INDUCTION OF VARIABILITY IN *Abelmoschus manihot var. ghana* BY IRRADIATION

BY

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THESIS

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DECLARATION

I hereby declare this thesis entitled "Induction of variability in *Abelmoschus manihot* var. *ghana* by irradiation" is a bonafide record of research work done by me during the course of research and 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.

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CERTIFICATE

Certified that the thesis entitled "Induction of variability in Abelmoschus manihot var. ghana by irradiation" is a record of research work done independently by Miss. Nirmala Devi, S. 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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CERTIFICATE

We, the undersigned members of the Advisory Committee of Miss. Nirmala Devi, S. a candidate for the degree of Master of Science in Horticulture agree that the thesis entitled "Induction of variability in *Abelmoschus manihot* var. *ghana* by irradiation" may be submitted by Miss. Nirmala Devi, S. in partial fulfilment of the requirement for the degree.

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INTRODUCTION

Bhindi is an important vegetable of kharif and zaid seasons, in many parts of our country having tropical and subtropical climates. The green tender fruits are rich in vitamins, protein, calcium, iron and magnesium. It is used in vegetable soups and fried preparations. The seeds also contain 15-26% protein and yield an oil, rich in unsaturated fatty acids, suitable as edible fat. The ground seeds are recommended as a coffee substitute and the meal is used in baked preparations. The plants yield fibre which has potential use in paper industry. Its mucilage can be used in sizing of paper and treatment of chronic dysentry.

Since the past few years yellow vein mosaic virus disease, which is a serious problem in bhindi growing areas, takes heavy toll of the crop infecting at all stages of growth. The disease occurs throughout India wherever okra is cultivated affecting the quality and yield of the fruits. Therefore, there is an urgent need to develop varieties resistant to yellow vein mosaic virus to replace the present susceptible varieties.

Abelmoschus manihot accessions received from Africa and Japan were reported to be 'symptomless carriers' of yellow vein mosaic virus. This information provides ample

scope for transfer of such character to cultivated types provided there is no substantial reduction in yield in the interspecific hybrids and they are resistant to yellow vein mosaic virus under natural conditions. But the species is still in a wild state of existence and needs modification before being used as a vegetable. Hence, the present study was formulated with the following objectives.

1. To study the 'symptomless carrier' nature of host resistance mechanism in Abelmoschus manihot var. ghana.

2. To find out compatibility between A. esculentus and A. manihot var. ghana.

3. To induce variability in A. manihot var. ghana to isolate edible vegetable type(s), if any.

Review of Literature

REVIEW OF LITERATURE

The kharif being the more favourable season for bhindi (Abelmoschus esculentus (Linn.) Moench.) cultivation, the incidence of yellow vein mosaic disease has been the main constraint during this period. The extent of damage varied from 45 to 100% if the crop is not sprayed 20 days after germination (Sastry and Singh, 1973). The loss due to incidence of yellow vein mosaic disease has been a function of age of plant at which the first incidence was noted and spread of inoculum measured in terms of white fly (Bemisia tabaci Genn.) population favoured by high temperature and humidity (Varma, 1952). Attempts to evolve resistant types (Pusa Sawani - Singh et al., 1962) have still not achieved the desired success. Reports collected so far (Nariani and Seth, 1958; Progress Report, AICVIP, 1974-76 and 1977-78; Gunathilagaraj et al., 1977 and Chauhan et al., 1980) indicated failure in the identification of resistant/tolerant lines to the disease in the cultivated varieties. This leads to think of alternative ways of disease control through appropriate plant breeding methods. Arumugam et al. (1975) reported high resistance to the yellow vein mosaic disease in two accessions of Abelmoschus manihot. The two accessions were received from Africa and Japan. Arumugam et al. (1975) side grafted a diseased scion of A. esculentus on a healthy A. manihot root stock. The root stock later did not show any

symptoms of disease. They later took scionic piece from A. manihot and grafted on a healthy A. esculentus plant. On grafting healthy A. esculentus plant became susceptible indicating thereby 'symptomless carrier' nature of A. manihot.

The symptomless carrier nature of host reaction would be desirable provided there is no appreciable decrease in economic performance in such type of plants.

The concepts put under test in the present investigations involve the following.

1. Testing for 'symptomless carrier' nature of host resistance mechanism and transfer of such character to A. esculentus.

2. Creation of useful variability in A. manihot to locate vegetable type(s). The present review centres round the above two concepts.

Testing for symptomless carrier nature of host resistance mechanism and transfer of such character to A. esculentus

Arumugam et al. (1975) reported for the first time the 'symptomless carrier' type of host reaction in A. manihot. Mohan Singh and Thakur (1978) grafted healthy scion of A. esculentus on A. manihot ssp. manihot. They employed wedge grafting as the method of grafting. The scion exhibited symptoms of disease conforming to the symptomless carrier nature of A. manihot ssp. manihot. Attempts to transfer desirable traits from A. manihot to A. esculentus have been

made by many workers (Tezima, 1930; Teshima, 1933; Ustinova, 1949; IARI, 1956; Kuwada, 1957; Mamidwar et al., 1980).

Tezima (1930) attempted interspecific hybridisation between A. manihot and A. esculentus. A. manihot x A. esculentus was observed fertile but its reciprocal yielded no seeds. Back cross of F_1 with A. esculentus was unsuccessful but when F_1 was used as male parent cross was successful. Teshima (1933) observed that the cross A. manihot x A. esculentus was successful only when A. esculentus was used as female parent. Reciprocal produced only abortive seeds. Even in successful crosses fertility of F_1 was less than 1%. He also observed that the back cross was successful only when A. esculentus was used as male parent. The above conflicting reports could either be due to varietal differences or method of pollination used in the above cases. Chizaki (1934) observed fertile F_1 plant A. manihot x A. esculentus crosses. The F_1 showed hybrid vigour and was intermediate between parents. F_2 and F_3 generations were uniform in form and growth habit and resembled F_1 generation. The work of Chizaki (1934) established the cross compatibility nature between A. manihot and A. esculentus. In F_1 and F_3 generations he recorded chromosome numbers $\pm$ 98 and $\pm$ 192 respectively. Ustinova (1937) made successful cross between A.manihot and A. esculentus.

He observed that intense yellow flower colour of A. manihot was dominant. The deeply seven lobed leaf character is observed dominant over slightly three lobed leaf character of A. esculentus. Ustinova (1949) reported that the degree of sterility was high in interspecific F_1 hybrid of A. manihot x A. esculentus in F_1 and F_2 plants. He attributed this to the disruption of meiosis during sporogenesis of pollen grain and embryo sac development. The progenies developed through back crosses were observed earlier in flowering. Ustinova(1949) initiated vegetative hybridisation between A. manihot as root stock and A. esculentus as scion. The scion took well when stock was at an early stage of development. Seeds from graft hybrids matured normally. The utility of such grafting in creating variability has been of only academic interest which needs further detailed study.

A. manihot var. tetraphyllus (n=69) x A. esculentus (n=65) was observed sterile and had 2n=134. The F_{1s} had 20$\bar{6}$42 bivalents. Chromosome pairs per cell indicate homology between 20$\bar{6}$42 chromosomes of A. manihot with equal number of chromosomes in A. esculentus (Scientific reports of IARI, 1956). Kuwada (1957) reported a chromosome number 2n=96 with 3 to 7 bivalents. This indicated a very poor homology between chromosomes of the two species. Obviously fertility of hybrid was low.

Kuwada (1957) reported that In the back cross of the hybrid to A. esculentus (2n=158) the meiotic configuration observed was 28 to 34 univalents + 56 to 62 bivalents + 0 to 6 trivalents. In the back cross to A. manihot the configuration was 60 Is + 32 IIs + 2 IIIs. The above figures indicate a certain extent of chromosomal homology between two species. Studies by Kuwada (1962) indicated that sterility in interspecific hybrid was associated with inability of pollen to reach ovule and also with embryo sac abnormalities. He also observed that fruit size of hybrid depended on female parent indicating considerable cytoplasmic effect on fruit size. He further reported that total nitrogen, total sugars, dry matter content and osmotic pressure of the interspecific hybrid were lower than those of the parents in early stage of growth. The interspecific hybrid was observed less resistant to cold than its parents. Kuwada and Okuno (1968) reported that fertility of interspecific F_1 was affected by gene concerned with fertility and a relation existed between genome and cytoplasm. Arumugam et al. (1975) could produce fertile F_1 hybrid between A. manihot and A. esculentus. The F_1 seeds were viable, but there was 90% sterility in F_2. Mamidwar et al. (1980) observed a fruitset of 83.33% in A. esculentus x A. manihot. Most of pollen mother cells had 72-76 univalents indicating reduced chromosome homology between the two species. The review indicates possible cross

compatibility between A. manihot and A. esculentus which can be made use of in transfering desirable traits to A. esculentus.

Mutation breeding for crop improvement

Brock (1970) suggested mutation breeding as a potential alternative to plant introduction and hybridisation. Mutations are efficient aids in domestication of natural species, removal or suppression of undesirable features such as toxin, spines or thorns and above all in creating useful variants. Appropriate selection can pick out desirable variant(s) from the variability created through mutation. Smith (1970) reported that seeds are the preferred experimental material for mutation breeding. The seeds can be exposed to a wide range of radiation doses and environmental conditions without much physical constraints.

The doses of radiation used in the related crop cotton varied from 0.5-30 kR γ-rays (Atazanov, 1965); 10-40 kR γ-rays (Uzenbaev and Rahimova, 1966); 1-50 kR γ-rays (Gulamov et al., 1968); 25 kR γ-rays (Narimov, 1968); 40 and 50 kR γ-rays (Hrishi and Kamalam, 1969); 20 and 40 kR γ-rays (Bazhanova and Eminov, 1970); 20-60 kR γ-rays (Konoplya and Fursov, 1970); 0.5-10 kR γ-rays (Kuliev et al., 1970); 50-1200 kR γ-rays (Rzaev, 1970); 5 and 15 kR γ-rays (Egamberdiev et al., 1971); 5-80 kR γ-rays (Islamov, 1971); 5-30 kR γ-rays (Rakhimkulov, 1971); 25-30 kR X-rays (Raut et al., 1971); 5-20 kR γ- rays

(Kurbangel 'Dyev and Dzhorakuliev, 1972); 5-30 kR γ-rays (Mamedov, 1972); 20-50 kR γ-rays (Mustafaev and Kulieva, 1979); 1-20 kR γ-rays (Azimova et al., 1979).

Atazanov (1965) reported that irradiation stimulated ~~stunted~~ growth, development and yield in cotton. Doses over 5 kR had a negative influence on earliness and yield. Azizov (1968) found that higher the dose and rate, lower the viability and greater the variability in M_1 due to irradiation. Gulamov et al. (1968) reported that mutations affected earliness, type of fruiting branches, length of fibre and presence of fuzz on seeds. Narimov (1968) could isolate a mutant in M_2 generation with determinate branching habit - the parent being indeterminate. Bazhanova and Eminov (1970) obtained single plants with combination of economically valuable characters. Kuliev et al. (1970) observed reduced height of first fruiting node and increased number of sympodial branches and bolls following irradiation with 0.5-10 kR γ-rays. Rφzaev (1970) selected five mutant families with economically valuable characters in the M_3 generation. Islamov (1971) found that changes in morphological characters of cotton began with a dose of 5 kR γ-rays. Rakhimkulov (1971) observed that the best result was obtained with 10 kR if seeds were sown at optimum time and if sown late a dose of 5 kR gave the best results. Raut et al. (1971) reported that mutants had more sympodial branches and bolls were more erect

than normal. Kurbangel 'Dyev and Dzhorakuliev (1972) found that the mutants were different from wild variety in growth period, type of branching, leaf and boll shape and size following irradiation with 5-20 kR γ-rays. They also found that as the dose increased seed viability decreased but mutation frequency increased. Mustafaev and Kulieva (1979) reported that when seeds were irradiated with 40 kR and higher doses of γ-rays, in the M_1 the plants died or took undesirable characteristics in cotton. Azimova et al. (1979) found that the mutants were superior in boll weight, number of seeds/locule and seed weight. Hrishi and Kamalam (1969) reported the LD 50 for γ-rays as 50 kR in cotton. Kuliev (1971) reported that γ-rays at 10 kR had the greatest mutagenic effect. Kuliev (1973) obtained mutants with economically valuable properties after 10 kR γ-rays. Kuliev (1977) reported that mutation frequency was 42-50% after treatment of seeds with 20 kR.

Reports on mutation breeding in bhindi are limited. Kuwada (1970) treated dry seeds of bhindi with X-rays and observed plants in M_1 generation having more number of nodes and branches. M_2 showed increased variation in plant height, pods/plant and seeds/pod. Nandpuri et al. (1971) obtained increased variation in plant height, days to flower and yield in M_1 generation. Rao and Giri Raj (1975) treated bhindi (var. Pusa Sawani) with 3 doses of X-rays and 4 doses of

γ-rays. Nassar (1976) reported that leaf dimensions, plant height, stem diameter, branches/plant, branching interval, fruit length and diameter are affected by radiation. They recorded reduced germination in M_2 generation and observed shorter seedlings with thicker and darker leaves. Koshy and Abraham (1978) irradiated bhindi seeds with 20-100 kR γ-rays and in M_1 they observed stem dichotomy, change in phyllotaxy, reduction in size of flowers, increase or decrease in number of petals, abnormal development of petals, androecium, gynoecium and occurrence of twin fruits ("siamese twins").

Utility of gamma radiation to develop useful variants in Abelmoschus manihot is being explored in the present study.

Materials and Methods

MATERIALS AND METHODS

The present studies were conducted during March to June 1981, June to October, 1981 and November to April 1981-82 at the Instructional Farm of the College of Horticulture, Vellanikkara, Trichur. This research farm is situated at an altitude of 22.25 m at 10° 32' N latitude and 76° 16' E longitude. The soil type is deep well drained sandy loam with pH 5.1.

The experiment consists of 2 parts

I. Test for 'symptomless carrier' nature of host resistance mechanism and studies on compatibility.

II. Induction of variability in Abelmoschus manihot var. ghana (Source IARI).

I. Experiment 1. Test for 'symptomless carrier' nature of host resistance mechanism and studies on compatibility

A. Materials

Two lines of Abelmoschus manihot var. ghana introduced, formed the basic material for the study. The morphological description of the lines are given in Table 3.1. Ochse (1977) described in detail the plant habit of A. manihot in general. To quote "Wild type A. manihot is a perennial shrub, 1.5-7.5m high, much branched from near the base; crown-broad, densely leafy; trunk and branches - thick, terete, slightly rough and

glabrous; leaves - alternate, long stalked, most variable as to shape and size, subentire, 5-9 nerved with cordate base and an acute apex, green, tinged with red and usually glabrous; inflorescence - a terminal, many flowered, more or less densely hispid raceme; flowers - solitary in the axils of bracts, stalked, large, beautiful; buds - ovoid, acute; pedicel - rather short, terete, clothed with stellate hairs; bracteoles - 5, rather large, subpersistent, broadly lanceolate, acute, valvate in bud, along the margin densely clothed with short hairs; calyx - companulate, obtusely dentate at apex and after anthesis falling off together with corolla; corolla - large, sulphureous with purple eye; petals - 5, broadly ovate with shortly narrowed fleshy base, rounded apex, glabrous with distinctly radiating veins; staminal tube - straight, erect, white, densely beset with pale yellow anthers throughout its length; style - far exerted from staminal tube; style branches -5; stigma - globose, disciform, papillose, dark red; capsules - ovoid, oblong, narrowed towards the acute or obtuse apex, broadly furrowed between the ribs, dehisce when ripe, many seeded, densely hispid; seeds - globose, reniform and black".

Table 3.1. Source and morphological description of two lines of *A. manihot* var. *ghana*

	Line 1	Line 2
Source	IARI	KAU
Habit	Perennial shrub	Perennial shrub
Stem	Thick, slightly rough with red tinge	Thick, slightly rough, light green in colour
Leaves	Alternate, long stalked, cordate base, acute apex	Alternate, long stalked cordate base, acute apex
Petiole	Long, red	Long, light green
Flower	Solitary, axillary, stalked, large, buds ovoid acute	Solitary, axillary stalked, large, buds ovoid acute
Bracteoles	Large with appressed stiff hairs	Large with appressed stiff hairs
Calyx	Companulate, obtusely dentate at apex with red tinge	Companulate, obtusely dentate at apex with red tinge
Corolla	Large sulphureous with purple eye	Large sulphureous with purple eye
Androecium	Staminal tube white with pale yellow anthers	Staminal tube white with pale yellow anthers
Gynoecium	Stigma globose, dark red	Stigma globose, dark red
Fruit	Capsule with red tinge in immature stage, green when mature and broadly furrowed between ridges	Capsule green in immature and mature stage and narrowly furrowed between ridges
Seeds	Dark grey and hairy	Brownish and non-hairy

B. Methods

1. Testing for 'symptomless carrier' nature of host resistance mechanism

Twentyfive seedlings of each line were grown in pots and exposed to natural conditions, favourable for disease reaction, during April-June 1981. Seeds of bhindi, A. esculentus cv. Pusa Sawani were sown and seedlings were raised in insect proof cages. The healthy bhindi scion was grafted on the A. manihot rootstock. The graft was again put inside insect proof cages to observe for yellow vein mosaic disease symptoms.

2. Compatibility between A. manihot var. ghana and A. esculentus cv. Pusa Sawani

A. esculentus cv. Pusa Sawani was used as female parent and about 200 crosses were effected. Observations were made on the following characters.

a) Percentage of fruitset in F_0 (A)

b) Percentage of fruitset in maternal parent (Pusa Sawani)

c) Seeds/fruit in F_0

d) Percentage of viable seeds in F_0 (B)

e) Seeds/fruit in maternal parent

f) Percentage of viable seeds in maternal parent

g) Percentage of germination in F_0 (C)

h) Percentage of germination in maternal parent.

The percentage of success/fruitset was calculated using the formula:

$$\text{Percentage success/fruitset} = \frac{\text{No. of fruits set in } F_0 \text{ level}}{\text{No. of crosses made}} \times 100$$

Crossability index was calculated (Rao, 1979), as

$$\text{Crossability index} = \frac{\text{Crossing efficiency of the cross}}{\text{Selfing efficiency of female parent}} \times 100$$

$$= \frac{A^{c^*} \times B^{c^*} \times C^{c^*}}{A^{s^*} \times B^{s^*} \times C^{s^*}} \times 100$$

*c = crossed

*s = selfed

i) The fertility of F_1 plant

The fertility of F_1 plant was estimated as percentage of viable seeds and as percentage germination of F_1 seeds.

Percentage of fruits carrying viable seeds

$$= \frac{\text{No. of fruits carrying viable seeds}}{\text{Total number of fruits}} \times 100$$

$$\text{Percentage of viable seeds} = \frac{\text{Number of viable seeds}}{\text{Total number of seeds}} \times 100$$

$$\text{Percentage of germination} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds sown}} \times 100$$

j) Estimation of interspecific F_1 hybrid vigour

The interspecific F_1 hybrid was grown along with parental species during November-April, 1981-82. There were 25 plants each in parents and 60 plants in F_1. The spacing

was 60 x 45 cm. Observations were made on following characters.

i) Days to flower

ii) Nodes to first flower

iii) Plant height (cm)

iv) Leaf length (cm)

v) Leaf width (cm)

vi) Fruit length (cm)

vii) Fruit girth (cm)

viii) Primary branches/plant

ix) Nodes on main stem

x) Fruiting nodes on main stem

xi) Internodal length (cm) (first fruiting node)

xii) Fruits/plant

xiii) Ridges/fruit

xiv) Marketable fruits/plant

xv) Seeds/fruit

xvi) Fruit yield/plant (g)

Observations were also made on

xvii) Yellow vein mosaic incidence - nil/high

xviii) Incidence of cercospora leaf spot - nil/high

xix) Incidence of fruit borer - nil/high

xx) Incidence of jassids - nil/high

xxi) Incidence of mites - nil/high

xxii) Incidence of powdery mildew and downy mildew -nil/high

The interspecific F_1 hybrid vigour was estimated using the formulae:

$$\text{Heterobeltiosis} = \frac{\bar{F}_1 - B\bar{P}}{B\bar{P}} \times 100$$

$$\text{Relative heterosis} = \frac{\bar{F}_1 - \bar{MP}}{\bar{MP}} \times 100$$

Heterobeltiosis was tested using standard error

$$SE = \sqrt{\frac{\sigma^2 F_1}{n_1} + \frac{\sigma^2 BP}{n_2}}$$

Where $\sigma^2 F_1$ = F_1 variance

$\sigma^2 BP$ = better parental variance

n_1 = number of F_1 plants

n_2 = number of better parental plants

The relative heterosis was tested using standard error

$$SE = \sqrt{\frac{\sigma^2 F_1}{n_1} + \frac{1}{4}\left(\frac{\sigma^2 P_1}{n_2} + \frac{\sigma^2 P_2}{n_3}\right)}$$

Where $\sigma^2 P_1$ = maternal parental variance

$\sigma^2 P_2$ = paternal parental variance

n_2 = number of maternal parents

n_3 = number of paternal parents

k) Estimation of genetic distance between the two species, A. manihot var. ghana and A. esculentus

The genetic distance was calculated considering the following characters.

i) Days to flower

ii) Nodes to first flower

iii) Plant height (cm)

iv) Fruit length (cm)

v) Primary branches/plant

vi) Nodes on main stem

vii) Internodal length (cm)

viii) Fruits/plant

ix) Ridges/fruit

x) Marketable fruits/plant

xi) Seeds/fruit

The method suggested by Mahalanobis (1928) was used to estimate the total D^2 between the two species with X_1, X_2, X_3 ..... X_{11} as the multiple measurements available on each species and d_1, d_2, d_3 ..... d_{11} as $\bar{x}_1^1 - \bar{x}_1^2$, $\bar{x}_2^1 - \bar{x}_2^2$ ..... $\bar{x}_{11}^1 - \bar{x}_{11}^2$ respectively, being the difference in the means of above two species, Mahalanobis D^2 statistics is defined as

$$^{11}D^2 = b_1d_1 + b_2d_2 + b_3d_3 \ldots\ldots b_{11}d_{11}.$$

Here the b_i values are to be estimated such that ratio of variance between population to variance within population is maximised. In terms of variances and covariances the D^2 value is obtained as follows.

$$11^{D^2} = wij\ (\bar{x}_i^1 - \bar{x}_i^2)\ (\bar{x}_j^1 - \bar{x}_j^2)$$

where wij is the inverse of estimated variance, covariance matrix.

The D^2 value was tested with χ^2 at 11 degrees of freedom as suggested by Rao (1948) and Singh and Chaudhary (1979).

The component character contributing maximum to total genetic distance was identified based on the relative magnitude of the component deviation squares.

II. Experiment 2 · Variability in M_1 generations of Abelmoschus manihot var. ghana

A. Materials: A. manihot var. ghana (source; IARI) formed the basic material for irradiation. The seeds were irradiated at Nuclear Research Laboratory, IARI at 3 doses, 10 kR, 15 kR and 20 kR.

B. Methods: The irradiated seeds were sown during March-June, 1981 and June-October, 1981. There were 50 plants each under the three treatments and the untreated control in both the seasons. The spacing was 60 x 45 cm. The axillary buds were clipped off as soon as they developed to make sure the differentiation, growth and development of mutant tissues generally present in the terminal bud.

Following observations were made in the M_0 generation to observe the immediate effect of irradiation on plant characters.

i) Plant height (cm)
ii) Girth of stem (cm)
iii) Internodal length (cm)
iv) Length of leaves (cm)
v) Length of fruit (cm)
vi) Weight of fruits (g)
vii) Ridges/fruit
viii) Seeds/fruit

The data were analysed using student 't' test (Panse and Sukhatme, 1978). The vigour was calculated as follows.

Vigour due to treatment 1 (10 kR)

$$= \frac{(\bar{x}_1 - \bar{x}_0)}{\bar{x}_0} \times 100$$

where $\bar{x}_1$ = mean performance at treatment 1

$\bar{x}_0$ = mean performance of untreated control

Likewise vigour due to treatment 2 (15 kR) and treatment 3 (20 kR) were estimated. The vigour was tested using corresponding standard errors.

Standard error for testing vigour due to treatment 1

$$= \sqrt{\frac{\sigma^2 x_1 + \sigma^2 x_0}{n_1}}$$

where $\sigma^2 x_1$ = variance due to treatment 1

$\sigma^2 x_0$ = variance in untreated control

Standard error for testing vigour due to treatment 2 (15 kR)

$$= \sqrt{\frac{\sigma^2 x_2 + \sigma^2 x_0}{n}}$$

where $\sigma^2 x_2$ = variance due to treatment 2

Standard error for testing vigour due to treatment 3 (20 kR)

$$= \sqrt{\frac{\sigma^2 x_3 + \sigma^2 x_0}{n}}$$

where $\sigma^2 x_3$ = variance due to treatment 3

C. Estimation of variability in M_1 generation

1. Materials: The selfed seeds from each treatment were used.

2. Methods: Selfed seeds from each treatment (10 kR, 15 kR, 20 kR) were sown during November to April 1981-82. The spacing was 45 x 30 cm. There were 356 plants in treatment 1 and 279 plants in treatment 2 and 327 plants in treatment 3.

Observations were made on the following characters.

a) Detailed morphological description of all the plants were recorded individually, as indicated below.

1. Plant habit : Branched/unbranched
2. Pubescence : i) Stem - smooth/pubescent/warty
   ii) Lamina - smooth/pubescent
   iii) Petiole - smooth/pubescent

3. Pigmentation:

   i) Stem - Green/green with red tinge/red/red with green tinge

   ii) Petiole - Green/green with red tinge/red/red with green tinge

   iii) Vein - Prominent/not prominent/green/whitish/green with red tinge/red with green tinge

   iv) Base of petal - present/absent

4. Leaf size : Small/medium/big (at first fruiting node)

5. Leaf shape : Cordate/hastate/sagitate/others

6. Laminal margin: Deeply fid/narrowly fid/serrated

7. Leaf tip : Pointed/blunt

8. Flower:

   i) Bud - hairy/scaly/smooth/resinous

   ii) Corolla - yellow/golden yellow; red throat/purple throat

   iii) Calyx - hairy/smooth; fleshy/nonfleshy

   iv) Stigma - bifid/multifid; purple/red/others; smooth/hairy

9. Fruits:

   i) Immature fruit colour - green/dark green/yellowish green/red/deep red/others

   ii) Size - small/medium/long/extra long

   iii) Shape - round/angular/ridged/straight/curved

   iv) Tip - pointed/blunt

   v) Dehiscence at maturity - dehiscent/indehiscent

vi) Hairiness of fruit - present/absent; less hairy/ highly hairy; only on ridges/entire fruit

vii) Bending - snaps/bends

10. Seeds : i) Seediness - low/medium/high

ii) Shape - round/depressed

iii) Hairiness - smooth/hairy

b) Quantitative characters:

1. Days to flower
2. Nodes to first flower
3. Plant height (cm)
4. Leaf length (cm)
5. Leaf width (cm)
6. Fruit length (cm)
7. Fruit girth (cm)
8. Primary branches/plant
9. Nodes on main stem
10. Fruiting nodes on main stem
11. Internodal length (cm) (first fruiting node)
12. Fruits/plant
13. Ridges/fruit
14. Marketable fruits/plant
15. Seeds/fruit
16. Seed yield/plant (g)
17. Fruit yield/plant (g)

c) Remarks

Observations were also made on

i) Incidence of yellow vein mosaic - nil/high

ii) Stage of mosaic appearance - early/mid/fag end

iii) Incidence of cercospora leaf spot - nil/high

iv) Incidence of fruit borer - nil/high

v) Incidence of jassids - nil/high

vi) Incidence of mites - nil/high

Coefficient of variation under the three treatments was estimated using the formula $\frac{\sigma x}{\bar{x}} \times 100$

where σx = standard deviation for character x

$\bar{x}$ = mean of x

The significance of difference, if any, among the treatments in M_1 generation was tested using student 't'.

Results

RESULTS

The data collected in the two sets of experiments were analysed and are presented below.

I. Test for 'symptomless carrier' nature of host resistance mechanism and studies on compatibility

All the 25 plants in each of the two line of Abelmoschus manihot var. ghana did not exhibit any symptom of yellow vein mosaic disease under natural conditions (Table41). The plants were apparently healthy and vigorous. The 25 plants of A. esculentus cv. Pusa Sawani did exhibit symptoms of yellow vein mosaic disease. The interspecific grafts under protected conditions exhibited symptoms of yellow vein mosaic disease. The scion plants carried yellow veined leaves typical of the disease.

It took 45 days from sowing for the var. Pusa Sawani to exhibit symptoms of the disease. The interspecific grafts took only 7-17 days from grafting to exhibit disease symptoms.

The cross compatibility between A. esculentus and A. manihot var. ghana was studied (Table42). The crossability index was estimated as 12.38. The percentage of fruitset in crosses was 65.41 while in the selfed maternal parent it was 92.1. Viable seeds/fruit in the cross at F_0 level was 69% while in the selfed maternal parent it was observed as 73%.

Table 4.1. Reaction of two species and interspecific grafts to yellow vein mosaic virus

Species	Number of plants/ grafts	Number of successful grafts	Number of plants showing symptoms	Number of plants free from disease	Days to appearance of disease after grafting/ sowing
Abelmoschus manihot var. *ghana* (Source IARI)	25	-	nil	25	-
A. manihot var. *ghana* (Source KAU)	25	-	nil	25	-
A. esculentus cv. Pusa Sawani	25	-	25	nil	45
A. esculentus ——— *A. manihot* var. *ghana* (Source IARI)	25	25	25	nil	7-12
A. esculentus ——— *A. manihot* var. *ghana* (Source KAU)	25	23	23	nil	14-17

Table 4.2. Compatibility between A. esculentus cv. Pusa Sawani and A. manihot var. ghana

	A^{c*}	B^{c*}	C^{c*}	A^{s**}	B^{s**}	C^{s**}
F_0 (A. esculentus x A. manihot var. ghana (Source IARI)	65.41	69.00	12.00	-	-	-
Maternal parent (A. esculentus cv. Pusa Sawani)	-	-	-	92.00	83.00	65.10

a. Compatibility as observed in F_0 level

$$\text{Crossability index} = \frac{A^{c*} \times B^{c*} \times C^{c*}}{A^{s**} \times B^{s**} \times C^{s**}} \times 100$$

$$= 12.38$$

A^{c*} - Percentage of fruitset in F_0

B^{c*} - Seeds/fruit in F_0

C^{c*} - Percentage of germination in F_0

A^{s**} - Percentage of fruitset in maternal parent on selfing

B^{s**} - Seeds/fruit in maternal parent on selfing

C^{s} - Percentage of germination in maternal parent

b. Compatibility as observed in F_1 level:

Percentage of fruits carrying viable seeds = $\frac{63}{278} \times 100 = 22.66$

Percentage germination of F_1 seeds = $\frac{10}{15} \times 100 = 13.33$

Fertility of F_1 plant = $\frac{\text{No. of viable seeds}}{\text{Total no. of seeds}} \times 100 = \frac{380}{1601} = 23.73$

The germination percentage of cross at F_0 level was 12 while in selfed maternal parent it was 65.1.

The cross compatibility was further studied in F_1 level. The percentage of fruits carrying viable seed was counted as 22.66. The germination of interspecific F_1 hybrid seed was 13.33%. Fertility of F_1 plant measured as percentage of viable seeds/total number of seeds was 23.73.

Significant heterosis was observed for days to flower, nodes to first flower, plant height, leaf length, leaf width, fruit length, primary branches/plant, ridges/fruit, marketable fruits/plant, seeds/fruit and fruit yield/plant. Heterosis was not significant for fruit girth and nodes on main stem (Table43). The interspecific F_1 hybrid was observed late in flowering. The highest heterobeltiosis of 300.33% was observed for the character plant height. The lowest heterobeltiosis was observed for nodes on main stem. The relative heterosis was the maximum (309.39%) for plant height, followed by marketable fruits/plant (100.86). The interspecific F_1 hybrid yielded 110.48 g while Pusa Sawani yielded 92.44 g/plant. The interspecific F_1 hybrid was specifically noted for its taller stature, higher leaf size, fruit length, more number of fruiting nodes on main stem, more fruits/plant, more ridges/fruit, more number of marketable fruits/plant and fruit yield/plant.

Observations were also made on incidence of yellow vein mosaic, cercospora leaf spot, powdery mildew and

Table 4.3. Interspecific F_1 heterosis

Characters	A. esculentus (cv. Pusa Sawani)	A. manihot var. ghana (Source IARI)	F_1	Percentage increase or decrease over		Standard error	
				A. esculentus (cv. Pusa Sawani)	Midparent	A. esculentus (cv. Pusa Sawani)	Midparent
Days to flower	43.44	56.44	58.72	35.17*	17.58*	1.64	1.59
Nodes to first flower	4.20	4.84	5.40	28.57*	19.47*	0.33	0.29
Plant height (cm)	24.40	23.32	97.68	300.33*	309.39*	4.61	4.63
Leaf length (cm)	23.06	24.60	29.36	27.32*	23.20*	1.477	1.47
Leaf width (cm)	13.64	16.20	18.24	33.72*	22.25*	1.08	1.05
Fruit length (cm)	17.83	12.52	15.88	-10.93*	4.64	0.76	0.64
Fruit girth (cm)	7.39	7.74	6.95	- 5.95	-8.13	0.505	0.43
Primary branches/ plant	4.48	3.50	3.00	-33.03*	-24.81*	0.41	0.34
Nodes on main stem	12.48	11.88	12.84	2.88	5.42	1.36	0.91
Fruiting nodes on main stem	9.00	2.24	10.36	15.11	84.34*	0.80	0.70
Internodal length(cm)	4.27	3.26	6.42	50.35*	70.51*	0.466	0.44
Fruits/plant	7.72	1.80	9.44	22.28*	98.32*	0.85	0.74
Ridges/fruit	5.44	6.40	7.04	29.41*	18.92*	0.37	0.37
Marketable fruits/ plant	7.72	1.56	9.32	20.72*	100.86*	0.73	0.59
Seeds/fruit	73.00	34.80	4.81	-93.41*	91.07*	2.80	2.84
Fruit yield/plant(g)	92.44	32.61	110.48	19.51**	76.71*	6.55	5.79

* p = 0.05

downy mildew and pests like fruit borer, jassids and mites. During the season under report the interspecific hybrids were free from above diseases and pests.

The expression of heterosis for many of the characters was observed as a function of genetic distance existing between the two species. The D^2 value was estimated. The pooled variance-covariance matrix is given (Table4.4). The coefficients of 'x' in the linear function of 'Y' is given (Table4.5). These coefficients were used to transform the correlated variables into uncorrelated linear function of 'Y'. The total D^2 value is estimated as $_{11}D^2=228.57$. The character, primary branches/plant has contributed maximum towards genetic distance (33.11%) and fruits/plant was minimum (0.11%) (Table4.6).

II. Variability in M_1 generation of A. manihot var. ghana (Source IARI)

The seeds of A. manihot var. ghana irradiated with 10, 15 and 20 kR r-rays were sown and the plants were observed for plant height, girth of stem, internodal length, length of leaves, length of fruit, ridges/fruit, seeds/fruit and fruit yield/plant. The M_0 lines were compared with untreated control and were observed positively significant for plant height, internodal length and length of leaves irrespective of doses of radiation given. No vigour due to irradiation was observed for characters like ridges/fruit

Table 4.4. Pooled variance-covariance matrix

x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}
5.088	-0.920	0.960	1.940	3.315	21.810	0.149	2.210	-0.067	-1.522	123.670
	0.860	1.838	-0.088	0.707	2.024	-0.081	0.262	-0.033	-0.755	11.024
		54.190	4.994	-0.743	58.895	4.229	2.550	1.043	0.440	76.449
			6.380	0.927	10.612	0.396	2.018	0.404	1.195	36.019
				1.295	2.343	-0.319	0.123	-0.638	-0.292	5.648
					25.095	3.610	6.932	3.165	6.534	77.570
						2.003	0.622	0.043	0.300	6.834
							3.515	0.439	2.759	11.145
								0.583	0.680	17.666
									3.355	10.337
										393.005

x_1 = Days to first flower
x_2 = Nodes to first flower
x_3 = Plant height (cm)
x_4 = Fruit length (cm)
x_5 = Primary branches/plant
x_6 = Nodes on main stem
x_7 = Internodal length (cm)
x_8 = Fruits/plant
x_9 = Ridges/fruit
x_{10} = Marketable fruits/plant
x_{11} = Seeds/fruit

Table 4.5. Coefficients of x in a linear function of Y used to transform correlated variables into uncorrelated variables

$$Y = \frac{1\ x_1}{5.088}$$

$$Y = \frac{(0.1808\ x_1) + (1\ x_2)}{0.6936}$$

$$Y = \frac{(-0.713\ x_1) + (-2.9000\ x_2) + (1\ x_3)}{48.1752}$$

$$Y = \frac{(-0.3925\ x_1) + (-0.1461\ x_2) + (-0.0824\ x_3) + (1\ x_4)}{5.2305}$$

$$Y = \frac{(-1.0997\ x_1) + (2.2055\ x_2) + (0.1006\ x_3) + (0.0799\ x_4) + (1\ x_5)}{-3.9107}$$

$$Y = \frac{(-0.0739\ x_1) + (4.4721\ x_2) + (-1.3209\ x_3 + (0.1730\ x_4) + (-4.9433\ x_5) + (1\ x_6)}{-55.0072}$$

$$Y = \frac{(0.0079\ x_1) + (0.1970\ x_2) + (-0.0694\ x_3) + (-0.00099\ x_4) + (0.1024\ x_5) + (-0.0128\ x_6) + (1\ x_7)}{1.6152}$$

$$Y = \frac{(0.1504\ x_1) + (0.7734\ x_2) + (-0.1388\ x_3) + (-0.2101\ x_4) + (-1.0462\ x_5) + (0.0818\ x_6) + (-0.2699\ x_7) + (1\ x_8)}{3.5429}$$

$$Y = \frac{(0.1164\ x_1) + (0.5216\ x_2) + (-0.1087\ x_3) + (0.0054\ x_4) + (-0.1976\ x_5) + (0.0622\ x_6) + (0.1713\ x_7) + (-0.3073\ x_8) + (1.x_9)}{0.6421}$$

(contd.)

Table 4.5. continued

$$Y = \frac{(-0.1928\ x_1) + (0.0097\ x_2) + (-0.0219\ x_3) + (-0.1341\ x_4) + (1.0506\ x_5) + (0.0492\ x_6) + (0.2567\ x_7) + (-0.8021\ x_8) + (0.4121\ x_9) + (1\ x_{10})}{1.6297}$$

$$Y = \frac{(2.2994\ x_1) + (-0.3001\ x_2) + (3.0602\ x_3) + (0.9384\ x_4) + (-15.0805\ x_5) + (-3.2027\ x_6) + (-7.9199\ x_7) + (4.6775\ x_8) + (45.9654\ x_9) + (6.1754\ x_{10}) + 1\ x_{11})}{-710.7226}$$

Table 4.6. Genetic distance (D^2) between *Abelmoschus esculentus* and *A. manihot* var. *ghana*

Character	Component D^2	Percentage contribution towards total D^2
Days to flower	33.219	14.53
Nodes to first flower	12.888	5.64
Plant height (cm)	3.090	1.35
Fruit length (cm)	20.739	9.07
Primary branches/plant	75.673	33.11
Nodes on main stem	0.805	0.35
Internodal length (cm)	0.392	0.17
Fruits/plant	0.250	0.11
Ridges/fruit	34.375	15.04
Marketable fruits/plant	10.329	4.52
Seeds/fruit	36.808	16.10
Total D^2	228.57*	

x^2 (11 df) = 19.68

* p = 0.05

and seeds/fruit. The vigour was also not significant for fruit yield/plant when the dose was 20 kR (Table47).

Morphological changes in M_1 generation due to irradiation were critically observed (Table48). Branched plants were more in number in all the three treatments. Warty stem pubescence was common. Leaf lamina and petiole were smooth in majority of plants. Stem with red and green tinge was more common. The pigmentation of veins were prominent in all plants. No plants with scaly flower buds were observed. The immature fruit colour was generally green tinged with red and red tinged with green, fruit size - medium, shape - ridged and tip - pointed. The fruits dehisced at maturity in all the plants. No plants with hairless fruits were observed in the three treatments. Majority of fruits were seeded. The seed shape in general was round and smooth.

The M_1 lines were grown and characters like days to flower, nodes to first flower, plant height, leaf length, leaf width, fruit length, fruit girth, primary branches/plant, nodes on main stem, internodal length, fruits/plant, ridges/fruit, marketable fruits/plant, seeds/fruit, seed yield/plant and fruit yield/plant were observed (Table49). The three lines exhibited considerable variability for the above characters. Days to flower ranged from 55-86 days, plant height from 7-123 cm, fruit length from 2.5-21 cm, fruits/plant from 1-10 and fruit yield/plant from nil to 221 g/plant.

Table 4.7. Vigour due to irradiation as observed in M_0 generation

Character	M_{0_1} (10kR)	M_{0_2} (15kR)	M_{0_3} (20kR)	Control	Standard error		
					M_{0_1}	M_{0_2}	M_{0_3}
Plant height (cm)	226.80* (31.75)	250.25* (45.37)	239.45* (39.09)	172.15	8.40	7.97	10.94
Girth of stem (cm)	9.75* (37.32)	9.10* (28.16)	8.15 (14.79)	7.10	0.62	0.53	0.59
Internodal length(cm)	5.58* (39.50)	6.00* (50.00)	6.35* (58.75)	4.00	0.36	0.33	0.36
Length of leaves (cm)	56.55* (56.40)	54.55* (50.89)	48.60* (34.44)	36.15	2.55	2.65	2.33
Length of fruit (cm)	14.40 (12.50)	13.11 (2.42)	10.19* (-20.39)	12.80	0.830	0.96	0.96
Ridges/fruit	7.93 (5.73)	8.56 (14.13)	8.38 (11.73)	7.50	0.50	0.64	0.44
Seeds/fruit	66.47 (-2.39)	62.78 (-8.47)	64.50 (-5.29)	68.10	4.78	3.99	4.18
Fruit yield/plant(g)	38.27* (48.33)	32.89* (27.48)	30.75 (19.19)	25.80	2.10	3.34	3.29

The data in parenthesis indicate percentage increase or decrease over control

* p = 0.05

Table 4.8. Frequency of plants falling under different morphological groupings

Morphological groupings	M_1(10kR)	M_1(25kR)	M_1(20kR)
1	2	3	4
1. Plant habit			
branched	350	277	323
unbranched	6	2	4
2. Pubescence			
i. Stem			
Smooth	131	95	139
pubescent	10	5	21
warty	215	179	167
ii. Lamina			
smooth	261	219	245
pubescent	95	60	82
iii. Petiole			
smooth	320	255	308
pubescent	36	24	19
3. Pigmentation			
i. Stem			
green	97	67	64
red	47	60	21
green with red tinge	67	49	106
red with green ringe	145	103	136
ii. Petiole			
green	45	25	40
red	3	2	6
green with red tinge	42	17	46
red with green tinge	266	235	235

(contd.)

Table 4.8. continued

1	2	3	4
iii. Vein			
prominent	356	279	327
not prominent	0	0	0
green	5	15	22
whitish	0	0	0
green with red tinge	33	0	4
red with green tinge	318	264	301
iv. Base of petal			
present	264	208	260
absent	0	0	0
4. Leaf size			
small	118	53	46
medium	118	110	99
big	120	116	182
5. Leaf shape			
cordate	356	279	327
hastate	0	0	0
sagitate	0	0	0
others	0	0	0
6. Laminal margin			
deeply fid	126	96	74
narrowly fid	230	183	253
serrated	0	0	0
7. Leaf tip			
pointed	232	157	257
blunt	124	122	70

(contd.)

Table 4.8. continued

1	2	3	4
8. Flower			
i. Bud			
hairy	177	118	58
scaly	0	0	0
smooth	87	90	202
resinous	0	0	0
ii. Corolla			
yellow	264	208	260
golden yellow	0	0	0
red throat	0	0	0
purple throat	264	208	260
iii. Calyx			
hairy	201	133	132
smooth	63	75	128
fleshy	63	75	128
nonfleshy	201	133	132
iv. Stigma			
Bifid	0	0	0
Multifid	264	208	260
purple	264	208	260
red	0	0	0
others	0	0	0
smooth	0	0	0
hairy	264	208	260
9. Fruits			
i. Immature fruit colour			
green	107	130	99
dark green	0	0	0
yellowish green	0	0	0

(contd.)

Table 4.8. continued

1	2	3	4
red	0	0	0
deep red	0	0	0
others	157	78	161
ii. Size			
small	116	46	78
medium	122	115	149
long	26	47	43
extra long	0	0	0
iii. Shape			
round	0	0	0
angular	0	0	0
ridged	264	208	260
straight	0	0	0
curved	0	0	0
iv. Tip			
pointed	189	128	161
blunt	75	80	99
v. Dehiscence at maturity			
dehiscent	264	208	260
indehiscent	0	0	0
vi. Hairiness of fruit			
present	257	206	252
absent	7	2	8
less hairy	0	0	0
highly hairy	257	206	252
only on ridges	0	0	0
entire fruit	257	206	252

(contd.)

Table 4.8. continued

1	2	3	4
vii. Bending			
snaps	120	105	146
bends	144	103	114
10. Seeds			
i. Seediness			
low	96	58	63
medium	96	81	109
high	58	60	87
ii. Shape			
round	173	140	105
depressed	77	59	154
iii. Hairiness			
smooth	203	173	227
hairy	47	26	32

Table 4.9. Variability in M_1 generation

Character	10 kR (356, 264)*			15 kR (279, 208)*			20 kR (327, 260)*		
	Range	Mean	Coefficient of variation	Range	Mean	Coefficient of variation	Range	Mean	Coefficient of variation
Days to flower	55-79	63.86[a]	7.80	57-86	69.66[b]	9.73	55-81	68.35[c]	6.38
Node to first flower	2-9	4.83[a]	27.12	3-11	5.37[b]	25.33	3-15	5.93[c]	32.04
Plant height (cm)	12-54	28.58[a]	26.99	7-62	24.79[b]	36.18	15-123	38.12[c]	34.05
Leaf length (cm)	6-47	24.31[a]	31.18	11-52	24.34[a]	22.97	11-45	26.81[b]	24.99
Leaf width (cm)	7-33	17.09[a]	31.03	6-32	16.58[a]	27.20	9-39	20.17[b]	28.56
Fruit length (cm)	2.5-21	11.03[a]	42.52	3.5-20	13.1[b]	26.34	4-19	10.83[a]	31.85
Fruit girth (cm)	4-14	10.97[a]	18.69	5-5-14	6.65[b]	64.36	4.5-15	9.85[c]	25.78
Primary branches/ plant	0-19	6.03[a]	56.38	0-21	5.38[b]	65.79	0-18	7.44[c]	45.43
Nodes on main stem	7-25	14.07[a]	25.52	4-21	12.66[b]	33.65	6-23	13.56[a]	27.28
Fruiting nodes on main stem	2-14	4.55[a]	51.65	1-9	4.03[b]	51.36	1-11	3.23[c]	66.56
Internodal length(cm)	1-4.6	2.83[a]	28.98	0.5-5.5	2.93[a]	37.20	1.5-7	3.75[b]	24.00
Fruits/plant	1-10	3.20[a]	54.38	1-7	2.59[b]	65.49	1-10	2.82[c]	61.34
Ridges/fruit	5-10	7.72[a]	24.09	5-10	7.49[ab]	10.15	4-10	7.32[b]	21.31
Marketable fruits/ plant	0-10	2.66[ab]	72.56	0-6	2.51[a]	56.97	0-9	2.72[b]	65.44
Seeds/fruit	0-90	27.61[a]	68.02	0-103	31.92[b]	59.87	8-140	37.52[c]	59.91
Seed yield/plant(g)	4.4-69	2.91[a]	54.29	0.40-3.74	1.69[b]	60.46	0.5-5.55	2.05[ab]	98.00
Fruit yield/plant(g)	0-221	45.94[a]	75.42	0-150.2	37.44[b]	78.61	0-127	38.34[b]	68.23

* Data in parenthesis indicate total number of plants and number of plants flowered under each treatment.

Similarity of letters in rows indicate non-significance.

Maximum variability in M_1 (10 kR) line was observed for fruit yield/plant.(75.42). In M_1 (15 kR) line maximum variability was again for fruit yield/plant. The same is true in M_1 (20 kR) line also.

No plants were observed affected by disease like yellow vein mosaic, cercospora leaf spot, powdery mildew and downy mildew and pests like fruit borer and jassids. Incidence of mites was observed.

Discussion

DISCUSSION

Bhindi is a popular warm season fruit vegetable grown as kharif and summer crops throughout the tropics and sub-tropics. The crop is important not only for its tender immature pods but also for its seeds used in baby food industry. Bhindi seed oil is a prospective vegetable product of the future. With the processing of pods as dehydrated pods, the importance of bhindi has gone up as an earner of foreign exchange.

The single most important bottleneck in the cultivation of bhindi has been the incidence of yellow vein mosaic disease especially during the peak kharif season. Sastry and Singh (1973) reported damage as high as 100% if the crop is not sprayed within 20 days after germination. Singh et al. (1962) received ovation and special recognition for the development of Pusa Sawani known for its resistance to the disease. Subsequently with the breakdown of resistance in Pusa Sawani as lately reported by Chauhan et al. (1980) an urgent need has come to evolve strategies to combat the disease.

The strategies could be formulation of package of agronomic practices whereby a safer planting season is identified, choice of effective disease management measures, development of integrated methods of disease control and genetic modification of plants resistant to the disease.

The last strategy seems to be the most practical and desirable one considering the existence of a good number of related species reported to be resistant to the disease. Arumugam et al. (1975) reported for the first time a 'symptomless carrier' type of host reaction in a related species Abelmoschus manihot. Present study was formulated to find out the reasons for the absence of disease symptoms in two sources of A. manihot var. ghana available in the Department of Olericulture, College of Horticulture, Vellanikkara, Trichur. The compatibility of one of the lines with A. esculentus cv. Pusa Sawani was also studied for possible interspecific hybridisation to evolve edible lines free from the disease. Another method conceived was to generate variability in A. manihot var. ghana through γ-irradiation and then select for edible vegetable type(s). The results obtained are discussed.

The two sources of A. manihot var. ghana were observed to be 'symptomless carriers' of yellow vein mosaic disease from the appearance of disease symptoms in A. esculentus healthy scion when grafted. It took only 7-17 days from grafting to exhibit disease symptoms in interspecific grafts. This indicated that the two sources of A. manihot var. ghana are potent carriers of yellow vein mosaic virus. The 'symptomless carrier' nature of host reaction would be

advantageous provided there is no substantial reduction in yield when compared with a perfectly healthy control. It would also be interesting to study the inheritance of 'symptomless carrier' nature as such.

Considering the 'symptomless carrier' nature as a useful host reaction the cross compatibility of A. manihot var. ghana with A. esculentus was studied. The crossability index value of 12.38 indicates that the above two species are comparatively crossable. Crossability index, being a function of percentage of fruit set, viable seeds/fruit and percentage germination both in crosses and selfed maternal parent, reflects a measure of crossability (Rao, 1979). The cross compatibility was further studied in F_1 level. The F_1 plants bore seeded fruits, seeds did germinate and germination percentage was 13.33. Formation of fruits in interspecific F_0 cross, presence of viable seeds in F_0 cross, development of normal F_1 plants and fertility of F_1 plants etc. indicated compatibility between the two species. The compatibility was earlier reported by Teshima (1933) and Chizaki (1934) in A. manihot

The compatibility of interspecific F_1 hybrid was further proved through the manifestation of heterosis for a number of quantitative characters. Heterosis was significant for characters like days to flower, nodes to first flower, plant

height, leaf length, leaf width, fruit length, primary branches/plant, nodes on main stem, internodal length, fruits/plant, ridges/fruit, marketable fruits/plant, seeds/fruit and fruit yield/plant. It was only for fruit girth and number of nodes on main stem that no significant heterosis was observed. Heterobeltiosis, being a function of overdominant gene action would lead to generation of considerable variability resulting in transgressive segregants for economic characters. In the present study, F_1 heterosis for many of the quantitative characters resulted from the genetic divergence existing between the two species. It was also observed that primary branches/plant contributed maximum to the genetic divergence. This was quite evident from the significant difference between Abelmoschus esculentus cv. Pusa Sawani and A. manihot var. ghana for the character primary branches/plant.

The above observations lead to the following conclusions. A. manihot var. ghana is a 'symptomless carrier' of yellow vein mosaic virus. This species is crossable with A. esculentus. The interspecific F_1 hybrid exhibits significant heterobeltiosis for many of the economic characters and segregating generation are expected to yield transgressive segregants which could be further selected for type(s), high yielding and are symptomless carriers of yellow vein mosaic virus.

Mutation breeding has been successfully utilised to evolve high yielding varieties in vegetables like S12 in tomato (Nandpuri, 1966) and Pusa Parvati in French bean (Gill et al., 1972). Reports on mutation breeding in bhindi are however limited (Kuwada, 1970; Nandpuri et al., 1971; Rao and Giriraj, 1975; Nassar, 1976 and Koshy and Abraham, 1978).

Considerable vigour was observed in M_0 generation for characters plant height, girth of stem, internodal length, length of leaves, fruit length and fruit yield/plant. This information could be made use of in seed production, seeds for sale could be treated with gamma rays before being sold. There is need to arrive at optimum doses of gamma radiation which would create desirable variants and which would invigourate seeds meant for market.

Abelmoschus manihot var. ghana is in a wild state of existence and needs a lot of modification for being transformed into a vegetable type. The morphological changes observed in M_1 generation were conspicuous. Fruits which are tender, medium seeded and which snap on bending provide ample scope for selection of edible vegetable type(s). The three levels of radiation were found equally effective in bringing out morphological changes in A. manihot var. ghana.

Considerable variability was observed in M_1 generation

for days to flower, nodes to first flower, plant height, leaf length, leaf width, fruit length, fruit girth, primary branches/plant, nodes on main stem, fruiting nodes on main stem, internodal length, fruits/plant, ridges/fruit, marketable fruits/plant, seeds/fruit, seed yield/plant and fruit yield/plant. The coefficient of variation in M_1 (10 kR) ranged from 7.8 for days to flower to 75.56 for marketable fruits/plant. In M_1 (15 kR) the coefficient of variation ranged from 9.73 for days to flower to 78.61 for fruit yield/plant. In 20 kR treated M_1 the coefficient of variation was 6.388 for days to flower and 98 for seed yield/plant. The mutation did create considerable variability for a number of quantitative characters. The seeds have been collected from desirable lines to develop edible vegetable type(s).

Summary

SUMMARY

The present investigations on the induction of variability in Abelmoschus manihot var. ghana through irradiation were conducted during March-June 1981, June-October 1981, and November-April 1981-82 at the Instructional Farm of the College of Horticulture, Vellanikkara, Trichur. The experimental materials consisted of two sources of A. manihot var. ghana and A. esculentus cv. Pusa Sawani.

2. The 'symptomless carrier nature' of host resistance mechanism of A. manihot var. ghana was studied by grafting healthy scion of A. esculentus on A. manihot var. ghana. The two sources of A. manihot var. ghana were tested. The number of plants showing symptoms typical of yellow vein mosaic disease were counted in the grafts and the related species was observed as 'symptomless carrier'.

3. The compatibility between A. manihot var. ghana and A. esculentus cv. Pusa Sawani was studied at F_0 and F_1 level. The crossability index at F_0 level was measured. The genetic distance between A. manihot var. ghana and A. esculentus was significant ($_{11}D^2$=228.57). Significant heterosis was observed for days to flower, nodes to first flower, plant height, leaf length, leaf width, fruit length, primary branches/plant, fruiting nodes on main stem, internodal length, fruits/plant, ridges/fruit and fruit yield/plant.

The interspecific F_1 hybrid was late in flowering. There was fruitset and seedset indicating the fertility of the hybrid. The interspecific hybrids were free from major pests and diseases.

4. Variability was induced in A. manihot var. ghana using 10 kR, 15 kR and 20 kR gamma rays. The M_0 lines were found significant for plant height, internodal length and length of leaves when compared to control irrespective of doses of radiation given.

The morphological characters of three M_1 lines were recorded for plant habit, pubescence on stem, lamina and petiole, pigmentation of stem, petiole, veins and base of petal, leaf size, leaf shape, laminal margin, leaf tip, flower, fruits and seeds. The three M_1 lines exhibited considerable variability (cv) for days to flower (6.38-9.73), nodes to first flower (25.33-32.04), plant height (26.99-36.18), leaf length (22.97-31.18), leaf width (27.20-31.03), fruit length (26.34-42.52), fruit girth (18.69-64.36), primary branches/plant (45.43-65.79), nodes on main stem (25.52-33.65), internodal length (24.00-37.20), fruits/plant (54.38-65.49), ridges/fruit (10.15-24.09), marketable fruits/plant (56.97-72.56), seeds/fruit (59.87-68.02), seed yield/plant (54.29-98.00) and fruit yield/plant (68.23-78.61). Maximum variability in the lines were for fruit yield/plant. The plants were free from major pests and diseases except for the incidence of mites.

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* Originals not seen

Appendices


Abelmoschus manihot var. purpureus

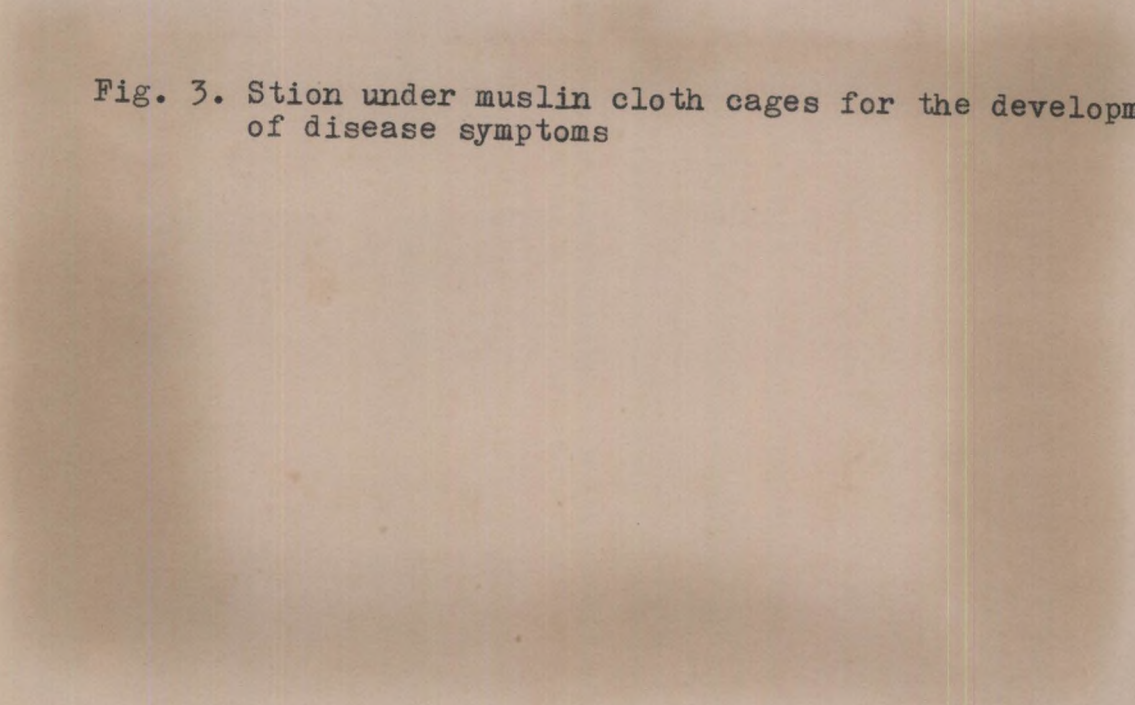

Fig. 3. Stion under muslin cloth cages for the development of disease symptoms

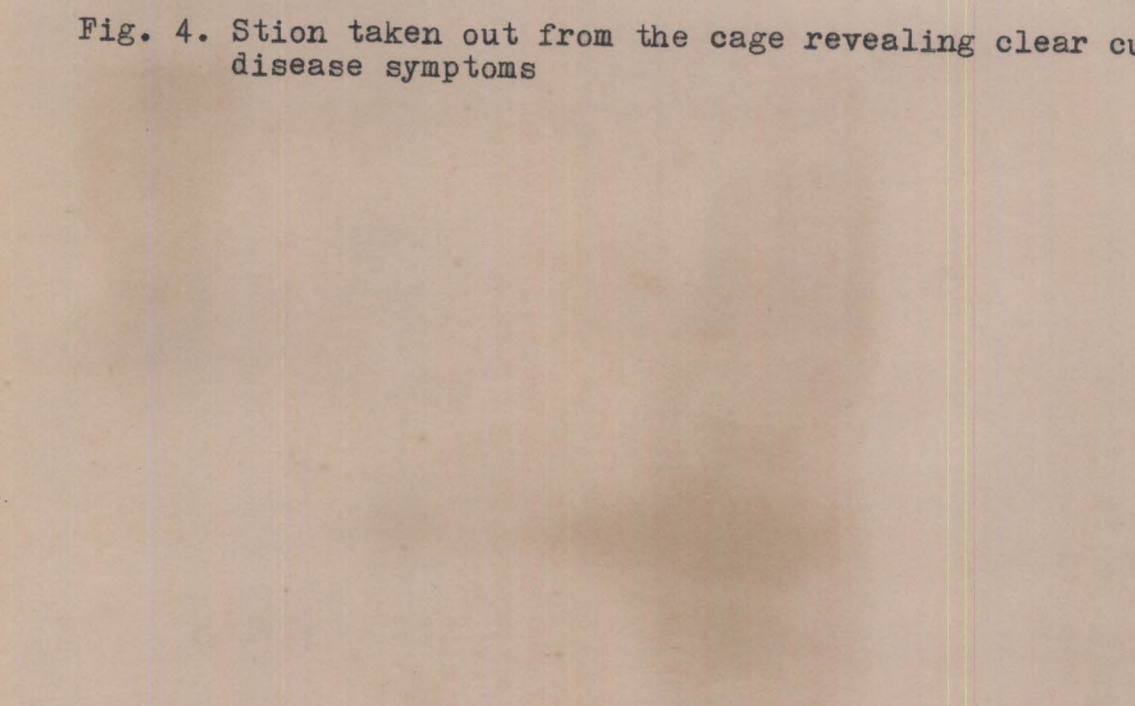

Fig. 4. Stion taken out from the cage revealing clear cut disease symptoms


Abelmoschus esculentus
Abelmoschus manihot var ghanaf(


Abelmoschus esculentus
Abelmoschus manihot var ghanaf(

INDUCTION OF VARIABILITY IN *Abelmoschus manihot* var. *ghana* BY IRRADIATION

BY

NIRMALA DEVI, S.

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the

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Master of Science in Horticulture

Faculty of Agriculture

Kerala Agricultural University

Department of Olericulture

COLLEGE OF HORTICULTURE

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ABSTRACT

Yellow vein mosaic, a viral disease transmitted by the white fly (Bemisia tabaci) is the most important disease of bhindi affecting the crop at all stages of growth. Pusa Sawani, reported to be resistant to the disease has, of late, become susceptible. A number of wild species have been reported to be resistant/tolerant to the disease. An experiment was planned and carried out during 1981-'82 at the Instructional Farm of the College of Horticulture, Vellanikkara, Trichur to induce variability in a reportedly resistant wild species, Abelmoschus manihot var. ghana and then to isolate edible vegetable type(s), if any.

The two sources of A. manihot var. ghana available in the Department of Olericulture were found 'symptomless carriers' of yellow vein mosaic virus. A. manihot var. ghana (Source IARI) was found comparatively compatible with A. esculentus. This was proved through F_0 fruitset, presence of viable F_0 seed, germination of F_0 seed, fertility of F_1 plant and viability of F_1 seed. The interspecific F_1 hybrid exhibited heterobeltiosis for days to flower, nodes to first flower, plant height, leaf length, leaf width, fruit length, primary branches/plant, fruiting nodes on main stem, internodal length, fruits/plant, ridges/fruit, marketable

fruits/plant, seeds/fruit and fruit yield/plant. The total genetic distance between the two species were found significant ($_{11}D^2$=228.57).

Variability was induced in the wild species using 10 kR, 15 kR and 20 kR gamma rays. Qualitative and quantitative characters of each and every plant in the M_1 line were observed. The performance of M_0 lines were compared with untreated control and vigour due to irradiation for characters plant height, internodal length and length of leaves were found significant irrespective of doses of radiation given. Maximum variability was observed for fruit yield/plant in the three lines. None of the plants were observed affected by diseases like yellow vein mosaic, cercospora leaf spot, powdery mildew and downy mildew and pests like fruit borer and jassids. Incidence of mites was, however, observed.