavy incidence of mosaic diseases, particularly yellow vein mosaic and pumpkin mosaic (Balakrishnan, 1988). None of the pumpkin varieties now available in the country have resistance or tolerance to mosaic diseases. Development of resistant varieties, especially to viruses, is a long and time consuming process. Successful cultivation or harvesting of economic crop, as done in seed tuber production of potato, will be one of the viable step for avoiding a wide spread and catastrophic disease like mosaic. Cultivation of the crop in the ideal season is also a pre-requisite for the full expression of the genetic potentiality of a crop. The optimum time of sowing is arrived at by considering the yield, quality, incidence of pests and diseases etc.

In the present study, the locally adapted and high yielding variety Ambili was sown at bimonthly intervals starting from March 1991 to study the seasonal influence on mosaic incidence, population of Bemisia tabaci, the vector of yellow vein mosaic, and yield in pumpkin. In addition to the schedule of bimonthly sowing, an additional crop was sown during October as practised by traditional growers in Kerala.

Based on the symptoms five mosaic diseases viz., yellow vein mosaic, pumpkin mosaic, bottle gourd mosaic, watermelon mosaic and cucumber mosaic were identified in different months. Symptoms of yellow vein mosaic were characterized by typical yellow network of veins and veinlets finally resulting in complete yellowing of the leaves. Occurrence of yellow vein mosaic in the early stages of the crop resulted in complete loss of yield (Jayashree, 1984 and Balakrishnan, 1988). Bhargava and Bhargava (1977) recorded 60% incidence of yellow vein mosaic in C. moschata. When pumpkin was sown in different months, yellow vein mosaic was most serious and wide spread in the crops sown during January, November and March (65%, 60% and 51.67% respectively) and maximum incidence was noticed in the summer months, especially March, April and May. The population of B. tabaci was at its peak during the same months, i.e., March and April 1992 and April and May 1991 (15.80, 19.50, 15.15 and 14.23 respectively) (Table 27). The build up of whiteflies, the vector of yellow vein mosaic, will be the obvious reason for heavy incidence of mosaic during these periods. A high temperature was found to promote the build up of whiteflies. The maximum temperature (36.9°C, 36.3°C, 35.6°C and 35.1°C respectively), minimum temperature (22.8°C, 24.4°C, 24.5°C and 25.5°C respectively) and mean temperature (29.9°C, 30.4°C, 30.1°C and 30.3°C respectively) were maximum whereas relative humidity was moderate and rainfall was meagre during these periods. The whitefly population was minimum during the months of June, July and August (1.88, 1.95 and 2.71 respectively) during which period the temperature was also minimum (26.8°C, 26.0°C and 25.9°C respectively) (Fig. 1). Whitefly population was negatively correlated with relative humidity and rainfall (Fig. 2 and Fig. 3). Relative humidity was the highest during June, July and August (88%, 86% and 87% respectively) and rainfall was also the highest during these periods (993.1 mm, 975.6 mm and 533.3 mm respectively).

Negative correlation between yellow vein mosaic and relative humidity and a highly positive correlation between the disease,

Table 27. Correlation between whitefly population and weather parameters

Month		Whitefly population/ plant	Maximum temperature (°C)	Minimum temperature (°C)	Mean temperature (°C)	Relative humidity (%)	Rainfall (mm)
April	1991	15.15	35.6	24.5	30.1	68	83.8
May	"	14.23	35.1	25.5	30.3	70	56.1
June	"	1.88	29.7	23.8	26.8	88	993.1
July	"	1.95	29.1	22.8	26.0	86	975.6
August	"	2.71	29.0	22.7	25.9	87	533.3
September	"	3.46	31.5	23.6	27.6	78	61.5
October	"	6.16	30.9	23.2	27.1	82	281.7
November	"	8.75	31.5	23.0	27.3	75	191.3
December	"	10.99	31.9	21.7	26.6	64	0.2
January	1992	9.08	32.6	20.9	26.5	53	0
February	"	9.78	34.5	21.8	28.2	65	0
March	"	15.8	36.9	22.8	29.9	61	0
April	"	19.5	36.3	24.4	30.4	65	0
Correlation coefficient with whitefly population			+0.94*	+0.15	+0.60*	-0.77*	-0.74*

* Significant at P = 0.05

Fig. 1. Relationship between whitefly population and temperature

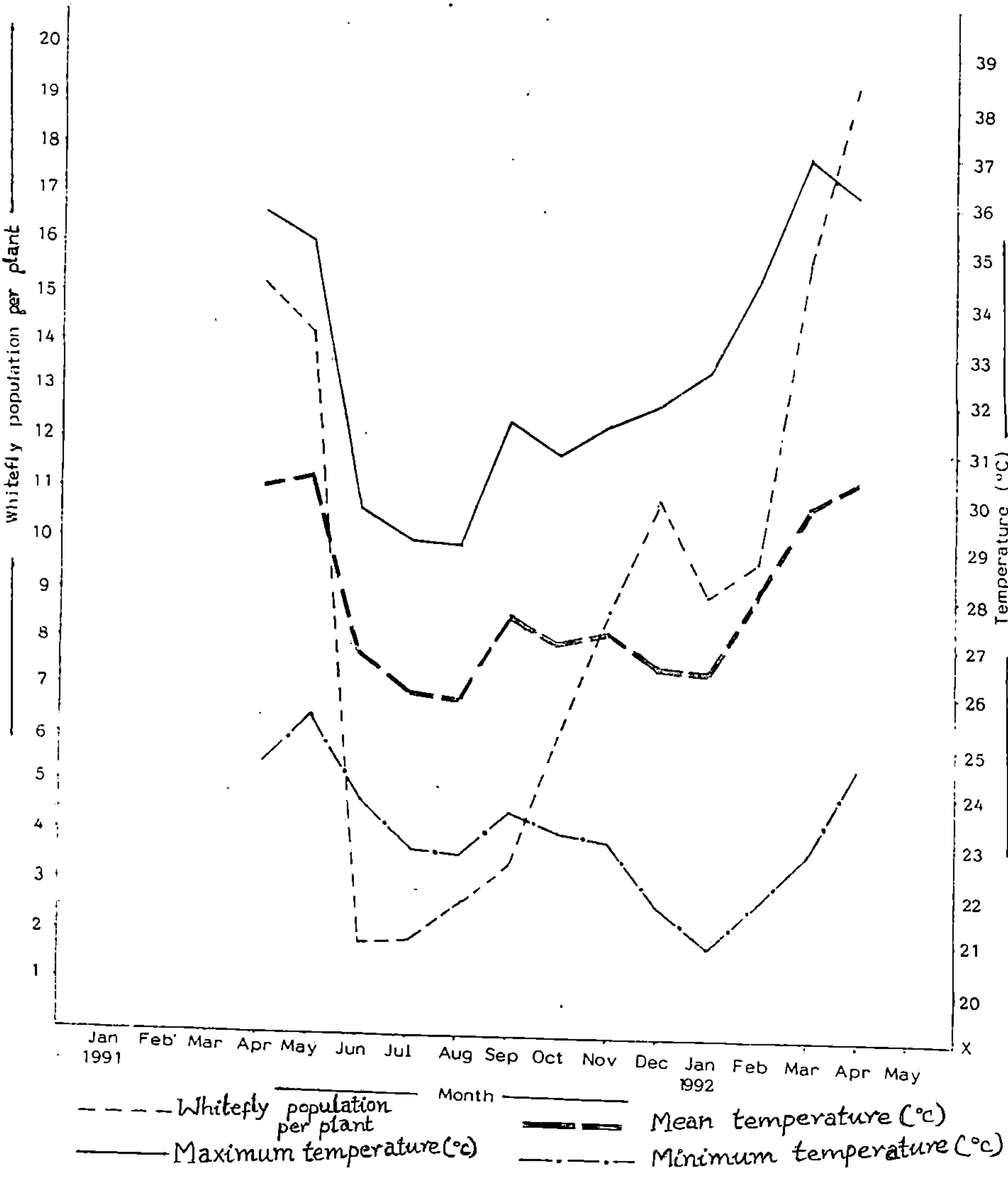


Fig. 2. Relationship between whitefly population and relative humidity

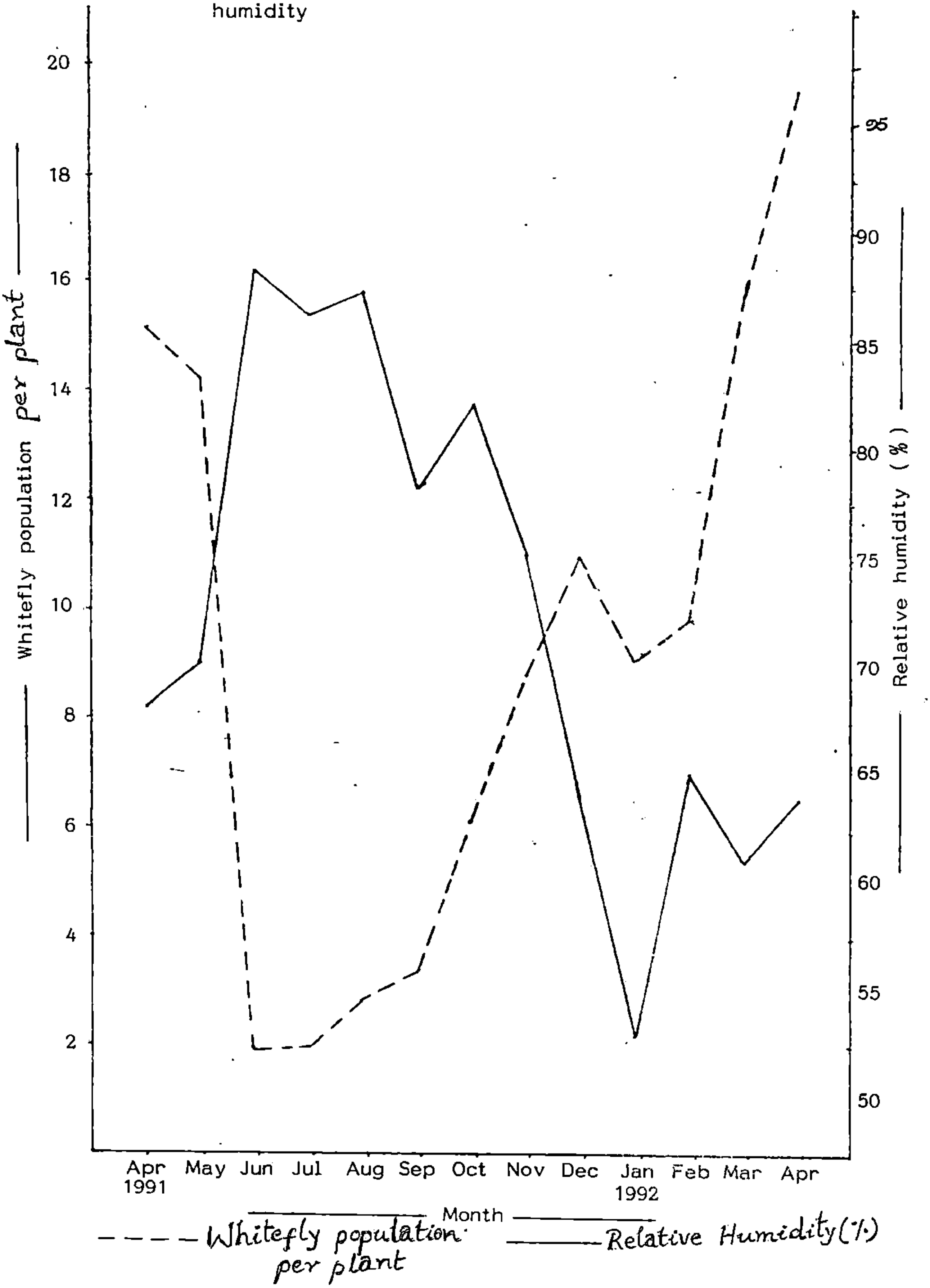
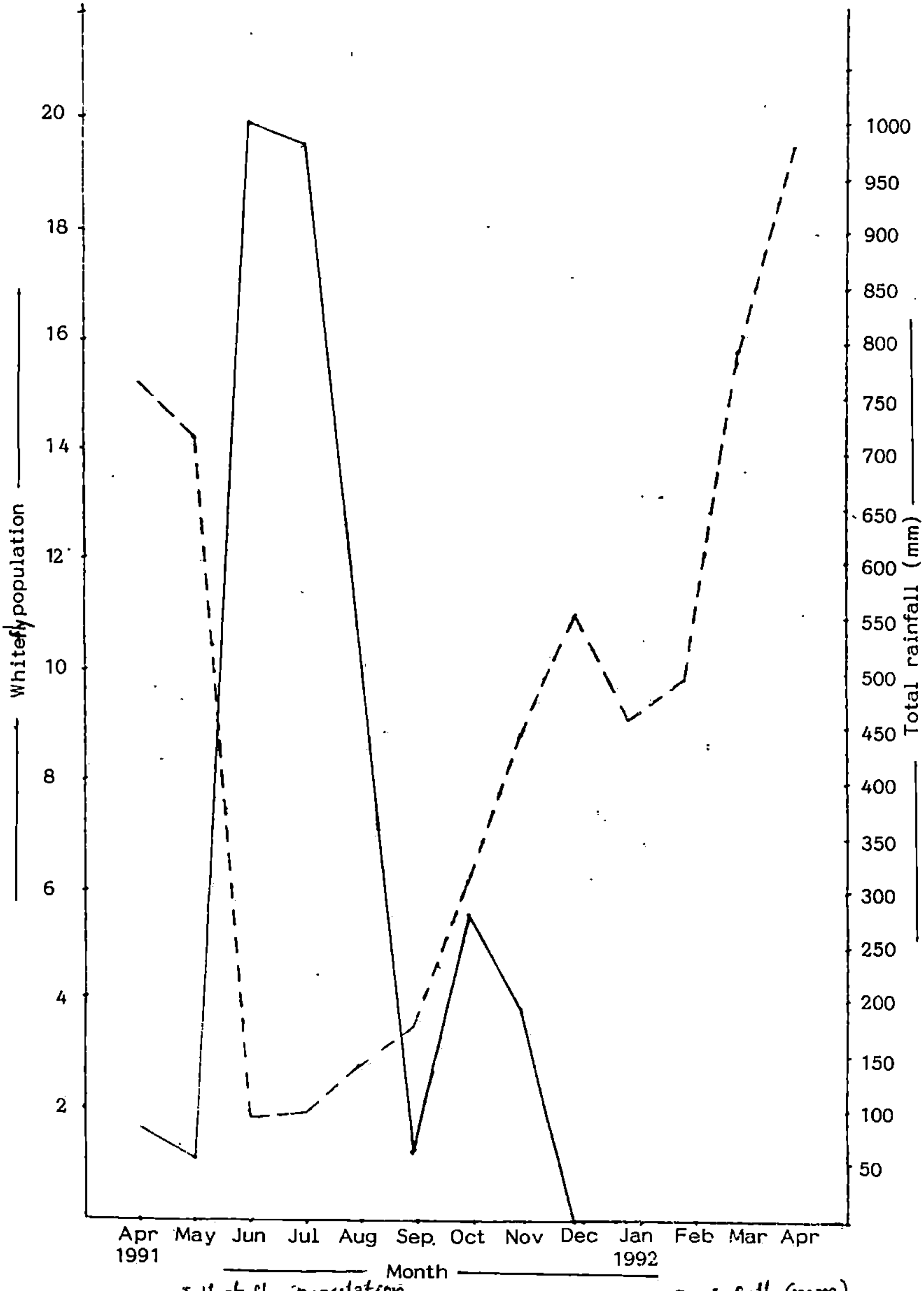


Fig. 3. Relationship between whitefly population and rainfall



whitefly population and temperature were earlier reported by Chelliah et al. (1975) and Keshwal and Jain (1983) in bhindi. Similar results were obtained in Phaseolus vulgaris infected by bean golden mosaic (Vicente et al., 1988) and in cassava infected by cassava mosaic (Lal, 1981; Seif, 1981; Lal and Pillai, 1982 and Singh and Butter, 1988). The high temperature, low rainfall and low relative humidity during the growth period will be the main reason for the maximum incidence of whiteflies and yellow vein mosaic in the crop sown in the middle of January. Crop sown in March was also severely affected by the disease, especially during the early vegetative stage. The mosaic symptoms appeared 32 days after sowing in March sown crop and 28 days after sowing in January sown crop.

Crops sown during May and July were completely free from yellow vein mosaic. The whitefly population was also comparatively less during these cropping periods which may be the reason for low mosaic incidence. Heavy rainfall during June, July and August and high relative humidity resulting in low temperature might have caused a sizeable reduction in the whitefly population. Suppression of whitefly population by heavy rainfall was earlier reported by Reddy et al. (1989) in cotton.

Pumpkin mosaic caused by cucumis virus-3 is characterized by light green and dark green patches on the leaf lamina. Even though the crop loss is not as drastic as in yellow vein mosaic, the plants affected by pumpkin mosaic were found to produce misshaped and undersized fruits. Pumpkin mosaic appeared 55 days after sowing compared to 39.5 days in yellow vein mosaic. As in the case of yellow vein mosaic, the incidence of pumpkin mosaic was maximum in summer sown crops (36.67% and 30% in March and January sown crops respectively). During these periods, symptoms appeared 42 and 25 days after sowing respectively. Rainy season crops, i.e., those sown during May and July, were completely free from pumpkin mosaic. The heavy rainfall resulting in the low temperature and high humidity might have caused the reduction in the population of aphids (Aphis gossypii) which is the vector of pumpkin mosaic. Crops sown in September and October had a comparatively low incidence of pumpkin mosaic (13.33% and 10% respectively) and symptoms also appeared very late.

The expression of mosaic symptoms is greatly influenced by factors like temperature and humidity. High temperature usually favours the expression while low temperature masks the symptoms. The low temperature during periods of November, December and January can be ascribed as the possible reasons for the late expression of pumpkin mosaic in September and October sown crops. Flock and Mayhew (1981) reported a high mortality of pumpkin plants infected by squash leaf curl at temperatures above 32.2°C and no distinct symptoms were observed when temperature was lower than 21°C. Similarly Foster and Webb (1965) observed complete masking of watermelon mosaic viruses 1 and 2, cucumber mosaic virus and squash mosaic virus in muskmelon at 18.3°C. In the order of disease severity and economic loss, bottle gourd mosaic, watermelon mosaic and cucumber mosaic came next to yellow vein mosaic and pumpkin mosaic.

Yield in pumpkin is an artefact of several contributing characters like average fruit weight, fruits/plant, earliness etc. The yield and the contributing characters were significantly influenced by different dates of sowing in pumpkin. All the characters except fruits/plant were significantly affected by time of sowing. Fruit yield was maximum in October sown crop (7.06 kg/plant) closely followed by crop sown in September (6.83 kg/plant). The average fruit weight was maximum for crops sown in July (3.58 kg) followed by those sown in September and October (3.16 kg). Early fruit set was noticed in October sown crop (52.2 days) and it had a comparatively good vegetative growth as indicated by the vine length (5.8 m). The probable reasons for the better performance of the crop sown during October may be the comparatively low incidence of yellow vein mosaic and pumpkin mosaic. Moreover in this crop the symptom expression took place after the vegetative phase and initial development of the fruits. As a result the yield was not drastically reduced. The crop sown during January yielded only 2.28

kg/plant and March sown crop did not yield at all due to the heavy incidence of mosaic diseases. The rainy season crops yielded 5.4 - 6.8 kg/plant.

Seasonal influence on yield may also be due to its effect on sex differentiation, fruitset etc. During periods of low temperature and short days, female flowers took minimum days for opening (47.17, 48.78 and 49.48 days for November, October and September sown crops respectively). The role of low temperature and short days on the female differentiation was earlier reported by Matsuo (1968) in several varieties of cucumber. Apart from heavy mosaic incidence, a high temperature during the growth periods of January and March sown crops might also result in failure of pollen grains to germinate as reported by Masui _et al_. (1971) in _Cucumis melo_. Considering the _per se_ performance in terms of fruit yield, fruit size and incidence of mosaic, sowing of pumpkin during October is most ideal followed by rainy season.

Information on the gene action of characters is a pre-requisite for any breeding programme. Using the means and variance of F_1, F_2, BC_1 and BC_2 generations of Ambili x CM 214, components of genetic variance were partitioned into additive, dominance and epistasis and the type and magnitude of epistasis were also estimated. Simple additive - dominance model fitted only for two characters viz., flesh thickness and seeds/fruit.

Significance of ABCD scaling tests for the remaining characters viz., fruit yield/plant, fruits/plant, average fruit weight, fruit length, fruit diameter, hundred seed weight, seed length, seed diameter, days to first female flower anthesis, days to first fruit set, female flowers/plant and length of main vine indicated the inadequacy of simple additive - dominance model and revealed the role of non-allelic interaction. The magnitude of dominance effect was higher for characters like fruit yield/plant, fruits/plant, female flowers/plant and length of main vine. The predominant role of dominance effect for the control of yield was earlier reported in watermelon by Brar and Nandpuri (1978), in muskmelon by Singh et al. (1976) and in bitter gourd by Lawande and Patil (1990) and for fruits/plant in bitter gourd by Lawande and Patil (1990). This shows that hybridization can play a key role for the genetic upgradation of the above characters. Significant additive effects were noticed for flesh thickness, seeds/fruit, fruit yield/plant, fruits/plant, average fruit weight, fruit diameter, seed length, seed diameter, female flowers/plant and length of main vine. Simple selection as a method of improvement for the above characters were suggested by Doijode and Sulladmath (1985) and Borthakur and Shadeque (1990) in pumpkin. Additive gene action for fruit yield/plant was earlier reported by Singh et al. (1988) in pumpkin, Rastogi and Deep (1990) in cucumber and Vijay (1987) in muskmelon. In muskmelon, Swamy et al. (1985) and Vijay (1987) earlier suggested additive gene effects for flesh thickness. High heritability and genetic gain for seeds/fruit were reported by Doijode *et al.* (1985) in pumpkin and Mariappan and Pappaiah (1990) in cucumber. In pumpkin, additive gene action was suggested by Gopalakrishnan *et al.* (1980) for fruits/plant, Singh *et al.* (1988) and Borthakur and Shadeque (1990) for average fruit weight, Doijode *et al.* (1988) for seed size index and Gopalakrishnan *et al.* (1980) and Borthakur and Shadeque (1990) for female flowers/plant.

The non–allelic interaction was detected for all the characters except flesh thickness and seeds/fruit. Epistasis was of complementary type for seed diameter and days to first female flower anthesis while for the rest of the characters it was of duplicate type. This necessitates the adoption of breeding methods like recurrent selection for the total improvement of the crop.

F_1 hybrid seed production has got a great momentum during the last few years and F_1 hybrids monopolised the cultivation of certain vegetables like tomato and watermelon in the country. Absence of inbreeding depression, more seeds/fruit, large and showy flowers, monoecious nature etc., provide an ideal condition for the exploitation of hybrid vigour in pumpkin. Utilizing discrete characters as marker genes, cost of production of F_1 seeds can be considerably reduced, when undertaken on a commercial scale.

Most of the commercial cultivars of pumpkin are characterized by silvery leaf trait where silvery patches can be seen at the intersects of veins and veinlets on the leaf lamina. In the present study, when Ambili was crossed to CM 214, all plants of F_1 were characterized by silvery leaves indicating the dominance of the character. Out of the 160 F_2 plants, 127 possessed and 33 lacked silvery leaves fitting in a ratio of 13:3 which showed the involvement of two genes for the control of this character. Dominance of silvery leaf trait was earlier reported by Coyne (1970) in Cucurbita moschata, Scarchuk (1954) in C. pepo and Scott and Riner (1946) in C. maxima. Involvement of two recessive genes indicates the possibility of utilizing non-silvery leaves as a marker character in a commercial F_1 seed production programme.

Observations on other discrete characters like warty appearance, green colour of mature fruits and light brown seed colour did not indicate a definite inheritance pattern. CM 214 was characterized by green warty fruits with light brown seeds. From CM 214, all these three characters were inherited together in the subsequent generations. This may be due to the possible linkage or pleiotropism of the above characters.

Development of resistant varieties would be the most effective method of disease control, particularly of mosaic. But it is a time consuming and complicated process because of the host-host-parasite interaction. Information on the pattern of inheritance is a pre-requisite for transferring resistant genes. The resistance of CM 214 (Nigerian Local) to zucchini yellow mosaic and its possible role in the development of resistant variety has been reported by Provvidenti . (1984). This line was also resistant to viral infections occurring in Australia, Taiwan, China, Japan, France, Italy, Egypt and Israel. It had also proved its resistance to yellow vein mosaic and pumpkin mosaic (Suresh Babu, 1989). In the present study, the mosaic resistant accession CM 214 was crossed to locally adapted and high yielding variety Ambili and F_1, F_2, BC_1 and BC_2 generations were made. All the generations were subjected to artificial inoculation.

Yellow vein mosaic was artificially induced using white-flies. In the F_1, nine out of ten plants were resistant indicating dominance of resistance over susceptibility. Out of the 100 F_2 plants inoculated, 69 were resistant and 31 susceptible fitting in a ratio of 3:1 indicating a monogenic dominance of resistance. When F_1 was backcrossed to the susceptible parent, the segregation of resistant and susceptible plants was in equal proportions, i.e., out of the 50 BC_1 plants inoculated, 29 were resistant confirming the monogenic dominant nature of inheritance of resistance. In the backcross to the resistant variety, out of 50, 43 were resistant. This shows that it is easy to transfer the yellow vein mosaic resistant gene to other varieties by simple crossing. Pumpkin being a monoecious plant there is enough scope for developing F_1s resistant to yellow vein mosaic.

Pumpkin mosaic caused by cucumis virus-3 is sap as well as aphid (Aphis gossypii) transmissible. When Ambili was crossed to CM 214, the F_1 was susceptible suggesting the recessive nature of resistance to pumpkin mosaic. Segregation of 100 F_2 plants into 72 susceptible and 28 resistant fitting in a 3:1 ratio indicated the role of a single recessive gene for the control of resistance to pumpkin mosaic. When susceptible F_1 was backcrossed to resistant parent, out of 50, 22 were susceptible and 28 were resistant fitting in a 1:1 ratio confirming the monogenic dominance of susceptibility over resistance. In the backcross with Ambili, out of a total of 50 inoculated, 44 were susceptible. The monogenic recessive nature of inheritance points to the need for adopting backcross method of breeding for developing resistant varieties.

In spite of the resistance to yellow vein mosaic and pumpkin mosaic in CM 214, the seed germination, fruit setting and fruit development are quite erratic and fruits are warty and knobbed. This necessitated the need for improving this line by different methods (Suresh Babu, 1989). Under normal conditions, the germination percentage of CM 214 was as low as 8% and even the germinated seeds required great care for its further development. Various seed treatments like mechanical scarification, hot water treatment, dipping in Gibberellic acid (GA) etc., did not improve the germination percentage considerably. When the seed coat was removed, the germination percentage could increase upto 71.4%. The presence of hard seed coat might have restricted the absorption of water and oxygen essential for germination of seeds. The removal of seed coat enabled easy penetration of water and oxygen resulting in emergence of the embryo. A significant increase in oxygen uptake was reported by Pesis and Na (1986) by removing seed coat of muskmelon seeds. An increase in germination rate and percentage by removal of seed coat was earlier noticed by Kim and Jeong (1990) in _Cucumis melo_ var. _microspermus_.

Presence of abundant variability is a pre-requisite for effective selection. Being a cross pollinated crop ample variability has been reported for fruit characters in pumpkin (Singh _et al._, 1988). Improvement through selection will have good prospects in a crop like pumpkin. When the mosaic resistant line CM 214 was subjected to individual plant selection, the resultant progeny had better performance. The per plant yield was increased by 0.48 kg and flesh thickness by 0.22 cm. The genetic gain for seed number as well as hundred seed weight were also considerable (81.83 and 1.13 g respectively). This indirectly improved the germination percentage from 8% in base population to 55% in selected progenies. The superior plants viz., CM 214-5-8, CM 214-8-9, CM 214-8-10, CM 214-11-4 and CM 214-11-6, selected based on the per se performance were still retaining warty appearance and green colour of fruits at maturity. This necessitates the need for further improvement. Identification of the five promising breeding lines viz., F_1-1-124, F_2-4-90, BC_1-1-67, BC_2-1-26 and BC_2-1-42 from the segregating populations of Ambili x CM 214 indicated the possible role of CM 214 as a source of mosaic resistance in pumpkin. The identified mosaic resistant selections as well as segregants should be progressed further till desired quality and uniformity are achieved. Since break down of resistance may happen at any time, breeding for resistance should be a continuous process.

Summary

SUMMARY

The present studies were conducted at the Department of Olericulture, College of Horticulture, Vellanikkara, Thrissur during November 1990 - April 1992. The seasonal influence on mosaic incidence, vector population and yield in pumpkin was studied by sowing locally adapted high yielding pumpkin variety Ambili at bimonthly intervals. To study the gene action of economic quantitative characters and inheritance of discrete characters and mosaic resistance, P_1, P_2, F_1, F_2, BC_1 and BC_2 generations of Ambili x CM 214 were utilized. The mosaic resistant line CM 214 was subjected to selection for improvement for consumer preference and yielding ability.

The findings of the study are summarized below:

Yellow vein mosaic, pumpkin mosaic, bottle gourd mosaic, watermelon mosaic and cucumber mosaic were found to cause crop loss in pumpkin.

Plants were affected by yellow vein mosaic much earlier than pumpkin mosaic (39.5 and 55 days after sowing respectively).

Yellow vein mosaic and pumpkin mosaic were maximum during summer months, i.e., March, April and May and minimum during rainy seasons.

Population of whiteflies (Bemisia tabaci Genn.), vector of yellow vein mosaic, was maximum during summer and minimum during rainy seasons.

Population of whiteflies was positively correlated with temperature and negatively correlated with relative humidity and rainfall.

Yield and contributing characters were significantly influenced by different dates of sowing. The crop sown in October was found to have maximum yield due to delayed incidence of mosaic diseases.

Magnitude of dominance effect was more for fruit yield/ plant, fruits/plant, female flowers/plant and length of main vine. Non—allelic interaction was detected for all characters except seeds/fruit and flesh thickness.

Resistance to yellow vein mosaic was found to be governed by a single dominant gene.

Resistance to pumpkin mosaic was governed by a single recessive gene.

Silvery leaf character was found dominant and controlled by two genes.

Germination percentage of CM 214 was considerably improved by removal of seed coat.

By adopting selection, improvement was observed in yield, flesh thickness, seeds/fruit, hundred seed weight and seed germination in CM 214. From the progenies, superior plants were selected for further improvement.

Based on *per se* performance and resistance to mosaic diseases, five promising selections from the segregating populations of Ambili x CM 214 were identified for further progress.

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* Originals not seen

Appendices

Appendix-I

Meteorological data during the cropping period

Month		Maximum temperature (°C)	Minimum temperature (°C)	Mean temperature (°C)	Relative humidity (%)	Rainfall (mm)	Mean sunshine (h)
November	1990	31.2	22.6	26.9	74	69.8	6.0
December	"	32.3	23.1	27.7	59	1.8	10.2
January	1991	33.6	22.2	27.9	57	3.9	8.9
February	"	35.9	21.7	28.8	51	0	10.1
March	"	36.4	24.9	30.7	66	1.8	8.7
April	"	35.6	24.5	30.1	68	83.8	8.9
May	"	35.1	25.5	30.3	70	56.1	7.5
June	"	29.7	23.8	26.8	88	993.1	4.8
July	"	29.1	22.8	26.0	86	975.6	2.5
August	"	29.0	22.7	25.9	87	533.3	2.8
September	"	31.5	23.6	27.6	78	61.5	7.3
October	"	30.9	23.2	27.1	82	281.7	4.3
November	"	31.5	23.0	27.3	75	191.3	7.1
December	"	31.9	21.7	26.6	64	0.2	8.6
January	1992	32.6	20.9	26.5	53	0	9.0
February	"	34.5	21.8	28.2	65	0	9.2
March	"	36.9	22.8	29.9	61	0	9.2
April	"	36.3	24.4	30.4	65	0	8.8

Appendix-II

Analysis of variance for different dates of sowing in pumpkin

Character	Treatment mean square	F - value
Yield/plant	13.48	4.585*
Fruits/plant	0.354	1.43
Average fruit weight	1.676	8.51*
Hundred seed weight	11.03	5.49*
Days to first female flower anthesis	75.33	9.85*
Days to first fruit set	338.76	26.18*
Length of main vine	9.58	36.85*

* Significant at P = 0.05

SELECTION FOR MOSAIC RESISTANCE IN PUMPKIN (*Cucurbita moschata* Poir)

By

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ABSTRACT OF A THESIS

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Department of Olericulture
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ABSTRACT

The present investigation "Selection for mosaic resistance in pumpkin (Cucurbita moschata Poir)" was conducted at the College of Horticulture, Vellanikkara, Thrissur during November 1990 - April 1992. The high yielding and locally adapted variety Ambili was sown at bimonthly intervals to study the seasonal influence on mosaic incidence, vector population and yield. Incidence of yellow vein mosaic, pumpkin mosaic, bottle gourd mosaic, watermelon mosaic and cucumber mosaic were observed in crops sown during different months. Incidence of yellow vein mosaic and population of whiteflies (Bemisia tabaci Genn.), the vector of yellow vein mosaic, were positively correlated with temperature and negatively correlated with rainfall and relative humidity. Fruit yield and contributing characters were significantly influenced by different dates of sowing and sowing in October was found to yield maximum because of the delayed incidence of mosaic.

From the study of P_1, P_2, F_1, F_2, BC_1 and BC_2 generations of the cross involving mosaic susceptible Ambili and resistant CM 214 (Nigerian Local), resistance to yellow vein mosaic was found to be governed by a single dominant gene and pumpkin mosaic by a single recessive gene. Silvery leaf trait was found to be dominant and governed by two genes. The study resulted

in the identification of five promising selections from the segregating populations.

Attempt was also made to improve the line CM 214 through selection. Improvement could be made in fruit set, seeds per fruit, hundred seed weight and seed germination. Germination percentage of CM 214 was significantly increased by removal of seed coat before sowing. Superior progenies of CM 214 were also selected for further improvement.